Comparative research between the Chinese and the Australian construction industries based on productivity and industrial competitiveness

A thesis submitted in fulfilment of the requirements for the degree of Ph. D

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Declaration

I certify that except where due acknowledgement has been made, the work is that of the author alone; the work has not been submitted previously, in whole or in part, to qualify for any other academic award; the content of the thesis/project is the result of work which has been carried out since the official commencement date of the approved research program; any editorial work, paid or unpaid, carried out by a third party is acknowledged; and, ethics procedures and guidelines have been followed.

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Abstract

In the last three decades, the Chinese construction industry has made significant achievements in the international market. Performance improvement of the Chinese construction industry in the international market is a widely held concern for academics, industry practitioners and policymakers in China. The performance gap between the Chinese and developed countries' construction industries may still exist and it is important that we analyse this to improve industry performance and to assist policymakers formulate future development strategies. This research aims to understand the performance of the Chinese construction industry and generate strategies for future development by comparing the Chinese and the Australian construction industries based on the concepts of productivity and industrial competitiveness. The current measurement methods for a country, industry, and/or a firm's status or level in the world are questionable. This study adapted the International Advanced Index (IAI) to measure the status and level of a country's construction industry in the international market. Porter's Diamond Model is one of the most popular and complete competitiveness theories and it has been improved by various scholars since it was first introduced. However, another very important theme that could contribute to this area of competitiveness is the concept of sustainable development. The research on the relationship between industrial competitiveness and sustainable development is lacking. Building upon the previous research, the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) was generated to enable the evaluation of industrial competitiveness. Sustainable development is a new element and it is composed of three sub-elements including economic sustainability, social sustainability and environmental sustainability. By using the Chinese and the Australian construction industries as cases, case study methodology is conducted in this research. The quantitative data was collected from several resources including; China Statistical Yearbook, Australian Bureau of Statistics, Engineering News Record, Dun & Bradstreet's "Who owns Whom" Database and Companies' Financial Reports. The data were analysed by various statistical methods including: Malmquist Productivity Index, Spearman Rank Correlation Coefficient, Degree of Coordination and Multivariate Cointegration Analysis. An important part of this thesis was to initiate the design and development of a practice based methodology that would be accessible by other researchers and potentially also by policymakers and industry analysts who could improve

the way in which we measure the performance of the construction industry. After the methodology was developed it was tested and then evaluated. This study compared the status and level of the Chinese and the Australian construction industries by using the IAI and proposed that the Chinese construction industry should be involved in a greater number of construction fields (diversification) or improve the level of activity in each involved field (specialization). Compared with the previous models, this study illustrated that the IAI is more comprehensive in reflecting the status and level of a country's construction industry in the international market. The index also provides a method to access and use data that is more readily available yet is still rigorous and robust. The Malmquist Productivity Index is adopted to explore the Total Factor Productivity (TFP) changes of the Chinese and the Australian construction industries in recent years and comparison were made. The gap in TFP between the Chinese and the Australian construction industries was significant and may become more significant due to the better growth rate of the Australian construction industry in productivity. The difference between the Chinese and the Australian construction industries industrial competitiveness was explored. As 'activities of the multinational enterprises' is new for Porter's Diamond Model and it has not been quantitatively tested, this study tested it by exploring the relationship between the degree of internationalisation and the performance at a construction firm and country levels by using the Spearman Rank Correlation Coefficient. The results indicated that the activities of the multinational enterprises could be included in the international competiveness model and is considered a determinant factor. For the sustainable development element, the Social Sustainability Index of the Chinese construction industry is the only sub-element which is lower than the Australian construction industry. The Degree of Coordination and Multivariate Cointegration analysis indicates that the three sub-elements of sustainability are interdependent and that they interact. The Social Sustainability Index should be considered as the priority to be improved. However, it was also found that for a long term point of view, if the Environmental Sustainability index needs to be improved, the best way is to improve the Economic Sustainability index, not the Environmental Sustainability index itself, which proved the importance of the interactivity principle of systems thinking and the Long-Term Influence Theory is proposed, as follows: *In order to improve the performance of an element/sub-system in a system for a long term point of view, stimulating the element/sub-system directly may be not the best way. It may be better to improve the other elements/sub-systems in the long term, because the dynamic and complex* *interrelationship among the elements/sub-systems exists within a system, and the influence level and direction between the elements/sub-systems may be different in the long term.*

Chapter 1 Introduction

1.1 Problem environment

China has recently fully engaged in internationalisation after one hundred years of a closed-door policy coupled with war and turbulence. Although China is an ancient civilisation, it has only in the last decade made dramatic moves towards modernisation and marketisation.

In 1978 Deng Xiaoping, a prominent Chinese reformer, introduced the ‘reform and opening-up policy’. He developed Socialism with Chinese characteristics and Chinese economic reform and partially opened China to the global market. The reform affected a shift of the economic system, and also the judicial and political systems. After the implementation of the ‘reform and opening-up policy’ in the 1980s, China embarked on a road of revival. With the development of globalisation, the performance of the Chinese economy has improved dramatically. In 2014, Foreign Direct Investment (FDI) in China reached 129 billion U.S. dollars. China is the largest FDI host economy in the world and accounted for more than half of this figure (UNCTAD, 2015). In 2014 the GDP of China was ranked the second in the world after the United States, whereas previously it was tenth in 1990 (Word Bank, 2015). It has often been claimed by both the popular business media and academic experts alike that the 21st century will be the Chinese century (Dyer, 2009; Thayer, 2009; Chan, 2008; Smith, 2006 and Hines, 1997). The construction industry is always considered to be an important industrial sector of the national economy. The important role of the construction industry in the national economy is reflected by these four aspects:

- The output of the construction industry accounts for a large proportion of the nation’s total output.
- The construction industry consumes a large amount of products, which promotes the development of other industries.
- The construction industry is the foundation of the economy and provides inputs to many other sectors.
- The construction industry provides numerous job opportunities.

(Shen & Zhang, 2004 and Chen, 2003).

For developing countries, the status of the construction industry is very important to the country's economic and social development (Wen, 2007). The next decade will be a critical period in China's modernisation during which the country will grapple with intractable problems and deep-rooted contradictions. These include an unbalanced economic structure, a widening economic gap between urban and rural areas, excessive energy and resource consumption, and a dramatic worsening of environmental pollution (Wen, 2007).

Similar to other countries, the construction industry plays an important role in the Chinese economy. Over the next few decades, the Chinese construction industry can play an important part in solving the following projected issues:

Economic growth

Between 2001 and 2010 the average annual increase of the Chinese gross domestic product (GDP) was approximately 15%. However the annual growth rate of the Chinese construction industry' Gross Output Value was 20% between 2001 and 2010, which is much higher than the GDP. This demonstrates the important role the construction industry plays in the growth of China's economy.

Environment protection and resources reservation

Due to serious problems caused by resource depletion, environment pollution and climate change, a policy aimed at building a resource conserving and environment-friendly society has been adopted by the Chinese government. The target was set to reduce energy consumption per unit of GDP by 20% and cut pollutant emission by 10% in the 11th Five-Year Plan period (2006–10) (Wen, 2007). As the construction industry is a main manufacturer of environmental problems, the Ministry of Construction has launched a program titled the 'Energy-Efficient and Land-Saving Building Initiative'.

Urbanisation progress

The level of urbanisation is expected to grow from 37.7% in 2001 to 50% in 2020, and finally to about 75% in 2050, with an annual increase of 1.2% (Jin, 2003). However, it is argued that this forecast is too optimistic and unrealistic, and an annual growth rate of 0.8–1.0% is generally expected (Sha *et al.*, 2006), which means there should be 10.4–13.0 million additional urban residents each year. In this sense, only a rapidly increasing construction industry can meet the need for buildings and infrastructure to accommodate the urban resident growth rate.

Countryside development and migrant workers

Ninety percent of the workforce of construction projects is made up of migrant workers or labourers from rural areas (Sha & Jiang, 2003). China is expanding its focus from urban to rural areas. Among all strategic tasks, top priority is given to solving the problems related to agriculture, rural area and farmers (Wen, 2007). The construction of small towns, and infrastructure and creating work opportunities for labourers from rural areas are the key issues to solving these problems. These issues cannot be separated from the Chinese construction industry.

In this sense, the Chinese construction industry is considered as a key element for solving the major issues and contradictions. It is therefore worthwhile to explore the generation of a sound strategy to promote the performance of the Chinese construction industry.

Due to the U.S. subprime mortgage crisis, European debt crisis and China joining the World Trade Organization (WTO), the international construction market has been in flux since 2000 and some new trends may arise. With the development of globalisation and internationalisation, the Chinese construction companies became more active in the international market. Significant achievements have been made by the Chinese construction multi-national enterprises (MNEs) in the last decades. For example, the number of Chinese construction enterprises listed in the top 225 international constructors by Engineering News-Record (ENR) has increased from 35 in 2000 to 51 in 2010 (Reina & Tulacz, 2011).

How to improve the performance of the Chinese construction industry in the international market is a concern of academics, industry participants and policymakers in China. The gap between the Chinese construction industry and the developed countries' construction industry may still exist and it is worth being identified. This could help the policymakers to formulate future development strategies.

As a developed country, the Australian economy plays an important role in the Asia Pacific area, even the world. Many Australian sectors are at the forefront of the world. Australia's economy is the third freest in the 2013 Index of Economic Freedom (Heritage, 2013).

Australia is the world's twelfth largest economy and has the fifth highest per capita GDP (nominal) and it is ranked second in the United Nations 2011 Human Development Index and first in Legatum's 2008 Prosperity Index (United Nation, 2011). In addition, all of Australia's major cities get good results in global comparative liveability surveys. For example, Melbourne reached first place on The Economist's 2011 world's most liveable cities list, followed by Sydney, Perth, and Adelaide in sixth, eighth, and ninth place respectively (The Economist, 2011).

The Australian construction industry plays an important role in Australia's economy. The construction industry was the fourth largest contributor to Gross Domestic Product (GDP) in the Australian economy during 2008-09 in current price terms, and plays a major role in determining economic growth. In chain volume terms, the construction industry accounted for 6.8% of GDP in 2008-09. The construction industry also provides infrastructure for other sectors, including "(a) parts of the manufacturing, wholesale and retail trade and finance industries, in supplying components, fittings and furnishings, and in financing building and construction, and (b) parts of the professional services industry, such as the architectural and engineering professions for design and erection methods embracing both proven and advanced innovative technological methods and products." (ABS, 2010) As at May quarter 2009 the construction industry employed 984,100 persons, which is 9.1% of the Australian workforce, making it Australia's fourth largest industry.

The Australian construction industry has also made significant achievements in the international market in recent years. Australian construction enterprises have been very active and occupied a certain degree of market share. For example, there are four Australian construction enterprises listed in the ENR top 225 international contractors in 2010. It was two in 2001. If the Chinese construction industry and Australian construction industry are compared, differences on some key indicators can be identified. The results can benefit both countries.

1.2 Research problem and current research

When comparison is conducted, the first question must be 'which one is better'. For these two countries' construction industries, the first question would be 'which country's construction industry's status and level is higher in the international market'. There are many sectors within an industry which can be compared across different countries. When the status, development level or position in the world is discussed, there are two kinds of measurement that are commonly used, including the one-dimensional financial measurement and complex measurements. The one-dimensional measurement doesn't reflect the whole picture and can lead to misunderstanding (Sullivan, 1996). Complex measurements cannot quantitatively measure all the elements and indicators. It cannot be considered as a standard measurement and it only can be used in small groups and samples. In order to avoid the limitations of the one-dimensional financial measurement and complex measurements, Zhang and London (2010) generated the International Advanced Index (IAI). There are three indexes in the IAI, including Depth Index (DI), Heigh Index (HI) and Width Index (WI).

After finding which countries' construction industries have higher status and level in the international market, we need to discuss how to improve the performance of the Chinese construction industry in the international market. As the core indexes in economics, productivity and industrial competitiveness can be considered as the basis of the status and level of a country's construction industry.

Productivity is a core index in economics. It can be used to measure technical progress, economic efficiency, real cost control and production technology (Latruffe, 2010). It can be calculated by the ratio of an output performance indicator to an input performance indicator. There are two kinds of measurement for productivity, including Partial Factor Productivity and Total Factor Productivity. Both of them have been used to analyze different countries' construction industries. Previous research has compared international productivity between China's and other countries' construction industries (Chui, 2010) and Australia's and other countries' construction industries (Young, *et al.*, 2008). However, the comparison between the Chinese and the Australian construction industries is still lacking.

These competitive advantages determine the performance and success of the different industries of a country in the international market. The industrial competitive advantages could be gained by its industrial competitiveness (Porter, 1990). The international competitiveness of the construction industry can thus be considered as the ability of a country's construction industry to achieve competitive advantage in international markets to provide better products and services, create added value and increase the wealth of the country (Di *et al.*, 1992).

A number of correlative theories related to the evaluation of industrial competitiveness have been trialled, tested and adopted in recent years. Some of the evaluation methods utilize 'show-indicators' in the measurement of industrial competitiveness (Ark, 1990 and 1993; Gersbach & Ark, 1994; Gersbach & Baily, 1996; Mason *et al*., 1994 and Jorgenson & Kurod, 1992). These indicators usually only reflect the phenomenon and present the results of the evaluation. The nature and reason for the phenomenon presented are typically not found or discussed (Pei & Wang, 2002) resulting in a significant gap in the development of targeted measures. Multi-factor comprehensive evaluation method is another type of international competitiveness evaluation method typically used. Diamond Model is an example of the multi-factor evaluation method and is also the most popular and complete competitiveness theory currently available for explaining the achievement of a country's industrial and a firm's competitive advantage. Following the modifications by various scholars, Porter's Diamond Model has been improved. In particular, the 'activities of the multinational enterprises' was added as a determinant (Dunning 1993 and 2003 & Cho and Moon, 2000). However, this modification lacks of quantitative support. This research tested and proved that it is appropriate to include the 'activities of the multinational enterprises' in industrial competitiveness.

In addition, another very important theme in today's world has not been considered. This is the concept of sustainable development. As a resource-intensive industry, the construction industry has played a very important role on economic development, but it also has a significant impact on many environmental and social issues. The concept of sustainable development has gained much attention as a way for dealing with the conflicts between human activities, natural resources, social issues and our future. The discussion and debates surrounding this topic have been extensive with the participation from numerous scholars across various disciplines.

The United Nations (1987) defines sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. Although sustainable development originates from a focus on environmental protection, it has moved beyond environmental protection as a guide for human existence into the future, which includes economic sustainable development, environmental sustainable development and social sustainable development. Therefore, when the development of the construction industry is discussed, in addition to the economic performance of the construction industry, the environmental and social perspectives should be addressed.

The research on the relationship between industrial competitiveness and sustainable development is lacking, and will be considered here. Building upon past work and adding an awareness of sustainable development, a new model for the evaluation of industrial competitiveness is generated, which is the Internationalisation Sustainable Development Competitiveness Model (ISDC Model). Eight elements are included in the ISDC Model. Except the Chance element, this study generated a quantitative measurement for each element. Sustainability, the new element of ISDC Model, is one of the most popular topics in the construction industry, which includes three sub-elements: economic sustainability, social sustainability and environmental sustainability.

Systems thinking is necessary and critical for analysing sustainability. A dynamic and complex interrelationship exists among the sub-systems within a system. These three sub-elements are interdependent and interact. Based on the interactivity principle of systems thinking, the long term relationships between the indicators/sub-systems in a system should be considered. In order to improve the performance of an indicator/sub-system in a system for a long term point of view, stimulating the element directly may be not the best way. It may be better to improve other elements in the long term, because of the changes in the influence direction and level between the elements.

1.3 Research questions and objectives

The purpose of this research is to find out the performance of the Chinese construction industry and the ways for future development by comparing the Chinese and the Australian construction industries based on the concepts of productivity and industrial competitiveness. To this end two research questions are posed;

> *What is the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010?*

> *What are the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?*

Underpinning research question 2, is the assumption that a new methodology to measure the industrial competitiveness should be generated. In addition, sustainable development has several elements and these elements are interactive. The interactivity principle of systems thinking should be adopted to analyse the interrelationship within the elements of sustainable development. In order to improve the performance of an element in a system for a long term point of view, stimulating the element directly may be not the best way. It may be better to improve the other elements in the long term. The contribution of new knowledge will be the results of a comparative empirical analysis of the China and Australian construction sectors as well as the development of industrial competitiveness theory through the creation and validation of a new methodology.

The objectives of this work include the following:

1) To discuss the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010 and identify the differences between them.
2) To explore the productivity changes of both the Chinese and the Australian construction industries
3) To develop a conceptual model of industrial competitiveness and generate quantitative measurements for the elements
4) To identify the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries in recent years
5) To propose ways to increase the sustainability of the Chinese construction industry in the long term.

1.4 Research methodology

Ontology and epistemology could be considered as the foundations upon which research is built. Methodology, methods and sources are closely connected to and built upon the ontological and epistemological assumptions.

There are two ontological positions, including Objectivism and Constructivism. Objectivism is 'an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors' (Bryman, 2001). A characteristic of an objectivistic worldview is the existence of objective, absolute and unconditional truths

(Lakoff & Johnson, 1980). Lakoff (1987) argues that objectivism is ‘one version of basic realism’ according to which reality exists independent of humans. This study will discuss the productivity and industrial competitiveness of construction industry. The theory of industrial competitiveness has been developed continually by numerous scholars in various ways. These developments are the results of the thoughts and activities of human beings. It is no doubt that it will be changed in the future when some new relevant theories or facts appear. Therefore, this study does not support an objective view of reality.

Alternatively, constructivism is an alternative ontological position that ‘asserts that social phenomena and their meanings are continually being accomplished by social actors. It implies that social phenomena and categories are not only produced through social interaction but that they are in a constant state of revision’ (Bryman, 2001). The basic and most fundamental assumption of constructivism is that knowledge does not exist independent of the learner, knowledge is constructed (Vrasidas, 2000).

In this study, the theory of industrial competitiveness is developed further based on the previous studies and the concepts of sustainability. A new model of industrial competitiveness is generated and could be used widely. Therefore, this research supports a constructive view of reality.

Epistemology is concerned with the nature of knowledge and justification (Miller & Brewer, 2003). There are three epistemological positions, including: positivism, interpretivism and post-positivism. Positivism is based on a realist, foundationalism (objectivism) ontology, which views the world as existing independently of our knowledge of it (Guba & Lincoln, 1998). Positivists believe that ‘There are patterns and regularities, causes and consequence, in the social world just as there are in the natural world’ (Denscombe, 2002). A positivist position believes in the possibility of making causal statements.

The interpretivist paradigm can be also called the ‘anti-positivist’ paradigm because it was developed as a reaction to positivism. Interpretivism ‘is predicated upon the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action’ (Bryman, 2001)

Post-positivists attempt to combine the 'how' (understanding – which is linked to interpretivism) and the 'why' (explanation – which is linked to positivism) approaches by bridging the gap between the two extremes (May, 2001). Post-positivists believe that while social science can use the same methods as natural science regarding causal explanation (in line with positivism), it also needs to move away from them by adopting an interpretive understanding (Sayer, 2000). In addition, Post-positivists conceive of social change and conflict in society as not always apparent or observable, believing that 'the immediately perceived characteristics of objects, events, or social relations rarely reveal everything' (Neuman, 2000). Post-positivists believe pre-existing structures affect and are affected by actors (Hay, 1995).

This research aims to understand the performance of the Chinese construction industry in the international market and the differences between the Chinese and the Australian construction industries in productivity and industrial competitiveness. Also, the ways to improve the sustainability of the Chinese construction industry will be discussed. This research includes both 'understanding' and 'explanation'. In addition, the development of the models for industrial competitiveness has never been stopped based on the changes of situation and emerging of new concepts, which is matched with Neuman's and Hay's statements about post-positivists. Therefore, this research is located within a post-positivism epistemological position.

Methodology is a branch of science concerned with methods and techniques of scientific enquiry; in particular, with investigating the potential and limitations of particular techniques or procedures (Grix, 2010). Methodology provides the tools whereby understanding is created (Miller & Brewer, 2003). This research will conduct case study methodology, with the Chinese and the Australian construction industries as cases.

Yin (1994) defined a case study as 'an empirical inquiry that: (1) investigates a contemporary phenomenon with its real-life context when (2) the boundaries between phenomenon and context are not clearly evident and in which (3) multiple sources of evidence are used.' A case study is not intended as a study of the entire organisation. Rather it is intended to focus on a particular issue, feature or unit of analysis (Noor, 2008). Case studies become particularly useful where one needs to understand some particular problem or situation in great-depth, and where one can identify cases rich in information (Patton, 1987). Case studies could be used for a range of purposes within social research. Generally speaking, case studies could be used in relation to the discovery of information following an inductive logic and in relation to the testing of theory following and deductive logic. This research will take a discovery led approach:

- Description – to better understand the performance of the Chinese and the Australian construction industries;
- Comparison – to identify the differences in productivity and industrial competitiveness between them;
- Exploration – to propose ways to increase the sustainability of the Chinese construction industry in the long term.

Quantitative data will be collected from several resources, including China Statistical Yearbook, Australian Bureau of Statistics, Engineering News Record, Government Work Report and Companies' Financial Reports. Some statistics methods will be adopted to analyze the quantitative data including: Data Envelopment Analysis, the Malmquist productivity index, Input-output analysis, Degree of coordination, Multivariate Cointegration Analysis and Spearman Rank Correlation Coefficient.

1.5 Findings

The status and level of the Chinese and the Australian construction industries both improved dramatically from 2001 to 2010. In 2001, the Chinese construction industry was better than Australia. However, in 2010, the Australian construction industry has surpassed China. The Chinese construction industry should make efforts to be involved in more construction fields (diversification) or improve the level in each involved field (specialisation), compared with the Australian construction industry.

In addition, although the construction work done, the number of persons employed in the construction industry and the gross value-added of the Chinese construction industry in 2010 are all much higher than the Australian construction industry in 2009-10, the total factor productivity of the Australian construction industry in 2009-10 is 503.4% higher than the Chinese construction industry in 2010. The gap between the Chinese and the Australian construction industries in relation to the total factor productivity is significant. Moreover, the gap seems to become bigger in the future. This is because the average growth rate for construction total factor productivity in Australian from 2001-02 to 2010-11 is higher than the average growth rate for the Chinese construction industry from 2001 to 2010. This is a notable problem for policymakers and industry participants.

Moreover, there are positive relationships between the degree of internationalisation and a construction firm's financial performance and between the degree of internationalisation and the construction industry performance in the international market at the country level. It is appropriate to include the activities of the multinational enterprises in the international competiveness and to consider this be a determinant.

Furthermore, by comparing each element of the industrial competitiveness of the Chinese and the Australian construction industries, some important conclusions are generated, including:

1) From the perspective of the factor conditions, compared with the Australian construction industry, the Chinese construction industry needs to improve the proportion of the R&D expenditure in construction work done.
2) The demand conditions of the Chinese construction industry are much better than the Australian construction industry.
3) The Chinese construction industry is shifting so that the status of the private sector is beginning to dominate the construction market and the public sector is playing a supporting role.
4) For the market structure, the CR_4 of the Chinese construction industry and the Australian construction industry in 2010 are quite similar and both located in the "Competition" group.
5) There are positive relationships between the degree of internationalisation and a construction firm's financial performance and between the degree of internationalisation and the construction industry performance in the international market at the country level. It is appropriate to include the activities of the multinational enterprises in the international competiveness and be a determinant factor.
6) In 2000, the degree of internationalisation of the Chinese construction enterprises is higher than the Australian ones. However, by 2010, the degree of internationalisation of the Australian multinational construction enterprises has surpassed the Chinese ones at the country level.

7) The closely related and supporting industries of the Chinese and the Australian construction industries did not perform well in recent years. Their capability to provide sustainably increasing support to the Chinese and the Australian construction industries is limited.
8) The total factor productivity of the Australian government in relation to the construction industry is much better than the Chinese government. The total factor productivity of the Chinese government in relation to the Chinese construction industry increased gradually from 2001 to 2010, while the Australian government decreased. Therefore, the gap between the Chinese and the Australian government would be narrowed in the future.
9) The degree of coordination among the economic sustainability, environmental sustainability and social sustainability of the Chinese construction industry is under the process of moving from ‘uncoordinated’ to ‘coordinated’ from 2001 to 2010. The sustainable development index of the Chinese construction industry from 2001 to 2010 is increasing dramatically, which is much higher than the Australian construction industry. However, the social sustainability of the Chinese construction industry is lower than the Australian construction industry. The two indicators included in the Social sustainability index – disposable income and the number of persons with a non-school qualification per thousand people – should be considered as the priority to be improved in order to enhance the development of the sustainability of the Chinese construction industry and narrow the gap with the Australian construction industry.
10) When the multivariate cointegration analysis conducted among the three sub-indexes of sustainability, it was found that for a long term point of view, if the Environmental Sustainability index needs to be improved, the best way is to improve the Economic Sustainability index, not the Environmental Sustainability index itself. This finding proved the importance of systems thinking. If the indicators in a system/model are interdependent and interact, the influence levels and flow between the indicators may be different. Therefore, in order to improve the performance of an indicator from a long term point of view, stimulating the indicator directly may be not the best way and it may be better to improve other indicators in the long term.

1.6 Outline of thesis

The following diagram in figure 1-1 indicates overall structure of how the thesis is organised.

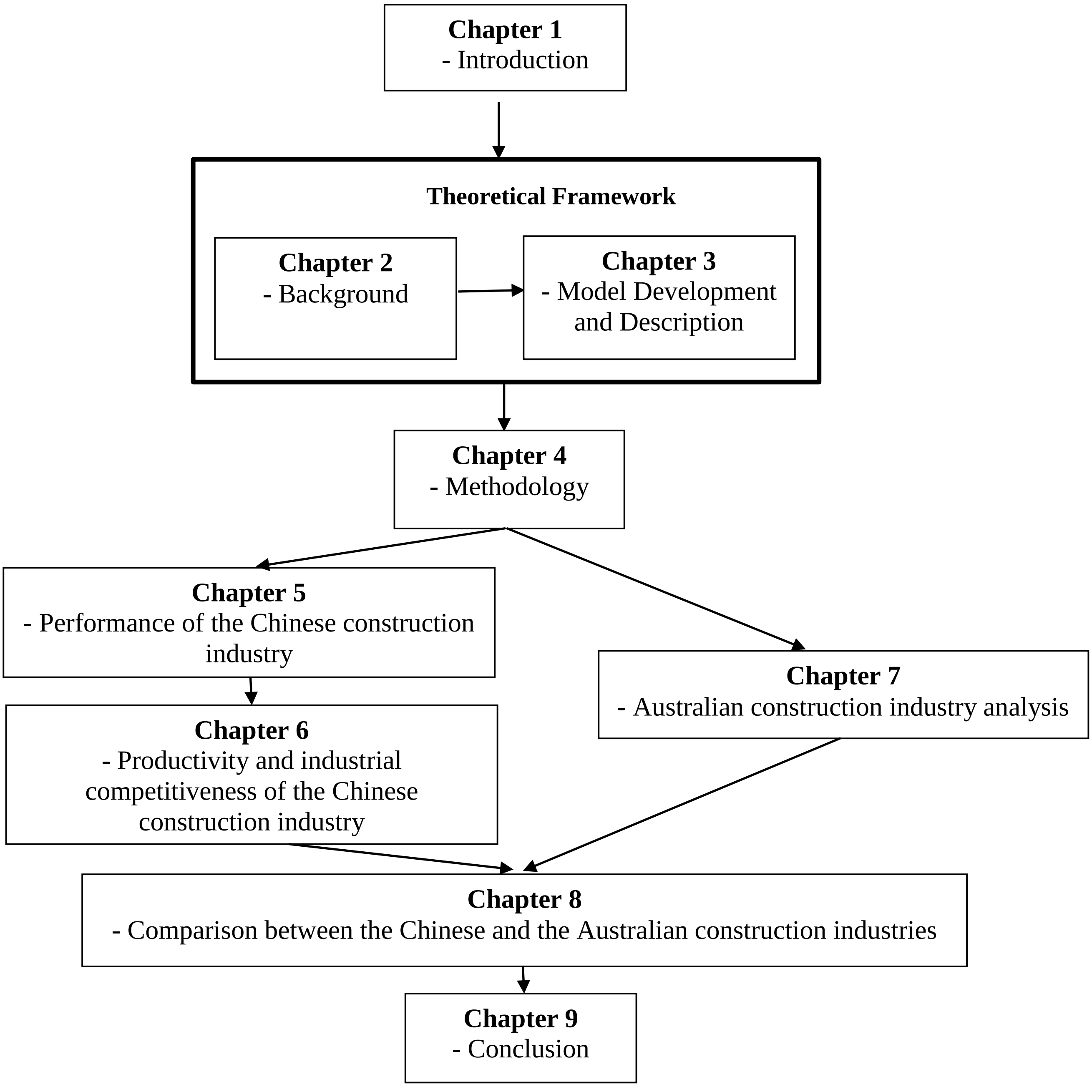


Figure 1-1 Overview of thesis structure

Chapter 1 describes the research problem and its environment and indicates where the thesis is located in terms of theoretical concerns including: ontological, epistemological and methodological issues. It then proposes the research questions and objectives and summarises the key findings and outlines the structure of the thesis.

Chapter 2 explores the trends of the international construction market from 2001 to 2010 and reviews the literatures about the measurements of a country/industry/firm's performance, development level or position in the world, productivity and industrial competitiveness of the construction industry and systems thinking. It then introduces the International Advanced Index to measure the status and level of a country's construction industry in the international market and generates the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) for the evaluation of industrial competitiveness. Also, two research questions are proposed in this chapter.

Chapter 3 generates a measurement method for each element of the ISDC Model. In particular, the Sustainable Development Indicators System of the Construction Industry (SDISCI) is generated to measure the sustainable development element. The productivity of government is introduced to measure the government element and the degree of internationalisation is proposed to measure the activities of multinational enterprises.

Chapter 4 discusses the ontological, epistemological and methodological issues of this research. This research is conducted using an interpretivist position and is based on a constructivist ontology. An inductive framework is adopted. Case study methodology is used and China and Australia's construction industries are considered as cases. Quantitative data are collected from several resources and analysed by various statistical methods.

Chapter 5 explores the development phases of the Chinese construction industry in both the domestic and international markets, especially new developments in the period from 2001 to 2010. It then discusses the status and level of the Chinese construction industry in the international market by using the International Advanced Index in the same period.

Chapter 6 studies the productivity of the Chinese construction industry by using the Malmquist productivity index to evaluate the total factor productivity changes from 2001 to 2010 and analyses the industrial competitiveness of the Chinese construction industry in the same period by using the ISDC Model.

Chapter 7 discusses the performance of the Australian construction industry from 2001-02 to 2010-11 and explores the productivity changes of the Australian construction industry in these ten years by using the Malmquist productivity index. It then studies the industrial competitiveness of the Australian construction industry by using the ISDC Model. It also explores the relationship between the degree of internationalisation and a construction firm's financial performance and the relationship between the degree of internationalisation and the construction industry performance in the international market at the country level. It proves that it is appropriate to include the activities of multinational enterprises in international competiveness and to consider this to be a determinant.

Chapter 8 comprises the cross-country analysis between the Chinese and the Australian construction industries by using the International Advanced Index, total factor productivity and ISDC Model and utilises multivariate cointegration analysis to explore the interaction among the economic sustainability, social sustainability and environmental sustainability of the Chinese construction industry, in order to help policymakers to make appropriate strategies for the Chinese construction industry to increase its sustainability.

Chapter 9 summarises the research findings and demonstrates how the research objectives have been achieved and how the research questions are answered. It then outlines the contributions and limitations of this study and suggests avenues for further research.

Chapter 2 Background

2.1 Introduction

The international construction market has been in flux since 2000 because of significant world events, including the U.S. subprime mortgage crisis, the European debt crisis and China joining the World Trade Organization (WTO). Some new trends may arise in the international construction market. The progress of the Chinese construction industry involvement in the international market is remarkable in the last decades, especially after the entry into the WTO. The purpose of this research is to understand the performance of the Chinese construction industry and the paths for future development by comparing the Chinese and the Australian construction industries based on the concepts of productivity and industrial competitiveness. This chapter will firstly explore the trends of the international construction market from 2001 to 2010. The literature about the measurements of a country/industry/firm's status and level in the world, productivity and industrial competitiveness of the construction industry and systems thinking will then be reviewed. The model used in this research for measuring the status and level of the construction industry in the international market is provided and the new model of industrial competitiveness is introduced.

2.2 International construction market

Five aspects of the international construction market will be discussed, including the international market size, growth rate of overall international revenue, diversification of fields, international marketing sharing and regional international construction market. The series of date of the international construction market from 2001 to 2010 is collected from the ENR Top 225 International Constructor list. This report provides information from a survey from the large construction enterprises worldwide. In the international construction sector, most of the direct participants are multinational enterprises (MNEs). Various researchers as well as world social institutions such as the United Nations and the International Monetary Fund, have acknowledged the importance of MNEs. MNEs are critical because of their influence due to their massive financial, technological, human, intellectual, and organisational resources (Barnet & Cavanagh, 1994; Hawken, 1993; Kanter, 1995; Korten, 1999 and Vernon, 1998). In this sense, the level of MNEs' development could be considered as the indicator of the country's level of development. The data provided by Engineering News Report (ENR) are the most comprehensive data set currently available. However, some limitations should be discussed.

Firstly, the quality of the data depends on the willingness of firms who wish to participate in the ENR's survey. If some firms do not wish to participate, the data will be different. For example, because the British contractors Trafalgar House PLG in 1996 and Kvaener Groupand Bovis Construction Ltd in 1999 did not participate in the ENR survey, the data changed dramatically. In addition, the authenticity of data depends on the firms' honesty. The country that the construction enterprise is attributable to is determined by the construction company's registration places. However, because the changes in equity, joint ventures, and mergers and acquisitions occur frequently in the international market, the data from ENR may not reflect these activities timely and comprehensively.

2.2.1 International market size

The overall international revenue of the top 225 international constructors has increased from US$106.5 billion to US$383.7 billion and the overall growth rate has reached 13.45% from 2000 to 2010 (Table 2-1). Especially from 2003 to 2008, the overall international revenue of the top 225 international constructors increased dramatically with an average growth rate of 22.15%. However, the dramatic increase ceased in 2009 and began to decrease in 2010 (Table 2-1).

Therefore, it could be said that the international market increased rapidly before 2008 and marginally less from 2009. This result could be caused by the world events that occured in 2008, 2009 and 2010, including the double-dip recession in United States and the debt crisis in Europe.

Year	Overall International Revenue(US$b)	Growth Rate
2001	106.5	-8.11%
2002	116.5	9.39%
2003	139.8	20.00%
2004	167.5	19.81%
2005	189.41	13.08%
2006	224.4	18.47%
2007	310.2	38.24%
2008	382.44	23.29%
2009	383.8	0.36%
2010	383.7	-0.03%

Table 2-1 Overall International Revenue and Growth Rate of the Top 225 International Constructors from 2001 to 2010

2.2.2 Diversification of fields

The fields within the construction industry are broad. The Engineering News Record categorises the construction industry into 10 fields, including: General Building, Manufacturing, Power, Water Supply, Sewer/Solid Waste, Industrial Process, Petroleum, Hazardous Waste, Transportation and Telecommunications. The detail description of these ten fields is summarised in Table 2-2.

Fields	Contents
General building	Commercial buildings, offices, stores, educational facilities, government buildings, hospitals, medical facilities, hotels, apartments, housing, etc.
Manufacturing	Auto assembly, electronic assembly, textile plants, etc.
Power	Thermal and hydroelectric powerplants, waste-to-energy plants, transmission lines, substations, cogeneration plants, etc.
Water supply	Dams, reservoirs, transmission pipelines, distribution mains, irrigation canals, desalination and drinking water treatment plants, pumping stations, etc.
Sewer/solid waste	Sanitary and storm sewers, treatment plants, pumping plants, incinerators, industrial waste facilities, etc.
Industrial process	Pulp and paper mills, steel mills, nonferrous metal refineries, pharmaceutical plants, chemical plants, food and other processing plants, etc.
Petroleum	Refineries, petrochemical plants, offshore facilities, pipelines, etc.
Transportation	Airports, bridges, roads, canals, locks, dredging, marine facilities, piers, railroads, tunnels, etc.
Hazardous waste	Chemical and nuclear waste treatment, asbestos and lead abatement, etc.
Telecommunications	Transmission lines and cabling, towers and antennae, web hotels, etc.

Table 2-2 Ten fields of construction industry

The overall revenue of the top 225 international contractors in the Hazardous Waste field from 2001 to 2010 fluctated. From 2001 to 2006, it increased in Manufacturing field. However, from 2007, it began to decrease. Until 2010, the overall revenue of the top 225 international contractors in the Manufacturing field started to increase. For the remaining eight fields, the overall revenue of the top 225 international contractors increased from 2001 to 2008. However, besides Sewer/Solid Waste and Power, all the other fields decreased markedly from 2009 to 2010. Although in the fields Transportation and Petroleum, the overall revenue of the top 225 international contactors increased slightly in 2009, compared with previous years the increase is small enough to be negligible and both of them decreased in 2010.

In addition, as we can observe from Table 2-4, the top three fields in relation to their international revenue out of these ten fields are Transportation, General Building and Petroleum respectively. The average percentage of each of these three fields' international revenue to the total revenue of all the ten fields from 2001 to 2010 is more than 20%. The total percentage of these three fields with regard to international revenue is over 70% in this decade. This result indicates the importance of Transportation, General Building and Petroleum in the construction industry. This is as expected.

Following the top three fields, the fields of Power and Industrial also occupied 5% to 10% of the total international revenue for the top 225 international contractors from 2001 to 2010. Water Supply, Manufacturing, Sewer/Solid Waste, Telecommunication and Hazardous Waste had a less than 3% market share in this decade. The percentage for Hazardous Waste was less than 0.5%.

Furthermore, in the top three fields (Transportation, General Building and Petroleum) the percentage of General Building's international revenue out of the ten fields decreased from 2001 to 2010 generally, while the other two increased (refer to Table 2-4). In the same time period, Hazardous Waste, Telecommunication and Manufacturing decreased. However, in this period, the percentages of Industrial, Sewer/Solid Waste and Water Supply fluctuated to a certain extent. From 2001 to 2007, the percentage for Power decreased from 7.02% to 5.54%, and then increased from 2008 to 2010, up to 10.06% (refer to Table 2-4).

	Industrial Process		Manufacturing		Sewer/Solid Waste		Hazardous Waste		Power		Water Supply	
	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate
2001	5,929.80	N/A	3,830.10	N/A	1,432.50	N/A	360.10	N/A	7,481.40	N/A	3,561.60	N/A
2002	6,618.10	11.61%	3,349.30	-12.55%	1,712.20	19.53%	288.70	-19.83%	8,015.00	7.13%	3,500.90	-1.70%
2003	8,680.60	31.16%	3,455.10	3.16%	2,091.80	22.17%	293.80	1.77%	9,458.80	18.01%	3,865.00	10.40%
2004	8,902.90	2.56%	5,028.30	45.53%	3,400.20	62.55%	668.30	127.47%	10,130.20	7.10%	4,188.40	8.37%
2005	10,159.50	14.11%	4,857.10	-3.40%	3,394.50	-0.17%	537.20	-19.62%	11,741.60	15.91%	4,382.80	4.64%
2006	11,780.80	15.96%	7,516.00	54.74%	2,849.10	-16.07%	606.30	12.86%	14,441.20	22.99%	5,803.30	32.41%
2007	15,330.50	30.13%	7,081.30	-5.78%	4,818.70	69.13%	605.00	-0.21%	17,180.60	18.97%	8,637.60	48.84%
2008	23,001.30	50.04%	6,916.90	-2.32%	5,813.90	20.65%	549.20	-9.22%	26,723.50	55.54%	14,234.20	64.79%
2009	20,601.50	-10.43%	3,805.60	-44.98%	6,289.70	8.18%	486.00	-11.51%	35,694.40	33.57%	11,221.80	-21.16%
2010	20,948.00	1.68%	4,652.60	22.26%	6,389.30	1.58%	630.20	29.67%	38,598.10	8.13%	12,380.80	10.33%

	Telecommunications		General Building		Transportation		Petroleum		Others	
	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate	Revenue US$m	Growth Rate
2001	1,301.80	N/A	30,087.80	N/A	25,239.80	N/A	20,749.30	N/A	6,493.10	N/A
2002	1,858.00	42.73%	33,385.90	10.96%	28,727.50	13.82%	24,009.20	15.71%	5,051.70	-22.20%
2003	2,020.90	8.77%	35,527.50	6.41%	38,444.70	33.83%	26,107.70	8.74%	9,877.10	95.52%
2004	1,951.60	-3.43%	41,565.70	17.00%	44,042.90	14.56%	30,679.20	17.51%	16,928.80	71.39%
2005	2,255.00	15.55%	52,629.40	26.62%	50,875.80	15.51%	33,497.00	9.18%	15,082.40	-10.91%
2006	2,900.20	28.61%	59,431.90	12.93%	58,927.80	15.83%	45,084.30	34.59%	15,086.90	0.03%
2007	3,323.40	14.59%	73,955.00	24.44%	79,377.70	34.70%	80,039.90	77.53%	19,897.30	31.88%
2008	3,937.30	18.47%	94,067.60	27.20%	104,092.20	31.14%	90,837.80	13.49%	19,833.70	-0.32%
2009	2,685.80	-31.79%	85,988.30	-8.59%	112,342.00	7.93%	91,421.50	0.64%	13,244.90	-33.22%
2010	2,959.60	10.19%	83,026.40	-3.44%	109,007.20	-2.97%	89,320.80	-2.30%	15,749.30	18.91%

Table 2-3 Diversification of fields

	Industrial	Manufacturing	Sewer/Solid Waste	Hazardous Waste	Power	Water Supply	Telecommunication	General Building	Transportation	Petroleum
2001	5.57%	3.60%	1.35%	0.34%	7.02%	3.34%	1.22%	28.25%	23.70%	19.48%
2002	5.68%	2.87%	1.47%	0.25%	6.88%	3.01%	1.59%	28.66%	24.66%	20.61%
2003	6.21%	2.47%	1.50%	0.21%	6.77%	2.76%	1.45%	25.41%	27.50%	18.68%
2004	5.32%	3.00%	2.03%	0.40%	6.05%	2.50%	1.17%	24.82%	26.29%	18.32%
2005	5.36%	2.56%	1.79%	0.28%	6.20%	2.31%	1.19%	27.79%	26.86%	17.68%
2006	5.25%	3.35%	1.27%	0.27%	6.44%	2.59%	1.29%	26.48%	26.26%	20.09%
2007	4.94%	2.28%	1.55%	0.20%	5.54%	2.78%	1.07%	23.84%	25.59%	25.80%
2008	6.01%	1.81%	1.52%	0.14%	6.99%	3.72%	1.03%	24.60%	27.22%	23.75%
2009	5.37%	0.99%	1.64%	0.13%	9.30%	2.92%	0.70%	22.40%	29.27%	23.82%
2010	5.46%	1.21%	1.67%	0.16%	10.06%	3.23%	0.77%	21.64%	28.41%	23.28%
Average	5.52%	2.42%	1.58%	0.24%	7.12%	2.92%	1.15%	25.39%	26.58%	21.15%

Table 2-4 Percentage of each field in the overall international revenue of the top 225 international contractors

	Canadian			European			Australian			Japanese		
	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue
2001	7	3,148.90	3	55	62,526.10	58.7	2	856	0.8	17	8,667.90	8.1
2002	5	2,657.10	2.3	55	72,224.00	61.7	2	975	0.8	18	10,674.80	9.1
2003	6	2,686.20	1.9	54	83,301.20	59.6	2	943.5	0.67	19	12,504.30	8.9
2004	8	3,076.20	1.8	56	99,672.40	59.6	4	1570.2	0.94	18	14,555.10	8.7
2005	7	2,402.20	1.3	59	115,627.50	61	3	1260.3	0.67	17	16,026.90	8.5
2006	10	6,452.50	2.9	54	129,495.00	57.7	3	1737.9	0.77	15	18,753.50	8.4
2007	11	8,015.70	2.6	64	179,576.60	58	4	10,115.00	3.3	16	23,858.50	7.7
2008	13	11,409.80	2.9	65	212,635.00	54.5	4	12,123.50	3.1	15	24,612.00	6.3
2009	12	16,343.80	4.3	62	200,013.10	52.1	4	12,011.20	3.1	13	17,574.10	4.6
2010	11	18,313.20	4.8	67	201,064.70	52.4	4	10,431.50	2.7	13	15,568.70	4.1
	China			**Korean**			**Turkish**			**American**		
	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue	No. of firms	Int'l Revenue US$m	% of Total Int'l Revenue
2001	40	5,947.40	5.6	7	3,148.90	3	8	730	0.69	79	21,775.10	20.5
2002	43	7,128.90	6.1	5	2,657.10	2.3	8	778.5	0.67	76	18,903.90	16.6
2003	47	8,332.90	6	6	2,686.20	1.9	11	1291.4	0.92	66	26,645.50	19.1
2004	49	8,829.10	5.3	8	3,076.20	1.8	14	2,178.10	1.3	55	32,299.20	19.3
2005	46	10,067.90	5.3	7	2,402.20	1.3	20	3,693.30	1.9	52	34,837.10	18.4
2006	49	16,289.40	7.3	10	6,452.50	2.9	22	6,069.60	2.7	51	38,297.50	17.1
2007	51	22,677.60	7.3	11	8,015.70	2.6	23	8,506.20	2.7	35	42,735.00	13.8
2008	50	43,202.50	11.1	13	11,409.80	2.9	31	14,046.80	3.6	25	51,116.20	13.1
2009	54	50,573.30	13.2	12	16,343.80	4.3	33	14,114.30	3.7	20	49,732.80	13
2010	51	57,062.40	14.9	11	18,313.20	4.8	31	14,583.30	3.8	22	44,903.20	11.7

Table 2-5 Regional companies share of the international construction market from 2001 to 2010

2.2.3 International market sharing

With the dramatic increase of the overall international revenue of the top 225 international constructors from 2001 to 2010, different regional companies have developed differently. Part 2.2.3 will analyse the development of the companies in different international regions, including Canada, Europe, Australia, Japan, China, Korea and Turkey.

Initially this first discussion focusses on the countries where there were increases in market share. From 2001 to 2010, the total international revenue of the Canadian, Chinese, Korean and Turkish construction companies listed in the top 225 international contractors increased every year (refer to Table 2-5). At the same time, the percentage of these countries' construction companies' international revenue out of the total international revenue of the top 225 international contractors increased. In addition, the numbers of Canadian, Chinese, Korean and Turkish firms listed in the top 225 international contractors increased. In particular, the Chinese international contractors are taking more international revenue in the international construction market. China's share has increased from 5.6% in 2001 to 14.9% in 2010 (refer to Table 2-5). The number of Chinese firms listed in the top 225 international contractors has climbed from 40 in 2001 to 51 in 2010 (refer to Table 2-5). This result indicates the increasing influence of Chinese construction companies in the international market. The share of Canadian and Korean international contractors only climbed slightly. Though the share of Turkish international contractors increased dramatically with an increasing rate of nearly 500% from 2001 to 2010, it is only counted as 3.8% out of the total international revenue of the top 225 international contractors in 2010 (refer to Table 2-5). However, the number of Turkish construction firms listed in the top 225 international contractors list increased significantly from 8 in 2001 to 31 in 2010 (refer to Table 2-5). It represents the increasing power of Turkish international contractors in the international construction market.

The total international revenue achieved by the European, American, Australian and Japanese construction companies increased from 2001 to 2008 (refer to Table 2-5). However, from 2009, they started to decline. The number of companies listed in the top 225 international contractors for Europe increased; Australia remained relatively stable; and American and Japanese numbers fell from 2001 to 2010. Among them, the largest decline is the number of American international contractors, which decreased from 79 in 2001 to 22 in 2010 (refer to Table 2-5), representing approximately a rate of 70%. For the share of the total international revenue of the top 225 international contractors, only Australia increased, Europe, America and Japan all declined in these ten years. In particular, American firms' share fell from 20.5% in 2001 to 11.7% in 2010, which is the biggest drop among the top 225 contractors (refer to Table 2-5).

For the total international revenue of construction firms from each of the 8 regions, European companies shared about half the total international revenues of the top 225 international contractors, which is the highest in these 8 regions. Australian only accounted for 2.7% in 2010 and has the lowest market share (refer to Table 2-5).

Along with the emerging of developing countries' international constructors in the international market, for example, China and Turkey, the competition is becoming increasingly much more intense. The influence of these developing countries' construction firms has increased as their market share has increased.

2.2.4 Regional international construction market

The overall international market can be divided into 9 regional markets, including Canada, the U.S.A, Latin America, the Caribbean, Europe, the Middle East, Asia/ Australia, North Africa, and South and Central Africa, based on the ENR. Part 2.2.4 will explore the trends in theses 9 regional markets.

Firstly, the number of firms working in Canada, Latin America, Asia/Australia and the Caribbean remained relatively stable, and increased in the U.S., Europe, the

Middle East, North Africa, and South and Central Africa. This indicates that international constructors are involved in more and more regions to spread their business (refer to Table 2-6).

In addition, for the total international revenue achieved from these 9 regions, Canada, the U.S. and Europe increased from 2001 to 2008, and then decreased in 2009 and 2010. The Middle East is quite similar. It increased from 2001 to 2009, but decreased in 2010. All the other regions including Latin America, the Caribbean, Asia/Australia, North Africa, and South and Central Africa increased from 2001 to 2010. It could be said that the negative influence of the 2008 European financial crisis on the Canadian, U.S. and European markets is relatively serious. However, the negative influence on other markets is limited. To some extent, the financial crisis enhances the development of major construction companies in third world countries' markets, for example, Latin America and Africa.

From the perspective of the presentation of different regions' international revenue out of the total international revenue of the top 225 international contractors, the U.S., Latin America and Europe all declined from 2001 to 2010. However, Europe is still the largest regional market. America's decline is the largest, which is from 20.4% in 2001 to 8.5% in 2010 (refer to Table 2-6). On the other hand, Latin America, the Middle East, North Africa, and South and Central Africa increased in these ten years, while Canada is stable. Asia/Australia increased from 2001 to 2005 and then decreased from 2006 to 2010. However, the overall change is very little (refer to Table 2-6). It suggests that in this decade, more and more companies began to direct more attention to Latin American, Middle Eastern, and African markets.

	Canada			U.S.			Latin America		
	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $
2001	60	6,547.00	6.1	44	21,700.90	20.4	100	8,855.50	8.3
2002	53	4,464.60	3.8	45	23,113.30	19.8	89	8,123.00	7
2003	42	4,756.10	3.4	48	22,778.80	16.3	81	7,630.10	5.5
2004	37	4,962.60	3	52	22,795.40	13.6	80	7,399.00	4.4
2005	40	6,307.30	3.3	56	24,974.20	13.2	80	10,662.80	5.6
2006	42	7,990.70	3.6	54	29,130.10	13	86	13,622.80	6.1
2007	44	8,281.30	2.7	63	36,906.10	11.9	92	19,249.60	6.2
2008	43	13,402.00	3.4	60	41,759.50	10.7	85	21,761.90	5.6
2009	34	13,383.40	3.5	57	34,878.20	9.1	82	24,819.90	6.5
2010	42	13,003.20	3.4	61	32,612.90	8.5	N/A	30,425.20	7.9
	Caribbean			**Europe**			**Middle East**		
	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $
2001	59	1,772.10	1.7	123	28,248.90	26.5	108	8,538.60	8
2002	53	1,428.30	1.2	115	33,091.50	28.4	95	9,743.60	8.4
2003	49	2,251.10	1.6	112	46,659.30	33.4	101	16,455.60	11.8
2004	40	1,654.60	1	114	60,265.90	36.2	123	25,415.40	15.2
2005	41	1,414.50	0.7	124	68,584.00	36.2	120	28,155.40	14.9
2006	43	2,247.10	1	119	71,858.20	32	130	41,380.80	18.4
2007	38	2,007.20	0.6	136	96,448.80	31.1	141	62,894.90	20.3
2008	39	2,077.80	0.5	140	114,106.20	29.3	155	77,470.60	19.9
2009	40	2,292.50	0.6	135	100,806.60	26.3	157	77,557.00	20.2
2010	N/A	3,620.70	0.9	N/A	94,183.40	24.5	N/A	72,434.00	18.9
	Asia/Australia			**North Africa**			**South & Central Africa**		
	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $	No. Of Firms	Revenue US$m	% Of Total $
2001	146	21,978.30	20.6	79	3,376.90	3.2	77	5,442.40	5.1
2002	131	22,684.10	19.5	83	5,200.50	4.5	79	5,937.50	5.1
2003	135	26,029.50	18.6	81	5,517.20	3.9	89	7,138.20	5.1
2004	146	30,465.30	18.2	93	7,061.90	4.2	90	7,221.90	4.3
2005	157	33,781.30	17.8	91	5,912.50	3.1	85	9,226.60	4.9
2006	149	40,185.20	17.9	93	7,515.80	3.3	87	10,395.40	4.6
2007	155	55,399.50	17.9	114	13,174.60	4.2	82	15,420.80	5
2008	160	68,532.50	17.6	123	21,622.90	5.5	95	29,262.20	7.5
2009	149	73,183.10	19.1	132	27,520.90	7.2	103	29,290.70	7.6
2010	N/A	76,639.70	20.0	N/A	29,540.40	7.7	N/A	31,051.80	8.1

Table 2-6 Regional international construction market

2.3 Status and level in the international construction market

New trends have arisen in the international construction market from 2001 to 2010. However, it is difficult to say which country's construction industry performed better in the international market and how to improve the performance. Comparison between countries can help to identify the differences and help the participants and policymakers to understand the current situation of their construction industry in the international market and make appropriate strategies for further development. There are many sectors within an industry which can be compared across different countries. When the performance or position in the world is discussed, there are two kinds of measurement that are commonly used. The first type of measurement is the one-dimensional financial method. For example, GDP and GNP are commonly used to measure a country's development level, performance and status in the world. For the industry or firms, the measurement could be financial factors, like total revenue, international revenue, return on assets, return on sale (Loncan & Nique, 2010), this kind of one-dimensional measurement does not reflect the whole picture and could lead to misunderstanding (Sullivan, 1996).

The other measurement is called the complex method. All the aspects are compared separately. It is a comparison strategy to find the gap and differences in each element to generate an appropriate further development strategy (Wei & Han, 2002). However, this complex comparison cannot quantitatively measure all the elements and indicators they mention. In addition, this kind of comparison does not generate a standard in this field. It can only be used in small groups and samples. Also it is difficult to tell the real position of the sample among the participants in field, because this method does not provide a standard quantitative index or indicator. In this sense, a proper measurement for a certain country's construction industry's status and level in the international market is needed.

In order to avoid the limitations of one-dimensional and complex measurement methods, Zhang and London (2010) generate the International Advanced Index (IAI). The IAI is a quantitative measure and index system which can intuitively reflect the status and level of a certain country's construction industry in the international market and overcome the problems in one-dimensional and complex measurement methods successfully. The indexes in IAI can be summarised as:

- Depth Index (DI): is defined as the ratio of overall international revenue of all companies of the country to total international revenue of all the companies of all the countries;
- Height Index (HI): is defined as the quantity and quality of a certain country's top enterprises. It is not only measured by the ratio of the number of a certain country's enterprises in the top international constructors list, which is only the quantity issue. In order to consider the qualitative issue, a 'weight' index should be mentioned, which reflects the distinction between the different rankings in the top list;
- Width Index (WI): is defined as a certain country's enterprises' market involvement in different specialised fields of the construction industry. It is measured in terms of the average of the ratio of the number of specialised fields that each construction firm within a certain country is involved with to the total number of specialised fields within the construction industry. However, the specialisation and diversification strategies are two different development strategies and firms may be successful in adopting either strategy. In order to reflect this issue, a company listed in the top 10 of any specialised fields' influence in the international market is considered the same as a company involved in all the other fields of construction industry. This means that if there are 10 different fields in the construction industry and a company is only involved with one field, and is listed in the top ten of this field, the number of its involved fields will be counted as 10 instead of 1; and

- The IAI of a certain country's construction industry is the sum of DI, HI and WI.

This research will adapt the International Advanced Index to explore the improvement of the status and level of the Chinese and the Australian construction industries in the international market. Moreover, the fundamental of the status and level of a country's industry in the international market is productivity and industrial competitiveness. The following two parts will discuss them respectively.

2.4 Productivity

Productivity is a core index in economics. It can be used to measure the technical progress, economic efficiency, real cost control and production technology (Latruffe, 2010). It can be calculated by the ratio of an output performance indicator to an input performance indicator. Generally, there are two kinds of measurement for productivity, including Partial Factor Productivity and Total Factor Productivity. The Partial Factor Productivity only considers a single input in the ratio. The formula then for partial-factor productivity would be the ratio of total output to a single input, for example, labor productivity (output/labor), capital productivity (using machine hours or dollars invested), energy productivity (using kilowatt hours), and materials productivity (using inventory dollars). Labor productivity and capital productivity are the two most popular. Much research in relation to Partial Factor Productivity has been conducted in the construction sector. For example, as the labor productivity index in the construction industry is closely tied to output per unit of work, Thomas and Napolitan (1995) quantified effect changes in construction labour productivity and analysed effect changes impacting on labour productivity by a factor model. Allmon *et al*., (2000) explored the productivity changes in the construction production of the U.S. They presented a study on long term productivity and used a corresponding statistical analysis to indicate that there was a stable decline in the construction productivity of the U.S. in the last decades. Moreover, fuzzy logic and fuzzy expert systems that adopt actual construction project data could be suitable to model industrial construction labour productivity.

Capital productivity as another main Partial Factor Productivity could express a construction company’s financial management though its use has not been more extensive than labour productivity (Lowe, 1987). Industrial capital productivity associated with industry gross value added could be suitable to measure the degree of output growth from cost consumption (BFC, 2006), which means capital productivity can be measured for detecting the return on invested capital. After evaluating the capital productivity of Australian industries, Pink (2008) states that capital productivity could be impacted by technical efficiencies and technologies. Pink (2008) also presents that the Goods and Services Tax, introduced by the Howard Government in 2000, reduced the capital productivity level as the construction industrial output was affected.

Though many studies have been completed by adopting Partial Factor Productivity, this type of productivity measurement considered in isolation does not provide an overall indication of the industry. Therefore, an overall performance indicator, Total Factor Productivity (TFP) is generated and playing a very important role in economics and industry sectors. The Total Factor Productivity is grown from the concept of multifactor productivity, which is first introduced by Solow in 1957. The growth in TFP drove the long-run trend income per capita in an economy with an aggregate neoclassical production function. The measurement by using three-dimensional production functions including capital, labour and time variables is generated by using Solow’s theory. Dievert (1976) indicates that the translog index was superlative by presenting that it was exact for the homogeneous translog aggregator function, a flexible functional form which had been widely used in previous empirical economic research. In addition, Jornerson *et al.* (1987) combine relative TFP theories and economic phenomena to investigate the link of productivity and American Economic trends. Parham (2004) measures Australian industry productivity from the 1960s to the 1990s, to identify key sources of Australian productivity changes, commenting that productivity trends were associated with change in both labour and capital inputs. Grafton *et al.* (2004) use 27 countries' data to measure the relationship between TFP and social divergence defined in their papers, concluding that levels of social divergence vary inversely based on the levels of TFP and per capita income. Vial (2006) evaluates new elasticities of value added by adopting the Cobb-Douglas production function.

Numbers previous studies have focused on measuring total factor productivity levels in the construction industry. For example, Xue *et al.* (2008) used the DEA-based Malmquist productivity index (MPI) to measure the total factor productivity change of the Chinese construction industry from 1997 to 2003. The results of analyses indicate that the productivity of the Chinese construction industry experienced a continuous improvement from 1997 to 2003 except for a decline from 2001 to 2002. The level of productivity development level in different regions was discussed and the gaps between the western, midland, eastern, and northeastern regions were identified. Wang *et al.* (2013) also explored the Total factor productivity changes from 2006 to 2010 based on the DEA-based Malmquist productivity index and differences between different regions.

Tan (2000) studies the Total Factor Productivity of Singapore's construction industry by adopting the Tornqvist index method by integrating respectively input and output variables. Zhi *et al.* (2003) explore the change of the Total Factor Productivity of Singapore's construction industry from 1984 to 1997. Liu and Song (2005) develop a new input-output multifactor productivity measurement for the construction industry. After comparing the seven selected countries, Liu and Song (2005) found that the Australian construction industry's productivity did not show an escalating trend during the 1970s and1980s and present numerous factors, including technology progress and economics of scale, significantly affect construction industry productivity.

In addition, previous research has used the international productivity comparison between China's and other countries' construction industries (Chui, 2010) and Australia's and other countries' construction industries (Young, *et al*., 2008). However, the comparison between the Chinese and the Australian construction industries is still lacking.

2.5 Industrial competitiveness

The industrial competitive advantages could be gained by its industrial competitiveness (Porter, 1990). These competitive advantages determine the performance and success of the different industries of a country in the international market. In this sense, the determinant of a country's construction industry status and level can be considered to rely on the competitiveness of the country's construction industry.

Within the context of economic globalisation in the international market, every country tries to generate competitive advantage in the various fields in order to improve the international competitiveness of their products or services and expand their market share. Different researchers define the concept of industrial competitiveness differently. Zhao and Wen (2004) define industrial competitiveness as a country's specific industry's ability to be able to to meet product or service demands of the international market and gain profits continuously, and by its more advanced capacity and production efficiency compared with other countries in the free trade international market. Zhao (2004) suggests that industrial competitiveness is the industry's ability to obtain and utilize resources to participate in competition. Typically, industrial competitiveness emphasizes a country's certain industry's capacity for acquiring competitive advantage in the international market. The international competitiveness of the construction industry can thus be considered as the ability of a country's construction industry to achieve competitive advantage in international markets in order to provide better products and services, create added value and increase the wealth of the country (Di *et al*., 1992).

The research in relation to industrial competitiveness could retrospectively take us back to the explorations in international trade issues in the 18th century. Though there is no clear concept of industrial competitiveness, Absolute Cost theory (Smith, 1776), Comparative Advantage Theory (Ricardo, 1817), Factor Endowment Theory (Hecksche, 1919 and Ohlin, 1933), Human Capital Theory (Schultz, 1975), Technological Gap Theory (Posner, 1961) and Product Life Circle Theory (Vernon, 1966), are essentially all studies in the field of industrial competitiveness. It appears that the clear conception of industrial competitiveness is first presented in the USA in the 1970s. In 1980, the World Economic Forum began to investigate and discuss this area. The theory system of industrial competitiveness was formed in 1986 (Zhao & Li, 2007). In China, researchers in this area began with the cooperation between the State Commission for Restructuring the Economic Systems and World Economic Forum (WEF) and The International Institute for Management Development (IMD) in the study of international competitiveness of several Chinese industries in 1989. Following this, Di *et al*. (1992) were the first to research international competitiveness and the evaluation methods and index systematically.

2.5.1 Evaluation methods for industrial competitiveness

A number of correlative theories related to the evaluation of industrial competitiveness have been trialled, tested and adopted in recent years. Many evaluation methods and indexes for industrial competitiveness have been generated. Some of the evaluation methods utilise 'show-indicators' in the measurement of industrial competitiveness (Ark, 1990 and 1993; Gersbach & Ark, 1994; Gersbach & Baily, 1996; Mason *et al*., 1994 and Jorgenson & Kurod, 1992). For example, the principle of adopting the Productivity Method to measure industrial competitiveness is based on the Purchasing Power Parity (PPP) method instead of the Exchange Rate

Method to compare the industrial outcome between two countries in determining the international competitiveness at an industry level. There are two different operational techniques. The first one is founded by the Groningen Growth and Development Centre (GGDC) of the University of Groningen in Holland, and is referred to as the Approach of Origin. It is adopted in the manufacturing industry by many scholars (Ark, 1990 and 1993; Gersbach & Ark, 1994; Gersbach & Baily, 1996 and Mason *et al.*, 1994). The main process involves the following steps:

- Collect historical data of the manufacturing industry in the major and powerful countries. Re-classify and sort the data according to a uniform criteria.
- Use Approach of Origin to calculate the Purchasing Power Parity (PPP) for every country's manufacturing industry.
- Use the data to calculate Labor productivity, Total Factor Productivity and Unit Labor Costs.
- Compare between countries.

Another example is called the Approach of Expenditure and is based on the data of 153 groups of goods used to calculate the GDP Purchasing Power Parity (Jorgenson & Kurod, 1992). Jorgenson and Kurod (1992) presented this approach of generating Industrial Outcome Purchasing Power Parity in 1992. In addition to calculating the Industrial Outcome Purchasing Power Parity, this approach also calculates the Input Purchasing Power Parity.

Calculating the evaluation index by using import and export data is the other major approach to evaluating the industrial international competitiveness. The most commonly used key indicators in this type of method are: Revealed Comparative Advantage Index (RCA), Trade Competition Index (TC), Market Share (MS), the Terms of Trade index (TOT), Intra-Industry trade Index (IIT), Domestic Resource Cost Coefficient (DRC).

The ‘show-indicators’ measurement methods usually only reflect the phenomenon and present the results of the evaluation. The nature and reason for the phenomenon presented are typically not found or discussed (Pei & Wang, 2002) resulting in a significant gap in the development of targeted measures.

Multi-factor comprehensive evaluation method is another type of international competitiveness evaluation method typically used. Porter's Diamond Model is a typical example. It is an analytical indicator method whereby each element can be analysed and compared in order to achieve the targeted strategies. The analytical indicators reflect the explanatory variables which are the current competitiveness or the competitive potential. These indicators also reflect the variable factors which determine the competition results in the international market, and explain the reasons for the different competitiveness or competition results in the international market (Pei & Wang, 2002). Through this analysis, the analytical indicators can be divided into direct and indirect cause indicators.

There are three categories of direct cause indicators:

- productivity-related indicators, such as labour productivity, cost, price, firm size
- marketing-related indicators, such as brand names, advertising costs, distribution channels
- enterprise organisation and management-related indicators, such as after-sales service network and global quality assurance system

Indirect indicators can be derived from Porter's four elements for competitive advantage of nations. For example, from Porter’s Production Factors theory, the indicators which reflect the advanced production factors indicators include Technology Patents Index, Research and Development Cost and the Production Total Cost Index, the number of technical personnel and Workforce quality Index. From

Porter's theoretical model on the factors of corporate organisation, strategic and competitive aspects, many indicators can be generated including:

- Debt ratio Index, reflecting the operation risk
- Capital structure Index, reflecting the difficulty of accessing capital markets
- Industrial Scale Structure Index, classifying firm's size grade by the production capacity.

This research aims to identify the differences in industrial competitiveness between the Chinese and Australian construction industries and explore the ways to improve the performance of the Chinese construction industry based on the comparison. A multi-factor comprehensive evaluation method will be used. Porter's Diamond Model is a typical example of the multi-factor evaluation method and is also the most popular and complete competitiveness theory currently available for explaining the achievement of a country's industrial and firm's competitive advantage. Porter's Diamond Model will be adapted in the research.

2.5.2 Introduction to Porter's Diamond Model

The diamond model is an economical model developed by Michael Porter in his book *The Competitive Advantage of Nations*, where in 1990 he published his theory of why particular industries become competitive in particular locations. The approach explores clusters of industries, where the competitiveness of one company is related to the performance of other companies and other factors tied together in the value-added chain, in customer-client relationships and in a local or regional context. The Porter analysis comprised two steps. Firstly, clusters of successful industries have been mapped in 10 important trading nations. Secondly, the history of competition in particular industries was examined to clarify the dynamic process by which competitive advantage was created. The second step in Porter's analysis deals with the dynamic process by which competitive advantage is created. The basic method in these studies is historical analysis. The phenomena that are analysed are classified into six broad elements. Four of them are determinants and two are auxiliary elements. (Figure 2-1) These elements interact with each other to form a dynamic mode of competition. The four determinants are: factor conditions, demand conditions, the role of related and supporting industries, and a firm's strategy, structure, and rivalry. The auxiliary elements are chance and government. These six elements are now briefly summarised.

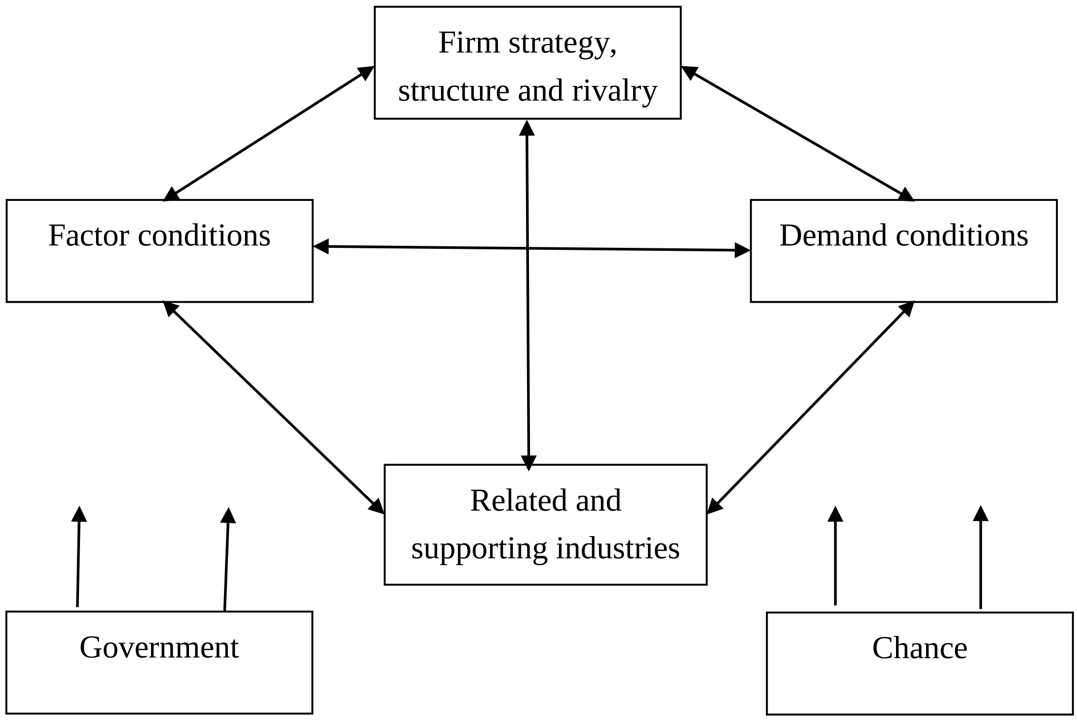


Figure 2-1 Porter's Diamond Model

Factor conditions refer to the production performance of a certain industry of the country. Production performance relies upon human resources, natural resources, knowledge resources, capital resources and infrastructure. The resources can also be categorised into basic and advanced factor conditions or general and specialised resources. Advanced and specialised resources are often specific for an industry and important for its competitiveness. Specific resources can be created to compensate for factor disadvantages, and factor conditions can influence the industrial competitiveness significantly. However, Porter believes that the mechanism to create factor conditions is much more important than owning the resources.

Demand conditions refer to the domestic demand of the products and services which are provided by a certain industry. Demand conditions in the home market can help companies create a competitive advantage, when sophisticated home market buyers pressure firms to innovate faster and to create more advanced products than those of competitors. Demand conditions can improve the industry's efficiency through the force of economies of scale. Meanwhile, the country's expected demand can lead to industrial competitiveness and market size and growth patterns can also improve industrial competitiveness.

Related and supporting industries provide a preponderant network for competitive advantage of nations. This network can be formed by a top-down spreading process. Related and supporting industries can also produce inputs that are important for innovation and internationalisation. These industries provide cost-effective inputs, but they also participate in the upgrading process, thus stimulating other companies in the chain to innovate. Therefore, related and supporting industries can play a role in influencing industrial competitiveness.

Firm strategy, structure and rivalry are the firm's organisation structure and management situation, and the performance of competitors in the domestic market. The way in which companies are created, set goals and managed is important for success, but the presence of intense rivalry in the home base is also important; as it creates pressure to innovate in order to improve competitiveness.

Chance can affect the four key elements. Chance can come from: inventions in basic science and technology; the emergence of disruption in traditional technologies; sudden increase in production costs (such as the oil crisis) caused by external factors; significant changes in financial markets or exchange rates; surge in market demand; major government policy decisions and war. These chance factors are important because they create discontinuities in which some gain competitive positions and some lose.

Governments can influence the supply conditions of key production factors, demand conditions in the home market, and competition between firms. Government interventions can occur at the local, regional, national or supranational level. However, governments should only provide the resources that firms need to create a good environment for the development of industry. Firms are the participants in industrial competition, not government. Firms are the main actors in creating a competitive advantage. Governments have a critical role to play in expanding the power of the diamond system. Governments should create new opportunities and reduce pressures within industries. The areas that governments should directly invest in are those in which firms cannot take strong global industry action, such as infrastructure development, opening up channels for capital and developing the information integration capabilities.

2.5.3 Evaluation and development of Porter's Diamond Model

After the introduction of the Diamond Model by Porter in 1990, it received widespread high level recognition by government, academia and industry. However, some scholars have had some doubts about this model and have thus queried it. In summary, it is believed that this model does not reflect completely the situation of a country's competitiveness in today's world. It has been claimed that the Diamond Model lacks formal model construction and expression by canonical economic language (Gray, 1991; Stopford & Strange, 1991 and Greenway, 1993) whilst others think this model offers nothing new (Gray, 1991; Bellak &Weiss, 1993; Dunning, 1992; Grant, 1991; Rugman, 1991 and 1993 and Thurow, 1990). In addition, some researchers suggest specifically that the key elements in the Diamond Model are not new (Dunning, 1993), and that they lack clear definitions (Grant, 1991; Thurow, 1990 and Dobson & Starkey, 1992). Furthermore, some scholars believe that the competitive advantages analysis framework is not derived and proven by a mathematical method (Waverman, 1995 and Greenway, 1993). The methodology applied by Porter has been resoundingly criticised (Bellak & Weiss, 1993; Jacobs & De Jong, 1992 and Narula, 1993). Though Porter's research achievement is applied and published in many countries, only very few scholars have tried to verify his theory (Rugman & D'Cruz, 1993; Öz, 1999 and 2002; O'Donnellan, 1994; Yetton, *et al,*. 1992; Van den Bosch & Van Prooijen, 1992; Cartwright, 1993; Moon *et al*., 1998 and Brouthers & Brouthers, 1997). It has been suggested that the lack of empirical testing is due to the difficulties in conducting a formal test on the Diamond Model (Öz, 2002).

Based on this, some scholars provide some suggestions for testing Porter's Diamond Model, and these approaches can be divided into two categories. Modifying the elements is the first approach. Stopford and Strange (1991) suggest changing the government to be the fifth determinant, not an auxiliary element, because of the disadvantages of developing countries. Öz (1999) finds that governments play a core role in the process of industry's development, after adopting Porter's Diamond Model to research the development process of Turkey's key industries. He states that governments should be a determinant for industrial competitiveness. This empirical work appears to verify Stopford and Strange's theory.

In addition, during the research in the process of global economic development, Dunning (1992) found that technological upgrading and the development of regional integration, countries' economic interdependence (especially the economically developed industrialised countries), as well as the interaction network between them, can affect the national competitive advantage in a great range. However, these elements are not considered by Porter in his Diamond Model. Dunning believes only focusing on 'home based' concepts is a limitation of Porter's Diamond Model. Porter (1985, 1990) suggests that the most effective global strategy is to centralise multinational activities to one country and that all the products and services should be provided by one exporter. This method does not consider the actual complexity of the operations of industries and the economy as a whole. Dunning (1992) holds that with the development of globalisation there could be a network between countries and that multinational enterprises can join the network both in the home country and abroad. Though effectively employing the different resources in different areas, the multinational enterprises can improve the home country's completive advantages. Therefore, Dunning (1993, 2000, 2003) treats multinational activities as an exogenous variable that should be added to Porter's model. In addition, Cho and Moon (2000) state that in today's global business environment, multinational activities represent much more than just an exogenous variable and that it should be a determinant.

Furthermore, in research into the competitiveness of New Zealan, Cartwright (1993) found that there are some concerns related to Porter's model in explaining the competitive advantages of countries with small economies that have a high degree of export-dependence and resource-based industries. Porter's model suggests that the determinants of competiveness are found from the domestic market, and ignores the international market. However, a country such as New Zealand has many industries that have a significant dependence on export. Without an international market, these industries are not able develop continuously. In order to deal with this issue, Cartwright (1993) added five new off-shore variables to Porter's model: capture of off-shore factor creation, linkage to related and supporting industries in the off-shore environment, access to demanding customers and rivalry in off-shore markets, and the extent to which the industry has international goals and structures.

Double diamond is the second approach to develop Porter's Diamond Model. Rugman and D'Cruz (1993) uncovered some problems with Porter's Diamond Model in relation to the analysis of small open trading contraries, when they applied the model to the study of Canada's competitive advantage. Porter (1990) suggested that only direct investment to foreign countries can increase competitiveness, and that the Foreign Direct Investment received by a certain country can not do that. However, Rugman and D'Cruz (1993) state that both the direct investment to foreign countries and the Foreign Direct Investment received by a certain country can increase the competitiveness. Safarian (1968), Rugman (1980) and Crookell (1990) prove that foreign owned firms and Canada local firms have the same power to influence competitiveness, because the Canadian domestic market is very small and more than 70% of its products are exported to the United States of America (U.S.). After the implementation of The Free Trade Agreement between Canada and the U.S., Canadian firms realised that the American market is not only an export source, but that effectively they are in the American Diamond Model and compete with American firms directly. In order to survive in competition with the U.S. firms, the Canadian firms have to integrate the Canada Diamond Model and the U.S. Diamond Model. Based on this finding, Rugman and D'Cruz generated the Double Diamond Model in 1993 (Figure 2-2).

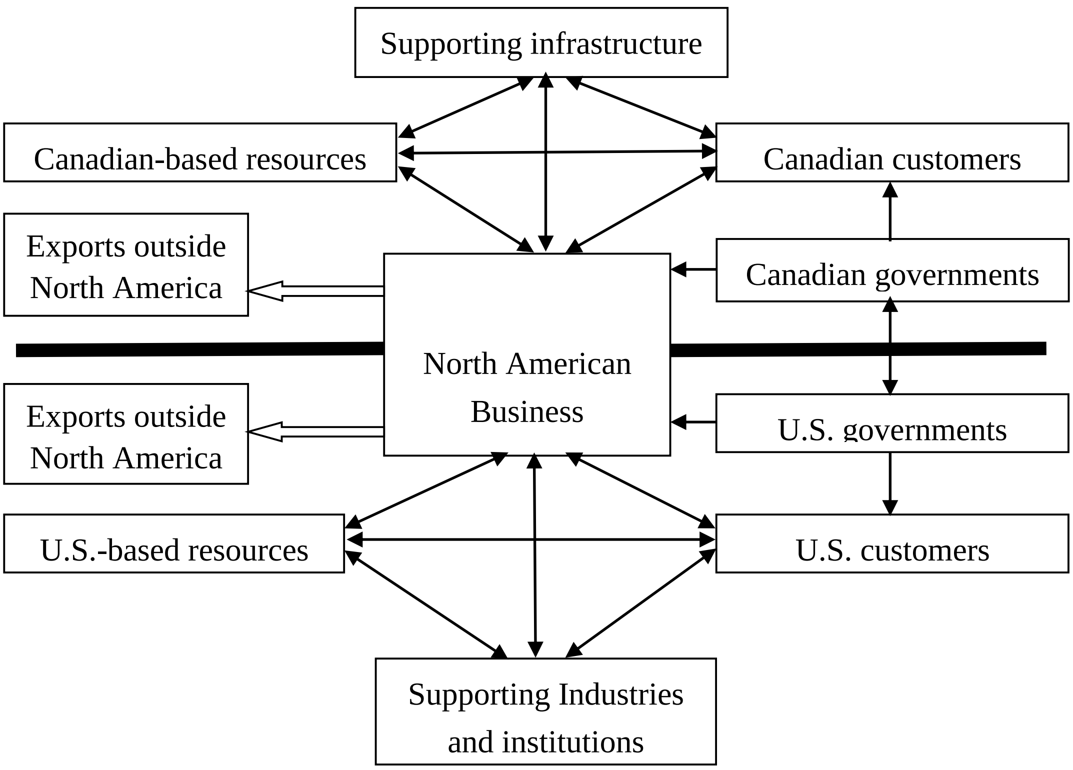


Figure 2-2 The Double Diamond Model

Source: Rugman, A.M. & D'Cruz, J.R., 1993, 'The "Double Diamond" Model of International Competitiveness: The Canadian Experience', Management International Review, Second Quarter, 1993; Vol.33, Iss.2, P.17—39

In addition, after applying the Diamond Model to analyse Korea and Singapore, Porter (1990) stated that Korea's future is very optimistic and claimed that Korea will achieve a 'developed' status in 10 years. He suggested that Singapore's future is pessimistic. However, the fact is that Singapore is much more successful than Korea. Therefore, Moon *et al.* (1998) believe Porter's model may not be applicable to various small-sized economies and based on this conclusion, they modified the Diamond Model and generated the Generalized Double Diamond Model.

Porter's Diamond Model has been improved by various scholars in different ways. However, the refinement of the model can continue. Another very important theme in today's world has not been considered – the concept of sustainable development. The research on the relationship between industrial competitiveness and sustainable development is lacking and is now considered.

2.5.4 Introduction to sustainable development

The conflict between human activities and nature and in terms of how increasing human activity is threatening the survival of nature has intensified in recent years. The concerns surrounding the future of humanity and the planet have led to the conception of sustainable development. Since the 1970s, 'sustainability' has been employed to describe an economy 'in equilibrium with basic ecological support systems' (Stivers, 1976). Daly (1973) indicates that a steady state economy should be built up in order to address environmental concerns. The United Nations (1987) defines sustainable development as 'development which meets the needs of the present without compromising the ability of future generations to meet their own needs'. In addition, the United Nations 2005 World Summit Outcome Document refers to the concept of sustainable development as one which focusses on social, cultural and economic issues in addition to environmental issues (World Health Organization, 2005). Sustainable development involves harmonisation of three key areas: sustainable economy, sustainable ecology and sustainable society. It requires us to pay attention to economic efficiency, ecological harmony and social justice during the development process. Although sustainable development originates from a focus on environmental protection, it has moved beyond environmental protection as a guide for human existence into the future. In this sense, sustainable development includes economic sustainable development, environmental sustainable development and social sustainable development.

Firstly, economic sustainable development is reflected in the encouragement of sustainable development through sustained economic growth. This means that economic growth should not be hindered for the sake of environmental protection because economic growth is the foundation of national strength and social wealth. However, sustainable development is not only concerned with the 'quantity' of economic growth, but also the 'quality' of economic growth. The quality of sustainable development can be reflected through technology innovation, efficiency improvement, resource savings and waste reduction (Allen, 2007).

Secondly, environmentally sustainable development is another bottom line (Hasna, 2007). It requires the development of the economy and society to be coordinated with natural carrying capacity of our earth's systems. Development has limits. No limit ultimately means no continuous development (Hasna, 2007).

Finally, from the perspective of social sustainable development, sustainable development emphasises social equity and is a mechanism to achieve the goal for environment protection. Various parts of the world are in different stages of development with different goals. However, the nature of development should include the improvement of the quality of human life, the level of health and creation of a social environment which should guarantee equality, freedom, education and human rights. This means that in the system of sustainable development, economic sustainable development is the basis, environmental sustainable development is a condition and social sustainable development is the goal (Allen, 2007; Hasna, 2007 and SUS.DIV, 2010).

Based on these three aspects of sustainable development, scholars have discussed the principles and requirements of sustainable development (Fang & Fang, 2007; Yang, 1999; He, 2000; Liu, 1996 and Bi, 1997), which can be summarised as:

- Common Development

  The earth is a complex 'giant' system. Every country or region is an integral subsystem of this system. The most fundamental characteristic of the system is integrity. Every subsystem is interrelated with another subsystem. If problems occur in one subsystem, the other subsystems can be directly or indirectly affected and the whole system can be affected. Therefore, the purpose of sustainable development is common development.

- Coordinated Development

  Coordinated development is the overall coordination of the three systems: economic, social and environmental. It also involves coordination at the space level: world, country and region. In addition, it involves the coordination of a country or region's economy with its population, resources, environment and society.

- Equitable Development

  Equitable development consists of two latitudes. The first element is time, whereby current development should not destroy the future generations' capacity to develop further. The second element is space which denotes that the development of a country or region should not destroy other countries or regions' development capacity.

- Efficient Development

  Equity and efficiency are the two wheels of sustainable development. The concept of efficiency in sustainable development can be referred to in both the economic sense and from a natural resources and environmental perspective.

- Multi-dimensional Development

  While globalisation is worldwide phenomena occurring in all parts of the world, the development level of different countries varies depending on a number of factors such as culture, system, geography and international environment. Multi-mode multi-dimensional choice sustainable development seeks to cater for this diversity in culture, geography, etc. to achieve a comprehensive and global sustainable development which is accepting of different geographical entities

In summary, sustainable development is a pattern of resource use that aims to meet human needs while preserving the environment so that these needs can be met in the present and also for future generations. Sustainable development ties together concerns for the carrying capacity of natural systems with the social challenges facing humanity. Sustainable development has attracted growing attention and is now a frequently encountered theme in today's world. It could affect the future of human beings and the planet. Sustainable development ties together concern for the carrying capacity of natural systems with the social challenges facing humanity.

2.5.5 Sustainable development and industrial competitiveness

Sustainable development is closely related to the social and economic fields. Industrial competitiveness is an important concept in the economic world thus should not be separated from sustainable development. Sustainable development can influence all the elements in Porter's Diamond Model for industrial competitiveness.

Sustainable development can affect the factor conditions through the implementation of various policies which require the reconsideration of human, natural and capital resources. The efficiency in terms of how resources are used can determine the success or achievement of sustainable development.

Sustainable development requires setting up an Ecological Model, which would include the ecological production process, the ecological economic operation mode and the ecological consumption mode. Ecological consumption mode can affect the demand conditions. Therefore the changes in demand conditions need to reflect the characteristics or needs of firms. New technology may be required to develop new products or change production operation processes. The concerns of sustainable development involve determining how to meet the need for achieving more effective and efficient products and processes.

Firms typically need to change their strategy (such as their objectives from one primarily centred on achieving economic goals to one more focussed on the sustainable development perspective), structure (such as new units/departments/suppliers/customers), and rivalry (from competitive mode to competitive-cooperative mode) in order to achieve the goals of sustainable development. Given that firms are the main actors in economic activities which in turn form a large part in the process of achieving sustainable development, firms can play a significant role in driving change in the achievement of sustainable development.

One of the key characteristics of sustainable development is systematism. Systematism implies that the changes in one element within the system can cause changes to occur to other elements. In this sense, sustainable development can influence related and supporting industries. As a consequence, the related and supporting industries are also the subsystems for achieving sustainable development whereby the development approaches and situations within these subsystems can also affect sustainable development.

Government, as the policy maker, typically determines the achievement of sustainable development at a high level, through the development and implementation of industry policy, environment policy and new product standard. And sustainable development provides government a measurement method for the results of policies.

Sustainable development can affect the chance factor in the following ways:

1) reducing the frequency of war and disasters and their destructiveness ;
2) increasing the possibility of innovation in basic science and technology;
3) reducing the possibility of the emergence of disruption in traditional technologies, and the sudden increase in production costs.

Therefore, sustainable development should be considered to be one of the elements for industrial competitiveness. After adding it into the system of industrial competitiveness, the definition and contents can be reshaped. Due to the importance of sustainable development, sustainable development should be one of the determinants.

Moreover, as one of the most popular topics in the construction industry, sustainable development of the Chinese construction industry is a widely held concern by academics, industry participants and policymakers in China. There are three elements included in sustainable development. They are economic sustainable development, environmental sustainable development and social sustainable development. These three aspects are interdependent and interact within a unified system. Systems thinking should be conducted to explore the dynamic and complex interrelationship among these three elements within the unified sustainable development system. The next section will discuss the concepts systems thinking.

2.5.6 Systems thinking

Systems thinking can be considered as the process of understanding how different parts of a system influence one another within the whole system (Juan, 2008). It is often defined as an approach to problem solving, by viewing ‘problems’ as parts of an overall system, rather than reacting to specific parts, outcomes or events. Responding to specific parts, outcomes or events can potentially contribute to further development of unintended consequences (Juan, 2008). Systems thinking can provide a better understanding of an entire phenomenon in relation to specific changes within a system. Spruill *et al.* (2003) believe that a major part of systems thinking theories arose from mathematics. However, the application of systems thinking and the related progress can be noticed in a variety of disciplines ranging from medicine to engineering, psychology, political studies and even the humanities and arts as well. Systems thinking enables the perception of reality from many different points instead of one with the concept of a ‘closed circle’ thinking originating from mathematics. It is also a principle in biology, the principle of homeostasis which is a tendency of biological systems to resist changes and to maintain a balance. This concept of systems trying to come back to some form of a balance after a change, event or shock to the system can also be found in control and communication theories and the theory of cybernetics (Skarzauskiene, 2010).

Effective systems methodology lies at the intersection of the following four principles of systems thinking: holistic thinking, operational thinking, interactivity and self-organisation (Ackoff, 1999; Gharajedaghi, 2006 and Maani & Maharaj, 2004).

Holistic thinking refers to a focus on the whole through systems logic and process orientation. Seeing the whole requires understanding structure, function, process and context at the same time. The systems approach enables the linking of objects of various types to a single whole, to organise different forms of activity into one whole. The basis of every successful system is successful communication between the separate parts. In human behavioural systems the effective development of this organisation can be achieved when various strategies, strategic planning, team work and organisational change principles are applied. Technical aspects are combined with the aspects of personal behaviours (personal mastery and intellectual models) and conceptual behaviours (Ackoff, 1999).

Operational thinking (dynamic thinking) refers to the conception of the system using the principles of systems dynamics. Systems dynamics involves evaluation of the multi-loop feedback systems, identification of the delay effect and barriers of growth, mapping stock and flow, etc. These principles can create an additional value for managing an organisation as business systems are interdependent. Reasons for system failure are searched for both internal and external to the organisation given the fact that an effect in one place of the system may cause an effect in another place – this should cause neither fear nor surprise (Maani & Maharaj, 2004).

Interactivity in systems thinking is a way of thinking about how to interact within and ‘design’ the system; that is to pursue a design of the desirable future and work towards its implementation. Ackoff's (1999) ‘interactive design’ is both the art of finding differences among things that seem similar and the science of finding similarities among things that seem different. Two distinct outputs of interactive design are defining problems (Formulation of the Mess), and identifying the leverage point and designing solutions (Idealisation). Interactivity, as opposed to those acting reactively or proactively, is when we mainly pay attention to the problem, its formulation and the search for a solution. Interactive design is based on the principle of a critical thinking that is defined by these steps: defining a problem, gathering information for problem solution, formulation of hypotheses, checking presumptions and correctness of findings, and then developing a solution. Interactive design involves a constant critical assessment, continuous learning and understanding of mental models. This dimension of systems thinking is based on intuitive thinking and stimulates creativity and provides an organisation with a foundation to create a unique competitive advantage. Interactive design seeks to broaden the thinking area and develops the openness of mind which leads to an opportunity to use the freedom of experimentation. Basically, this creative process can produce neither right nor wrong decisions, since the decision-making process becomes a unique one. The original seeing of the world creates preconditions for original decisions.

Self-organisation is a movement towards predefined order. 'Biological systems self-organize through genetic codes, and social systems self-organize through cultural codes. The DNA of social systems is their culture' (Gharajedaghi, 2006). Self-organising, purposeful, socio-cultural systems must be self-evolving in order to be viable. They cannot passively adapt to their environments but should co-evolve with them and be able to change the rules of interaction as they evolve over time.

> *'Capitalism is by nature a form or method of economic change and not only never is but never can be stationary ... It is not price competition within a static set of production methods and organizational forms which counts but the competition from the new technology, the new type of organization – competition ... which strikes not at the margin of the profits and the outputs of the existing firms but at their foundations and their very lives'* (Schumpeter, 1994).

Success comes from a self-renewing capability to spontaneously create structures and functions that fit this moment. The ability to continuously match the portfolio of internal competencies with the portfolio of emerging market opportunities is a foundation of a concept of new business architecture (Gharajedaghi, 2006).

Furthermore, according to Skyttner (2006), the systems thinking approach incorporates several tenets, including interdependence of objects and their attributes, holism, goal seeking, inputs and outputs, transformation of inputs into outputs, entropy, regulation, hierarchy, differentiation, equifinality, and multifinality.

The previous research in the Chinese construction industry mainly focused on the individual parts or issues and therefore did not undertake a systems thinking, especially for the interactivity principle. The interrelationship among the indicators/factors was not concerned by most of them. The typical logic of them is 'if an element of the system does not perform well, this element should be improved directly' (Hao & Wang, 2005; Yang *et al.*, 2006; Shen *et al.*, 2004; Xu *et al.*, 2005; Cheah & Chew, 2005; Mayo & Liu, 1995; Schüler-Zhou & Schüller, 2009 and Luo & Gale, 2000). This logic may be useful in the short term. However, if systems thinking is used in order to improve the performance of a element for a long term point of view, stimulating the element directly may be not the best way and it may be better to improve other elements in the long term. This research will adapt systems thinking to analyse the sustainability of the construction industry and indicators included in sustainability.

2.5.7 Internationalisation Sustainable Development Competitiveness Model

The Double Diamond models, which are particularly suited for smaller sized export-dependent and resources-dependent countries are not appropriate for many larger developing countries such as China, India and Brazil. Cartwright's (1993) model and Duning's (1993) model explain the internationalisation issues in industrial competitiveness. In particular, the activities of multinational enterprises (MNEs) are suggested by Duning whereby MNEs can also be one of the determinants. Further, for a developing country, Stopford and Strange (1991) suggest that the government should be the fifth determinant, not an auxiliary element. Building upon the past work of Duning and Stopford and Strange, a new model for the evaluation of industrial competitiveness is generated (Figure 2-3), which is the Internationalisation Sustainable Development Competitiveness Model (ISDC Model).

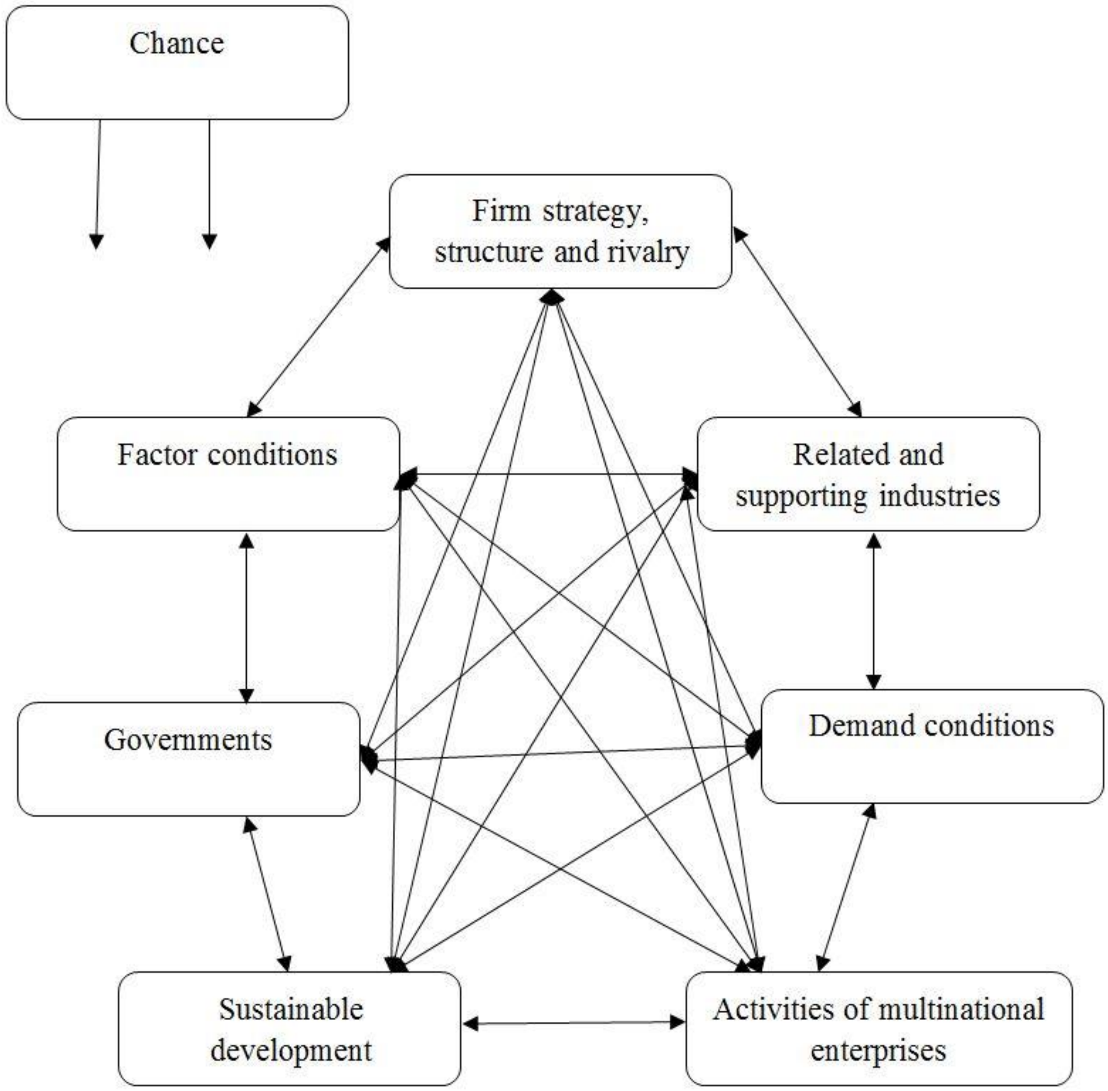


Figure 2-3 The Internationalisation Sustainable Development Competitiveness Model

The Internationalisation Sustainable Development Competitiveness Model (ISDC Model) is composed of eight elements: factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of Multinational Enterprises and sustainable development. Chance is the only accessorial element while all the others are determinants.

2.6 Research Questions and Summary

The Chinese construction industry plays an important role in the national economy. Over the next few decades, the Chinese construction industry can help to solve the many projected issues, including economic growth, environment protection and resources reservation, urbanisation progress, countryside development and employment for migrant workers. With the development of globalisation and internationalisation, the Chinese construction industry has become more active in the international market. Understanding the current situation and the gap with developed countries could help the Chinese construction industry to formulate future development strategies. Two research questions are proposed, including:

> *What is the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010?*

> *What are the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?*

This chapter is organised in four parts. Firstly, the trends of the international construction market from 2001 to 2010 are discussed. Secondly, this chapter reviews the literature about the measurements of a country/industry/firm's status and level in the world and provides the International Advanced Index to be used in this research. Next, discussions on productivity and industrial competitiveness of the construction industry and systems thinking are presented. The Internationalisation Sustainable Development Competitiveness Model (ISDC Model) is generated for the evaluation of industrial competitiveness.

Chapter 3 Model Development and Description

3.1 Introduction

Porter's Diamond Model has been re-formed as the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) to meet the trends of internationalisation and sustainable development in Chapter 2. The ISDC Model is composed of eight elements: factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of multinational enterprises and sustainable development. The measurement for each element of the ISDC Model is needed. In particular, the model represents the first time that the sustainable development element has been considered within the context of industrial competitiveness. The element of government is not new; however, its status has been changed. In addition, the element of activities of multinational enterprises was not a part of Porter's Diamond model previously. There are thus three 'new' elements which are introduced through the ISDC Model. The other five elements have already been discussed extensively by various scholars and the associated measurement methods are very clear. Therefore the following sections will describe the three new elements in detail.

3.2 Sustainable development

A number of sustainability assessment frameworks have been used to evaluate a firm's performance (Guo & Zhao, 2009). However, sector wide sustainability performance measures have had less attention. Some countries and international organisations also develop indicators for measuring sustainable development (Department of Environment, Food and Rural Affairs, UK, 2005 and United Nations 1996). The aims of these efforts have been to improve both information and communication on the state of sustainable development. These indicators are helpful in the decision-support and policy-making processes used to make progress towards sustainable development. However, some of the indicators in these index systems are difficult to locate. At times it may require several years and a large amount of information gathering. In addition, these indicators should be revised according to different industry characteristics.

Towards this, Guo and Zhao (2009) provide the 'four levels' indicator system to measure the sustainable development of the Chinese construction industry. This indicator system provides policy makers with an overview of the level of sustainable development of the construction industry from different perspectives. However, it is proposed that there are a number of problems related to these indicator systems including; category confusion, inappropriate sub-index and over-reliance on economic indicators which ignore the social and environment indicators.

A sustainable development index system was generated to measure the construction sector by Zhang and London in 2011, which considered the nature of construction industry, data availability and other performance indicator systems which have been proposed previously, as well as Guo and Zhao's (2009) four levels indicator system. This Sustainable Development Index is composed of three main categories, including Economic Sustainability, Social Sustainability and Environmental Sustainability and four aspects, including Development Level, Development Efficiency, Development Potential and Resource Consumption and Environmental Benefits. A multidimensional sustainable development indicator system is thus proposed.

One of the important factors that has a far-reaching impact on the construction industry is Occupational Health and Safety (OHS). 'Creating a safe work environment is critical to the success of your business, and is one of the best ways to retain staff and maximise productivity' (Business.gov.au, 2012). Many scholars have studied the importance of OHS and the ways to create safety climates and improve the levels of safety performance (Cooper & Phillips, 2004; Tharaldsen et al., 2008; Neal & Griffin, 2006 and Lingard *et al*., 2011). OHS has not been included in the sustainable development of the construction industry in previous research, including Guo and Zhao's (2009) four aspects indicator system and Zhang and London's (2011) Sustainable Development Indicators System of Construction Industry. It is reasonable to include OHS in the social sustainability index of the sustainable development indicators system. OHS could be measured by the number of deaths on site and number of accidents on site per billion dollars of gross output value of the construction industry.

The Chinese construction industry will be compared with the Australian construction industry in this research. Therefore, the development index system should be suitable for both countries. It should be universal and be applicable to international cross country comparison. However, it will be tested for these two countries in the first instance. As some data for indicators are not available in both countries, the index system has to be revised. For example, for the number of deaths on site and number of accidents on site per billion dollars of gross output value of the construction industry, the data of the Chinese construction industry is missing. Although some data after 2006 could be found from the website of the Ministry of Housing and Urban-Rural Development of the People's Republic of China (MOHURD), this data is confined to the housing construction works in urban areas. The data for other fields of the construction industry and the housing construction works in rural area is not included. Therefore, these indicators will not be studied in this research.

In this research, the Sustainable Development Indicators System for the Chinese and Australian construction industries is generated as Figure 3-1. In this system, the sub-indexes in each main category are:

1) Economic Sustainability
   A. Gross Output Value of Construction Industry

B. Labour Productivity in terms of gross value added of the construction industry
C. Profit margin
D. Gross Domestic Product (GDP)
E. Gross fixed capital formation

2) Social Sustainability
A. Disposable Household Income
B. Number of persons with a non-school qualification per thousand people

3) Environmental Sustainability
A. Construction Waste / Gross Output Value (GOV) of Construction Industry
B. Energy Consumption / Gross Output Value of Construction Industry

The sub-indexes in each aspect include:

1) Development Level
A. Gross Output Value of Construction Industry

2) Development Efficiency
A. Labour Productivity in terms of value added
B. Profit margin

3) Development Potential
A. GDP
B. Gross fixed capital formation
C. Disposable Household Income
D. Number of persons with a non-school qualification per thousand people

4) Resource Consumption and Environmental Benefits
A. Construction Waste / GOV of the Construction Industry
B. Energy Consumption / GOV of Construction Industry

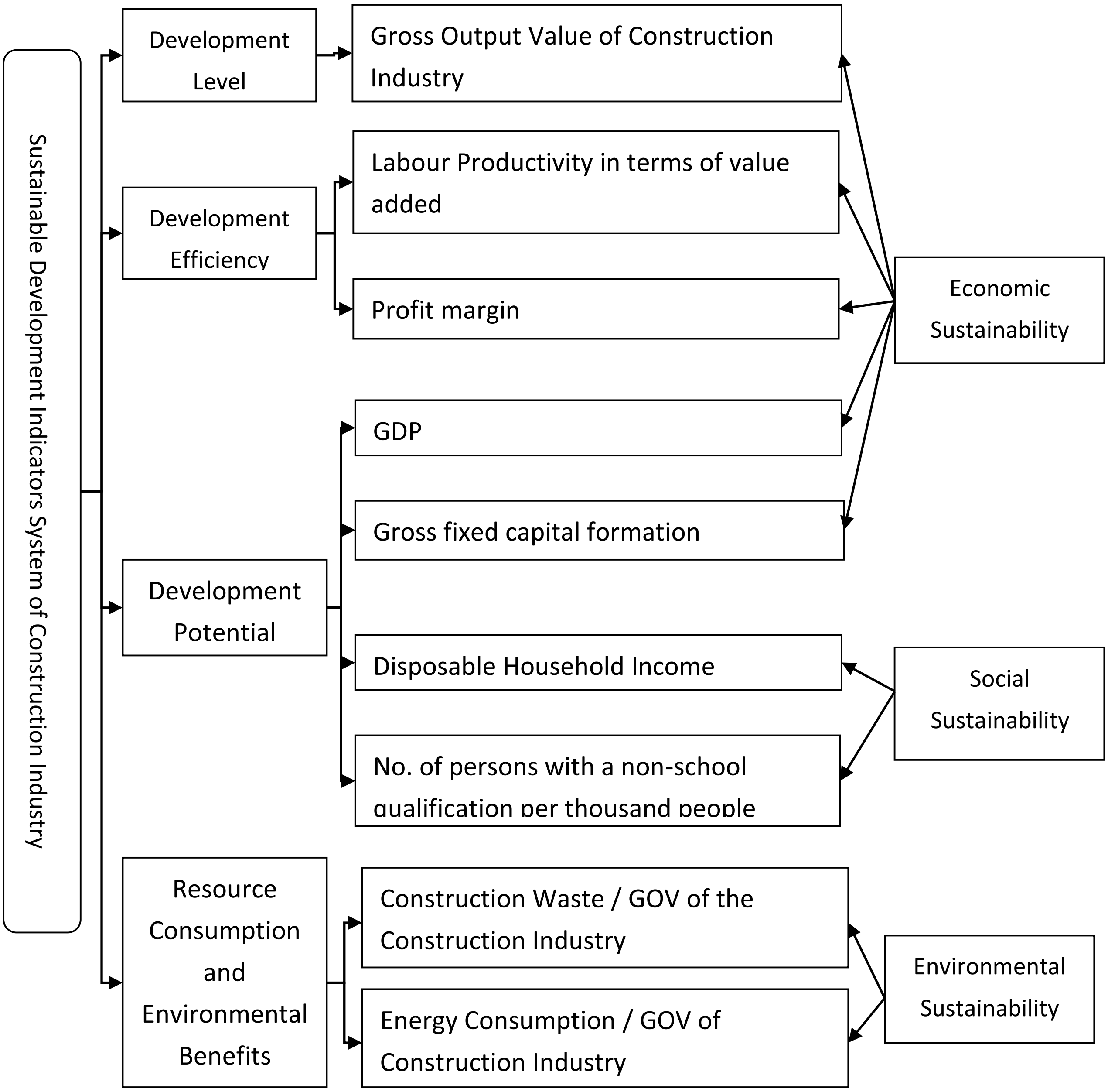


Figure 3-1 Sustainable Development Indicators System for the Construction Industry

Sustainable development in the construction industry is an important issue. A multidimensional measurement has been generated based upon a consideration of the various methods for measuring sustainable development in the construction industry. This method of measurement ensures clarity of the classification, and reflects the characteristics of the construction industry's sustainable development from different perspectives. Furthermore, this measurement method broadens the application of the measurement by facilitating inter-country comparisons of the construction industry's sustainable development performance. It can also be used to analyse the coordination between the main aspects including: economic sustainability, social sustainability and environmental sustainability.

3.3 Government

Even though the government element is not new and has been included in Porter's Diamond Model, its application has been modified from being a determinant to be considered an auxiliary element in the Internationalisation Sustainable Development Competitiveness Model. Some researchers have previously raised the need to consider the government element as an auxiliary element (Stopford & Strange, 1991). However, these researchers have tended to discuss the application of the government element either theoretically or qualitatively in terms of competitiveness. There has been little discussion around the government element in a quantitative manner and therefore a quantitative method for measuring this element is lacking. When the performance of government is discussed, 'productivity' would be a widely recognised measurement.

Both profit and non-profit organisations are constantly seeking to improve their efficiency and productivity in order to survive in an intense and competitive climate. Improvements in efficiency form the basis for achieving improvements in productivity. By measuring efficiency policy makers can develop a better understanding of how resources can be allocated more effectively, which is also an important issue in modern organisational management (Wu & He, 2008).

Productivity is one of the most popular concepts discussed in the governmental and academic communities currently. Government officials appeal to improve government departments' productivity whilst economists advocate improving enterprises' productivity. Scholars and businesses constantly stress the importance of productivity.

In the past, productivity has tended receive attention beyond the private sector. Since the 1970s, the community has demanded government agencies improve their productivity. In the 1973 Harvard Business Review, an article entitled ‘The real productivity crisis is in government’ was published, which has become a thought-provoking warning to government officials and public administration scholars worldwide. Since the mid-1980s there has been increased pressure on governments in industrialised countries to constrain spending and improve budget outcomes. This has necessitated that the public sector improve its productivity by adopting more efficient practices in service provision. This can be done in one of two ways, either by maintaining the level of inputs while increasing outputs, or by maintaining output levels while reducing inputs. The details of productivity and its measurements will be discussed in Chapter 4.

Put simply, productivity is the reflection of output to input. When discussing productivity of government, how to identify the output and input is an important question. Firstly, for the input, the most popular and widely recognised factors are labour and capital. Most of the time, these factors are easy to determine. However, the output is always complex. In order to find an acceptable way to identify the output for government administration services, it is necessary to explore the various activities that governments undertake. The significant influence governments of can be found at the local, regional, national or supranational level. However, according to Porter (1990), governments should provide only the resources that firms need, in order to create a good environment for the development of industry. If the government performs appropriate activities and develops effective policies, then better performance and high industrial competitiveness can be achieved by the industry. Government should create a good environment for the continuous improvement of industrial competitiveness, for example, making the appropriate industrial product or service standard and affecting customers demand conditions. In addition, the activities of governments should help to generate and improve the high level and professional factors. In contrast, if the government is deeply involved in the market competition, even monopolising the construction industry, the competition in the domestic market will be repressed. Therefore, in the Internationalisation Sustainable Development Competitiveness Model, input will be measured by the labour and capital and output will be measured by the results of these activities including:

1) Fostering advanced factors –reflected by the number of persons with a non-school qualification per thousand people
2) The competition degree in the domestic market –reflected by the number of construction firms
3) The performance of non-State-owned companies –indicated by the Gross Output Value of the non-State-owned construction companies.

3.4 Measurement for activities of multinational enterprises

The element of activities of Multinational Enterprises was first suggested to be included in Porter’s Diamond model by Dunning. Dunning (1993) states that multinational enterprises (MNEs) are very important participants of the international economy. MNEs can help their home countries to achieve many advantages, including locational, ownership and internalisation. Active multinational enterprises can bring benefits and advantages to their home countries (Dunning 1992 and 1993). In this sense, the more involved in the international or global market MNEs are, the more significant are the impacts of the activities of MNEs on industrial competitiveness. Therefore, the degree of internationalisation of construction multinational enterprises should be used to measure this element.

However, this element is new for Porter’s Diamond Model. The quantitative test is still missing to support the statement that the activities of the multinational enterprises could impact the improvement of the construction industry’s competitiveness and hence to improve the performance of an industry in the international market. This research will test it by exploring the relationship between the degree of internationalisation and a construction firm's financial performance and the relationship between the degree of internationalisation and the construction industry's performance at the country level.

A number of specific functional forms have been suggested to describe the relationship between the degree of internationalisation and performance, such as the U-shaped curve, an inverted J-curve, an S-shaped curve and an open-V shaped curve. A pattern of 'local minima-inflection point-local maxima' in the relationship between the degree of internationalisation and financial performance is suggested by some of the theories of foreign direct investment. These theories highlight another abnormality occurring beyond the threshold of internationalisation. According to Hymer (1976), when firms increasingly invest in dissimilar markets, competition (difficulty of dislodging better positioned rivals), commitments (increased capitalisation of overseas operations), contingencies (adjusting transaction protocols for different market structures), complexities (how to internalise activities), and constraints (insufficient capital and human resources) arise. These factors increase the disadvantages of foreignness, with the consequence of diminished financial performance for the internationalised firms (Caves, 1982). With further internationalisation, the profitability of the internationalised firms is reduced as a result of strategic and organisational factors. As a result, multinational enterprises experience stagnant growth in mature markets with obsolete technologies, which hamper innovation (Buckley & Casson, 1985 and Caves, 1982). The diseconomies of managing overly-large operations organisationally increase administrative costs and reduce the timeliness of decision making (Bartlett & Ghoshal, 1989). Geringer *et al.* (1989) study the relationship between a multinational enterprise's financial performance and its degree of internationalisation over the five year period 1977-1981. The paper measured financial performance by using the average Return on Sales (ROS) and Assets (ROA), and average of foreign subsidiaries' sales to total sales for the degree of Internationalisation. Means and frequency analysis showed that financial performance exhibited increased values as the degree of internationalisation of a multinational enterprise increased, until a point beyond which performance weakens. The study found that an inverted-J pattern exists between the degree of internationalisation and firm performance.

Sullivan (1994) subscribes to theories of metamorphic transformation (Chandler, 1962), periodic reorientation (Mintzberg & Waters, 1982), and gestalt reconfiguration (Miller & Friesen, 1980), proposing that internal change is necessary in internationalisation. Existing organisational structures will fail to fit the new global environment as expansion activities are implemented. This results in diminishing corporate performance with an increasing degree of internationalisation. In view of this threat, firms are obliged to restructure the organisation (Benito & Welch, 1997). Successful restructuring activities restore firm performance and they progress to the 'convergence phase' (Tushman & Romanelli, 1985). The mechanism outlined above leads to a U-shaped relationship between the degree of internationalisation and firm performance. In addition, Hitt *et al.* (1997) state that managerial experience with complex business environments is an intangible asset used to maintain superior performance at a high degree of internationalisation. In their study, they found a standard-U curve only for companies with little or no product diversification, but an inverted-U shape for firms with moderate product diversification. Their findings suggest that properly managed firms may not always experience declining performance with a higher degree of Internationalisation. Thus, successful management during the reorientation period will enable firms to restore positive performance development. This is in contrast to Sullivan's viewpoint that firms are not destined to experience declining performance after the threshold point.

Furthermore, Rieck *et al.* (2005) clarify that the relationship between the degree of internationalisation and firm performance should be an open-V shape. Statistical analysis of data from 51 companies in the top 100 telecommunication firms in the financial year ending 2003 largely confirmed the conjecture (Rieck *et al.*, 2005). The inverted open-V relationship implies that firm performance increases with initial expansion until a point where the marginal firm performance decreases with higher levels of degree of internationalisation. This suggests that it may be more advisable for firms to slow down their rate of international expansion at a certain point.

Much research has been conducted on the relationship between degree of internationalisation and performance. However, some concerns and problems should be noted. Firstly, a majority of the past work in this area has tended to explore the findings without distinguishing the different industries (Sledge, 2007). Different industries may have different characteristics and therefore different results when comparing the degree of internationalisation and performance. Some scholars have acknowledged this problem and have conducted research in specific industries such as manufacturing (Zeng *et al.,* 2008), telecommunication (Rieck *et al.*, 2005), banks (Slager, 2005) and ceramics (Pereira *et al.*, 2009). However, there is less research on the construction industry. Furthermore, most of the past researchers have adopted an approach whereby historical data sets from various years are gathered and then horizontally analysed (Hitt *et al.,* 1997). None of these past studies have vertically studied different firms, industries or countries in the same period of time.

In addition, another very important problem with the past research in this area is the weakness associated with the models or measurement indicators to describe the relationships between degree of internationalisation and industry performance. A large percentage of the existing models use a one-dimensional measurement for the degree of internationalisation and industry performance. Even though some models use several indicators for measurement, such as Tobin's Q (Rieck *et al.,* 2005), the ratio of foreign sales over total sales and foreign assets with total assets (Loncan & Nique, 2010), Return on Sales (ROS) and Assets (ROA) (Geringer *et al.*, 1989), these indicators are all simply related to financial performance. Furthermore, most of the previous research has typically been focused at the firm level to explore the relationship between degree of internationalisation and firms' performance. As a result there has been a lack of discussion and debate surrounding the relationship between degree of internationalisation and industry performance at the national level. Given that this research focuses on the comparison of the performance of the construction industry at the country level, the degree of internationalisation needs to be measured at the country level.

3.4.1 Previous research

The measurement of degree of internationalisation at either the firm or country level has evolved over recent decades. The early researchers adopted unidimensional measurement methods, such as performance measurement (Vernon, 1971; Stopford & Dunning, 1983, Daniels & Bracker, 1989 and Riahi-Belkaoui, 1998), structural measurement (Stopford & Wells, 1972) and attitudinal measurement (Perlmutter, 1969). Various scholars have since raised concerns about adopting the unidimensional measurement method (Ramaswamy, 1992; Ramaswamy *et al*., 1996; Sullivan, 1996; Bagozzi *et al*., 1991; Nunnally, 1978; Bollen 1989; and McDonald & Marsh, 1990). The concerns can be summarised in terms of the method's lack of rigour in the specification and operationalisation of the concept of internationalisation.

There have been various attempts to develop a multidimensional measurement for internationalisation. It is useful to consider these measurements and develop insights, so that a unique construction industry measurement can be developed. Ramaswamy (1992) provides a multidimensional conceptualisation of degree of internationalisation measurement, which consists of three independent factors: Scope (activities pursued abroad), depth (the ratio of foreign assets to total assets, and foreign sales to total sales), and dispersion (the number of foreign countries' firms involved). Sullivan (1994) as well as Kennelly and Lewis (2002) present another measurement which is comprised of five variables: foreign revenue to total revenue, overseas subsidiaries to total subsidiaries, foreign assets to total assets, psychic dispersion of international operations and top management's international experience.

In addition, Tong (2000) provides another model to measure the degree of internationalisation of a firm, which includes six factors: pattern of international business management, financial management, marketing, human resource management, management structure, and the transnationality index. The transnationality index has been adopted by the United Nations (2001) which takes the average of three ratios: foreign assets to total assets, foreign revenue to total revenue and foreign employment to total employment to evaluate multinational corporations (United Nations, 2001).

Most of the methods developed have been used for measuring a firm’s degree of internationalisation in various industries in a generic manner. However, different industries have different and unique characteristics, and for this reason it is more beneficial to generate a measurement method which is tailored to suit the unique characteristics of the construction industry. In relation to internationalisation, the characteristics of the construction industry are mobility of foreign assets based on project locations, one-off project nature and heavy involvement of local work force (Ofori, 2000).

‘Eclectic paradigm’, established by Dunning in 1977, is the traditional measurement method which is used most widely in analysing the international products/services and the multinational enterprises. The eclectic paradigm identifies four key facts that affect the international process of firms including the structure of the organisation, ownership advantages (or O-advantages, including trademark, production technique, entrepreneurial skills, and returns to scale), locational advantages (or L-advantages, including the existence of raw materials, low wages, special taxes or tariffs) and internalisation advantages (I-advantages, the advantages from producing through a partnership arrangement such as licensing or a joint venture) (Twomey, 2000). Further to this, Low and Jiang (2003) refine the method through simplification and quantification of the theory based upon the nature of international construction activities to generate an OLI-S model to determine a firm's degree of internationalisation. Low and Jiang (2003) then generated the first three indexes including O-IRTR, L-IBD and I-OMS, They also added 'Specialty' to the model, and generated the fourth index: S-ISF. Finally, by the sum of these four indices, the Overall Internationalisation Index (OII) was generated, which is used to reflect a firm's Degree of Internationalisation (DOI) intuitively (Low & Jiang, 2003).

Low and Jiang's (2003) OLI-S model is based upon the premise that a firm which is involved in more specialised fields achieves better performance in their internationalisation process. However, specialisation and diversification are two different types of development strategies. Both of these strategies can lead to organisational success and the next section will discuss these two marketing strategies in detail.

3.4.2 Specialisation

Following a strategic analysis of an organisation's external environment and internal conditions, as well as determining its strategic goals, an appropriate growth path needs to be chosen to ensure its success. Diversification and specialisation can be considered as two different approaches to achieve business growth. The decision on which approach to employ is particularly critical, however, it is also complex and therefore is worthy of further exploration.

Firstly, specialisation refers to the operations and activities of businesses that mainly focus on a single business sector or specialised business field (Kang & Ke, 1999). Specialisation could enable companies to make full use of their resources and capabilities by focusing on a specialised business field to improve efficiency, increase economic efficiency and reduce total costs (Li, 2002). In addition, specialisation can be conducive to the development of economies of scale and can also help companies achieve a competitive edge in specific product lines or target markets (Yin *et al*, 1999). Furthermore, the cohesion force of specialisation is useful to resist enterprises' internal risks (Xu & Zhang, 2006).

Alternatively, there are also some concerns associated with the specialisation marketing strategy and these can be summarised as two key issues. Firstly, the capacity of any industry and any market is always limited. Market expansion is limited by the capacity. In addition, each industry or product has its own life cycle. After reaching a specific period of maturity, industries and products tend to shrink or even disappear. Secondly, industries or products which are highly matured tend to offer little added value and average profit margin to businesses. There is no industry that could continue getting high profits. In this sense, industry upgrade becomes a key strategic issue to consider (Zhu, 2006).

3.4.3 Diversification

According to Xu and Zhang (2006), the diversification marketing strategy refers to the business strategy of organisations which are involved with several industries and a variety of products simultaneously. It involves the expansion activities of firms which are at a certain stage of their business development aimed at achieving long-term growth. Diversification has also been described as a marketing strategy that businesses produce when delivering more than one type of commercial product or services at the same time (Zhang, 2004). The diversification marketing strategy was first adopted in Western developed countries in the 1930s. Nearly all the businesses in these countries were moving in multiple directions (Martin & Sayrak, 2003). By the end of the 1960s, the number of businesses which adopted a diversification marketing strategy accounted for 93.8% of the number of total businesses in the U.S. In Japan a total of 83.5% of all businesses had adopted the diversification marketing strategy by the mid-1970s, and in South Korea the figure was over 91% by the end of 1980s (Martin & Sayrak, 2003).

Calori and Harvatopoulos (1988) state that there are two dimensions of rationale for utilising the diversification strategy. The first rationale for using the diversification strategy is related to an organisation's strategic objectives whereby diversification can be seen to offer either a defensive or offensive approach for organisations seeking to grow and maintain their business success. Organisations are forced to diversify when seeking to spread the risks associated with market contraction of their current product offering or when the market seems to provide no further opportunities for growth,. Organisations which are forced to diversify are considered to be adopting the defensive approach to diversification (Calori & Harvatopoulos, 1988). On the other hand, the offensive approach is undertaken when companies seek to conquer new positions, take opportunities that promise greater profitability and expansion opportunities, or use retained cash that exceeds total expansion needs (Calori & Harvatopoulos, 1988).

The second reason why organisations diversify is related to the expected beneficial outcomes resulting from diversifying. Management often expect to achieve great economic value (growth, profitability) or greater coherence in terms of their current activities (exploitation of know-how, more efficient use of available resources and capacities) as potentially resulting from their diversification efforts. In addition, organisations may also explore the use of the diversification strategy as a way to obtain a valuable comparison between this strategy and others such as the expansion strategy (Calori & Harvatopoulos, 1988).

3.4.4 Diversification strategies

In contrast with the corporate strategy of specialisation, diversification enables companies to increase their profitability by achieving greater sales volume by offering new products and entering new markets. There are several ways that businesses can adopt the diversification strategy including through internal development of new products or identification of new markets, acquisition of another firm, development of alliances with complementary companies, licensing of new technologies, and distribution or importation of product lines manufactured by other firms. In addition, these methods are usually used synthetically. An organisation's diversification strategy can be developed based upon existing available opportunities as well as consistency with the objectives and the resources of the company.

In general, there are two different types of diversification strategies. The first one is called relevant diversification strategy. It refers to the resources which are shared between an original business and its expanded business whereby there is a strong correlation in product, technology or market between them (Xu & Zhang, 2006). Diversification strategies could be divided into two types. The first one is called concentric diversification, which means that there is a technological similarity between the industries. Therefore, firms with unique technical expertise are able to leverage their technical know-how to gain some advantage over the other firms which are largely similar in terms of technological capacity and, in turn, product or service offering. Such an approach to diversification also enables an organisation to increase its market share by launching a new product line which in turn contributes to the company's profitability. Organisations may seek new products that have technological or marketing synergies with existing product lines which at the same time are appealing to a new group of customers. This also helps the company to access that part of the market which remains untapped, and which presents an opportunity to earn profits (Li, 2002).

The second type of diversification strategy is the horizontal diversification approach, which means that a company may add new products or services that are often technologically or commercially unrelated to current products but that may appeal to current customers (Xu & Zhang, 2006). In a competitive environment, this form of diversification is desirable if the present customers are loyal to the current products and if the new products have a good quality and are well promoted and priced. Moreover, the new products are marketed to the same economic environment as the existing products, which may lead to rigidity and instability. In other words, this strategy tends to increase the firm's dependence on certain market segments. Horizontal integration occurs when a firm enters a new business (either related or unrelated) at the same stage of production as its current operations (Li, 2002 and Matsusak, 2001).

Yet another type of diversification strategy is the irrelevant diversification strategies, which is also called conglomerate diversification or lateral diversification (Grant *et al*., 1988). Under this form of diversification strategy, a company markets new products or services that have no technological or commercial synergies with current products but that may appeal to new groups of customers (Jain, 1997). The irrelevant diversification strategy has very little relationship with a firm's current business operations. Therefore, the main reasons for an organisation adopting such a strategy would be firstly to improve its profitability and flexibility, and secondly to obtain better capital returns from markets as the company grows (Yin *et al*, 1999).

3.4.5 Benefits and concerns of diversification strategies

As a widely used corporate strategy, diversification can bring many benefits to organisations. Firstly, through diversification organisations can improve their efficiency in terms of resource allocation to maximise returns. Furthermore the cooperation and sharing of resources between business units may lead to synergies being generated among units, which can in turn be helpful for the formation of economies of scope as well (Zhang, 2004). Secondly, diversification may help enterprises improve their external adaptability to deal with the uncertainties of market demand (Li, 2002). Another beneficial outcome resulting from the diversification strategy is that it enables enterprises to obtain or improve their core competitiveness (Yin *et al.*, 1999).

According to Ansoff (1957), there are four main growth strategies including: 1) market penetration, which refers to a firm seeking to achieve growth through their existing product offering within their current market segments, which is ultimately aimed at increasing its market share; 2) market development, which involves a firm seeking to achieve growth by targeting its existing product offer to new market segments; 3) product development, which refers to a firm developing new product offerings targeted at its exiting market segment; and 4) diversification, which involves a firm growing by diversifying into new businesses through the development of new product offerings for new markets. In addition, Ansoff (1957) states that diversification is different from the other three growth strategies. Market Penetration, Market Development and Product Development strategies are usually pursued using the same technical, financial, and merchandising resources used in the operations of an organisation’s original product line. However, the diversification strategy usually requires a company to acquire new skills, techniques and facilities. In this sense, diversification can be considered the riskiest of the four strategies and therefore requires the most careful investigation prior to adoption (Ansoff, 1957).

The diversification strategy has been derived from the practice of Modern Portfolio Theory on business activities (Xu & Zhang, 2006). Based upon Modern Portfolio Theory an organisation’s portfolio can comprise of more than one form of financial assets. Through this diversified form of portfolio management investors are provided with the opportunity to spread the risks associated with the reliance on individual securities by holding a variety of different securities (Shipway, 2009). However, some of the common risks associated with securities are inevitable (Amenc & Le Sourd, 2003). In this sense, the diversification strategy may not be able to resist the economic cycle and industry risks (Xu & Zhang, 006).

The diversification strategy can also reduce direct contact between the units, which can contribute to a reduction of the industry risks to a certain extent (Li, 2002). However, it can also lead to a significant increase in total cost. Diversification often means entry into a new field, which can lead to the need to expend high ‘learning costs' (Grant *et al*., 1988). Entering an unknown market with an unfamiliar product offering means a lack of experience in the new skills and techniques required. Therefore, the company puts itself in a position of great uncertainty. In addition, because of the lack of correlation between different units within an organisation, much higher management skills of entrepreneurs are required. Furthermore, although divisional organisation is implemented in some enterprises, asymmetry of information can still exist among business units and between business units and decision-making departments, which could dramatically increase the management and operational risks (Etgara & Rachman-Moorea, 2010).

Another important reason for enterprises to engage in diversification concerns the need to spread business risk. However, through an organisation's efforts to spread risks by adopting the diversification strategy, organisational resources can also be distributed across various business units (You & Daigler, 2010). Given that organisational resources are typically always limited, further distribution of limited resources into various business sectors can lead to difficulties in individual business units obtaining adequate resources (Xu & Zhang, 2006). The overall size of the enterprise with diversification strategy may be very big. However, it may be difficult for individual sectors to achieve economies of scale.

Another problem associated with over-diversification is the difficulty in developing a characteristic management, which can be a disadvantage for companies in competition with other businesses which have adopted the contrasting specification strategy. Furthermore, a diversification strategy requires organisations to expend a large amount of money which in most organisations is often not readily available and can be supported only with difficulty from internally accumulated funds. Therefore, external financing is typically sought. An extensive use of loan funds for industrial investment and to facilitate company operations will inevitably increase an organisation's debt ratio. Large debts can become a heavy burden for organisations since they are highly dependent upon the international and domestic financial environment because changes occurring in the financial environment can lead to disastrous consequences (Grant *et al.*, 1988). Therefore, a firm needs to choose this option only when the current product offering or current market orientation does not offer further opportunities for growth.

3.4.6 Specialisation vs. diversification

In summary, based upon the discussion presented in the previous sections, there is perhaps not a clear answer in terms of which of the two types of corporate strategies an organisation should adopt. Both of the strategies can lead to organisational success in the domestic and international markets (Yin *et al.*, 1999). A key to choosing between the two strategies is to consider the specific situation in question in terms of organisational characteristics and capacity and market conditions. In the case where an organisation lacks remaining resources and has limited management capability, the organisation should adopt the specialisation strategy. When the technology of an enterprise places them in a leading position within the industry and there is still plenty of room for market expansion, the firm does not need to adopt the diversification strategy (Kang & Ke, 1999). However, if the industrial cycle has not reached maturity, or if there are still opportunities to continue to expand the market in the industry, the most effective strategy is to continue focusing on the current industry to consolidate and enhance the market leading position. If the product has achieved maturity in the market, upgrading or achieving technical innovation may help the product transfer from its current life cycle to a new one. Should internal input be saturated, or good investment opportunities emerge and enough resources have been accumulated, the firm should begin to implement the diversification strategy.

3.4.7 Reformative OLI model

Low and Jiang's OLI-S model states that the diversification strategy may offer a better opportunity for enterprises to develop and be involved in the international market. However, both the diversification and specification strategies may help enterprises occupy more market share and achieve increased profits in both domestic and international markets as presented by Low *et al.* (2004)

> *'In some cases, the more diversified technical specialties a firm possesses, the more,business shares it may obtain. However, in some other cases, the international strength of a firm can be pursued through extremely strong specialty advantages in just a few specialized fields…'* (Low *et al.*, 2004)

Due to the S-ISF's emphasis on the significance of diversification unilaterally, its adoption can mislead measurement and the associated results.

Through a combination of Low and Jiang's (2003) improvement and a removal of the S-ISF concept, this research will develop a 'reformative OLI model' (ROLI Model) to measure the degree of internationalisation of construction enterprises at a firm level. The Average O-IRTR (A-O), Average L-IBD (A-L), Average I-OMS (A-I) and Total DOI (T-DOI) indexes will also be generated to measure the degree of internationalisation of construction enterprises at a country level. In summary, the indexes included in the ROLI Model are:

- O-IRTR, defined as the ratio of international revenue to total revenue (O-IRTR). According to Sullivan (1994) a company's international revenue includes the first-order indicators for its involvement in international business. The level of international revenue is a very important factor to estimate the degree of internationalisation of a firm (Buckley, *et al.*, 1977, Stopford & Dunning, 1983, and Daniels & Bracker, 1989).
- L-IBD, defined as international business distribution (L-IBD), and measured in terms of the ratio of the number of countries in which the firm has worked in a particular period to the number of countries in which the firm may have the potential to work.

- I-OMS, defined as the overseas management structure (I-OMS), and measured in terms of the ratio of the number of overseas subsidiaries and associates to the total number of such affiliates.
- OII, defined as the overall internationalisation index of a firm, and measured by the sum of O-IRTR, L-IBD and I-OMS.
- A-O, defined as the level of O-IRTR for a country, and measured by the average of O-IRTR of a country.
- A-L, defined as the level of L-IBD for a country, and measured by the average of L-IBD of a country.
- A-I, defined as the level of I-OMS for a country, and measured by the average of I-OMS of a country.
- T-DOI, defined as the degree of internationalisation at a country level, and measured by the sum of A-O, A-L and A-I.

3.5 Measurements for other elements

Measurements for factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries have been elaborated by Porter and other scholars. These various elements have been extensively explored and the manners in which they have been used are largely accepted by the research community.

According to Porter (1990 and 2000), factors can be divided into two types: basic factors and advanced factors. Basic factors refer to natural resources, climate, geographical location, non-skilled workers and capital. Advanced factors include modern communications, information, transportation infrastructure, a workforce with high education levels and research institutes. Porter (1990) points out that demand can be satisfied more easily through the global market network and that demand for basic factors is continuously decreasing. The importance of advanced factors in obtaining competitive advantage is unquestionable. Advanced factors can only be achieved through sustainable investment of substantial human resources and capital. For example, senior research training and education programs for fostering the advanced factors require the employment of advanced personnel. Therefore, a high level of production factors is difficult to obtain from the outside. In this sense, this research will pay more attention on the advanced factors, which will be indicated by the investment in R&D and the number of persons with a non-school qualification per thousand people.

Domestic demand is the driver for industrial development (Rodrik，2007). It is often easier for local companies to identify and attract customers in the domestic market compared to foreign competitors. This is supported by Porter (1990) who argues that the globalisation phenomenon has not reduced the importance of the domestic market. In addition, Porter also pointed out that the specific demands and characteristics of local customers are very important, particularly when it comes to experts and discerning customers. A country’s companies’ competitive advantage can be stimulated through the critical level of local customers demand for high-quality products and services which are recognised as the best in the international community (Porter, 1990). Another important aspect to consider is the expected demand. If the local customers’ needs are ahead of other countries, this can be seen as an advantage for local companies because advanced products require the demand and support of avant-garde needs. This research measures the element of demand conditions through the size of the domestic market, and the demand growth rate in the domestic market.

There is an interdependent relationship between an industry and other industries in which it competes with and receives support from related industries. Porter’s research drew attention to the phenomenon of ‘industrial clusters’ (Porter, 2000). An industry does not function on its own and must be associated with other industries. Local suppliers are an indispensable component of the innovation process and contribute towards the improved performance of industries (Wang, 2004). Another key component for driving innovation and achieving improved performance is the promotion of competition between industries (Porter, 2000). Central to this is an identification of the specific industries which are interrelated and the interdependencies. Therefore this research will seek to identify the industries which have an interdependent relationship with the construction industry. This will be conducted through an analysis of the construction industry and its interdependent industries in Australia and China in order for a comparison to be made between the two countries. The productivity and some general indicators will be compared.

Firm strategy, structure and rivalry are the firm's organisation structure and management situation, and the performance of competitors in the domestic market. Porter (1990) pointed out that the drivers of internationalisation for enterprises results from the pull of international demand, the pressure of local competitors or the thrust of market. Child and Rodrigues (2005) state that there are a number of factors which are particularly relevant to internationalisation by Chinese firms, refers to Table 3-1.

Drivers	Facilitators
• Hazard of relying on a highly competitive domestic market, with low margins. • Opportunities to export based on domestic cost advantages. • Potential to complement domestic cost advantages with differentiation advantages acquired abroad. • Need to secure and develop advanced technology and internationally recognised brands. • Desire to gain entrepreneurial and managerial freedom.	• Strong governmental support for globalisation, especially financial backing and tolerance of domestic moves (such as M&A) that build corporate strength. • Ability to reach a favourable accommodation with government, so as to combine support with strategic freedom to act entrepreneur ally, raise capital abroad, etc. • Access to state-supported scientific and technical research. • Willingness of foreign firms to sell or share international-standard technology, know-how, and brands.

Table 3-1 Drivers and facilitators of internationalisation by Chinese firms

A highly competitive domestic market has been highlighted as a key driver. This is supported by Porter who believes that the most dominant factor for creating a sustainable competitive advantage for an industry is the existence of strong domestic market competition. Through internationalisation domestic firms are forced to compete with international firms and vice versa, which in turn contributes towards the achievement of improvements and innovations in the industry. In this sense international markets can be seen as an extension of domestic market. 'Super Star Enterprise', which has no powerful domestic competitors under the protection of government, usually does not have international competitiveness (Porter, 1990). This research will measure this element by estimating and analysing the industrial capital structure and market structure (e.g. industrial concentration).

Furthermore, among these eight elements, chance can be considered as the most non-representational element. As described in Chapter 2, chance refers to happenstance, such as inventions in basic science and technology, the emergence of disruption in traditional technologie, a sudden increase in production costs caused by external factors, significant changes in financial markets or exchange rates, a surge in market demand, major government policy decisions and war (Porter, 1990). This element is something which is beyond the control of firms and governments. This research will not discuss this element.

3.6 Summary

The discussion in Chapter 2 highlighted the need to develop an appropriate method for measuring the industrial competitiveness of the construction industry. The Internationalisation Sustainable Development Competitiveness Model (ISDC Model) was developed in response to the gap in past models and methods of measurement related to internationalisation competitiveness. There are three 'new' elements in the ISDC Model, including sustainable development, the activities of multinational enterprises and the re-positioned government.

This chapter proposes the Sustainable Development Indicators System of the Construction Industry to measure the sustainable development element which built upon past work in this area and took into consideration the purpose and operability of research and the characteristics of construction industry. The productivity of government is also introduced to measure the government element. In addition, the activities of multinational enterprises will be measured by the degree of internationalisation of the construction enterprises at country level. The ROLI Model is generated to measure the degree of internationalisation of construction enterprises at the firm and country level through a combination of Low and Jiang's (2003) improvement and removal of the S-ISF.

Chapter 4 Methodology

4.1 Introduction

This chapter describes and discusses the ontological, epistemological and methodological issues in this research. The boundaries in ontological, epistemological and methodological frameworks are becoming increasingly blurred. More and more studies have accepted the statement that frameworks for research studies are not dichotomous. The research studies and the approaches, which encompasses the ontology, epistemology and methodological assumptions, may lie along a continuum or at least a number of choices, such as Creswell’s (2003) Quantitative, Qualitative, and Mixed Methods Approaches, Chang’s (2004) System Science Approaches, Morgan and Smircich’s (1980) continuum of research paradigms and tripartite model of positivism/post-positivism, interpretive/constructivism and emancipatory approaches, and Knupfer and McLellan’s (1996) Descriptive research methodologies.

Ontology and epistemology to research are what ‘footings’ are to house: they form the foundations of the whole edifice. Some scholars believe there is no need to worry about such footings as this is best left to philosophers and the like, who have time to dwell on the theories of being and knowledge. However, in this research dissertation a different view has been taken. The necessary thing is to know the core assumptions that underpin the work and inform the choice of research questions, methodology, methods and even data sources, for studies to present clear, precise and logical work, and engage with and debate other’s work (Grix, 2010). In addition, the relationship between ontology and epistemology could not be changed freely, because the research foundations are a skin, not a sweater to be changed every day and many combinations are not logical (Marsh & Furlong, 2002).

Grix (2010) indicates that more importantly, a clear and transparent knowledge of the ontological and epistemological assumptions that underpin research is necessary to:

- understand the interrelationship of the key components of research (including methodology and methods).
- avoid confusion when discussing theoretical debates and approaches to social phenomena.
- be able to recognise others' position and defend our own.

He also stated that clarity and consistency of terms is very important, because if researchers are unclear about the ontological and epistemological basis of a piece of work, they may end up criticising a colleague for not taking into account a factor which the ontological position does not allow for. Also, Clough and Nutbrown (2002) give their advice as:

> *'Many researchers…do not select one research paradigm to investigate all their questions, choosing either a normative or interpretive approach. In our own work we have – during the course of our research careers – worked within both positivist and interpretivist paradigms…The important point here is that we adopt research stance as they are appropriate to our work.'*

Ontology and epistemology could be considered as the foundations upon which research is built. Methodology, methods and sources are closely connected to and built upon the ontological and epistemological assumptions. The relationship and logic between ontology, epistemology, methodology, methods and sources could be summarized as Figure 4-1:

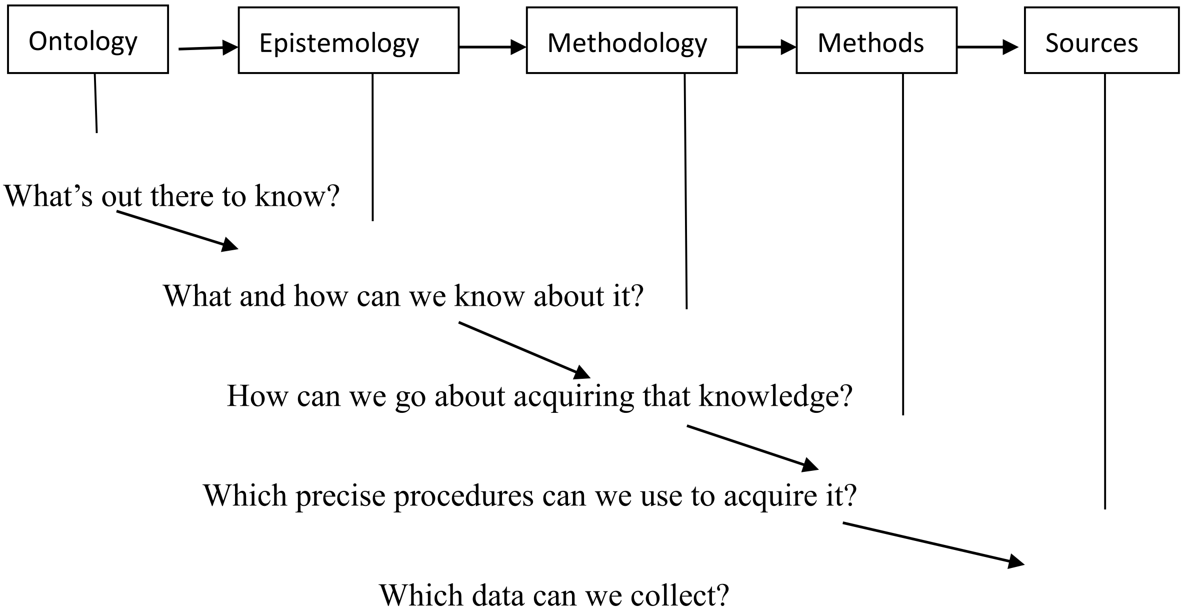


Figure 4-1 The relationship between ontology, epistemology, methodology, methods and sources

Source: Grix, J., 2010, The Foundations of Research (2nd ed.), London: Palgrave Macmillan, p. 68

Methodology is concerned with the logic of scientific enquiry, in particular with investigating the potentialities and limitations of particular techniques or procedures (Grix, 2010). The term pertains to the science and study of methods and the assumptions about the ways in which knowledge is produced. The difficulty in understanding just what the term 'methodology' means has not been helped by the fact that it is used interchangeably with 'research methods' and is often considered, mistakenly, to be close in meaning to 'epistemology', 'approach' and even 'paradigm'. Epistemology should be looked upon as an overarching philosophical term concerned with the origin nature and limits of human knowledge, and the knowledge-gathering process itself. On the other hand, methodology is concerned with the discussion of how a particular piece of research should be undertaken and so can best be understood as the critical study of research methods and their use. The term refers to the choice of research strategy taken by a particular scholar – as opposed to alternative research strategies. Furthermore, Grix (2010) argues that a researcher's methodology is driven by certain ontological and epistemological assumptions and consists of research questions or hypotheses, a conceptual approach to a topic, the methods to be used in the study – and their justification – and, consequently, the data sources. All these components are inextricably linked to one another in a logical manner.

The following parts in this Chapter will discuss and analyse the ontological and epistemological issues and methodological framework of this research. Research approaches, research methods and data resources will be discusses as well.

4.2 Ontological issues

Ontology is the starting point of all research, after which one's epistemological and methodological positions logically follow. To understand 'ontology' is very important. Lewis (2002) succinctly sums up the reasons, which are:

> *'It is impossible to engage in any sort of ordered thinking about the political [or social] world without making a commitment (if only implicitly) to some sort of social ontology, because any attempt to conceptualize political phenomena inevitably involves the adoption of some picture of the nature of social being. Explicit reflection about ontological issues can help clarify the precise character of theoretical positions and arguments. This is useful in a number of ways: it allows intuitions to be more fully articulated and developed; it helps to reveal internal inconsistencies in arguments; and it enables researchers to identify more accurately the differences between competing approaches.'*

There are two kinds of ontological positions, including objectivism and constructivism. The next two sections will discuss objectivism and constructivism respectively.

4.2.1 Objectivism

According to Bryman (2001), objectivism is 'an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors'. A characteristic of an objectivistic worldview is the existence of objective, absolute and unconditional truths (Lakoff & Johnson, 1980). The objective meaning of a statement is given from a set of conditions of truth or falsity, and human understanding is a matter of knowing these conditions, requiring precise and unambiguous definitions and rational explanations relying on deductive logic. Hence, sense-making from an objectivist point of view is considered as rational analysis of data in a mental problem space and construction of deductive arguments of cause-and-effect (Boland & Tenkasi, 1995)

In addition, Lakoff (1987) argues that objectivism is 'one version of basic realism' according to which reality exists independent of humans. According to Jonassen (1991) and Lakoff (1987), the major assumptions of objectivism could be summarised as:

- There is a real world consisting of entities structured according to their properties and relations. Categorisation of these entities is based on their properties.
- The real world is fully and correctly structured so that it can be modeled.
- Symbols are representations of reality and can only be meaningful to the degree that they correspond to reality.
- The human mind processes abstract symbols in a computer-like fashion so that it mirrors nature.
- Human thought is symbol-manipulation and it is independent of the human organism.

- The meaning of the world exists objectively, independent of the human mind and it is external to the knower.

This study will discuss the productivity and industrial competitiveness of construction industry and explore the ways to improve the sustainability of the Chinese construction industry. The theory and practice on this topic are changing along with the changes of social actors. From the literature review in Chapter 2, it could be found that the theory of industrial competitiveness has been developed continually by numerous scholars in various ways and a new model of industrial competitiveness was established by considering the current situation (e.g. internationalisation) and the new concept, that is, sustainable development. These developments are the results of the thoughts and activities of human beings. There is no doubt that they will change in the future when some new relevant theories or facts appear. Therefore, this study does not support an objective view of reality.

4.2.2 Constructivism

Alternatively, constructivism is an alternative ontological position that 'asserts that social phenomena and their meanings are continually being accomplished by social actors. It implies that social phenomena and categories are not only produced through social interaction but that they are in a constant state of revision' (Bryman, 2001). The basic and most fundamental assumption of constructivism is that knowledge does not exist independent of the learner, knowledge is constructed (Vrasidas, 2000). There are several schools of thought within the constructivist paradigm (Cobb, 1994 and Prawat & Floden, 1994). The two most prominent ones are personal constructivism and social or sociocultural constructivism. They cannot be separated because both complement each other (Cobb, 1994). Their major difference is the locus of knowledge construction. For the personal constructivists, knowledge is constructed in the head of the learner while the learner is re-organising his/her experiences and cognitive structures (Piaget, 1970 and Von Glasersfeld, 1989). However, for the social constructivists, knowledge is constructed in communities of practice through social interaction (Brown *et al*., 1989; Kuhn, 1996; Lave & Wenger, 1991 and Vygotsky, 1978).

By analysing the previous literature, Totland (1997) believes there are three key traits of a constructivism worldview, including:

- Realities are local and specific in the sense that they vary between groups of individuals (Guba & Lincoln, 1998). Constructions, being ontological elements of realities, are not absolutely true or correct in any sense, only more or less informed and sophisticated (Schwandt, 1998). However, even if all constructions are meaningful, some may rather be termed malconstructions, as they obviously are too simplistic or inconsistent. Whether a construction is malformed depends upon the paradigm the constructor operates within.
- Reality is actively constructed, not merely discovered. Hence, the distinction between ontology and epistemology is blurred, as what constitutes reality depends on a particular actor and his values (Guba & Lincoln, 1998). The objective, value-free actor does not exist.
- Reality is socially constructed, i.e., the constructions are not personal or technical (Dahlbom, 1992). Although perception and thinking necessarily is individual, the construction process involves other social and cultural artifacts and therefore inevitably becomes social.

After studying these two different ontological positions, a table called 'Assumptions Inherent in Objectivism and Constructivism' was provided by Jonassen in 1991 (Table 4-1).

	Objectivism	Constructivism
Reality (real world)	External to the knower Structure determined by entities, properties, and relations Structure can be modelled	Determined by the knower Dependent upon human mental activity Product of mind Symbolic procedures construct reality Structure relies on experiences/interpretations
Mind	Processor of symbols Mirror of nature Abstract machine for manipulating symbols	Builder of symbols Perceiver/interpreter of nature Conceptual system for constructing reality
Thought	Disembodied: independent of human experience Governed by external reality Reflects external reality Manipulates abstract symbols Represents(mirrors) reality Atomistic: decomposable into "building blocks" Algorithmic Classification What machines do	Embodied: grows out of bodily experience Grounded in perception/construction Grows out of physical and social experience Imaginative: enables abstract thought More than representation (mirrors) of reality Gestalt properties Relies on ecological structure of conceptual system Building cognitive models More than machines are capable of
Meaning	Corresponds to entities and categories in the world Independent of the understanding of any organism External to the understander	Does not rely on correspondence to world Dependent upon understanding Determined by understander
Symbols	Represent reality Internal representations of external reality ("building blocks")	Tools for constructing reality Representations of internal reality

Table 4-1 Assumptions Inherent in Objectivism and Constructivism

Source: Jonassen, D.H., 1991, "Objectivism versus Constructivism: Do We Need a New Philosophical Paradigm?", Educational Technology Research and Development, Vol. 39, No. 3, pp. 5-14

In this study, the theory of industrial competitiveness is developed further based on the previous studies and the concepts of sustainability. A new model of industrial competitiveness is generated and could be used widely. Therefore, this research supports a constructive view of reality.

4.3 Epistemological questions

Further to the discussion of ontology, the next key building block of the design of the research strategy that needs to be addressed is epistemology. Epistemology is from the Greek words 'episteme', meaning knowledge, and 'logos', meaning explanation. The term is concerned with the nature of knowledge and justification (Miller & Brewer, 2003). Hirschheim *et al.* (1995) state that epistemology is 'the nature of human knowledge and understanding that can possibly be acquired through different types of inquiry and alternative methods of investigation'. Crotty (1998) defines epistemology as 'the theory of knowledge embedded in the theoretical perspective and thereby in the methodology'. Rosamond (2000) believes epistemology refers to the 'strategies through which a particular theory gathers knowledge and ensures that its reading of phenomena is superior to rival theories'. Assumptions about forms of knowledge, access to knowledge and ways of acquiring and gathering knowledge are epistemological issues. These epistemological issues could impact on the research process and importantly, data collection and analysis (Holloway, 1997).

There are three epistemological positions, including: positivism, interpretivism and post-positivism (Grix, 2010). The stance taken in this study is post-positivism. A brief discussion on these three epistemological positions and why post-positivism was taken will be provided in the next sections.

4.3.1 Positivism

Positivism is an approach to the creation of knowledge through research which emphasises the model of natural science: the scientist adopts the position of objective researcher, who collects facts about the social world and then builds up an explanation of social life by arranging such facts in a chain of causality (Finch, 1986). Positivism is based on a realist, foundationalism (objectivism) ontology, which views the world as existing independently of our knowledge of it (Guba & Lincoln, 1998). Positivists believe that 'There are patterns and regularities, causes and consequence, in the social world just as there are in the natural world' (Denscombe, 2002). A positivist position believes in the possibility of making causal statements.

The positivist paradigm for applying the scientific method to research on human affairs is questionable. It is impossible for any theory in social science to be simple and precise because the world we live in and peoples' multiple perspectives and interpretations of events make theories complex and chaotic. Many variables affect different events and people's actions that it is impossible to determine an absolute truth (Mack, 2010).

4.3.2 Interpretivism

The second epistemological position is interpretivism. The interpretivist paradigm can be also called the 'anti-positivist' paradigm because it was developed as a reaction to positivism. Interpretivism 'is predicated upon the view that a strategy is required that respects the differences between people and the objects of the natural sciences and therefore requires the social scientist to grasp the subjective meaning of social action' (Bryman, 2001). Interpretivism's main tenet is that research can never be objectively observed from the outside rather it must be observed from inside through the direct experience of the people. Furthermore, uniform causal links that can be established in the study of natural science cannot be made in the world of the classroom where teachers and learners construct meaning. Therefore, the role of the scientist in the interpretivist paradigm is to, 'understand, explain, and demystify social reality through the eyes of different participants' (Cohen *et al.*, 2007). Researchers in this paradigm seek to understand rather than explain.

4.3.3 Post-positivism

As another epistemological position, post-positivism is not a clear philosophical school of thought, it is subjected to the general term of correction for positivism. Some theorists place post-positivism in the same category of paradigms as positivism (Guba & Lincoln, 1998 and Lather, 1992), whereas others describe post-positivism as a definite rejection of all that is positivist (Reichardt & Rallis, 1994 and Trochim, 2001). Simply speaking, post-positivists attempt to combine the ‘how’ (understanding – which is linked to interpretivism) and the ‘why’ (explanation – which is linked to positivism) approaches by bridging the gap between the two extremes (May, 2001)

Post-positivism admits that a researcher cannot ‘prove’ a theory or other causal propositions, but the theory or causality could be enhanced by the elimination of other explanations (Letourneau & Allen, 1999). Also, Cook and Campbell (1979) present that post-positivists accept that ‘observations are theory-laden…the construction of sophisticated scientific apparatus and procedures for data presentation usually involve the explicit or implicit acceptance of well-developed scientific theories over…the theories being tested.’ Post-positivism recognises that the same set of data could be explained by different theories. The subjective factors of theories and research processes can be included in the observation (Trochim, 2001).

In addition, Post-positivists believe that while social science can use the same methods as natural science regarding causal explanation (in line with positivism), it also needs to move away from them by adopting an interpretive understanding (Sayer, 2000). In addition, Post-positivists conceive of social change and conflict in society as not always apparent or observable, believing that ‘the immediately perceived characteristics of objects, events, or social relations rarely reveal everything’ (Neuman, 2000). Post-positivists believe pre-existing structures affect and are affected by actors (Hay, 1995).

This research aims to understand the performance of the Chinese construction industry in the international market and the differences between the Chinese and the Australian construction industries in productivity and industrial competitiveness. Also, the ways to improve the sustainability of the Chinese construction industry will be discussed. This research includes both 'understanding' and 'explanation'.

The development of the models for industrial competitiveness and the indicators of industrial competitiveness has never stopped based on the changes of situation and emerging of new concepts, which is matched with Neuman's (2000) and Hay's (1995) statements about post-positivists. These models, results and findings could be changed in the future when new concepts appear or new actions are done by policymakers or industry participants.

Moreover, by considering the interactivity principle of systems thinking, the long-term influence theory will be introduced in the study. The long-term influence theory concerns the long term relationships between the indicators in a system. In order to improve the performance of an element in a system for a long term point of view, stimulating the element directly may be not the best way and it may be better to improve other elements in the long term, because of the changes in the influence direction and level in the long term between the elements.

This study will identify the long term relationships between the three indicators of the sustainable development of the Chinese construction industry, including economic sustainability, social sustainability and environmental sustainability. However, the long term relationships between these three indicators in other countries or in a different period may be different. This aligns with Sayer's (2000) statement about the post-positivists. Therefore, this research is located within a post-positivism epistemological position.

4.4 Methodological framework

Methodology is a branch of science concerned with methods and techniques of scientific enquiry; in particular, with investigating the potential and limitations of particular techniques or procedures (Grix, 2010). Methodology provides the tools whereby understanding is created (Miller & Brewer, 2003). The term pertains to the science and study of methods and the assumptions about the ways in which knowledge is produced. In addition, Irny and Rose (2005) state methodology is generally a guideline system for solving a problem, with specific components such as phases, tasks, methods, techniques and tools.

A certain methodological approach will be underpinned by and reflect specific ontological and epistemological assumptions. These assumptions will determine the choice of approach and methods adopted in a given study by emphasising particular ways of knowing and finding out about the world. Methodology deals with the logic of enquiry, of how theories can be generated and subsequently tested. The choice of which methodology to employ is dependent upon the nature of the research problem. Morgan and Smircich (1980) argue that the actual suitability of a research method derives from the nature of the social phenomena to be explored. For this research a case study methodology will be employed. The following section will explain the rationale for this choice of methodology.

4.4.1 Case study

The case study as a social scientific method of research has a long and controversial history. According to Yin (2003), a case refers to an event, an entity, an individual or even a unit of analysis. It is an empirical inquiry that investigates a contemporary phenomenon within its real life context using multiple sources of evidence (Yin, 1989). Anderson (1993) states that case studies should be concerned with how and why things happen, allowing the investigation of contextual realities and the differences between what was planned and what actually occurred. Case studies constitute a category of research that is difficult to characterise with a simple definition. Because case studies often include the use of observation and archival methodologies, the distinctions among them are not always clear (McBurney & White, 2004). Yin (1994) tries to define a case study as 'an empirical inquiry that: (1) investigates a contemporary phenomenon with its real-life context when (2) the boundaries between phenomenon and context are not clearly evident and in which (3) multiple sources of evidence are used.'

Case study is not intended as a study of the entire organisation. Rather is intended to focus on a particular issue, feature or unit of analysis (Noor, 2008). This method enables us to understand the complex real-life activities in which multiple sources of evidence were used. Case study can be useful in capturing the emergent and immanent properties of life in organisations and the ebb and flow of organisational activity, especially where it is changing very fast (Hartley, 1994). The use of case study to probe an area of interest in depth is particularly appropriate. As described by Patton (1987), case studies become particularly useful where one needs to understand particular problems or situations deeply, and where one can identify cases rich in information. The major characteristics of case studies were summarised by Kazdin in 1982, including:

- They involve the intensive study of an individual, family, group, institution, or other level that can be conceived of as a single unit.
- The information is highly detailed, comprehensive, and typically reported in narrative form as opposed to the quantified scores on a dependent measure.
- They attempt to convey the nuances of the case, including specific contexts, extraneous influences, and special idiosyncratic details.
- The information they examine may be retrospective or archival.

This research intends to explore the differences in productivity and industrial competitiveness between the Chinese and Australian construction industries by comparison. This explores ‘how things happen’. Furthermore, this study will discuss the causes of these differences and provide suggestions for policymakers and industry participants, this is the matter of ‘why things happen’. In addition, this research will generate a quantitative measurement for the new industrial competitiveness model. Quantitative data will be collected and analysed. The data resources are various, including the Australian Bureau of Statistic (ABS), National Bureau of Statistics of China, Year Book, Company Annual Report, D&B’s ‘Who owns Whom’ Database, Engineering News Report and Companies’ Financial Reports. Therefore, it could be said that case study is suitable for this research.

Case studies have been criticised by some as lacking scientific rigor and reliability and that they do not address the issues of generalisability (Johnson, 1994). In addition, it is difficult to establish any cause-and-effect links between what you see and what you think might be responsible for the outcomes (Salkind, 2012). Like all nonexperimental approaches, they merely describe what occurred, but they cannot tell the reason of why it occurred (Marczyk *et al.*, 2005). Furthermore, the experimenter bias could be involved in case studies. Salkind (2012) states that ‘the notes you record in your log or journal may accurately reflect “reality” (or what you observe), but it is only one reality. Everyone comes to a given situation with a bias…’ Nevertheless, Salkind (2012) provides another two disadvantages of the case study methodology, including: 1) case study is actually one of the most time-consuming research methodologies imaginable, because the researcher needs to collect data in a wide variety of setting and sources, under a wide variety of conditions, and the researcher rarely has the choice about the settings and conditions; and 2) ‘what case studies provide in depth, they lose in breadth. Although they are extremely focused, they are not nearly as comprehensive as other research methods’. Last but not the least, the other major epistemological issue of case study is it is difficult to draw the boundaries (Chadderton & Torrance, 2011).

However, case study has its own strengths and focus. Comparing other methodologies, firstly, case study emphasises depth of study rather than breadth of study. Denscombe (2010) states ‘when a researcher takes the strategic decision to devote all his or her efforts to researching just one instance, there is obviously far greater opportunity to delve into things in more detail and discover things that might not have become apparent through more superficial research.’ Salkind (2012) claims case studies can make depth-research, as case studies focus only one individual or one thing, which enables a very close examination and scrutiny and the collection of a great deal of detailed data, and help to ‘get a richer account of what is occurring’ than other methodologies, by achieving a ‘thick description’ (Geertz, 1973) of a phenomenon in order to represent it from the participants’ perspective and seeking ‘illuminate’ the readers’ understanding of an issue (Parlett & Hamilton, 1974). ‘Case studies focus on one or just a few instances of a particular phenomenon with a view to providing an in-depth account of events, relationships, experiences or processes occurring in that particular instance’ (Denscombe, 2010). The use of case studies has become extremely widespread in social research, particularly with small scale research. Case study is the best choice when researchers want ‘to investigate an issue in depth and provide an explanation that can cope with the complexity and subtlety of real life situations’ (Denscombe, 2010). The productivity and industrial competitiveness of the Chinese and Australian construction industries need to be studied in detail in this research. Eight elements are included in the new model of industrial competitiveness. All the elements have their own measurements and causal relationship with internal and external factors.

Secondly, case study emphasises relationship or processes rather than outcomes. It emphasises an end-product, holistic view rather than isolated factors (Denscombe, 2010). Relationship and process are interconnected and interrelated within social settings. If you want to understand one thing, many others are also needed to understand and how the various parts linked. The case study approach will not only deal with the case as a whole, but can discuss the separated parts and how the parts affect one another. In this sense, 'case studies tend to be "holistic" rather than deal with "isolated factors"' (Denscombe, 2010). Gummesson (1991) states the case study methodology enables the researcher to gain a holistic view of a certain phenomenon or series of events. This research aligns with this point perspective. For example, when the Chinese and the Australian construction industries are discussed, the industrial competitiveness should be studied holistically. While, the indicators and elements included in the model of industrial competitiveness as the 'parts' have to be discussed. In addition, though the end-product and outcomes remain important for some case study researchers, if the processes which led to those outcomes are not discussed, the value of the case study would be lost. 'The real value of a case study is that it offers the opportunity to explain "why" certain outcomes might happen – more than just find out what those outcomes are' (Denscombe, 2010). This research will discuss the current situation and chrematistics of the Chinese and the Australian construction industries in relation to the productivity and industrial competitiveness, the differences between them via comparison, and the causes of the differences.

Furthermore, case study emphasises natural settings rather than artificial situations. Yin states that the case is a 'naturally occurring' phenomenon. It exists prior to the research and will continue to exist after the finished, it is hoped. Denscombe (2010) indicates that 'The case' is normally something that already exists. It cannot be artificially generated only for the purpose of the research. 'The case' in this research is the Chinese and the Australian construction industries, is a naturally occurring phenomenon.

Case studies could be used for a range of purposes within social research. Generally speaking, case studies could be used in relation to the discovery of information following an inductive logic and in relation to the testing of theory following and deductive logic. The use of a case study could be summarised as Table 4-2:

Discovery led	
Description	Describes what is happening in a case study setting (e.g. events, processes and relationships)
Comparison	Compares settings to learn from the similarities and differences between them
Exploration	Explores the key issues affecting those in a case study setting (e.g. problems or opportunities)
Theory led	
Explanation	Explains the causes of events, processes or relationship with a setting
Illustration	Use a case study as an illustration of how a particular theory applies in a real-life setting
Experiment	Uses a case study as a test-bed for experimenting with changes to specific factors (or variables)

Table 4-2 The use of a case study

Source: Denscombe, M., 2010, The Good Research Guide for Small-scale Social Research Projects Fourth Edition, Berkshire: McGraw Hill, p.55

The purpose of this research is to take a discovery led approach to the case study methodology. This research is going to better understand the performance of the Chinese construction industry and the differences with the Australian construction industry by in-depth study based on the concepts of productivity and industrial competitiveness, and to explore the ways to improve the performance of the Chinese construction industry. Therefore, firstly, this research study requires describing what is happening in the Chinese construction industry and the Australian construction industry. Next, the Chinese and the Australian construction industries will be compared to identify the differences between them. After that, this study will explore the key issues of the Chinese construction industry arising from this research. This is the typical use of discovery led approach following an inductive logic to the case study methodology suggested by Denscombe (2010) in Table 4-2.

4.4.2 Case selection

Case selection is an important issue in a case study. All case studies need to be chosen on the basis of their relevance to the practical problems or theoretical issues being researched. The general principles of case selection are: 1) cases should be informative, and expected to represent the phenomenon under study quite clearly; and 2) cases should be representative (typical) (Swanborn, 2010). Denscombe (2010) added that practical considerations could affect the selection of cases, including matters of convenience and a case being intrinsically interesting. Sometimes there is no real choice for case studies, for example, 1) the study is part of commissioned research, and 2) there are unique opportunities (Denscombe, 2010).

For this research, the Chinese and Australian construction industries will be selected as cases. Firstly, as a developing country, and with the development of globalisation, the performance of the Chinese economy has improved dramatically. Significant achievements have been made by the Chinese construction industry. For example, according to Engineering News-Record (ENR) (2012), Chinese construction enterprises (CCEs) have accounted for 52 among the world's top 225 international constructors in 2011. The success and developments of the Chinese construction industry has been noticed worldwide. In particular, for other developing countries, China is potentially a model for economic development and internationalisation. Therefore, it is appropriate and meaningful to choose the Chinese construction industry as a case.

As a traditional developed country, the Australian economy plays an important role in the Asia Pacific area, even the world. Australia is the world's twelfth largest economy and has the fifth highest per capita GDP (nominal) and it is ranked second in the United Nations 2011 Human Development Index and first in Legatum's 2008 Prosperity Index (United Nation, 2011). The Australian construction industry plays an important role in Australia's economy. The construction industry was the fourth largest contributor to Gross Domestic Product (GDP) in the Australian economy during 2008-09 in current price terms and plays a major role in determining economic growth. As at May quarter 2009 the construction industry employed 984,100 persons, which is 9.1% of the Australian workforce, making it Australia's fourth largest industry. The Australian construction industry has also made very important achievements in the international market in recent years. Australian construction enterprises have been very active and occupied a certain degree of market share. There are four Australian construction enterprises listed in the ENR top 225 international contractors in 2010. Two of them are listed in the top 25. Their total international revenue is more than 12 billion USD, which is 3.13% of total international revenue of the top 225 international constructors. Therefore, this research chooses the Australian construction industry as a case.

Secondly, according to Swanborn's (2010) general principles of case selection, informative cases are preferred. An informative case requires more comprehensive and clear information. As the researcher's background and resources are based on Australia and China, it is most likely that the researcher is able to access information from these two countries. In addition, because of the background and location of the author, this research also tries to be particularly useful for the Chinese and Australian construction industries.

4.4.3 Case study research design

Case study has its own research design. According to Yin (2003), the research design 'is the logical sequence that connects the empirical data to a study's initial research questions and, ultimately, to its conclusions' and five components should be included in a research design:

- A study's questions
- Its propositions

- Its units of analysis
- The logic linking the data to the propositions
- The criteria for interpreting the findings.

For this research, there are two research questions, including '*What is the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010?*' and '*What are the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?*'. The purpose (proposition) is firstly to help the Chinese and the Australian construction industries to understand their current situation and performance, and particularly for Chinese construction industry to identify the gap with developed countries. Secondly, by analysing the elements and indicators of productivity and industrial competitiveness of the Chinese and Australian construction industries, it could be helpful for policymakers and industry participants to know which part should be strengthened towards making an appropriate development strategy. 'The units of analysis' should be the productivity and industrial competitiveness of the Chinese and Australian construction industry.

For the last two steps of research design, there is no detailed guidance provided by the current state of the art (Yin, 2003). For this research, the quantitative data will be collected to measure the productivity and industrial competitiveness of the Chinese and the Australian construction industries. By comparison of these indicators and elements, the differences of productivity and industrial competitiveness between the Chinese and the Australian construction industries can be identified. Because all the indicators and elements will be measured quantitatively, statistical analyses will be conducted in this research, including Data Envelopment Analysis, the Malmquist productivity index, Input-output analysis, Degree of coordination and Multivariate Cointegration Analysis. Each statistical analysis model used in this research has its own explicit criteria for interpreting the findings. This will be discussed in the following sectors.

Moreover, case studies may either focus on a single case or use a number of cases: 'A single case may form the basis of research on typical, critical or deviant cases, while multiple cases may be used to achieve replication of a single type of incident in different settings, or to compare and contrast different cases' (Schell, 1992). According to the unit\s of analysis, case study designs could be divided into holistic designs and embedded designs. Holistic designs include a single unit of analysis and aim to study the global nature of the phenomenon when no logical sub-units can be pointed. Embedded designs include multiple units of analysis and study may include main and smaller units on different levels. This type of design is looking for consistent patterns of evidence across units, but within a case. Yin (2003) summarised them in a 2 x 2 matrix (Figure 4-2).

This research will compare and contrast different cases: the Chinese and the Australian construction industries, which belongs to the multiple-case design. In addition, as this research includes two main and several smaller units on different levels, which has been provide in previous chapters, embedded designs should be adopted.

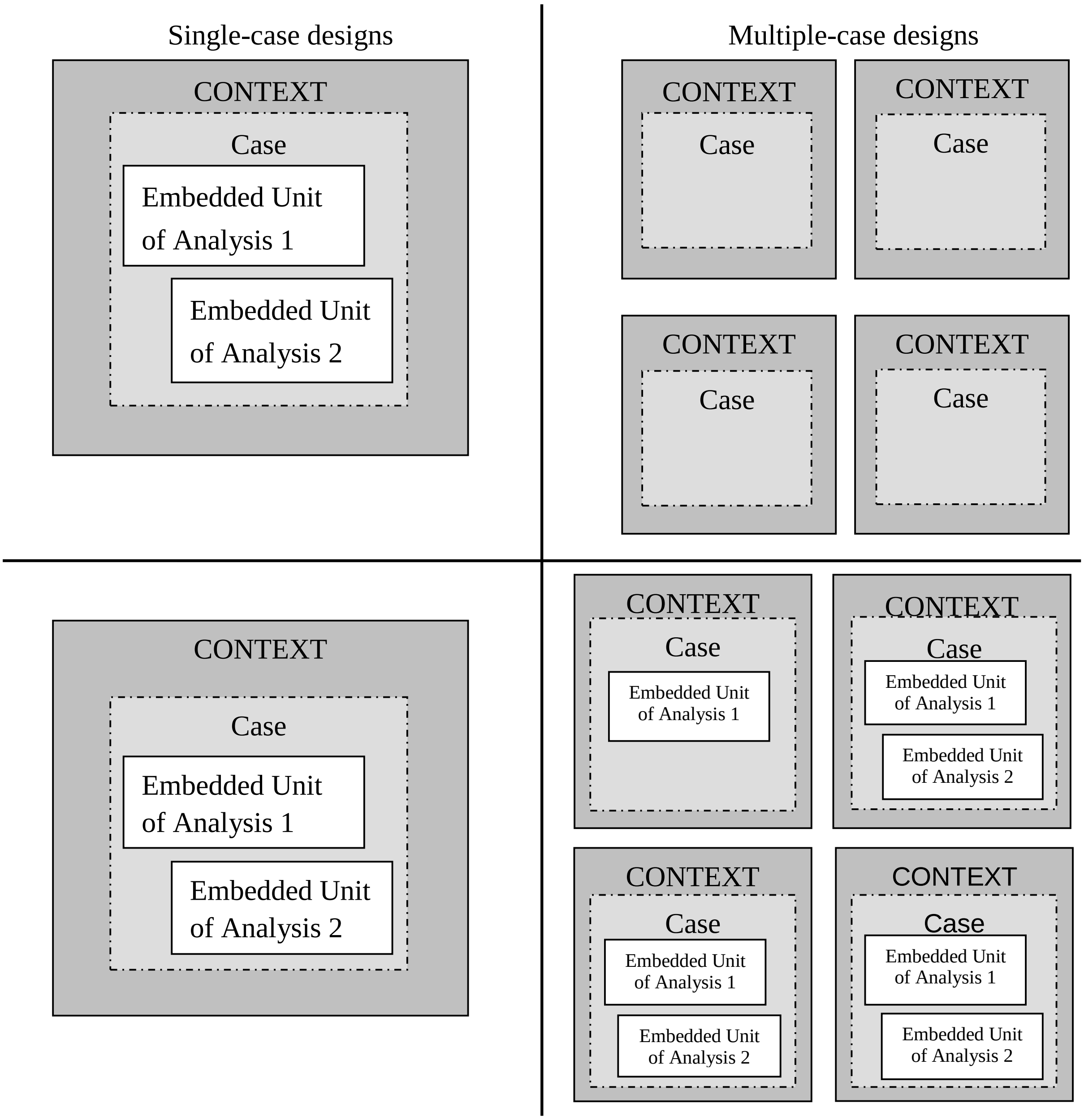


Figure 4-2 Basic Types of Design for Case Study

Source: Yin, R.K., 2003, Case study research: design and methods (3rd edition), London: SAGE, p. 40

4.4.4 Research analysis

A comparative approach will be used in this research. The comparative approach has been used in various disciplines including social policy (Lawrence, 1986 and Freeman, 2011), economic (Kravis *et al.*, 1975) and education (Zheng, 2014).

Comparative approach is the act of comparing two or more things with a view to discovering something about one or all of the things being compared. This technique often utilises multiple disciplines in one study. The multidisciplinary approach is good for the flexibility it offers, yet comparative programs do have a case to answer against the call that their research lacks a 'seamless whole' (Jones, 1985). Quantitative analysis is much more frequently pursued than qualitative, and this is seen in the majority of comparative studies which use quantitative data (Clasen, 2004; Heidenheimer *et al*., 1983; Deacon, 1983 and Esping-Anderson, 1990).

Comparison lies at the heart of human reasoning and it always exists in the observation of the world, 'thinking without comparison is unthinkable' (Swanson, 1971). Comparison is a fundamental principle of science as well as a basic element of everyday life. With classification, comparison is one of the crucial conceptual processes making the world intelligible (Caramani, 2009). Comparative research aims to make comparisons across different sectors in the social sciences. When the practice of comparative approach began is a matter of debate. This method has been used for over 2,000 years (Deutsch, 1987). Comparing things is essential to basic scientific and philosophical inquiry, which has been done for a long time (Deutsch, 1987). Most authors are more conservative in their estimate of how long the comparative approach has been with us. It is largely an empty debate over the definition of the tradition with those questioning whether comparing things counts as comparative approach.

Textbooks on the comparative approach were beginning to appear by the 1880s, but its rise to extreme popularity began after World War II (Clasen, 2004). There are numerous reasons that comparative approach has come to take a place of honor in the toolbox of the social scientist. Globalisation has been a major factor, increasing the desire and possibility for educational exchanges and intellectual curiosity about other cultures. Information technology has enabled greater production of quantitative data for comparison, and international communications technology has facilitated this information to be easily spread (Clasen, 2004).

In the first place, to compare means to describe variables. Together with explanation and prediction, description is one of the main tasks of scientific enterprise (Caramani, 2009). Descriptive comparisons focus on the degree of similarity and difference between two or more cases. Descriptive comparisons can be '(1) nominal: presence/absence or different types of attributes; (2) ordinal: more/less; or earlier/later and faster/slower in temporal comparisons; or quantitative (interval and ratio) when the values are continuous and quantifiable' (Caramani, 2009).

The comparative approach can take many forms. Two key factors are space and time. Spatially, cross-national comparisons, also called vertical comparisons, are very common, although comparisons within countries, contrasting different areas, cultures or governments also subsist and are very constructive (Heidenheimer *et al.*, 1983). Recurrent interregional studies include comparing similar or different countries or sets of countries, comparing one's own country to others or to the whole world. For the time perspective, the historical comparative approach, called the horizontal comparison, involves comparing different time-frames. The two main choices within this model are comparing two stages in time (either snapshots or time-series), or just comparing the same thing over time, to see if a policy's effects differ over a stretch of time (Deacon, 1983).

For this research, because the Chinese and the Australian construction industries will be discussed, the vertical comparison will be conducted. In addition, as the date of the Chinese and the Australian construction industries from 2001 to 2010 will be analysed, horizontal comparisons will be adopted as well.

4.5 Data collection

Previously, the models for productivity and industrial competitiveness of construction industry, and the sub-models, indicators and variables, have been generated and discussed. The quantitative data using in this research and the data resources is summarised in Table 4-3

	Indicators	Data resource
International advanced index	1. Depth Index 2. Height Index 3. Width Index	China Statistical Yearbook, Australian Bureau of Statistics and Engineering News Record
Productivity	1. Construction work done 2. Employed person 3. Gross Value-added	China Statistical Yearbook, Australian Bureau of Statistics
Elements of Competitiveness		
Factor conditions	1. Human resources 2. Natural resources 3. Investment in R&D 4. Number of persons with a non-school qualification per thousand people	China Statistical Yearbook, Government Work Report, Australian Bureau of Statistics
Demand conditions	1 Domestic demand growth rate 2 Domestic market size	China Statistical Yearbook, Government Work Report, Australian Bureau of Statistics
Related and supporting industries	1. Performance of these industries	China Statistical Yearbook, Government Work Report, Australian Bureau of Statistics
Firm strategy, structure and rivalry	1. Capital structure 2. Market structure	China Statistical Yearbook, Company's financial report, Australian Bureau of Statistics
Enterprises international activities	1. Degree of internationalisation	Financial reports, D&B's "Who owns whom", Engineering News Record
Government	1. labour and capital 2. high level factors 3. Number of construction firms Performance of un-State-owned construction companies	China Statistical Yearbook, Government Work Report, Australian Bureau of Statistics
Sustainable development	1. Economic sustainability 2. Environmental sustainability 3. Social sustainability	China Statistical Yearbook, Government Work Report, Australian Bureau of Statistics
Chance	External Elements, no need to discuss deeply	

Table 4-3 The quantitative data using in this research

4.6 Research analysis

4.6.1 Analysis for Research Question 1

The first research question is '*What is the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010?'*. In order to answer this question, firstly, the development phases of the Chinese and the Australian construction industries in the international market will be discussed and the International Advanced Index will be adopted to measure the status and level of the Chinese and the Australian construction industries in the international market in 2001 and 2010. Next, the IAI of the Chinese and the Australian construction industries will be compared and the differences between them will be identified and possible ways to improve the IAI of the Chinese construction industry will be proposed.

As described in Chapter 2, there are three elements in the International Advanced Index, including Width Index (WI), Height Index (HI) and Depth Index (DI). It is difficult to gather data for the Depth Index based on the definition. Therefore, adopting the ENR's statistics, Depth Index is generated as the ratio of overall international revenue of all companies of a certain country to total international revenue of all companies in the Top 225 international constructors list. In addition, the Height Index has been presented previously and is measured as the number of a country's construction enterprises in the top 225 international constructors list and the 'weight', which is the value of the average international revenue in the top 100 international constructors to the average international revenue in the remaining 125 (Zhang & London, 2010). The 'weight' could be called Gap index (GI), which is the indicator of the gap between the top international constructors. A smaller value indicates a smaller gap between these top companies, and a larger value indicates a larger gap. The following equation is presented (Zhang & London, 2010)

$$\mathrm{HI} = \frac{\text{No.of CCCEs in top the 100 ICs list} \times \text{GI} + \text{No.of CCCEs in the rest 125}}{225} \quad (1)$$

$$GI = \frac{\sum_{i=1}^{100} f(Ti)}{\sum_{i=101}^{225} f(Ti)} \times \frac{125}{100} \quad (2)$$

Though the previous International Advanced Index realises the difference between the top 100 and the remaining 125 construction companies by using the Gap Index, the difference between each company should be measured, not only in groups. Therefore to accommodate this, Zhang and London (2011) give a rank score to reflect this issue. According to the rank of these companies listed in the top 225 international constructors, the top one could get a score of 225; the second one is 224 scores, until the last one is 1. The Height Index of a certain country's construction industry is the total score of all the companies of a certain country in the Top 225 international constructors list to the total scores of all the companies in the list (which is 1+2+3+...+225). A higher value of Height Index indicates the better performance of the country's construction industry in the global market.

Furthermore, according to the classification of ERN, there are 10 specialisations in the construction industry. However, the data from the Industrial sector and the Petroleum sector are put together by ENR. Therefore, in this research, they are recognised as one field in the construction industry. In this sense, there are nine fields totally in the construction industry. ERN also provides the number of a certain country's construction enterprises listed in the top 10 of each specialised field. If a company is only involved with one field, and is listed in the top ten of this field, the number of its involved fields will be counted as 9 instead of 1. The equation for generating WI will be:

$$WI = \frac{\sum_{i=1}^{N} f(W'i)}{N} \quad (3)$$

$$N = \text{No. of CCCEs in top 225 IC list} \quad (4)$$

$$f(W'i) = \frac{W'i - M + 9M}{9} = \frac{W'i + 8M}{9} \quad (5)$$

$$W'i = \text{No. of fields each CCCE involved} \quad (6)$$

$$M = \sum \text{NO. of CCCEs listed in top 10 of each field} \quad (7)$$

4.6.2 Analysis for Research Question 2

Research Question 2 is '*What are the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?'*. In order to answer this question, firstly, the productivity of the Chinese construction industry from 2000 to 2010 and the Australian construction industry from 2000-01 to 2010-2011 will be explored. In addition, due to the data availability in different final year systems, the productivity of the Chinese construction industry in 2010 will be compared with the Australian construction industry in 2009-10 by using the data envelopment analysis. Next, for industrial competitiveness, besides the 'Chance' element, the development of each element included in the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) in recent years will be explored and all of them will be compared between the Chinese construction industry in 2010 and the Australian construction industry in 2009-2010. In particular, the long-term influence theory based on the interactivity principle of systems thinking will be introduced based on the discussion in the 'sustainable development' element. The next two sections will explain the analysis processes of the Research Question 2 more in detail.

4.7 Productivity analysis

Productivity is a core index in economics. It could be used to measure technical progress, economic efficiency, real cost control and production technology (Latruffe, 2010). It can be calculated by the ratio of an output performance indicator to an input performance indicator. Generally, there are two kinds of measurements for productivity, including Partial Factor Productivity and Total Factor Productivity. The Partial Factor Productivity only considers a single input in the ratio. The formula then for partial-factor productivity would be the ratio of total output to a single input, for example, labor productivity (output/labor), capital productivity (using machine hours or dollars invested), energy productivity (using kilowatt hours), and materials productivity (using inventory dollars). Labor productivity and capital productivity are the most popular two.

Numerous research in relation to Partial Factor Productivity has been conducted in the construction sector. For example, as the labor productivity index in the construction industry is closely tied to output per unit of work, Thomas and Napolitan (1995) quantify effect changes in the construction labor productivity and analysed effect changes impacting on labor productivity by a factor model. Allmon *et al.*, (2000) present research on productivity changes in the construction production of the U.S. where they presented a study on long term productivities and used a corresponding statistical analysis to indicate that there was a stable decline in the construction productivity of U.S. in the last decades. Moreover, fuzzy logic and fuzzy expert systems adopting actual construction project data could be suitable to model industrial construction labor productivity.

Capital productivity as another main model of the Partial Factor Productivity could express a construction company's financial management though its use was not more extensive than labor productivity (Lowe, 1987). Industrial capital productivity associated with industry gross value added could be suitable to measure the degree of output growth from cost consumption (BFC, 2006), which means capital productivity can be measured for detecting the return on invested capital. After evaluating the capital productivity of Australian industries, Pink (2008) stated that capital productivity could be impacted by technical efficiencies and technologies. Pink (2008) also suggested that the Goods and Services Tax introduced by the Howard Government in 2000 reduced the capital productivity level as the construction industrial output was affected.

Though many studies have been completed by adopting Partial Factor Productivity, this type of productivity measurement considered in isolation does not provide an overall indication of the industry performance. Therefore, an overall performance indicator, Total Factor Productivity (TFP) is generated. The Total Factor Productivity was developed from the concept of multifactor productivity, which was first introduced by Solow in 1957. The growth in TFP drove the long-run trend income per capita in an economy with an aggregate neoclassical production function. The measurement uses three-dimensional production functions including capital, labor and time variables and is generated by conducting Solow's theory. Jornerson *et al.* (1987) combined relative TFP theories and economic phenomena to investigate the link of productivity and American Economic trends. Parham (2004) measured Australian industry productivity, which are from 1960s to 1990s, to identify key sources of Australian productivity changes, commenting that productivity trends were associated with change in both labor and capital inputs. Grafton *et al.* (2004) used data from 27 countries to measure the relationship between TFP and social divergence, concluding that levels of social divergence vary inversely based on the levels of TFP and per capita income. Vial (2006) evaluated new elasticity of value added by adopting the Cobb-Douglas production function.

Numbers previous studies have focused on measuring total factor productivity levels in the construction industry. For example, Tan (2000) studied the Total Factor Productivity of Singapore's construction industry by adopting the Tornqvist index method by integrating respectively input and output variables. Zhi *et al.* (2003) explored the change of the Total Factor Productivity of Singapore's construction industry from 1984 to 1997. Liu and Song (2005) developed a new input-output multifactor productivity measurement for construction industry. After the comparison within the seven selected countries, Liu and Song (2005) found that Australian construction industry's productivity did not show an escalating trend during 1970s-1980s and presented numerous factors, including technology progress and economics of scale, significantly affecting the construction industry's productivity.

This research will discuss Total Factor Productivity of the Chinese and the Australian construction industries. The input is the number of employees in construction sector and the construction work done. The output is the construction industry gross value added. Because it has multi inputs, a technique known as Data Envelopment Analysis (DEA) will be used in this research to measure the Total Factor Productivity and this is now explained in detail.

4.7.1 Data Envelopment Analysis

As a nonparametric method in operations research and economics, Data envelopment analysis (DEA) is a linear programming methodology to measure the efficiency of multiple decision-making units (DMUs) when the production process presents a structure of multiple inputs and outputs, which is based on the economic notion of Pareto Optimality. DEA is a multi-factor productivity analysis model for measuring the relative efficiencies of a homogenous set of decision making units (DMUs). The efficiency score in the presence of multiple input and output factors is defined as:

$$\text{Efficiency} = \text{weighted sum of outputs} / \text{weighted sum of inputs} \qquad (8)$$

Assuming that there are n DMUs, each with *m* inputs and s outputs, the relative efficiency score of a test DMU *p* is obtained by solving the following model proposed by Charnes *et al.* (1978) according to the ideas of Farrell (1957), named CCR:

$$\max \frac{\sum_{k=1}^{s} \mathrm{v}_{\mathrm{k}} y_{kp}}{\sum_{j=1}^{m} u_j x_{jp}}$$

$$\text{s.t} \ \frac{\sum_{k=1}^{s} v_k y_{ki}}{\sum_{j=1}^{m} u_j x_{ji}} \leq 1 \forall i$$

$$v_{k,}, u_{j \geq 0} \ \forall k, j \qquad (9)$$

Where:
k = 1 to s,
j = 1 to m,
i = 1 to n,
y_{ki} = amount of output k produced by DMU i,
x_{ji} = amount of input j utilized by DMU i,
v_k = weight given to output k,
u_j = weight given to input j.

The fractional program shown as (9) can be converted to a linear program as shown in (10).

$$\max \sum_{k=1}^{s} v_k y_{kp}$$

$$\text{s.t} \sum_{j=1}^{m} u_j x_{jp} = 1$$

$$\sum_{k=1}^{s} v_k y_{ki} - \sum_{j=1}^{m} u_j x_{ji} \leq 0 \quad \forall i$$

$$v_k, u_j \geq 0 \quad \forall k, j. \tag{10}$$

The above problem is run n times in identifying the relative efficiency scores of all the DMUs. Each DMU selects input and output weights that maximise its efficiency score. In general, a DMU is considered to be efficient if it obtains a score of 1 and a score of less than 1 implies that it is inefficient.

For every inefficient DMU, DEA identifies a set of corresponding efficient units that can be utilised as benchmarks for improvement. The benchmarks can be obtained from the dual problem shown as (11).

$$\text{Min} \quad \theta$$

$$\text{s.t} \sum_{i=1}^{n} \lambda_i x_{ji} - \theta x_{jp} \leq 0 \quad \forall j$$

$$\sum_{i=1}^{n} \lambda_i x_{ki} - y_{kp} \geq 0 \quad \forall k$$

$$\lambda_i \geq 0 \quad \forall_i \qquad (11)$$

Where

θ = efficiency score, and

λ s = dual variables.

Based on problem (11), a test DMU is inefficient if a composite DMU (linear combination of units in the set) can be identified which utilises less input than the test DMU while maintaining at least the same output levels. The units involved in the construction of the composite DMU can be utilised as benchmarks for improving the inefficient test DMU. DEA also allows for computing the necessary improvements required in the inefficient unit's inputs and outputs to make it efficient.

The CCR model calculates relative values about efficiency by means of linear programming under constant return to scale (CRS, changing inputs result in a proportional change in outputs). This model neither needs to suppose production functions nor demands to evaluate parameters. However, the CCR model is unable to judge whether scale or technical inefficiency results in final inefficiency. Therefore, the BCC model is presented by Banker *et al*. (1984) to further explain the result of efficiency analysis by distinguishing between technical and scale inefficiencies through estimating pure technical efficiency at the give scale of operations, and evaluate scale effects of observations in the analysis. The CCR model could be applicable to technologies of variable returns to scale (VRS, changing inputs do not result in a proportional change in outputs).

There are two types of DEA models based on the proportional movement towards the efficient frontier, including: input oriented and output oriented models. The input oriented model is to work out the input quantities that can be proportionally reduced without the change in output level. The output oriented model is to evaluate the output quantities that can be proportionally expanded without the change in the input level

(Li & liu, 2011). Shephard (1970) first defines an output distance function of period *t* under the production technology of period *t* as:

$$D_o^t\left(x^t, y^t\right) = \inf\left\{\theta : (x^t, y^t / \theta) \in s^t\right\} \qquad (12)$$

Where:
"o" represents an output oriented distance function.

x^t = input vector in period *t*

y^t = output vector in period *t*

The input oriented distance functions can be defined similarly.

The output oriented distance function concerned with the input-output vector $\left(x^t, y^t\right)$ of period *t* in production technology s^{t+1} (or in named the production frontier) of period *t+1* can be generated as:

$$D_o^{t+1}\left(x^t, y^t\right) = \inf\left\{\theta : (x^t, y^t / \theta) \in s^{t+1}\right\} \qquad (13)$$

The output oriented distance function concerned with the input-output vector $\left(x^{t+1}, y^{t+1}\right)$ of period *t+1* in production technology s^t of period *t* can be generated as:

$$D_o^t\left(x^{t+1}, y^{t+1}\right) = \inf\left\{\theta : (x^{t+1}, y^{t+1} / \theta) \in s^t\right\} \qquad (14)$$

Where a production technology represents the set of all output vectors, *y*, which can be produced using the input vector *x*. That is:

$$s^t = \left\{\left(x^t, y^t\right) : x^t \text{ can produce } y^t \text{ at time t}\right\} \qquad (15)$$

To calculate the component distance functions, this study adopts a linear programming approach. For example, $D_o^t\left(x^t, y^t \middle| CRS\right)$ and $D_o^t\left(x^t, y^t \middle| VRS\right)$ are defined as follows for the *i*th observation: the target function

$\max_{\theta,\lambda} \theta = \left[D_o^t(x^t, y^t | CRS)\right]^{-1}$ subjects to: $-\theta y_i^t + Y^t\lambda \geq 0$, $x_i^t - X^t\lambda \geq 0$ and $\lambda \geq 0$.

The convexity constraint $N1'\lambda = 1$ should be added when calculating $\max_{\theta,\lambda} \theta = \left[D_o^t(x^t, y^t | VRS)\right]^{-1}$ for ensuring that an inefficient DMU is only benchmarked against DMUs of a similar size. Therefore, $\max_{\theta,\lambda} \theta = \left[D_o^t(x^t, y^t | VRS)\right]^{-1}$ should subject to $-\theta y_i^t + Y^t\lambda \geq 0$, $x_i^t - X^t\lambda \geq 0$, $\lambda \geq 0$ and $N1'\lambda = 1$.

By conducting the Data Envelope Analysis, it is possible to define which Total Factor Productivity level is higher between the Chinese and the Australian construction industries. The Malmquist productivity index will be adopted to explore the changes on the Total Factor Productivity of both the Chinese and the Australian construction industries.

4.7.2 The Malmquist productivity index

The Malmquist productivity index as a panel data of DEA is used to evaluate the total factor productivity changes. The traditional DEA model can only calculate the relative efficiency in each period. The Malmquist index was first introduced by Malmquist in 1953 as a quantity index for use in the analysis of consumption of inputs. The Malmquist productivity index introduced in the production analysis by Caves *et al.* (1982) could handle this problem well. Färe *et al.* (1994) specified an output-based Malmquist productivity change index as the geometric mean of two indices from period *t* and period *t+1*. The Malmquist productivity index was decomposed into a component measuring technical efficiency changes and the other component measuring technological changes. These two terms were calculated on the benchmark technologies satisfying constant returns to scale (CRS). In addition, the technical efficiency index can be further decomposed into the pure technical efficiency change index and the scale efficiency index under variable return to scale (VRS)

Färe *et al.* (1994) provide a measurement for the Malmquist total factors productivity index by using the geometric mean of such indices calculated both for period *t* and period *t+1* reference technologies as:

$$\text{Malmquist productivity change} = \left[\frac{D_0^t(x^{t+1}, y^{t+1} \mid CRS)}{D_0^t(x^t, y^t \mid CRS)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1} \mid CRS)}{D_0^{t+1}(x^t, y^t \mid CRS)}\right]^{1/2} \quad (16)$$

The Malmquist TFP index can be considered as the product of the technological change index and the technical efficiency change index.

Malmquist productivity change =

$$\frac{D_0^{t+1}(x^{t+1}, y^{t+1} \mid CRS)}{D_0^t(x^t, y^t \mid CRS)} \times \left[\frac{D_0^t(x^{t+1}, y^{t+1} \mid CRS)}{D_0^{t+1}(x^{t+1}, y^{t+1} \mid CRS)} \times \frac{D_0^t(x^t, y^t \mid CRS)}{D_0^{t+1}(x^t, y^t \mid CRS)}\right]^{1/2} \quad (17)$$

According to Equation (17), the ratio outside the bracket is the index measuring technical efficiency change between periods t and $t+1$, while the bracketed term is to evaluate the technological change between periods t and $t+1$. The calculation for the Malmquist TFP index from adjacent periods includes four different distance functions, namely $D_0^t(x^t, y^t \mid CRS)$, $D_0^t(x^{t+1}, y^{t+1} \mid CRS)$, $D_0^{t+1}(x^t, y^t \mid CRS)$ and $D_0^{t+1}(x^{t+1}, y^{t+1} \mid CRS)$.

The Malmquist index is composed either of the output-oriented distance functions or of the reciprocal of the input-oriented distance functions $\theta(x, y) = [1/D_0(x, y)]$. The reciprocal of the input distance function, which is equivalent to the measurement of technical efficiency proposed by Farrell (1957), is the smallest ratio by which an input bundle can be multiplied and is still capable of achieving a given level of output.

Lovell (2003) indicates that the scale efficiency change obtained from the conventional decomposition was not really associated with scale economies. Therefore, the technical change does not conform to best practice production model, and cannot be interpreted in terms of economic meaning. Lovell (2003) further presents the renovated decomposition, in which the productivity analysis will be more suitable for economic practices.

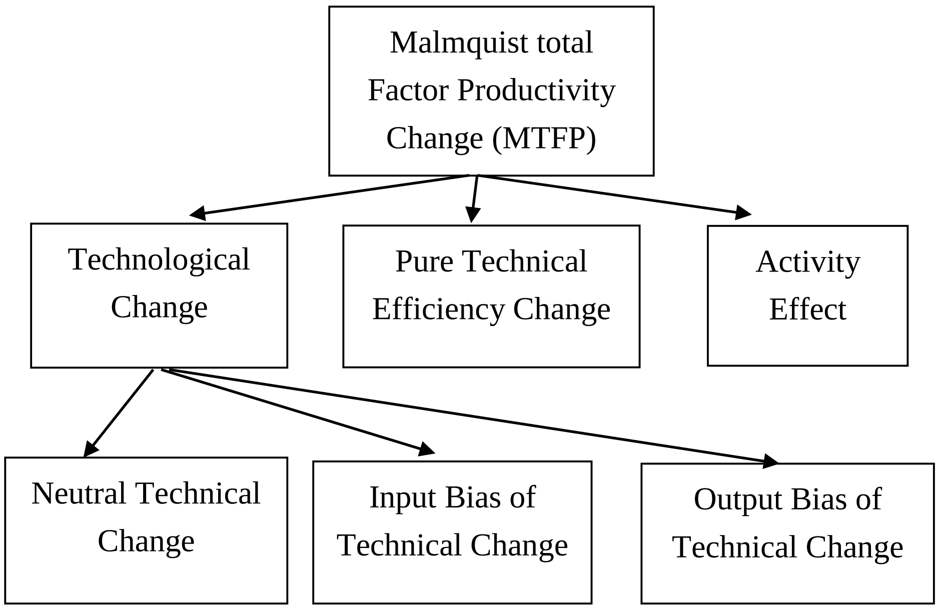


Figure 4-3 The new decomposition of Malmquist total factor productivity

The MTFP index is to measure productivity changes between two adjacent periods. The value of MTFP index may be greater than, equal to or less than 1 depending on productivity level increase, stagnation or decline between period t and period t+1 in Equation (18). The numerical value of the Malmquist productivity change is same as the expression of the previous Equation (16).

Malmquest total factor productivity change (MTFP) =

$$[\frac{D_0^t(x^{t+1}, y^{t+1} | CRS)}{D_0^t(x^t, y^t | CRS)} \times \frac{D_0^{t+1}(x^{t+1}, y^{t+1} | CRS)}{D_0^{t+1}(x^t, y^t | CRS)}]^{1/2} \quad (18)$$

The technological change index (TC) quantifies the contribution of technological factors to productivity change. The TC index may be greater than, equal to or less than 1 depending on technical progress, stagnation or decline between periods t and t+1 in Equation (19). Refering to Figure 4-3, TC includes three elements. They are the product of the neutral technical change (T), output bias index (OB) and input bias index (IB).

Technological change (TC) =

$$[\frac{D_0^t(x^{t+1}, y^{t+1} | VRS)}{D_0^{t+1}(x^{t+1}, y^{t+1} | VRS)} \times \frac{D_0^t(x^t, y^t | VRS)}{D_0^{t+1}(x^t, y^t | VRS)}]^{1/2} \quad (19)$$

The neutral technical change index (T) identifies the value of technical change on the basis of a ray traversing (x^t, y^t), measuring technical change for unchanged outputs and inputs with period *t* date under VRS in Equation (20)

$$\text{The neutral technical change (T)} = \frac{D_0^t(x^t, y^t | VRS)}{D_0^{t+1}(x^t, y^t | VRS)} \quad (20)$$

The output bias index (OB) compares two technical changes that are respectively from period t and period $t+1$, in output combinations in Equation (21). The formula is provided below.

Output bias of technical change (OB) =

$$\left[\frac{D_0^t(x^{t+1}, y^{t+1} | VRS)}{D_0^{t+1}(x^{t+1}, y^{t+1} | VRS)} \times \frac{D_0^{t+1}(x^{t+1}, y^t | VRS)}{D_0^t(x^{t+1}, y^t | VRS)}\right]^{1/2} \quad (21)$$

The input bias index (IB) compares two technical changes that are respectively from period t and period $t+1$ in the bundle of inputs in Equation (22). The IB index may be greater than, equal to or less than 1 depending on if the deployment of production factors is improvement.

Input bias of technical change (IB) =

$$\left[\frac{D_0^{t+1}(x^t, y^t \mid VRS)}{D_0^t(x^t, y^t \mid VRS)} \times \frac{D_0^t(x^{t+1}, y^t \mid VRS)}{D_0^{t+1}(x^{t+1}, y^t \mid VRS)}\right]^{1/2} \tag{22}$$

The pure technical efficiency change index (PTEC) evaluates the contribution of technical efficiency change to total factor productivity change. The PTEC index may be greater than, equal to or less than 1 depending on technical efficiency improvement, stagnation or decline between periods t and $t+1$ in Equation (23).

Pure technical efficiency change (PTEC) =

$$\frac{D_0^{t+1}(x^{t+1}, y^{t+1} \mid VRS)}{D_0^t(x^t, y^t \mid VRS)} \tag{23}$$

The activity effect index (AE) is to measure economies of scale changes. The index AE may be greater than, equal to or less than 1 depending on economies of scale improvements, stagnations or declines between period t and $t+1$ in Equation (24).

Activity effect (AE) =

$$\left\{\left[\frac{D_0^t(x^{t+1}, y^{t+1} \mid CRS) / D_0^t(x^{t+1}, y^{t+1} \mid VRS)}{D_0^t(x^t, y^t \mid CRS) / D_0^t(x^t, y^t \mid VRS)}\right] \times \left[\frac{D_0^t(x^{t+1}, y^{t+1} \mid CRS) / D_0^{t+1}(x^{t+1}, y^{t+1} \mid VRS)}{D_0^{t+1}(x^t, y^t \mid CRS) / D_0^{t+1}(x^t, y^t \mid VRS)}\right]\right\}^{1/2} \tag{24}$$

According to Lovell's decomposition presented in Figure 4-3, the equation for The Malmquist total factor productivity (MTFP) could be generated as:

$$MTFP = TC \times PTEC \times AE = T \times OB \times IB \times PTEC \times AE \quad (25)$$

Furthermore, the DEA-based Malmquist productivity index has been used by various researchers to evaluate the productivity change over time. For example, an empirical investigation of the catch-up hypothesis for a group of high and low countries was conducted by Taskin and Zaim (1997). The Malmquist productivity index was calculate by dividing it into technical change, change in technical efficiency, and change in scale efficiency by Mahadevan in 2002, in order to explore the performance of Malaysia's 28 manufacturing industries from 1981 to 1996 in relation to the growth of productivity. Chen and Ali (2004) provide an extension to the DEA-based Malmquist approach by further analysing the two Malmquist components: technical change and frontier shift. González and Gascón (2004) estimate Malmquist productivity index by dividing it into four sources of productivity change to analyse the evolution of the productive patterns in a sample of 80 Spainish pharmaceutical laboratories from 1994 to 2000. Camanho and Dyson (2006) used DEA and Malmquist indices to develop measures for comparing groups of DMUs and illustrated the approach with an application to assess the performance of commercial bank branches in Portugal. They construct different indices to reflect the relative performance of branches in four different regions including an index for the comparison of within-group efficiency spread, evaluating internal managerial efficiencies, and an index for the comparison of frontier productivity, reflecting the impact of environmental factors and regional managerial policies on branches' productivity.

Therefore, the Malmquist productivity index could be divided into different components to derive detailed information to assist analysis of the productivity change in different situations. In this research, the Malmquist productivity index is divided into two components including technical efficiency change and technological change to measure the productivity change of the Chinese construction industry from

2001 to 2010. The technical efficiency change could be further divided into pure technical efficiency change and scale efficiency changes. A Data Envelopment Analysis computer program named DEAP Version 2.1 will be used to generate the Malmquist total factor productivity of the Chinese construction industry. If the result is lower than 1, it means the productivity decreased from previous year to the observation year. If the result is equal to 1, it means there is no change in the productivity. If the result is greater than 1, it shows an increase in the productivity from last year to the observation year. The increasing/decreasing rate could be calculated by minus 1 from the result achieved by DEAP Version 2.1.

4.7.3 Summary

This study will adopt the Malmquist productivity index to explore the total productivity changes of the Chinese construction industry from 2001 to 2010 and the Australian construction industry from 2001-02 to 2010-11. The software DEAP Version 2.1 will be used to calculate the Malmquist total factor productivity changes of the Chinese and the Australian construction industries. In addition, the productivity of the Chinese construction industry in 2010 will be compared with the Australian construction industry in 2009-10, due to the data availability in different final year system by using the data envelopment analysis.

4.8 Industrial competitiveness

There are eight elements in the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) including factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of multinational enterprises and sustainable development. Chance is the only accessorial element whereby all the others are determinants. Factor conditions, demand conditions and firm strategy, structure and rivalry are easy to be calculated based on the discussion in Chapter 3. However, related and supporting industries, government, activities of multinational enterprises and sustainable development need more discussion.

4.8.1 Related and supporting industries

When the element of ‘related and supporting industries’ is discussed, the first question is ‘what’s are the related and supporting industries and how are they recognised?’ In order to answer this question, input-output analysis will be adopted in this research to identify the related and supporting industries.

4.8.1.1 Input-output analysis

The input-output analysis was developed by Wassily Leontief (1905-1999) and helped him to win the Nobel Prize in Economics in 1973. As a quantitative technique in economics, the input-output analysis represents the interdependencies between different aspects of a national economy or different regional economies and it can be conducted in various economic fields, such as economic analysis, policy simulation, economic forecasting, planning and economic control, etc. (Raa, 2009). Simply speaking, in order to conduct the input-output analysis, the economic system needs to be separated to a number of sectors first. Next, the flows of commodities and services in and out of each sector will be considered (Hu, *et al.*, 2010).

The input-output analysis is comprehensive but easy-to-understand in relation to complex economic systems. For this reason it has been one of the major statistical tools for most economically important countries in the world for years (Xu, *et al.*, 2010). In addition, because nearly all the input-output databases are free for researchers and professionals, the input-output analysis has always been popular in economic analysis and related fields.

The input-output analysis includes two sections, input-output table and input-output model. The input-output table, also named sector linkage balance sheet or industry association table, is a checkerboard balance sheet based on the materials flow in and out of the economic sectors of a national economic system. This table presents the description of the two basic relations. The first one could be summarised as (1) each sector's total output is equal to the sum of its intermediate and final products, (2) the intermediate products should be able to meet the input demand of all the other sectors, and (3) the final product should be able to meet the needs of accumulation and consumption. The second one is (1) the input of each sector is all the sectors' intermediate products which is directly required during the production of this sector, and (2) the input is determined by its total output if the technical conditions of production is the same (Zhao, *et al.*, 2009).

The input-output table could be classified in many ways. According to the different units of measurement, the input-output table could be divided into monetary input-output table (MIOT) and physical input-output table (PIOT). PIOT uses physical data to present material relationships between economic sectors, which makes more accurate approximations of real material flows in the economic system than analysis based on MIOT. However, there are not yet internationally recognised standard methods for PIOT compilation. In order to compare the Chinese and Australian construction industries, this study will adopt monetary input-output table (MIOT). The simplified monetary input-output table is shown as Table 4-4.

Output / Input		Intermediate demand					Final Use	Total output
		Sector 1	Sector 2	…	Sector *n*	Total		
Intermediate Input	Sector 1	x_{11}	x_{12}	…	x_{1n}	$\sum x_{1j}$	Y_1	X_1
	Sector 2	x_{21}	x_{22}	…	x_{2n}	$\sum x_{2j}$	Y_2	X_2
	…	…	…	I	…	…	…	…
	Sector n	x_{n1}	x_{n2}	…	x_{nn}	$\sum x_{nj}$	Y_n	X_n

	Total	$\sum x_{i1}$	$\sum x_{i2}$	…	$\sum x_{in}$	$\sum\sum x_{ij}$	$\sum Y_i$	$\sum X_i$
Value-added		N_1	N_2	…	N_n	$\sum N_j$		
Total Input		X_1	X_2	…	X_n	$\sum X_j$		

Table 4-4 Simplified input-output table

On the other hand, the input-output model is generated based on the ‘Ⅰ’ part of the input-output table and it is expressed as the form of coefficient. The ‘Ⅰ’ part represents the input and output of each sector. Each number has a double meaning. Horizontally, it represents the value of a certain sector’s intermediate input products and services, which are provided by the various output sectors. Vertically, it could reflect a certain sector’s intermediate demand on the input sectors.

The input-output model adopts the concept of the interdependences of economic activity based on the general equilibrium, and describes the interdependences by algebraic simultaneous equations system (Zhao, *et al.*, 2009). The input-output model could be expressed as linear equations in matrix form:

- AX+ Y= X (Intermediate product + Final product = Total output)
- After transformation: Y= (I – A) X
- If the matrix (I-A) exists, X= $(I-A)^{-1}$ Y, $(I-A)^{-1}$ is Leonti ef inverse matrix.

In addition to being used to study the proportional relationship and the structural characteristics between sectors, the input-output analysis can explore the effect on other data when some data is changed (e.g. induced effect and ripple effect analysis) based on the parameter calculated by using the input-output table. The usefulness of the input-output analysis could provide solutions for measuring the degree of industrial linkages.

The industrial linkage means the direct and indirect interdependence and mutual restraint economic ties between the sectors of the national economy generated in the process of reproduction. The industrial linkage is the technical economic relationship between a certain industry and the other industries in the national economy, which means the objectively existing relationship of mutual consuming and providing products between sectors (Zhao, *et al*., 2009). The industrial linkages could reflect the division of work and cooperation between sectors, which could be divided into two aspects including forward and backward perspective. Generally, the backward sectors of a certain sector are the 'suppliers' of this certain sector. They proved their output as the input of this certain sector. The related and supporting industries will be identified from the backward perspective.

The degree of industrial linkages is the degree of spread and effect on other industry's input and output level when a certain industry's input and output relationship changes. When the Industrial linkage effect is discussed, Direct Consumption Coefficient, Total Consumption Coefficient and Influence Coefficient are used to measure the degree of industrial linkages between a certain sector and its backward sectors. These indicators could be helpful for this research to measure the backward correlation effects between the Chinese construction industry and other industries. The details of these indicators will be discussed below.

A. Direct Consumption Coefficient

The Direct Consumption Coefficient, also known as the input coefficient, refers to the direct consumption of intermediate inputs during the production process to the total output. It can be expressed as:

$$a_{ij}= x_{ij} / X_j \ (i, j= 1, 2, \ldots, n) \qquad (26)$$

Where: x_{ij} refers to the consumption amount of sector i in order to get the total output of the sector j in the current period. X_j is the total output of the sector j. a_{ij} is the demand of the sector *j*'s per unit output on sector *i*'s products.

The Direct Consumption Coefficient is the basis of input-output analysis, and it reflects the direct economic technological relationship between sectors under a certain level of technical and production organisation management. A greater a_{ij} indicates a stronger interdependence between the sector *i* and sector *j* and closer direct economic technical relationship. To be different with the flow of intermediate inputs, the direct consumption coefficient could (1) exclude the impact of the sector size, (2) more directly reflect the sector input structure determined by technical and economic factors and (3) represent the dependence between sectors, which is truly comparable and analysable.

B. Total Consumption Coefficient

The Total Consumption Coefficient refers to the direct and indirect consumption of all kinds of products and services of the sectors in order to increase one unit of final use of a certain sector. The Total Consumption Coefficient is equal to the sum of the Direct Consumption Coefficient and all Indirect Consumption Coefficients. The economic implications of the Total Consumption Coefficient is the total consumption of a certain sector's per unit output of final product and service to another sector's product and service. The Total Consumption Coefficient can be expressed as:

$$b_{ij} = \text{Direct consumption coefficient} + \text{first indirect consumption coefficient} + \text{secondary indirect consumption coefficient} + \ldots, \ (i, j=1, 2, \ldots, n) \quad (27)$$

I is a unit matrix, and then the formula of total consumption coefficient matrix B calculated by direct consumption coefficient matrix A is:

$$B = (I - A)^{-1} - I \quad (28)$$

The difference between the total consumption coefficient and direct consumption coefficient is that the total consumption coefficient could indicate the linear proportional relationship between the final output total consumption during the production process. The greater b_{ij} represents that the direct and indirect technical and economic relationship between two sectors are closer, and the dependence or traction effect of sector j to sector i will be stronger. Moreover, the coefficient in the total consumption coefficient matrix is an important indicator to express the degree of industrial relevance.

C. Influence Coefficient

The Influence Coefficient indicates the increasing degree of all the sectors' production demand when a certain sector increases one unit of final use. The sectors with a higher Influence Coefficient have stronger radiation ability to the national economy. Influence Coefficient (G_j) can be expressed as:

$$G_j = \sum_{i=1}^{n} b_{ij} \setminus 1/n \sum_{i=1}^{n} \sum_{j=1}^{n} b_{ij} \; (i, j = 1, 2, \ldots, n) \qquad (29)$$

Where:

$\sum_{i=1}^{n} b_{ij}$ is the sum of column j in Total Consumption Coefficient Matrix, which indicates the total demand on all the sectors of national economy when sector j produces one unit of final production. It expresses the influence or driving ability of sector j to the national economy.

$1/n \sum_{i=1}^{n} \sum_{i=1}^{n} b_{ij}$ is the mean of the sum of columns in Total Consumption Coefficient Matrix.

$G_j > 1$ indicates that the degree of influence of sector j to other sectors is higher than the average level of influence of all the sectors.

$G_j < 1$ indicates that the degree of influence of sector j to other sectors is lower than the average level of influence of all the sectors.

To identify the related and supporting industries of the Chinese construction industry, these three coefficients will be adopted. However, the Australian construction industry is composed by four sectors and measured separately in the input-output table generated by the Australian Bureau of Statistics. These four sectors are residential building, non-residential building, engineering construction and construction trade services. The details will be provided in Chapter 7. This research will use the 'Industry by Industry Flow Table (Indirect Allocation of Imports) – 2012-13' (ABS, 2015) to calculate the Direct Consumption Coefficient (Indirect Allocation of Imports) and identify the closely related and supporting industries of the Australian construction industry.

4.8.1.2 Identification and discussion

This research will adopt the input-output analysis to find out the related and supporting industries of the Chinese construction industry. When the direct and total consumption coefficients of the Chinese construction industry to another industry are larger than the average level, this industry will be considered a closely related and supporting industry of the Chinese construction industry. The top two related and supporting industries will be further discussed.

The Direct Consumption Coefficient (Indirect Allocation of Imports) will be used to identify the closely related and supporting industries of the Australian construction industry. After identifying the closely related and supporting industry, the general developments and productivity changes of the top two industries in recent years will be discussed.

4.8.2 Sustainable Development Index

4.8.2.1 Developments in sustainability

For the sustainable development, the indicators in each category and aspect could be calculated based on the dissection in Chapter 3. In order to explore the developments of the sustainable development of the Chinese construction industry from 2001 to 2010, this research will do the progress of dimensionless for all the indicators in the sustainable development index system first. This research considers them as equal. The average level of the indicators in a certain year from 2001 to 2010 will be the suitable development index in this year during these ten years. In the same way, the sub-indexes – economic sustainability, social sustainability and environmental sustainability – can be generated and named as economic sustainability index, social sustainability index and environmental sustainability index. In addition, the degree of coordination analysis will be conducted in this research to find out the relationship among the economic sustainability index, environmental sustainability index and social sustainability index of the Chinese and Australian construction industries from 2001 to 2010.

A. Dimensionless

The process of dimensionless can be divided into two steps. The first step is process of same trend. To direct sum the indicators with different nature would not reflect the consolidated results from different forces correctly. The nature of the data for inverse indicators has to be changed to make the forces from all the indicators have the same trend. In this research Construction Waste / Construction work done and Energy Consumption / Construction work done are inverse indicators. Simply speaking, we want to reduce waste generated and energy consumption in construction. For these two indicators, smaller is better. However, for all the other indicators, bigger is better. Therefore, Construction Waste / Construction work done and Energy Consumption / Construction work done should be changed to have the same trend with others. The method is multiply (-1) to the original data of these two indicators.

The second step is standardisation. In this research, Min-max standardisation method is conducted. Min-max standardisation method is to do linear transformation on the original data. MinA and MaxA is the minimum and maximum of A. x is one original value of A, which could be mapping into the interval of [0,1] as x' by Min-max standardisation. It can be expressed as:

$$x' = (x - MinA)/(MaxA - MinA) \quad (30)$$

B. Degree of coordination

As a management function, coordination refers to adjusting the relationship of all the activities or units in one organisation or system based on its aim, in order to connect these activities or units together, reduce conflicts and achieve organisational goals (Li *et al.,* 2003). The sustainable development system of construction industry is a complex system and includes three sub-systems: Economic sustainability, Environmental sustainability and Social sustainability. There are complex interactions between them. The essence of the sustainable development of the construction industry is to promote and make full use of the positive relationship between the various subsystems to achieve a virtuous circle between them, so that the construction industry can achieve the stable economic development, rational and efficient resource utilisation, and environmental harmony.

As a benign relation of two or more systems or system elements dependent upon each other, coordination could be measured with the degree of coordination (Bai & Han, 1999). If two subsystems need to be discussed, their comprehensive development level could be considered as the evaluation function, named as $f(x)$ and $f(y)$. A higher degree of coordination between the systems means a smaller deviation. It could be expressed by coefficient of variance as:

$$C_v = \frac{s}{\frac{1}{2}[f(x) + f(y)]} = \sqrt{1 - \frac{f(x) \cdot f(y)}{\left[\frac{f(x) + f(y)}{2}\right]^2}} \quad (31)$$

Where: s is standard deviation. The necessary and sufficient condition for the smaller C_v is $C' = \frac{f(x) \cdot f(y)}{\left[\frac{f(x)+f(y)}{2}\right]^2}$ becoming bigger. Therefore, the formula of the degree of coordination between two systems is:

$$C = \frac{f(x) \cdot f(y)}{\left[\frac{f(x)+f(y)}{2}\right]^2} \quad (32)$$

Where: $0 \le C \le 1$. This research is going to study the degree of coordination of Economic sustainability, Environmental sustainability and Social sustainability. Therefore it is necessary to expand the formula to suit three systems. The formula for three subsystems is:

$$C_v = \frac{s}{\frac{1}{3}[f(x) + f(y) + f(z)]} = \sqrt{2\{1 - \frac{3[f(x) \cdot f(y) + f(x) \cdot f(z) + f(y) \cdot f(z)]}{[f(x) + f(y) + f(z)]^2}\}}$$

(33)

The formula of the degree of coordination for three subsystems is:

$$C = \frac{3[f(x) \cdot f(y) + f(x) \cdot f(z) + f(y) \cdot f(z)]}{[f(x) + f(y) + f(z)]^2} \quad (34)$$

Where: C is the degree of coordination of three subsystems; $0 \le C \le 1$. *f(x)*, *f(y)* and *f(z)* respectively represented the growth rates of Economic sustainability, Environmental sustainability and Social sustainability. In this paper, the criterions of coordination degree are as follows:

- 0-0.29: Extremely maladjusted
- 0.30-0.49: Maladjusted
- 0.50-0.59: Weakly maladjusted
- 0.60-0.69: Weakly coordinated
- 0.70-0.79: Relatively coordinated
- 0.80-0.89: Coordinated
- 0.90-1.00: Well-coordinated

For the Australian construction industry, the sustainable development index will only be compared between 2002-03 and 2009-10 due to the date availability.

4.8.2.2 Cross country comparison on sustainable development index

In order to find the difference on sustainable development index between the Chinese and Australian construction industry, the indicators in the sustainable development index of the Australian construction industry in 2009-10 will be considered as the 'base' and the value is 1. The value of indicators in Economic Sustainability and Social Sustainability of the Chinese construction industry in 2010 divided by the value of indicators in Economic Sustainability and Social Sustainability of the Australian construction industry in 2009-10 will be considered as the index value of the Chinese construction industry for each indicator in Economic Sustainability and Social Sustainability in 2010. However, for the Environmental Sustainability, the smaller value of the indicators is the better. The index value of the indicators in Environmental Sustainability will be measured by 2 minus the value of indicators in Environmental Sustainability of the Chinese construction industry in 2010 divided by the value of indicators in Environmental Sustainability of the Australian construction industry in 2009-10.

In addition, the value of sustainable development index and the sub-indices including economic sustainability index, social sustainability index and environmental sustainability index will be expressed by the average of the value of indicators included in each index. After that, these indices will be compared between the Chinese and Australian construction industries.

In order to answer research question three, '*What are the differences of productivity and industrial competitiveness between the Chinese and Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?*', the interaction among the economic sustainability index, social sustainability index and environmental sustainability index will be studied by the multivariate cointegration analysis and the long-term influence theory based on the interactivity principle of systems thinking, which will be introduced. Furthermore, based on the result of comparison between the Chinese and the Australian construction industries, the suggestions for improving the sustainability of the Chinese construction industry will be proposed.

4.8.2.3 Multivariate Cointegration Analysis

In macroeconomics, cointegration analysis put forward by Engle-Granger (1987) has become an important measurement tool for economic and social analysis. This theory lays a theoretical foundation for finding a balance between two or more non-stationary variables, as well as establishing error correction model among variables with a cointegration relationship (Engle, 1987). This research will mainly be based on empirical research and analysis of performance characteristics, the nature of linkages and internal rules of the relationship of the growth rates of Economic sustainability, Environmental sustainability and Social sustainability of the Chinese and Australian construction industries from 2001 to 2010 using unit root test, cointegration test, error correction model, Granger causality test and VAR dynamic econometric model.

A. Unit Root Test

In time series analysis, if the mean value of time series changes as time goes on, the sequence is non-stationary time series. There will be spurious regression with statistically significant regression parameters if we use time series analysis on non-stationary time series, which is also known as statistically meaningless correlation. Therefore cointegration analysis must be made after unit root test of research data.

(1) <u>DF test</u>

Dickey and Fuller (1979) argue that DF (Dickey-Fuller) test based on regression lag-one autoregression needs to consider three random processes:

$$y_t = \rho y_{t-1} + u_t \tag{35}$$

$$y_t = \rho y_{t-1} + a + u_t \tag{36}$$

$$y_t = \rho y_{t-1} + a + t\delta + u_t \tag{37}$$

Where： ρ is rational number； a is constant term； $t\delta$ is time tendency part； u_t is white noise. If $|\rho|<1$, series y_t is stable； if $|\rho|=1$, series y_t is unstable； and if $|\rho|>1$, series y_t is strong non-stationary, explosive and meaningless. Therefore we can test the stationarity of y_t through testing whether $|\rho|$ is strictly less than 1.

When doing the test, we minus y_{t-1} from both sides of formula (35), (36) and (37) to get these three test equations:

$$\Delta y_t = \gamma y_{t-1} + u_t \tag{38}$$

$$\Delta y_t = \gamma y_{t-1} + a + u_t \tag{39}$$

$$\Delta y_t = \gamma y_{t-1} + a + \delta t + u_t \qquad (40)$$

Where： $\gamma = \rho - 1$, and the hypotheses of the test are:

H_0： $\gamma = 0$ （y_t is unstable）

H_1： $\gamma < 0$ （y_t is stable）

In normal circumstances, significance test statistic t of the estimates of parameter γ does not obey the conventional t distribution. In Eviews, it uses the unit root test threshold improved by Machinnon. The DF test is left single-end testing and its inspection rules states that if the DF is more than the critical value, it should be accepted, meaning H_0 and y_t are non-stationary; and if the DF is less than the critical value, then it should be rejected, meaning H_0 and y_t are stable.

(2) ADF test

The DF test only applies to a situation when sequence is an AR (1) process. If the sequence is higher order lag correlation, the assumption that random disturbance term is white noise will be undermined. Here Augmented Dickey-Fuller, namely the ADF test, can be used to test the unit root test of a sequence with higher order serial correlation. Hypothesis and inspection rules of the ADF test are similar to the DF test except test equations.

The ADF test assumes sequence y_t is AR (p) process. Test equations are:

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \Delta y_{t-i} + u_t \qquad (41)$$

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \Delta y_{t-i} + a + u_t \qquad (42)$$

$$\Delta y_t = \gamma y_{t-1} + \sum_{i=1}^{p} \Delta y_{t-i} + a + t\delta + u_t \qquad (43)$$

During the ADF test the important issue is the choice of lag order *p*. We usually determine *p* by AIC criterion (Akaike Information Criterion).

Whether the DF test or ADF test is used there are three kinds of test equations. It is also important to choose which kind of test equation, that is, whether or not joining constant term and time trend term. We can determine this by observing line chart of the sequence. A sequence similar to the random walk can be tested by formulas (38) and (41) without adding items; a sequence with a linear trend can be tested by formulas (39) and (42) which have constant term; and a sequence with a quadratic trend can be tested by formulas (40) and (43) with both constant term and time trend item. When it is difficult to judge the form of a test equation through visual observation of the line chart, we can make use of the auxiliary equation to observe the significance of constant term and coefficient of time trend item.

B. Integration, Cointegration and Cointegration Test

(1) Integration

If the sequence y_t reached a plateau by d-differential and its d-1 differential is not smooth, then the sequence y_t is d order integrated sequence, denoted by $y_t \sim I(\mathrm{d})$. Where d represents the order of integration, which is the number of unit root of the sequence (number of times of differential in order to make sequence smooth). If the sequence y_t is stationary, then it is zero order integrated sequence, denoted by $y_t \sim I(0)$.

(2) Cointegration

Cointegration refers to a situation where a single time series is not smooth, but the linear combination of two or more time series is stationary. This co-movement of variables leads a kind of long-term linear relationship among the set of variables. Its significance is that it reveals a long-term stable equilibrium relationship. Economic variables which meet cointegration cannot be separated from each other too far, and only one shock can make them deviate from the equilibrium position within a short period of time, and in the long term they will automatically revert to the balanced position. In order to avoid the problem of spurious regression we generally first use the differential method to make a sequence stable and then establish a model. However the different sequence limits the range of economic issues discussed, and sometimes does not have a direct economic significance.

The strict definition of cointegration is: If the components of the k-dimensional vector $y_t = (y_{1t}, y_{2t}, \cdots, y_{kt})$ are all d order integrated sequence, that is $I(d)$, there is a non-zero vector $\beta = (\beta_1, \beta_2, \cdots, \beta_k)$ which can result in $\beta y_t' = I(d-b)$, $0 < b \le d$, then components of the vector y_t is called (d, b) order of cointegration, denoted by $y_t \sim CI(d, b)$, and β is called cointegrated vector.

(3) Cointegration Test

For two variables which follow their own law of long-term fluctuations, if they are cointegrated, there is a long-term equilibrium relationship between them. Conversely, if the two variables are not cointegrated, there is not a long-term equilibrium relationship between them. In order to test whether the two variables x_t and y_t are cointegrated, Engle and Granger (1987) propose a two-step test method, called the EG test. If sequence x_t and y_t are d order integrated, we can use regression method between two variables, namely:

$$y_t = \alpha + \beta x_t + u_t \tag{44}$$

If we use $\hat{\alpha}$ and $\hat{\beta}$ to represent the estimated value of the regression coefficient, the model's residuals are:

$$\hat{u}_t = y_t - \hat{\alpha} - \hat{\beta} x_t \tag{45}$$

If $\hat{u}_t \sim I(0)$, x_t and y_t have a co-integration relationship and a long-term stable equilibrium relationship, vector $(1, -\hat{\beta})$ is the cointegration vector and formula (44) is the cointegration equation. Here, we can use the unit root test method described above to make d-order integration test of sequence x_t and y_t, and zero-order integration test of sequence $\hat{u}_t$.

If there are more than three variables, we need to use the Johansen maximum likelihood method to perform the cointegration test (Johansen, 1988). The Johansen maximum likelihood method can determine the number of cointegration equation, which is called cointegration rank. The Cointegration likelihood ratio test has the following hypotheses:

H_0: There are at most *r* cointegration relations;

H_1: There are *m* cointegration relationships.

The empirical method of multiple regressions is a prior assumption – that the relationship is first assumed to exist between the variables and then verified; however cointegration analysis is a post assumption which first determines integrated order. The equation will be assumed only if there is the same integrated order for all variables or there is a long-term equilibrium relationship in theory for variables with different integrated orders after some combination.

C. Vector Error Correction Model

In order to further define the specific influence relationship between the variables, according to cointegration theory, once the short-term fluctuations deviate from the long-run equilibrium, the existence of the error correction mechanism can correct this bias (Davidson, *et al*., 1978). If an internal variable y_t is represented only a function of the exogenous variables x_t at the same time, it is easy to find the long-term impact on y_t by x_t. If the lag terms of each variable also appear in the model, the long-term impact will be reflected by distributed lag function which is Auto-Regressive Distributed Lag (ADL).

One order of autoregressive distributed lag model is recorded as ADL (1, 1):

$$y_t = \beta_0 + \beta_1 y_{y-1} + \beta_2 x_t + \beta_3 x_{t-1} + u_t \tag{46}$$

Where: $u_t \sim IID(0, \delta^2)$. After transposition, we can get as follows:

$$\Delta y_t = \beta_0 + (\beta_1 - 1)(y_t - \frac{\beta_2 + \beta_3}{1 - \beta_1} x_t)_{t-1} + \beta_2 \Delta x_t + u_t \tag{47}$$

Equations (46) and (47) are equivalent, but each equation has a different interpretation and meaning. Equation (47) is called ECM (Error Correction Model), and $y_t - \frac{\beta_2 + \beta_3}{1 - \beta_1} x_t$ is called error correction item, denoted as ECM. Thus, the equation (48) can be abbreviated as:

$$\Delta y_t = \beta_0 + \alpha ecm_{t-1} + \beta_2 \Delta x_t + u_t \tag{48}$$

Where: $\alpha = (\beta_1 - 1)$

Model (49) explains how the short-term fluctuations Δy_t of the explanatory variables y_t is determined. On the one hand, it is subject to the impact of short-term fluctuations Δx_t of the explanatory variables; on the other hand, it depends on the ECM. If y_t and x_t have a long-term stable equilibrium relationship, that is $y^* = bx^*$, then ECM can be rewritten as:

$$y^* = \frac{\beta_2 + \beta_3}{1 - \beta_1} x^* \tag{49}$$

ECM reflects the short-term deviation of y_t on x_t in period t, that is, the degree of deviation from their long-run equilibrium relationship in the short-term fluctuations. Generally, since $|\beta_1| < 1$ in equation (47), the coefficients of the error correction term in equation (49) $\alpha = (\beta_1 - 1) < 0$, and is usually referred to as the adjustment factor or a correction coefficient which represents the adjustment speed of deviation between y_{t-1} and $\frac{\beta_2 + \beta_3}{1 - \beta_1} x_{t-1}$ in the period t-1. It is thus clear that, when $y_{t-1} > \frac{\beta_2 + \beta_3}{1 - \beta_1} x_{t-1}$, ecm_{t-1} is positive, αecm_{t-1} is negative, Δy_t reduces, and vice versa, which reflects the control of balanced error on y_t. That is, when the correction factor is 1, balanced error of the variable in that very year can be adjusted to a balanced state next year. If the correction factor is a negative number less than -1, the non-equilibrium error of variable last year makes reverse correction to variables this year at the speed of the coefficient ratio. Therefore y_t changes constantly in the process of correction 'preliminary' error and the relationship of y_t and x_t is always around the long-run equilibrium relationship $y^* = \frac{\beta_2 + \beta_3}{1 - \beta_1} x^*$.

The most common estimation method of ECM model is the EG two-step method. The first step is to find an OLS estimation of model by

$$y_t = bx_t + u_t \tag{50}$$

It is also known as cointegration regression which can produce the residual sequence:

$$\hat{u} = y_t - \hat{b}x_t \tag{51}$$

The second step is to replace the ECM in (49) with $\hat{u}$, as:

$$\Delta y_t = \beta_0 + \alpha\hat{u}_{t-1} + \beta_2 \Delta x_t + u_t \tag{52}$$

The final step is to do OLS estimate to the formula (52) to obtain estimates of the parameters, whereby getting the ECM Model.

D. Granger causality test

Cointegration test results indicate whether there is a long-term equilibrium relationship between variables, but we need further validation to find out whether this relationship constitutes the causal relationship. Therefore, Granger (1969) and Sims (1972) propose causality test model (Granger Test of Causality). The model is able to determine whether a variable can help predict another variable. Granger test based on cointegration analysis has a more comprehensive and accurate judgment on the causal relationship between variables. Granger causality includes two-way relationships: if the past and present information of the variable X_t is helpful for improving the forecast of variables Y_t, then there is causality from X to Y; if the past and present information of the variable Y_t is helpful for improving the forecast of variables X_t, then there is causation from Y to X. Causality test is used on variables whose causal relationship is unclear or doubtful; therefore General Granger inspection is always a two-way test.

First, we should test the null hypothesis: " X is not the reason for any changes of Y ", and then estimate the following two models.

Regression with unrestricted conditions:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \sum_{i=1}^{p} \beta_i X_{t-i} + \mu_t \tag{53}$$

Regression with restrictive conditions:

$$Y_t = \sum_{i=1}^{p} \alpha_i Y_{t-i} + \mu_t \tag{54}$$

μ_t is the white noise sequence, has zero mean, equal variance and is non-autocorrelation. p is lag phases. α_i and β_i are coefficients to be estimated.

Then we should calculate statistical values of F using the residual sum of squares of each regression , and verify that the coefficient $\beta_1, \beta_2, \cdots \beta_p$ is significant and is not zero. If at least one of them is significantly non-zero, the null hypothesis of ' X is not the reason for any changes of Y ' will be rejected and ' X is the cause for changes of Y ' will be accepted. The value of test statistic F is calculated as follows:

$$F = \frac{\frac{RSS_0 - RSS_1}{P}}{\frac{RSS_1}{t-2p-1}} \sim F(p, t-2p-1) \tag{55}$$

In equation (55), RSS_0 is the regression sum of squares of the regression model with restricted conditions; and RSS_1 is the regression sum of squares of the regression model without restricted conditions. $F_\alpha^*(P, t-2p-1)$ is obtained by looking up the significance table of α . When $F > F_\alpha^*$, H_0 is refused and the explanation of ' X is the cause of change of Y ' is accepted. Otherwise, H_0 is accepted, which is ' X is not the reason for any changes of Y '.

Finally, we should test the null hypothesis which is ' Y is not the reason for any changes of X ' using the same regression estimation method except replacing Y with X in the model (53) and model (54).

E. Vector Autoregression Model

Sims (1980) proposes the Vector Autoregression Model (VAR) as a way to predict the relevant time series and dynamic effect of random perturbations in variable systems by conducting regression analysis on some lagged variable in all variables and all current variables. The mathematical expression of the vector autoregression model is as follows:

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + \cdots + A_p y_{t-p} + B_1 x_t + \cdots + B_r x_{t-r} + \varepsilon_t \qquad (56)$$

In equation (56), y_t is m dimensional endogenous variable vector, x_t is d dimensional exogenous variables vector, and $A_1, A_2, \cdots, A_p$ and $B_1, B_2, \cdots, B_r$ is matrix of parameters to be estimated. Endogenous variables and exogenous variables have respective lag period: p and r. ε_t is a random perturbation term, which means homochromous elements can be related to each other, but cannot be associated with their own lag values or variables on the right side of the model. There are mainly two ways to study VAR model which are Impulse Response Function (IRF) and forecast variance decomposition.

The impulse response function is used to examine the impact of one standard deviation of the random disturbance on current value and future value of endogenous variables, which can measure the impact of one standard deviation (called 'pulse') of the random disturbance term from an endogenous variable on the current and future value of all the endogenous variables in the VAR model. For simplicity, considering the following VAR model which contains two endogenous variables and first-order lag:

$$Y_{1t} = a_{11}Y_{1t-1} + a_{12}Y_{1t-1} + \varepsilon_{1t} \tag{57}$$

$$Y_{2t} = a_{21}Y_{2t-1} + a_{22}Y_{2t-1} + \varepsilon_{2t} \tag{58}$$

Disturbance terms ε_{1t} and ε_{2t} in model (57) and (58) are called 'innovation'. If ε_{1t} changes, Y_{1t} will change immediately. In addition, the value of the next phase of the Y_{2t} also changes, and due to the lagged phases and changes of Y_{2t}, the future value of Y_{1t} will change. Thus, as time goes on, the diffusion of the initial impact of disturbances in the VAR model will cause greater changes of all the endogenous variables.

Forecast variance decomposition decomposes variances of prediction error of each exogenous variable in the VAR model according to its forming reason as components related with each endogenous variable. By analysing the contribution of each innovation shock to the change of each endogenous variable, we can understand the relative importance of each innovation on the endogenous variables in the model. Impulse response function is to track the impact of the system on an endogenous variable.

Multivariate Cointegration Analysis will be conducted in this research to explore the long-term equilibrium relationship between the Economic sustainability, Environmental sustainability and Social sustainability of the Chinese construction industry.

4.8.3 Government

The productivity of government will be adopted in this research to measure the government element. The Data Envelopment Analysis and the Malquist productivity index will be utilised to analyse and compare the Chinese and Australian construction industries. In the Internationalisation Sustainable Development Competitiveness Model, input will be measured by the labour and capital and outputs will be measured by the results of these activities including:

- Producing high level factors: reflected by the number of persons with a non-school qualification per thousand people
- The competition situation of the domestic market: reflected by industrial concentration
- and the performance of non-State Owned Company: indicated by their Gross Output Value.

4.8.4 Activities of multinational enterprises

The ROLI Model which is provided in Chapter 3 Section 3.4.7 will be adopted to measure the activities of multinational enterprises. The data from ENR will be used to calculate O-IRTR and L-IBD. The total number of countries which the firms may have the potential to work in is the number of the countries in which firms listed in the ENR report worked in for each year. However, I-OMS is the most difficult to calculate, because there is no database about the details of all the firms' subsidiaries and associates. The ENR's 'top 225 subsidiaries list' and 'subsidiaries at rank' do not provide enough information.

Therefore, this data will have to be sourced through other methods, such as Dun and Bradstreet (D&B)'s 'Who Owns Whom (WoW)' ownership tree structure database. However, some family trees are more than six levels, and the position or role (parent or subsidiaries) could be changed. Therefore, only the subsidiaries/associates within three levels down from its own level in the family tree shall be counted. If the data could not collected from ENR and WoW, some other resources will be adopted, such as the annual report, finance report, company brochures and company websites.

In order to quantitatively test the impact of the activities of the multinational enterprises on industrial competitiveness, this research will explore the relationship between the degree of internationalisation and a construction firm's financial performance and construction industry's performance at the country level. This study adopts the Spearman Rank Correlation Coefficient to analyse the relationship between the degree of internationalisation and construction firm's performance, and the relationship between degree of internationalisation and the construction industry performance in the international market at the country level.

The Spearman Rank Correlation Coefficient is used to discover the strength of the relationship between two sets of data. Spearman's rank correlation coefficient allows you to identify the strength of correlation within a data set of two variables. Spearman Rank Correlation Coefficient assesses the relationship between ranks without making any assumptions about the nature of their relationship. Therefore it is a non-parametric measure. This feature has contributed to its popularity and widespread use (Myers & Well, 2003). Another advantage with this measure is that it is much easier to use since it does not matter which way we rank the data, ascending or descending (Maritz, 1995). We may assign rank 1 to the smallest value or the largest value, provided we do the same thing for both sets of data. The only requirement is that data should be ranked or at least converted into ranks. In statistics, Spearman's Rank Correlation Coefficient or Spearman's rho, named after Charles Spearman and often denoted by the Greek letter ρ (rho) or as r_s. The Spearman Correlation Coefficient is often thought of as being the Pearson correlation coefficient between the ranked variables. In practice, however, a simpler procedure is normally used to calculate ρ. The n raw scores X_i, Y_i are converted to ranks x_i, y_i, and the differences $d_i = x_i - y_i$ between the ranks of each observation on the two variables are calculated. According to Myers and Well (2003) and Maritz (1995), if there are no tied ranks, then ρ is given by:

$$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}. \quad (59)$$

If tied ranks exist, Pearson's correlation coefficient between ranks should be used for the calculation:

$$r = \frac{\sum_i (x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_i (x_i - \bar{x})^2 \sum_i (y_i - \bar{y})^2}}. \quad (60)$$

The numerical value of the correlation coefficient ranges between -1 and +1. The correlation coefficient is the number indicating how the scores are related. The closer ρ is to 1, the better the agreement, while if ρ is closer to -1, this indicates strong agreement in the reverse direction. To summarise:

- $\rho > 0$ implies positive agreement among ranks
- $\rho < 0$ implies negative agreement (or agreement in the reverse direction)
- $\rho = 0$ implies no agreement

Correlation is an effect size and so we can verbally describe the strength of the correlation using the following guide for the absolute value of ρ:

- .00 - .19 ‘very weak’
- .20 - .39 ‘weak’
- .40 - .59 ‘moderate’
- .60 - .79 ‘strong’
- .80 – 1.0 ‘very strong’

For the relationship between the degree of internationalisation and construction firm’s performance, according to the data availability and the period of financial year, 25 international construction firms will be analysed (selected from the ENR top 225 international contractors list 2010) (Reina & Tulacz, 2011) from 6 countries, including: China, Brazil, Italy, France, German and Spain. Their financial performance will be measured by Return on Assets (ROA), which will be sourced from their annual reports.

For the relationship between degree of internationalisation and the construction industry performance in the international market at the country level, this research will analyse sixteen countries' construction industry. Only the countries which have more than three construction multinational enterprises in the ENR top 225 international contractors list in 2010 were selected in this research. The countries are China, Turkey, Italy, USA, Japan, Korea, Span, France, UK, German, Australia, Canada, Egypt, U.A.E., Brazil and India. The International Advanced Index will be adopted to measure the construction industry performance in the international market at the country level (refer to Chapter 2).

4.9 Summary

This chapter discussed the ontological, epistemological and methodological issues. This research will be conducted using an Interpretivism position based on the Constructivism ontology. Case study methodology will be used in this research. The Chinese construction industry and the Australian construction industry will be studied as cases. The discovery led approach following an inductive logic will be conducted.

The data could be collected from several resources. Comparison analysis and various statistics methods will be adopted to analyse the quantitative data including: Data Envelopment Analysis, the Malmquist productivity index, Input-output analysis, Degree of coordination, Multivariate Cointegration Analysis and Spearman Rank Correlation Coefficient.

Chapter 5 Development of the Chinese construction industry

5.1 Introduction

In recent decades, China has made remarkable achievements in various fields. As one of the most active emerging economies in today's world, China has attracted worldwide attention. As a mainstay industry, the construction industry has made a great contribution to the development of the Chinese economy. Moreover, over the decades of development in the international market, the Chinese construction industry has occupied a certain position in the international market.

In order to understand the performance of the Chinese construction industry from 2001 to 2010, this chapter will firstly explore the development phases in both the domestic and international markets, especially the new developments in the phase 2001 to 2010. Next, the status and level of the Chinese construction industry in the international market in 2001 and 2010 will be discussed. The results should contribute to answering Research Question 1.

5.2 Development phases

The Chinese construction industry has experienced a rapid development during the past two decades. From an historical point of view, Jiang (2006) stated that the development of the Chinese construction industry may be phased into four periods, which could be summarised in Table 5-1. However, after the entry into the World Trade Organization (WTO), many new developments and characteristics have emerged. Therefore, the period following entry into the WTO could be considered as the fifth phase and called 'Post WTO Time'. This phase will be discussed in the next section.

Phase	Time	Activities	Remarks
Creation Time	**1949–1957**	➢ In the 1950s, some state owned construction enterprises were established following some government Acts. ➢ From 1956, the construction sector of China started the process of industrialisation. Several Acts were developed by the Chinese government to regulate the construction sector, including the scope of infrastructure, the organisation, the compiling and approval procedures of the design and construction works, the construction and supervision works. ➢ The construction sector was following a 'tree shape' administration system: construction ministry at central government level and the construction bureaus at provinces and municipal levels. ➢ The design institutions were established at the same time and had a similar organisational structure.	➢ The Chinese construction industry was formed from the central planning economic system and absorbed many low productive resources (low skill workers and non-industrial production systems), which caused many problems when the demand on construction works increased rapidly later on. ➢ The construction sector grew readily. The share of the construction sector in the total GDP of China was 1.1% at the beginning of the 1950s, and reached 5% in 1957 (NSB, 1999).
Frustrated Time	**1958-1976**	➢ Most of the design institutions and research units were abrogated and the management of construction enterprises was led to paralysis. ➢ Disorder occurred in all economic sectors including the construction sector. Low productivity, high accident rate and poor construction quality were characteristics of the sector. ➢ Some achievements were also made in this phase, especially in the infrastructure field. Much of the infrastructure with very important roles in the Chinese economic development prior to the mid-1980s were constructed, including many inter-province and inter-city highways, power plants, hydro-electrical plants, water control works and petroleum factories. Some of them are still in operation now with significant contribution to the local economy.	➢ The labor force in the construction industry was significantly expanded in 1958 and was suddenly compressed in 1960s. ➢ The growth of the construction sector was stopped by the 'great leap' from 1958 and the 'cultural revolution' in the 1960s and 1970s.
Rehabilitation Time	**1977-1983**	➢ The productivity of the Chinese construction industry increased dramatically. The total production output of the construction industry in 1983 was 105.3 Billion CNY or 1.4 times of that in 1976. The share of the construction sector in the whole economy increased from 8.1% in 1975 to 9.5% in 1983 (NSB, 1999). ➢ The wage system in construction enterprises was reformed, which lead to the increase of the productivity.	➢ From the late 1970s, the 'reform and open' policy in China directed the rehabilitation of the whole economy, the construction sector was included.
Development Time	**1984-2001**	➢ In 1983, the competitive mechanism and bidding system in the construction industry were introduced, and the open bidding system was expanded to the entire sector. ➢ Many Non-State Owned construction enterprises were established and got developed. ➢ The organisational structure of construction enterprises was changed and the management skills and types were improved significantly. ➢ The Chinese construction industry was becoming more regulated due to the gradual building up and enhancement of the legal system with respect to construction work from the mid-1990s. The Construction Law and Bidding Acts and several other legal mechanisms were put into force in recent years.	➢ The management system of the whole Chinese economy was changing from a planned system to market system. ➢ A further reform to cater to the marketing system in construction has now met some difficulties and therefore the construction sector is probably one of the least open sectors in China's economy.

Table 5-1 The development stages of Chinese construction industry

Source: Jiang, H. B., 2006, Chinese multinational construction firms in international and domestic markets: a re-examination of the eclectic paradigm, Department of Building, School of Design and Environment, National University of Singapore.

5.3 Post WTO time

The construction industry contributes a great deal to internationalisation activity. According to the Engineer News Report (2011), the ENR top 225 international contractors generated $383.7 billion in revenue from projects outside their home countries in 2010. The degree of competition becomes more intense and the scope becomes much broader when firms internationalise. Different countries have made different adjustments in their construction industry to suit this trend, in order to gain more achievements in the international market and this is no different for the Chinese construction industry.

Even though the Chinese construction industry does not have a long history of internationalisation the Chinese construction industry has undergone dramatic changes as a result of internationalisation in recent years. The industry has become integrated into the world economy to a greater degree and has become an important part of the global industrial chain; particularly upon gaining entry into the World Trade Organization (WTO) in 2001 whereby the relationship between China and the rest of the world has become much closer. Following this the internationalisation process of the Chinese construction industry can be considered to have entered a new era.

In the past several years, the Chinese construction industry has made remarkable achievements, from gradually opening up to the world economy in the early stages to becoming highly integrated into the international construction industry chain. There are many new features which will be considered.

5.3.1 Market condition

Firstly, the Chinese construction market is extremely large and growth has been rapid (refer to Figure 5-1 and Table 5-2). By 2010, the Gross Output Value of the Chinese construction industry has risen to 9603.1 billion CNY from 1536.2 billion CNY in 2001. The growth rate of the Gross Output Value is significant in these ten years. Besides the 19% growth in 2005, the growth rate of the Gross Output Value (GOV) of the Chinese construction industry is not less than 20% in this period (refer to Table 6-2). However, the average annual increase rate of the Chinese gross domestic product (GDP) is approximately 15% from 2001 to 2010, which is lower than the GOV of the Chinese construction industry. This demonstrates the important role the construction industry plays in the growth of China's economy.

Year	Gross Output Value (Billion CNY)	Growth Rate of Gross Output Value
2001	1536.20	23%
2002	1852.70	21%
2003	2308.40	25%
2004	2902.10	26%
2005	3455.20	19%
2006	4155.70	20%
2007	5104.40	23%
2008	6203.70	22%
2009	7680.80	24%
2010	9603.10	25%

Table 5-2 Gross Output Value of the Chinese construction industry and its growth rate

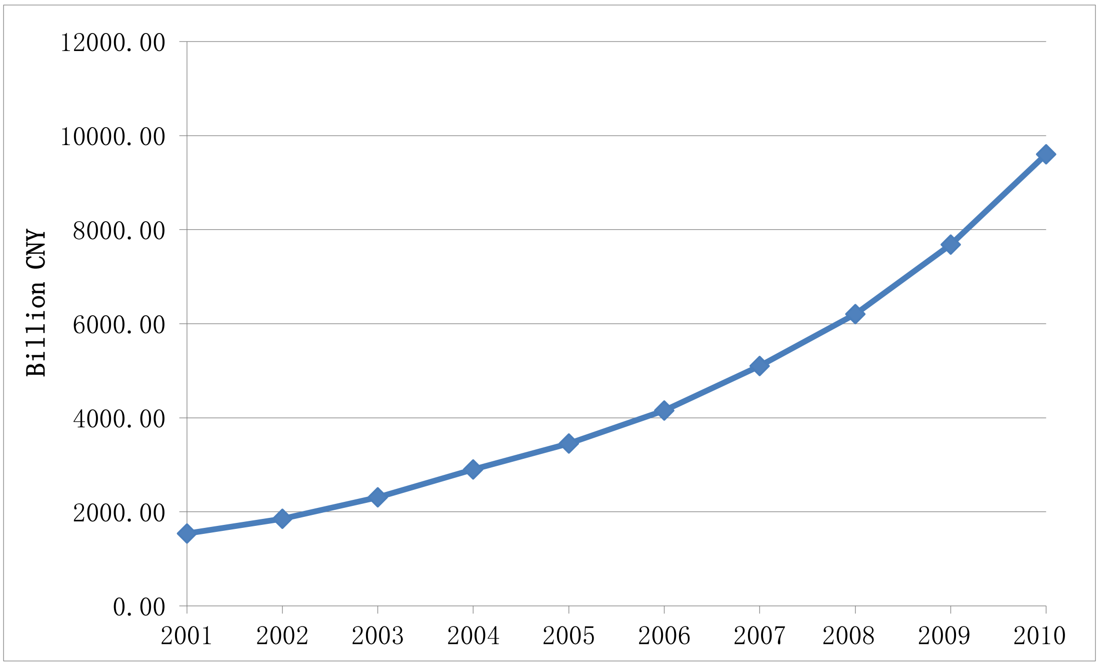


Figure 5-1 Gross Output Value of Chinese Construction Industry

5.3.2 Employment

Secondly, the Chinese construction industry provides a diverse range of jobs and offers many new opportunities (refer to Figure 5-2 and Table 5-3). By the end of 2010, there were more than 41.6 million people working in the Chinese construction industry (NBSC, 2011). From Figures 5-2, we can observe that the number of workers in the Chinese construction industry greatly increased from 2001 to 2010. The average growth rate is about 7.67% in these ten years and the growth rate is still increasing (refer to Table 5-3). The construction industry has made an outstanding contribution towards solving China’s employment problem.

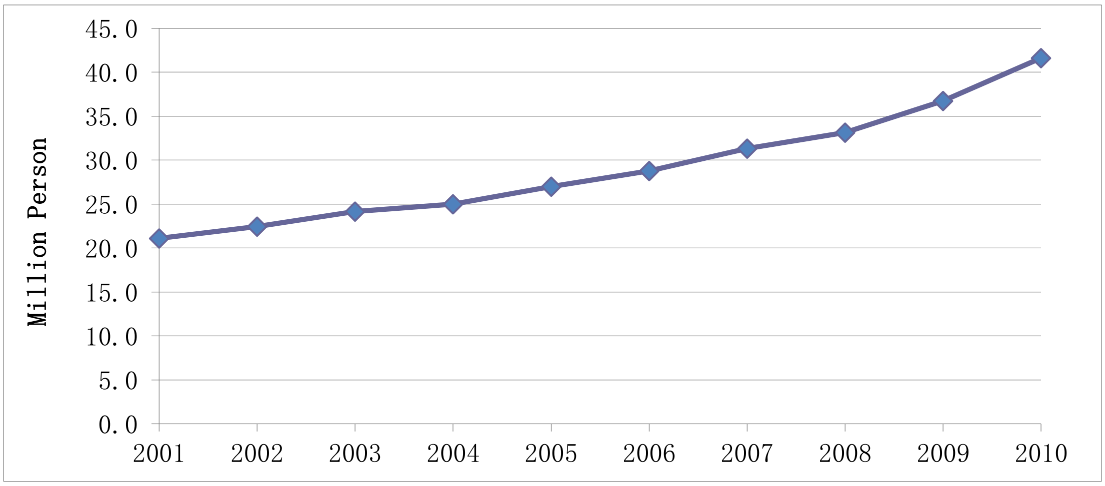


Figure 5-2 Number of Persons Employed (NPE)

Year	Number of Persons Employed (Million)	Growth Rate (%)
2001	21.1	5.83
2002	22.5	6.37
2003	24.1	7.53
2004	25.0	3.56
2005	27.0	7.98
2006	28.8	6.60
2007	31.3	8.88
2008	33.1	5.80
2009	36.7	10.80
2010	41.6	13.30

Table 5-3 Number of Person Employed and Growth Rate

5.3.3 Level of technology

Thirdly, the level of technology has continuously improved (Figure 5-3), which is mainly reflected in the Value of Machines per Labour (VML). The VML has increased from 7136 CNY/Person in 2001 to 9547 CNY/Person in 2010. However, after the China’s accession to the WTO in 2001, there was a decline from 2002 to 2007 and then it was restored a little. But until 2010, the VML is still less than 2002. In this sense, China's accession to the WTO did not bring the increase as anticipated in the level of technology of Chinese construction enterprises in recent years.

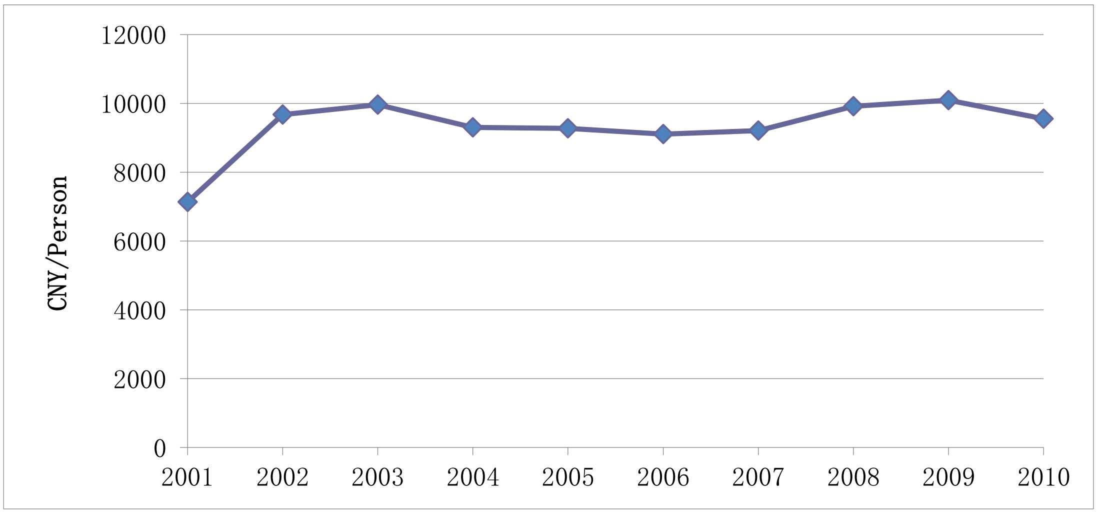


Figure 5-3 Value of Machines per Labour

5.3.4 Classification of firms

Macroeconomic indicators provide insights on the impact of China joining the WTO, as well as industrial organisation economic indicators and measures. The classification of firms in the Chinese construction industry has changed from three categories named State Owned Enterprises (SOEs), Urban and Rural Collectives (URCs) and Rural Construction Teams (RCTs) to five categories: state owned enterprises (SOEs), collective owned enterprises (COEs), private owned enterprises (POEs), enterprises founded by Hong Kong, Macao and Taiwan (HMTEs), and foreign founded enterprises (FFEs).

Category		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
SOEs	**Number**	8264	7536	6638	6513	6007	5555	5319	5315	5009	4810
	Percentage in Total No. of Chinese Construction Firms	18.01%	15.76%	13.63%	11.04%	10.22%	9.23%	8.57%	7.48%	7.07%	6.69%
	Gross Output Value (Billion CNY)	536.28	558.29	606.02	732.56	843.20	921.86	1063.09	1223.17	1519.01	1814.86
	Percentage in the Chinese Construction Industry Gross Output Value	34.91%	30.13%	26.25%	25.24%	24.40%	22.18%	20.83%	19.72%	19.78%	18.90%
COEs	**Number**	19096	13177	10425	8959	8090	7051	6614	5843	5352	5026
	Percentage in Total No. of Chinese Construction Firms	41.61%	27.56%	21.41%	15.18%	13.77%	11.72%	10.66%	8.22%	7.56%	6.99%
	Gross Output Value (Billion CNY)	377.59	333.85	327.07	275.61	281.52	290.45	315.37	321.64	328.18	365.53
	Percentage in the Chinese Construction Industry Gross Output Value	24.58%	18.02%	14.17%	9.50%	8.15%	6.99%	6.18%	5.18%	4.27%	3.81%
POEs	**Number**	17637	26196	30803	42649	43749	46711	49294	59100	59661	61280
	Percentage in Total No. of Chinese Construction Firms	38.43%	54.78%	63.27%	72.26%	74.47%	77.64%	79.41%	83.13%	84.25%	85.27%
	Gross Output Value (Billion CNY)	604.73	940.06	1349.98	1860.02	2288.33	2891.87	3658.09	4588.05	5758.62	7334.36
	Percentage in the Chinese Construction Industry Gross Output Value	39.37%	50.74%	58.48%	64.09%	66.23%	69.59%	71.67%	73.96%	74.97%	76.37%
HMTEs	**Number**	622	632	535	511	516	479	482	474	444	416
	Percentage in Total No. of Chinese Construction Firms	1.36%	1.32%	1.10%	0.87%	0.88%	0.80%	0.78%	0.67%	0.63%	0.58%
	Gross Output Value (Billion CNY)	10.26	11.39	12.37	13.70	17.25	24.05	28.20	32.11	33.46	44.40
	Percentage in the Chinese Construction Industry Gross Output Value	0.67%	0.61%	0.54%	0.47%	0.50%	0.58%	0.55%	0.52%	0.44%	0.46%
FFEs	**Number**	274	279	287	386	388	370	365	363	351	331
	Percentage in Total No. of Chinese Construction Firms	0.60%	0.58%	0.59%	0.65%	0.66%	0.61%	0.59%	0.51%	0.50%	0.46%
	Gross Output Value (Billion CNY)	7.31	9.14	12.94	20.25	24.90	27.49	39.63	38.71	41.52	43.97
	Percentage in the Chinese Construction Industry Gross Output Value	0.48%	0.49%	0.56%	0.70%	0.72%	0.66%	0.78%	0.62%	0.54%	0.46%

Table 5-4 Five categories of the Chinese construction industry

The number of SOEs and COEs shows a clear trend of contraction, and their dominance in the industry significantly declines correspondingly. The numbers of SOEs and COEs have reduced from 8264 and 19096 in 2001 to 4810 and 5026 in 2010 respectively. The proportion of the numbers of SOEs and COEs in all the Chinese construction enterprises has declined down to 6.69% and 6.99% in 2010 from 18.01% and 41.61% in 2001. Moreover, the Gross Output Value of COEs and the proportion of COEs in the Gross Output Value of the Chinese construction industry have decreased from 377.59 Billion CNY and 24.58% in 2001 to 365.53 Billion CNY and 3.81% in 2010. Thought the Gross Output Value of SOEs has climbed to 1814.86 Billion CNY in 2010 from 536.28 Billion CNY in 2001, the Gross Output Value of SOEs only accounted for 18.90% in the total Gross Output Value of the Chinese construction industry, in 2010, compared with 34.91% in 2001.

On the other hand, POEs are growing rapidly and becoming the main force in the Chinese construction industry. The number of POEs increased from 17637 in 2001 to 61280 in 2010. POEs have accounted for 85.27% in the total number of the Chinese construction firms, compared with 38.43% in 2001. The Gross Output Value of POEs has increased from 604.73 Billion CNY in 2001 to 7334.36 Billion CNY in 2010. The percentage of POEs' Gross Output Value in the total Chinese construction industry's Gross Output Value has risen from 39.37% in 2001 to 76.37% in 2010.

HMTEs and FFEs only have a very small market share. For HMTEs, besides the Gross Output Value increasing from 10.26 Billion CNY in 2001 to 44.4 Billion CNY in 2010, the number of firms, the percentage of the number of HMTEs in total number of the Chinese construction firms and the Gross Output Value of HMTEs in the Chinese construction industry Gross Output Value declined to certain extent. The number of FFEs has increased from 274 in 2001 to 331 in 2010. However, it only accounted for 0.46% in the total number of Chinese construction firms, which is 0.60% in 2001. The Gross Output Value of FFEs has climbed to 43.97 Billion CNY in

2010 to 7.31 Billion CNY in 2001. Meanwhile the percentage of the Gross Output Value of FFEs in the total Gross Output Value of the Chinese construction industry was increasing from 0.48% in 2001 to 0.78% in 2007, and decreasing to 0.46% in 2010. Before 2001, the foreign construction companies have limited access to the industry. After the five year transition period of China's entry to the World Trade Organization (WTO), the foreign companies were supposed to have more opportunities within the Chinese construction market. However, the result in Table 5-4 does not support this.

5.3.5 Industrial organisational structure

Last but not least, after joining the WTO, the industrial organisational structure of the Chinese construction industry has changed. In order to adapt to the new international environment and industry competitiveness, in 2001 the Chinese government introduced the 'construction enterprise qualification grades standards'. After its implementation in 2002, the Chinese construction industry initially formed a structured system, which was composed of the general contractors (GCs), professional contractors (PCs) and labour subcontractors (LSs). The development of the different types of contractors is summarised in Table 5-5 and Table 5-6.

Year	General Contractors	Professional Contractors	Labour Subcontractors
2003	29359	19329	2021
2004	31458	23256	2546
2005	32389	26361	3101
2006	33175	26991	3748
2007	34071	28003	4357
2008	38212	32883	6837
2009	38375	32442	6756
2010	39430	32433	6835

Table 5-5 The number of construction firms in different types of contractors

Year	General Contractors		Professional Contractors		Labour Subcontractors	
	Gross Output Value Billion CNY	% in Total GOV	Gross Output Value Billion CNY	% in Total GOV	Gross Output Value Billion CNY	% in Total GOV
2003	1974.36	85.12%	334.03	14.40%	11.05	0.48%
2004	2464.72	85.63%	398.96	13.86%	14.66	0.51%
2005	2983.41	85.88%	471.80	13.58%	18.85	0.54%
2006	3603.33	86.18%	552.39	13.21%	25.38	0.61%
2007	4441.93	86.38%	662.44	12.88%	37.90	0.74%
2008	5422.68	86.54%	781.00	12.46%	62.10	0.99%
2009	6796.46	87.64%	884.32	11.40%	74.29	0.96%
2010	8515.47	87.81%	1087.64	11.22%	94.10	0.97%

Table 5-6 Gross Output Value of different types of contractors and the percentage in the total Gross Output Value of the Chinese construction industry

The number of General Contractors is increasing continuously from 29359 in 2003 to 39430 in 2010. Other than the decrease in 2009, the numbers of Professional Contractors and Labour Subcontractors both increased from 2003 to 2010 (refer to Table 5-5). The Gross Output Value of all these three types of contractors has increased dramatically from 2001 to 2010.

General Contractors are the most significant part of the Chinese construction industry and dominate the market in relation to the Gross Output Value, because they account for more than 85% of the total Gross Output Value of the Chinese construction industry, and this number is increasing every year. Gross Output Value of Professional Contractors has climbed from 334.03 Billion CNY in 2001 to 1087.64 Billion CNY in 2010. However, the percentage of the Gross Output Value of Professional Contractors in the total Gross Output Value of the Chinese construction industry declined from 14.40% in 2001 to 11.22% in 2010. For the Labour Subcontractors, the Gross Output Value and the percentage in the total Gross Output Value of the Chinese construction industry are all increasing dramatically. Labour Subcontractors only account for 0.97% of the total Gross Output Value of the Chinese construction industry (refer to Table 5-6).

As a pillar industry, the construction industry plays an important role in all the country's economic and social issues. In the last decades, the Chinese construction industry has gained significant achievements, and importantly some changes have occurred. This section summarised the new developments of the Chinese construction industry from 2001 to 2010. It is mainly focused on the domestic market. In the next section, the performance of the Chinese construction industry in the international market from 2001 to 2010 will be discussed.

5.4 Development phases in the international market

The development of the Chinese construction multinational enterprises in the international construction market can be divided into four phases, including 1) Economic and Technical Aid Time, 2) Emergence Time, 3) Towards Multinational Time and 4) WTO Time. These four phases will be discussed in detail in this section.

5.4.1 Phase 1: Economic and Technical Aid Time

The first stage could be called 'Economic and Technical Aid Time', which is prior to 1979. The Economic and Technical Aid (ETA) to foreign countries, which is also known as 'Development Aid' commonly refers to one country's government providing endowments or favourable loans with no less than 25% of endowments to the developing countries or to the international multilateral organisations, in order to help these countries develop. The ETA provided to some developing countries prior to the 1970s by the Chinese government could be considered as an important means to support China's international politics and foreign relationships. It determined the objective of these ETAs was not for business purposes but for the political issues, so-called 'liberation and independence of brother countries in the third world'. The Chinese construction firms were involved in the international market by doing ETA projects in other developing countries funded by the Chinese government.

These type of projects were set up and administered by the governments, not by the independent enterprises. The decision to undertake these projects was motivated not by the market place or profit's for enterprises. In addition, there are fewer business risks and managerial issues in these projects because of the endorsement of the Chinese government on all project costs and other expenditure. Also, because these projects are all 'aid' projects, the Chinese construction enterprises could not earn profits. However, the ETA projects during this stage did bring some intangible benefits for the Chinese construction enterprises. These enterprises obtained the very rare chances at that moment to get some information and understanding about the international construction market and access connections to various foreign organisations. Moreover, many technical and managerial personnel were trained during these projects. These benefits became their advantage on overseas projects when they were allowed to bid for the international projects later on. As a result, the Chinese construction enterprises undertaking ETA projects in this period became the pioneers in the international process of the Chinese international construction, and many of them still play a very important role in the domestic and international construction market nowadays.

Besides technical and financial aid, the ETA projects funded by the Chinese government normally included a complete package of project aids, which consisted of project investigation, design, construction, and permanent equipment supply and installation. More than 1,300 complete packages of projects under ETA have been provided by the Chinese government for about 70 developing countries from 1954 to 1978.

5.4.2 Phase 2: Emergence Time

The Emergence Time was the second stage of the Chinese construction enterprises involved in the international construction market. It began from the late 1970s, and ended in the early 1990s. From the late 1970s, The Chinese construction enterprises began to be involved in international construction projects and to export the contracted labor in the international construction market, and many improvements were gained by the Chinese construction enterprises in the international construction market. There were 27 international engineering construction contracts and 9 labor contracts signed by Chinese international contractors with the contract value of US$ 33.52 million and US$ 17.65 million respectively in 1979, with most of these projects located in the Middle East. Up to 1982, of 755 international contracts with the total contract value of US$ 1.2 billion, 27 were secured by Chinese construction companies working in about 45 countries in Asia, Africa, America and Europe.

Jiang (2006) summarised the reasons for the development of Chinese construction enterprises working internationally during the period. Firstly, the affluent labor resources and the sufficient engineering and construction expertise in Chinese construction enterprises allowed them to work internationally. The second driver was the working experiences in the international market gained through the ETA projects during the 1960s and 1970s by the large Chinese construction enterprises. In addition, the third boom of the international construction market in the late 1970s became another key factor to help the initiation of the international involvement of Chinese construction enterprises. However, almost all the enterprises contracting overseas were still organised by the Chinese government and the participation in international contracting had to be strictly approved by the related government departments. The political issues were still controlled business considerations.

Due to the open-door policy initiated in China from the end of the 1970s, the Chinese construction industry started to reform. In the early 1980s, the Chinese government introduced regulations to set up the basic ground rules for the construction industry. The companies were allowed to operate as ‘commercial entities’. Hence, some State Owned Enterprises (SOEs) were separated from governmental departments. However, their priority was still to work for ETA projects until the mid-1980s. In this period, some SOEs at the central government level, which were under the direct administration of the corresponding Ministries, were allowed to apply for the licenses issued by the Ministry of Foreign Economic Relations and Trade to bid for projects in the international market. From then on, these enterprises became more independent from the governmental administration and profit-driven motivation, and started to participate in international bidding, tender for commercial projects and negotiate with their foreign counterparts. This was the first stage of transition and reform of the Chinese construction and other related sectors enterprises. It indicates the prelude of

5.4.3 Phase 3: Towards Multinational Time

The third phase is 'Towards Multinational Time', which started in the early 1990s and ended in the early 2000s. Following decades of development, some large Chinese state owned construction enterprises had gained considerable experience in the international market. Moreover, from the early 1990s, some lower level companies such as provincial level and local level companies were allowed to apply for the licenses to contract overseas. A large amount of Chinese construction companies started their performance on the world stage. They secured a variety of construction projects in many developing countries. In this phase, the Chinese international construction enterprises started to develop a multinational development perspective in relation to their organisational structure and business strategies. The top management realised the necessity of setting up long term international business development strategies. They began to operate their businesses in many countries using a long term operating strategy, rather than completing one-off projects as before. They also understood the importance of establishing international networking in the construction market, and learnt to build this networking through their subsidiaries, representatives and project offices outside China.

During this stage, because of the profit-driven motivation, the Chinese construction companies commenced a price-war in some traditional markets such as Middle Eastern and African countries. At the same time, some successful Chinese construction companies expanded their businesses rapidly into the new markets in

Central and South America, and Europe. By 2000, there were 35 Chinese construction firms listed in the top 225 international contractors generated by ENR (Reina & Tulacz, 2001). The value of overseas contracts won by the Chinese international construction firms from 1990 to 2000 has an average annual increase of 20%.

5.4.4 Phase 4: WTO Time

With China's entry into the World Trade Organization at the end of 2001, the Chinese construction industry was now entering a fourth stage. The Chinese construction industry and enterprises faced new opportunities and challenges. The performance of the Chinese construction industry and multinational enterprises in this phase is summarised in Table 5-7.

Firstly, significant achievements have been made by the Chinese construction industry and multinational enterprises in the international market in the last decade. The number of firms listed in the top 225 international contractors has increased from 40 in 2001 to 51 in 2010. It peaked at 54 in 2009. The international revenue of these particular Chinese construction enterprises has climbed to $57062.4 million in 2010 from $5947.4 million in 2001, which accounted for 14.9% and 5.6% respectively in the total international revenue of all the top 225 international contractors. This is a dramatic increase. The average growth rate of the total international revenue of the Chinese construction enterprises listed in the top 225 is 28.86%. To compare with 2007, the listed Chinese construction enterprises' total international revenue nearly doubled in 2008.

Next, the international revenue of the listed Chinese construction enterprises increased rapidly in all the regional markets from 2001 to 2010, except the Canadian market. The average growth rates are all higher than 37%, except in the Asian market with an average growth rate of 17.67%.

The Asian, Middle Eastern and African markets are still the most important markets for Chinese construction enterprises. Nearly 90% of their international revenue was gained from these three markets in 2010. An historically good relationship between these markets is be the key reason. These three markets are the 'start point' of the international process of the Chinese construction industry. The international revenue of all the listed Chinese construction enterprises achieved from the African market accounted for 11% in the total international revenue of these enterprises in 2001 and it increased dramatically to 41.13% in 2010. The proportion of the international revenue of all the listed Chinese construction enterprises made in the Middle Eastern market to the total international revenue of these enterprises increased slightly. However, the proportion in the Asian market declined rapidly from 64.66% in 2001 to 30.51% in 2010.

The percentage of the international revenue achieved in the Latin America and Caribbean market in the total international revenue of all the listed Chinese construction enterprises climbed to 5.86% in 2010 from 2.26% in 2001 with an increase rate of more than 150%. The share of the U.S market decreased from 1.99% in 2001 to 0.68% in 2010. The proportion of the European market remains stable. The share of the Canadian market is small enough to be negligible.

The competitiveness and influence of the Chinese construction enterprises in developing countries' markets is much higher than in developed countries' markets. It could be represented by the share of the international revenue of the Chinese construction enterprises in the total international revenue of this regional market. In the Middle East, Asia, Africa, South America and Caribbean markets, Chinese construction enterprises occupied a certain percentage of the overall international revenue and the share had a very substantial increase from 2001 to 2010. Especially in the Asia market and Africa market, the share of the Chinese construction enterprises in the total international revenue has risen significantly from 17.5% in 2001 to 22.7% in 2010 and from 7.4% in 2001to 38.7% in 2010 respectively. In contrast, in the developed countries' markets, including the European market, the U.S. market and

Canadian market, the share of the Chinese construction enterprises is very small, even small enough to ignore. Also, besides the sudden increase in the European market in 2010, the share of Chinese construction enterprises in all these markets has not improved much. This indicates that the development of Chinese construction enterprises in the developed countries is still difficult.

5.4.5 Summary

The four development phases of the Chinese construction industry in the international market are discussed in this section. Each phase has different characteristics. The Chinese construction industry is now in the fourth phase. Significant achievements in the international market have been made by the Chinese construction industry. The International Advanced Index will be used to measure the status and level of the Chinese construction industry in the international market in the next section.

Year		2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Number of firms		40	43	47	49	46	49	51	50	54	51
International revenue $ MIL		5947.4	7128.9	8332.9	8829.1	10067.9	16289.4	22677.6	43202.5	50573.3	57062.4
Growth rate of international revenue %		10.47	19.87	16.89	5.95	14.03	61.80	39.22	90.51	17.06	12.83
% in the total international revenue		5.6	6.1	6	5.3	5.3	7.3	7.3	11.1	13.2	14.9
Middle East	International revenue $ MEL	808	731.7	963	1034.1	1329.6	1980.1	3482.2	5048.4	8386.9	10009.2
	Growth rate of international revenue %	64.90	-9.44	31.61	7.38	28.58	48.92	75.86	44.98	66.13	19.34
	% in the total international revenue of this area	9.5	7.5	5.9	4.1	4.7	4.8	5.5	6.5	10.8	13.8
	% in the total international revenue of all the Chinese construction firms	13.59	10.26	11.56	11.71	13.21	12.16	15.36	11.69	16.58	17.54
Asia	International revenue $ MEL	3845.5	4148.1	5373.6	5112.8	5070.8	7563.4	9177	13723.9	18210.6	17409.9
	Growth rate of international revenue %	-3.35	7.87	29.54	-4.85	-0.82	49.16	21.33	49.55	32.69	-4.40
	% in the total international revenue of this area	17.5	18.2	20.6	16.8	15	18.8	16.6	20	24.9	22.7
	% in the total international revenue of all the Chinese construction firms	64.66	58.19	64.49	57.91	50.37	46.43	40.47	31.77	36.01	30.51
Africa	International revenue $ MEL	654.1	1103.9	1492.1	2106.8	3233.5	5083.5	7695.8	21578.2	20799.1	23467.7
	Growth rate of international revenue %	21.13	68.77	35.17	41.20	53.48	57.21	51.39	180.39	-3.61	12.83
	% in the total international revenue of this area	7.4	9.9	11.8	14.7	21.4	28.4	26.9	42.4	36.6	38.7
	% in the total international revenue of all the Chinese construction firms	11.00	15.48	17.91	23.86	32.12	31.21	33.94	49.95	41.13	41.13
Europe	International revenue $ MEL	378	468.6	234.7	255.2	115.6	509.9	990.6	1461.7	1608.8	2443.1
	Growth rate of international revenue %	277.62	23.97	-49.91	8.73	-54.70	341.09	94.27	47.56	10.06	51.86
	% in the total international revenue of this area	1.3	1.4	0.5	0.4	0.2	0.7	1	1.3	1.6	2.6
	% in the total international revenue of all the Chinese construction firms	6.36	6.57	2.82	2.89	1.15	3.13	4.37	3.38	3.18	4.28
U.S.	International revenue $ MEL	118.2	174.6	91.2	174.4	58.5	311.4	389.4	323.4	175.9	389.3
	Growth rate of international revenue %	23.13	47.72	-47.77	91.23	-66.46	432.31	25.05	-16.95	-45.61	121.32
	% in the total international revenue of this area	0.5	0.8	0.4	0.8	0.2	1.1	1.1	0.8	0.5	1.2
	% in the total international revenue of all the Chinese construction firms	1.99	2.45	1.09	1.98	0.58	1.91	1.72	0.75	0.35	0.68
Canada	International revenue $ MEL	5.3	5.7	0.5	0	2.5	22	44.8	12.9	46.9	2.6
	Growth rate of international revenue %	N/A	7.55	-91.23	-100.00	N/A	780.00	103.64	-71.21	263.57	-94.46
	% in the total international revenue of this area	0.1	0.1	0	0	0	0.3	0.5	0.1	0.4	0
	% in the total international revenue of all the Chinese construction firms	0.09	0.08	0.01	0.00	0.02	0.14	0.20	0.03	0.09	0.00
Latin America & Caribbean	International revenue $ MEL	138.3	496.5	177.8	145.8	257.5	783	897.9	1046.4	1345.1	3342.6
	Growth rate of international revenue %	-17.97	259.00	-64.19	-18.00	76.61	204.08	14.67	16.54	28.55	148.50
	% in the total international revenue of this area	1.3	5.2	1.8	1.6	2.1	4.9	4.2	4.4	5	9.8
	% in the total international revenue of all the Chinese construction firms	2.33	6.96	2.13	1.65	2.56	4.81	3.96	2.42	2.66	5.86

Table 5-7 Performance of the Chinese construction industry in the international market

5.5 Status and level in the international market

The data collected in 2001 and 2010 regarding the Chinese construction industry was used to calculate the International Advanced Index and the sub-indexes, including the Width Index, Height Index and Depth Index. The annual report about the top 225 international contractors provided by Engineering News-Record (ENR) was adopted. By using the formulas generated and presented in Chapter 3 Section 4.6.1, the International Advanced Index, Width Index, Height Index and Depth Index of the Chinese construction industry were calculated and are summarised in Table 5-8.

WI		**HI**		**DI**		**IAI**		**M***	
2001	**2010**	**2001**	**2010**	**2001**	**2010**	**2001**	**2010**	**2001**	**2010**
0.4	0.5076	0.1566	0.2027	0.056	0.149	0.6126	0.8593	4	10

M= The total number of each country's firms listed in the top 10 of the ten construction fields

Table 5-8 The International Advanced Index of the Chinese construction industry

According to Table 5-8, the International Advanced Index of the Chinese construction industry has increased 40.27%, from 0.6126 in 2001 to 0.8593 in 2010. The Width Index, Height Index and Depth Index are all increasing dramatically. The Width Index reached 0.5076 in 2010 with an increase of 26.9% compared with 0.4 in 2001. 'M' – the total number of Chinese firms listed in the top 10 of the ten construction fields has climbed from 4 in 2001 to 1 in 2010, which impacts the Width Index and the International Advanced Index of the Chinese construction industry. These results indicate that the status and level of the Chinese construction industry in the international market has increased and the Chinese construction industry has increased its influence in more fields of construction in the international market, shared more total international revenue, and improved the quantity and quality of the Chinese top construction firms from 2001 to 2010.

5.6 Conclusion

Jiang (2006) divided the development of the Chinese construction industry from 1949 to 2001 into four phases, including Creation Time, Frustrated Time, Rehabilitation Time and Development Time. This chapter explores the development of the Chinese construction industry after the entry into the World Trade Organization (WTO) from five perspectives, including market condition, employment, level of technology, classification of firms and industrial organisation structure. The time after the entry into the WTO could be considered as the fifth phase and called 'Post WTO Time'. After that, this chapter discusses the development phases of the Chinese construction industry in the international market, including, Economic and Technical Aid Time, Emergence Time, Towards Multinational Time and WTO Time.

This chapter then analyses the status and level of the Chinese construction industry in the international market in 2001 and 2010. The results indicate that the status and level of the Chinese construction industry in the international market has increased dramatically.

Chapter 6 Productivity and industrial competitiveness of the Chinese construction industry

6.1 Introduction

Productivity and industrial competitiveness are the basis of the performance of the construction industry. This chapter will study the productivity of the Chinese construction industry based on the Malmquist productivity index to evaluate the total factor productivity changes from 2001 to 2010. The industrial competitiveness of the Chinese construction industry will then be analysed. All the elements of the Internationalisation Sustainable Development Competitiveness Model will be discussed. The results will contribute to answering the Research Question 2.

6.2 Productivity

6.2.1 Input and output variables in total factor productivity

The Total Factor Productivity measurements conducted in this research are based on two inputs including the construction work done and the number of employees in the construction sector, and one single-output variable which is the construction industry gross value added. The analysed time is designated from 2001 to 2010. Data is sourced from the China Statistical Yearbook to evaluate productivity changes.

The construction work done is represented by the Gross Output Value of Construction in the China Statistical Yearbook, which is the sum of the construction products and services provided by the Chinese construction enterprises in a given period in monetary form. The Gross Output Value includes;

- Construction output value: refers to the value of construction projects included in the projects' budget
- Installation works output value: refers to the value of equipment installation excluding the value of the equipment
- Output value of repairing the structures of the construction
- Output value of nonstandard equipment manufacturing
- Management fees charged from subcontractors by the general contractors, and
- Output value of the construction activities which cannot be clearly classified.

The number of employees in the construction sector is the other input variable, which is concerned with labour. The gross value added to the construction industry represents the final results of the construction production activities in the form of money during the reference period.

Table 6-1 shows the descriptive statistics of the Chinese construction industry on the construction work done, the number of employees and the gross value added. The trends of the Gross Output Value and the number of employees have been discussed in Chapter 5 Section 5.3.1 and 5.3.2. The Gross Value Added of the Chinese construction industry decreases from 402.36 Billion CNY in 2001 to 382.24 Billion CNY in 2002. However, after that, the Gross Value Added of the Chinese construction industry indicates a rapid growth from 2002 to 2010. The average growth rate is approximately 17% from 2001 to 2010.

Year	Gross Output Value (Billion CNY)	NO. of Employees (Million)	Gross Value Added (Billion CNY)
2001	1536.20	21.1	402.36
2002	1852.70	22.5	382.24
2003	2308.40	24.1	465.47
2004	2902.10	25.0	566.59
2005	3455.20	27.0	689.97
2006	4155.70	28.8	811.64
2007	5104.40	31.3	994.44
2008	6203.70	33.1	1191.17
2009	7680.80	36.7	1561.98
2010	9603.10	41.6	1898.35

Table 6-1 The construction work done, the number of employees and the gross value added of the Chinese construction industry from 2001 to 2010

6.2.2 Malmquist Total Factor Productivity changes

To calculate the Malmquist total factor productivity changes (MTFPC) of the Chinese construction industry, the DEAP Version 2.1 is adopted. The results of the Malmquist total factor productivity changes of the Chinese construction industry from 2001 to 2010 are summarised as Table 6-2. The Malmquist total factor productivity changes from 2001 to 2002 is 0.838. This indicates a decrease of the total factor productivity of the Chinese construction industry. The decrease rate is 16.2% from 2001 to 2002. China joined the World Trade Organization (WTO) at the end of 2001. Many regulations had to be changed to align with the requirements of WTO. China received more opportunities by being exposed to the international market. China also had to open its market to foreign countries' enterprises. The Chinese construction enterprises also have to learn and suit the new regulations, understand new competition situations in both domestic and international markets and change their strategies to target these new situations. In the first year of entry into the WTO, it is reasonable and acceptable to expect some mistakes and poor performance. This is also the reason for the Chinese government asking for a five year transition period from WTO for the Chinese construction industry.

Year	EFFCH	TECHCH	PECH	SECH	MTFPC
2001-2002	1	0.838	1	1	0.838
2002-2003	1	1.054	1	1	1.054
2003-2004	1	1.066	1	1	1.066
2004-2005	1	1.074	1	1	1.074
2005-2006	1	1.039	1	1	1.039
2006-2007	1	1.06	1	1	1.060
2007-2008	1	1.057	1	1	1.057
2008-2009	1	1.119	1	1	1.119
2009-2010	1	1.021	1	1	1.021
Mean	1	1.033	1	1	1.033

Table 6-2 The Malmquist total factor productivity changes of the Chinese construction industry from 2001 to 2010

From 2002 to 2010, the Malmquist total factor productivity changes are all higher than 1. This represents a continuous increase of the total factor productivity of the Chinese construction industry. Because of the big decrease from 2001 to 2002, the average increase rate from 2001 to 2010 is only 3.3%. Therefore, it could be concluded that the total factor productivity of the Chinese construction industry has increased from 2001 to 2010, but the increase rate is not significant. After studying the productivity changes of the Chinese construction industry, the next section will discuss the industrial competitiveness in detail.

6.3 Industrial competitiveness

In Chapter 2, after the discussion of previous research, Porter's Diamond Model is re-formed as the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) to meet the trends of internationalisation and sustainable development. The ISDC Model is composed of eight elements including factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of multinational enterprises and sustainable development. Chance is the only external element, all the others are determinants. In order to adopt this model to compare between countries, the measurement for each element is identified in Chapter 3. The measurements and indicators for these eight elements are summarised in Table 6-3.

Elements	Indicators
Factor conditions	*Basic factors* 1 Human resources 2 Natural resources *Advanced factors* 1 Investment in R&D 2 The number of persons with a non-school qualification per thousand people
Demand conditions	3 Domestic demand growth rate 4 Domestic market size
Related and supporting industries	1 Performance of these industries
Firm strategy, structure and rivalry	1 The capital structure 2 The industry's market structure
Enterprises' international activities	1 Degree of internationalisation
Government	1 Labour and capital 2 High level factors 3 Competition situation of the domestic market 4 Performance of non-State Owned Company
Sustainable development	1 Economic sustainability A. Gross output value of the construction industry B. Labour productivity in terms of value-added of the construction industry C. Ratio of profit before tax to gross output value of the construction industry D. GDP E. Gross fixed capital formation 2 Social sustainability A. The number of persons with a non-school qualification per thousand people B. Per capita disposable income/year 3 Environmental sustainability A. Construction waste / GOV of the construction industry B. Energy consumption / GOV of construction industry
Chance	External element

Table 6-3 The measurements and indicators of the elements of the Internationalisation Sustainable Development Competitiveness Model

This section discusses the performance of the elements of the Internationalisation Sustainable Development Competitiveness Model of the Chinese construction industry from 2001 to 2010. Firstly, these three elements will be explored, including factor conditions, demand conditions and firm strategy, structure and rivalry. Next, the activities of multinational enterprises will be discussed and the relationship between the degree of internationalisation and a firm's financial performance and the relationship between degree of internationalisation and the construction industry performance in the international market at the country level.

After that, the related and supporting industries element will be analysed. The first step is to identify which industries are the related and supporting industries for the Chinese construction industry by adopting the input-output analysis (refer to Chapter 4 Section 4.7). The second step is to briefly describe the current development of these industries, and explore their productivity changes.

In addition, the government element will be analysed by adopting the Malmquist productivity index to explore the total factor productivity changes in these ten years as well. However, it is difficult to identify the inputs (labour and capital) of the government only for the construction industry. All the departments and government agencies are in a unified system. They influence and mutually support each other. All the policies and decisions are made across departments. Therefore, this study will use the national data as the inputs of the government element. The inputs are administrative expenses and the number of civil servants in China.

Administrative expenses are the expenditure used for performing the functions for the state power department, administrative department, judicial department and diplomatic department. It reflects the nature of the country and the main political and economic directions in a certain period. It depends on the structure and scope of state power. The administrative expenses primarily consist of general public services expenses, foreign affairs expenses and public order and safety expenses according to the China Statistical Yearbook.

The number of civil servants in China is missing in almost all data resources. This data was only leaked out once by staff of the Chinese Civil Service Bureau in 2013 for the number of civil servants in China in 2008, 2009 and 2010. If the double inputs are used to explore the changes of productivity of the Chinese government, only these three years could be conducted. Therefore, the signal input (administrative expenses) will also be adopted in this study to analyse the productivity changes of the Chinese government from 2001 to 2010. However, because of the reform of the revenue and expenditure accounts in the China Statistical Yearbook 2008, especially for the expenditure account, the data is not comparable with previous years from 2007. Therefore, this research will adopt signal input (administrative expenses) to explore the changes of the total factor productivity of the government in relation to the Chinese construction industry from 2001 to 2006 and 2007 to 2010 separately. In addition, the two inputs (administrative expenses and the number of civil servants) model will be used to explore the productivity changes from 2008 to 2010. As discussed in Chapter 3 Section 3.3 and Chapter 4 Section 4.8.3, the outputs are:

1) Producing high level factors: it could be reflected by the number of persons with a non-school qualification per thousand people.
2) The competition situation of the domestic market: it will be reflected by the number of construction companies.
3) and the performance of non-State Owned Company: it will be indicated by their Gross Output Value of the non-State Owned Company.

Moreover, the new added element, sustainable development of the industrial competitiveness of the Chinese construction industry will be discussed. The indicators and variables at different levels and in different categories will be calculated and compared one by one from 2001 and 2010. Also, the growth rate for each variable (for Energy Consumption/Gross Output Value of the construction industry and Construction waste/GOV of the construction industry, which are decreasing) will be generated. The growth of average earning will be measure by the Real Growth Rate of Average Earning. Furthermore, the degree of coordination analysis will be conducted next, to find out the relationship among economic sustainability, environmental sustainability and social sustainability of the Chinese construction industry from 2001 to 2010.

6.4 Factor conditions

There are two types of factors, including basic factors and advanced factors (Porter 1977 and 2000). Basic factors refer to natural resources, climate, geographical location, non-skilled workers and capital. Advanced factors include modern communications, information, transportation infrastructure, manpower with high education and research institutes. Porter (1977) stated the importance of the advanced factors in helping countries to obtain competitive advantage is much higher than the basic factors.

For the basic factors, the human resources are summarised as Table 6-4, and examples of the natural resources are provided in Table 6-5. It is well known that China is the most populous country in the world. Sufficient labour force contributes much to the development of the Chinese economy. The one-child policy which was implemented by the Chinese government in the 1980s has impacted the natural growth rate of population. The population has declined gradually from 6.95‰ in 2001 to 4.79‰ in 2010.

With respect to the perspective of the age distribution of the Chinese population, the share of elderly people which are more than 65 years old increased from 7.1% in 2001 to 8.9% in 2010. China is an aging society. However, the Gross Dependency Ratio has declined from 42% in 2001 to 34.2% in 2010 and the reasons are 1) the increase of the proportion of the working-age population from 15 to 64 years old, which increased from 70.4% in 2001 to 74.5% in 2010 and 2) the decrease of the proportion of children from 0 to 14 years old, which fell to 16.6% in 2010 from 22.5% in 2001.

In addition, from a natural resources point of view, the examples listed in Table 6-12 could demonstrate the advantages of China to some extent. The area of territory of China is about 9.6 million square kilometres, which is the third largest in the world. China also has a 4.73 million square kilometre area of sea. Moreover, more than 170 kinds of minerals have been found in China. These could be divided in to four general categories according to their characteristics and usefulness, including: energy minerals (Coal, Petroleum, Natural Gas and Geothermal), metal mineral resources (Iron, Manganese, Copper, Lead and Bauxite) nonmetallic minerals resources (Diamond, Limestone and Clay) and groundwater and gas minerals (Groundwater, Mineral water and Carbon Dioxide). The metal mineral resources can be divided into six categories based on the material elements and their nature, including: ferrous metals minerals, nonferrous metals minerals, noble metals minerals, rare metals minerals, rare earth minerals and disperse element metal minerals. Among them, both the production and ensured reserves amount of Coal in China is the highest in the world. The ensured reserve of Iron is the third highest in the world. The ensured reserves of Zinc, Rare Earth, Tin, Tungsten, Antimony, Vanadium, Magnetite, Lithium and Titanium are also the highest in the world.

Year	Total Population* (year-end) MIL	Natural Growth Rate of Population	Aged 0-14		Aged 15-64		Aged 65 and Over		Children Dependency Ratio %	Old Dependency Ratio %	Gross Dependency Ratio %
			Population MIL	Proportion	Population MIL	Proportion	Population MIL	Proportion			
2001	1276.27	6.95‰	287.16	22.5%	898.49	70.4%	90.62	7.1%	32.0	10.1	42.0
2002	1284.53	6.45‰	287.74	22.4%	903.02	70.3%	93.77	7.3%	31.9	10.4	42.2
2003	1292.27	6.01‰	285.59	22.1%	909.76	70.4%	96.92	7.5%	31.4	10.7	42.0
2004	1299.88	5.87%	279.47	21.5%	921.84	70.9%	98.57	7.6%	30.3	10.7	41.0
2005	1307.56	5.89‰	265.04	20.3%	941.97	72.0%	100.55	7.7%	28.1	10.7	38.8
2006	1314.48	5.28‰	259.61	19.8%	950.68	72.3%	104.19	7.9%	27.3	11.0	38.3
2007	1321.29	5.17‰	256.60	19.4%	958.33	72.5%	106.36	8.1%	26.8	11.1	37.9
2008	1328.02	5.08‰	251.66	19.0%	966.80	72.7%	109.56	8.3%	26.0	11.3	37.4
2009	1334.50	4.87‰	246.59	18.5%	974.84	73.0%	113.07	8.5%	25.3	11.6	36.9
2010	1340.91	4.79‰	222.59	16.6%	999.38	74.5%	118.94	8.9%	22.3	11.9	34.2

Table 6-4 Human resources information

* Annual statistics on the Total Population (year-end) refers to the number of population at 24:00 on 31th December each year. The total number of population doesn't include the number of population in Hong Kong, Macao, Taiwan, and overseas Chinese.

** The Natural Growth Rate of Population refers to the ratio of the number of natural population increased (the number of births minus the number of deaths) to the average/midterm population over a certain period of time (normally one year). The equation is: The Natural Growth Rate of Population = (The births of the year - The deaths of the year)/ The average population of the year ×1000‰ = the births rate – the deaths rate

*** Gross dependency ratio refers to the ratio of the non working-age population to the working-age population. It is expressed with percentage. It indicates how many non working-age people are borne per 100 working-age people. Gross dependency ratio represents the relationship between the population and the economic development from the perspective of population.

The equation is $GDR=\frac{P_{0\sim14}+P_{65^+}}{P_{15\sim64}}\times100\%$ (GDP: Gross Dependency Rate; $P_{0\sim14}$: The population of children from 0 to 14 years old; P_{65^+}: The population of elderly people which are more than 65 years old; $P_{15\sim64}$: The population of the working-age from 15 to 64 years old)

Year	Total Amount of Water Resources (Billion cu.m)	Per Capita Water Resources (cu.m/person)	Ensured Reserves of Major Mineral							
			Petroleum MIL tons	Natural Gas BIL cu.m	Coal BIL tons	Iron BIL tons	Copper MIL tons	Lead MIL tons	Zinc MIL tons	Bauxite MIL tons
2001	2686.78	2112.5	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
2002	2826.13	2207.2	2424.926	2016.9	331.76	21.36	29.669	12.511	37.56	71557.3
2003	2746.02	2131.3	2431.936	2228.87	334.2	21.24	30.03	12.48	37.625	69453.7
2004	2412.96	1856.3	2490.979	2529.26	337.34	21.76	29.29	13.147	41.515	72069
2005	2805.31	2151.8	2489.721	2818.54	332.64	21.6	28.564	13.934	42.691	73057.8
2006	2533.01	1932.1	2758.568	3000.92	333.48	22.09	30.699	13.514	42.271	74167
2007	2525.52	1916.3	2832.5377	3212.363	326.126	22.364	29.3211	13.4632	42.5081	75072.71
2008	2743.43	2071.1	2890.43	3404.962	326.144	22.64	28.9104	13.5958	42.8169	73513.99
2009	2418.02	1816.2	2949.198	3707.42	318.96	21.3	29.51	13.401	38.385	83923.9
2010	3090.64	2310.4	3174.353	3779.32	279.39	22.2	28.707	12.72	32.514	89732.7
Area of Territory	9.6 million sq.km									
Area of Territory	4.73 million sq.km									

Table 6-5 Examples of the natural resources

A high level of production factors is difficult to obtain from the outside. Advanced factors can only be achieved through sustainable investment of substantial human resources and capital. Therefore, Porter (1970 and 2000) states the advanced factor is much more important than the basic factor in generating the competitive advantages for the countries and industries. As discussed in Chapter 3, the advanced factors are indicated by the investment in R&D (including: R&D expenditure, the R&D expenditure/total sales, and the R&D personnel full-time equivalent—also referred to as person years of effort) and the number of persons with a non-school qualification per thousand people.

Various data resources do have the information about the R&D expenditure of China, including the China Statistical Yearbook and China Science and Technology Statistics Data Book. The data for different industries are also provided by these yearbooks. However, the data of the R&D expenditure for the Chinese construction industry is not provided. China did the national R&D resources inventory in 2000 and 2009. The statistical communiqués on the 2000 and 2009 national census of research and experimental development resources are only available after 2000. Therefore, this section will use the data from the China Statistical Yearbook and China Science and Technology Statistics Data Book to briefly introduce the developments of the R&D activities in China from 2001 to 2010 and adopt the data from statistical communiqués on the 2000 and 2009 national census of research and experimental development resources to explore the trend of the Chinese construction industry in relation to the R&D expenditure. The total sales of the Chinese construction industry will be measured by the gross output value of Construction. The R&D personnel full-time equivalent refers to the sum of R&D full time personnel workload and R&D part time personnel workload based on effective working time, which is also available in the statistical communiqués on the 2000 and 2009 national census of research and experimental development resources.

The R&D expenditure in China from 2001 to 2010 is summarised in Table 6-6. The Gross Expenditure on R&D has increased nearly 700% from 104.2 billion CNY in 2001 to 706.3 billion CNY in 2010. The ratio of Gross Expenditure on R&D to Gross Domestic Product (GDP) increased gradually from 0.95% in 2001 to 1.76% in 2010. Moreover, the R&D person years of effort (PYE) is 2.554 million in 2010, whereas it is only 0.957 million PYE in 2001. It indicates that China realised the importance of R&D in the development of the Chinese economy and other sectors and it would be one of the key reason for the achievements of China in the last two decades. It could be easily speculated that China must continue increasing the investment in R&D activities.

Year	**Gross Expenditure on R&D (BIL CNY)**	**Gross Expenditure on R&D/GDP**	**R&D PYE**
2001	104.2	0.95%	0.957
2002	128.8	1.07%	1.035
2003	154	1.13%	1.095
2004	196.6	1.23%	1.153
2005	245	1.32 %	1.365
2006	300.3	1.39%	1.503
2007	371	1.40%	1.736
2008	461.6	1.47%	1.965
2009	580.2	1.70%	2.291
2010	706.3	1.76%	2.554

Table 6-6 The development of the R&D expenditure in China from 2001 to 2010

Approximately ten years ago, the Chinese construction enterprises did not have R&D departments. There are only a few construction R&D institutes, which are administrated by the line ministries, provincial or municipal governments (Low & Jiang, 2003). Now, more and more Chinese construction enterprises set up their own R&D department. The R&D activities have received more attention from both the public and private sectors. The comparison of the R&D expenditure and personnel full-time equivalent of the Chinese construction industry between 2000 and 2009 is summarised in Table 6-7.

Year	Human resources in R&D		R&D Expenditure		
	PYE	Proportion	Gross (MIL CNY)	Proportion	% in GOV
2000	N/A	N/A	530	0.6%	0.03%
2009	63432	2.77%	13512.4	2.33%	0.18%

Table 6-7 The R&D expenditure and personnel full-time equivalent of the Chinese construction industry between 2000 and 2009

In 2000, R&D expenditure in the Chinese construction industry was only 530 million CNY, accounting for only 0.6% of the whole country's R&D expenditure. In 2010, the expenditure on R&D has increased up to 13512.4 million CNY, accounting for 2.33% of the whole country's R&D expenditure. It represents a significant improvement in the degree of attention in R&D by the construction industry. The proportion of the expenditure on R&D in the gross output value of the Chinese construction industry has increased dramatically from 0.03% in 2000 to 0.18% in 2009.

From the perspective of R&D personnel full-time equivalent, because of the lack of data in 2000, the comparison between 2000 and 2009 could not be conducted. However, from the statistical communiqué on the 2009 national census of research and experimental development resources, it was found that the top three industries in term of the R&D personnel full-time equivalent are Manufacturing, Scientific research, technical services and geological prospecting, and Education. The construction industry is listed seventh out of the 14 industries.

For the educational level of people, the trend of the number of persons with a non-school qualification per thousand people of China from 2001 to 2010 is provided in Figure 6-1. It has increased from 34.5 in 2001 to 89.3 in 2010, with the average growth rate of 11.7%. It presents the increase of a high-level talent pool in China. It will benefit the long-term development of the industries and economy of China.

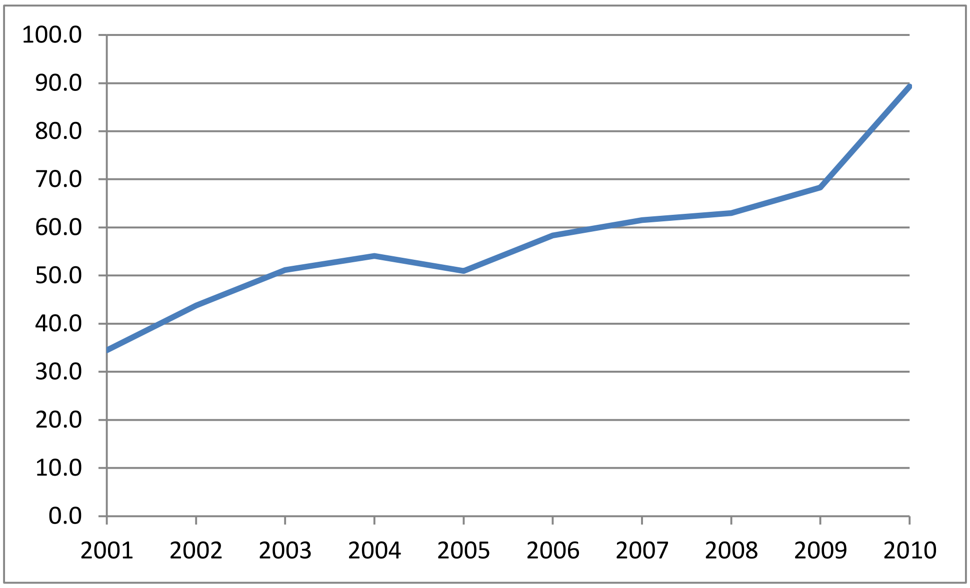


Figure 6-1 Number of persons with a non-school qualification per thousand people of China from 2001 to 2010

In the basic factors, China is vast in territory and rich in resources and therefore has high values for basic factors. However, for improving competitiveness, advanced factors are much more critical. Therefore, China increased the investment in the advanced factors. For example, there was an increase in R&D activities, from 2001 to 2010 both on the expenditure and personnel. The performance of the Chinese construction industry has improved in the R&D activities. Various indicators have been improved. In addition, the number of persons with a non-school qualification per thousand people of China increased significantly as well from 2001 to 2010. Increasing the investment in R&D and improving the educational level of people should be attended continuously. This result proves the importance of the investment and expenditure in Research and Development (R&D), which has been addressed by various scholars (Blayse and Manley, 2004; Mushin et al., 1996 and Dulaimi *et al.*, 2002), and it should be considered as a major driver for the development of an industry and a country.

6.5 Demand conditions

Domestic demand is the driver for industrial development (Rodrik， 2007). This research measures the element of demand conditions through the size of the domestic market, and the demand growth rate in the domestic market. The size of the domestic market is reflected by the gross output value of the Chinese construction industry. The demand growth rate in the domestic market is represented by the growth rate of the gross output value of the Chinese construction industry. These two indicators have been discussed in Chapter 5 Section 5.3. The details can found in Table 5-2: Gross Output Value of the Chinese construction industry and its growth rate. The Gross Output Value of the Chinese construction industry has climbed to 9603.1 billion CNY in 2010 from 1536.2 billion CNY in 2001, with the average growth rate at 23% in these ten years. Therefore, the size of the Chinese domestic construction market is extremely large. The demand growth rate in Chinese domestic construction is significant.

6.6 Firm strategy, structure and rivalry

According to Porter (1977), firm strategy, structure and rivalry refers to the firm's organisation structure and management situation, and the performance of competitors in the domestic market. In this research, this element of the Internationalisation Sustainable Development Competitiveness Model will be measured by the capital structure and market structure. The data for the Chinese construction industry was sourced from the China Statistical Yearbook.

6.6.1 Capital structure

The classification of firms in the Chinese construction industry has changed from three categories: State Owned Enterprises (SOEs), Urban and Rural Collectives (URCs) and Rural Construction Teams (RCTs) to five categories: state owned enterprises (SOEs), collective owned enterprises (COEs), private owned enterprises (POEs), enterprises founded by Hong Kong, Macao and Taiwan (HMTEs), and foreign founded enterprises (FFEs). This classification is based on the industrial capital structure. The trends of the number, percentage in total number of the Chinese construction firms, gross output value, and the percentage in the Chinese construction industry gross output value of each category from 2001 to 2010 were previously addressed section 5.3, Chapter 5. The results are summarised as:

(1) The position of the SOEs and COEs in the Chinese construction industry is declining dramatically.
(2) POEs dominate the Chinese construction market.
(3) The market share of HMTEs and FFEs has not changed. It is still low. Their status in the Chinese construction industry has not improved along with the China's entry into the WTO.

This section will compare each category in terms of the number of employees, total profits, overall labor productivity in terms of gross output value, value of machines per laborer, power of machines per laborer, and ratio of profit to gross output value between 2001 and 2010 to explore the changes that may have occurred in the Chinese construction industry in these ten years.

The number of employed person in both SOEs and COEs decreased from 2001 to 2010. It echoes the statement in Chapter 5 Section 5.3, which is that SOEs and COEs have lost their dominant position in the Chinese construction industry. In contrast, the number of employees in POEs has increased 297% from 8.35 million in 2001 to 33.151 million in 2010. Their proportion of the total number of employees in the Chinese construction industry has reached 80%.

Though the total profits of SOEs have risen dramatically with an increase rate of 1259%, its proportion in the total profits of the Chinese construction industry in 2010 is only 13%. On the other hand, the proportion of POEs has increased to 81% in 2010.

In 2010 the total profits of POEs were about 6 times higher than the SOEs, with an increase rate of 1464%.

Many researchers have highlighted that the Chinese state owned enterprises (SOEs) are less efficient than non-state owned enterprises in terms of profits, productivity, and growth (Zhang, 2004 and Dougherty *et al*., 2007). Li, *et al.* (2010) compare the performance of the Chinese state owned enterprises (SOEs) and private firms in terms of rates of return, productivity, growth, costs, and investment by adopting a panel data set of more than 200,000 Chinese firms constructed by merging the Chinese census of manufacturing firms for 2000-2005. They find that the Chinese industrial state owned enterprises are indeed less efficient than the non- state owned enterprises. The reasons might be the state owned enterprises normally pay less attention to costs, inventories, accounts receivables, investment, employee welfare, financing, and administration. This research presents the similar results from the construction industry perspective.

The overall labour productivity in terms of gross output value (GOV) of all these five categories is increasing significantly. SOEs, COEs and POEs are called domestic enterprises. HMTEs and FFEs are collectively called foreign enterprises. Hong Kong, Macao and Taiwan are the special administrative regions of China. The companies from these areas are generally considered foreign enterprises. According to this classification, the level of productivity of the Chinese domestic construction enterprises has greatly improved, and the gap with foreign companies has been reduced from 61% in 2001 to 18% in 2010 (refer to Table 6-8).

There is no doubt that the use of new equipment and new technology will improve labor productivity. The Power of machines per labourer and value of machines per labourer are the key indicators to measure technological progress. For the power of machines per labourer, COEs and POEs are both growing, while foreign enterprises (HMTEs and FFEs) declined from 2001 to 2010 (refer to Table 6-8).

In addition, from the perspective of the value of machines per labourer, these three types of the Chinese domestic construction enterprises are all increasing, while HMTEs and FFEs are experiencing negative growth from 2001 to 2010 (refer to Table 6-8) and this will help Chinese domestic construction enterprises to increase their labor productivity in terms of GOV.

However, from the point of view of ratio of net profit to gross output value, the Chinese domestic construction enterprises are still significantly lagging behind the foreign enterprises, and the gap between them has not narrowed. The gap between the domestic enterprises and foreign enterprises is 75% both in 2001 and in 2010 (refer to 6-8). Therefore, the Chinese domestic construction enterprises need to learn ways to improve their profit margins. Besides relying on the advanced technologies and equipment, the advanced management experience is an important issue to address.

The characteristics of the development of the capital structure of the Chinese construction industry from 2001 to 2010 can be summarised as follows:

A. The dominant position of SOEs and COEs in the Chinese construction industry has been replaced by POEs;
B. The performance of the non-public ownership enterprises including POEs, HMTEs and FFEs is better than the public ownership enterprises, including SOEs and COEs, as the nature of them is the same. The Chinese construction industry is converting from being dominated by the public ownership enterprises to the non-public ownership enterprises.
C. Chinese domestic construction enterprises have achieved rapid development and significant progress. The gap between the Chinese domestic construction enterprises and foreign enterprises was narrowed substantially in relation to labour productivity. However, from the perspective of profit margins, the distance between them has not been reduced. Therefore, it urgently needs to find a way to narrow the gap in the future.

Year	Employed person										Total profits									
	Number (Thousand)					Proportion					Value (Billion CNY)					Proportion				
	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs
2001	5907	6730	8350	77	43	28%	32%	40%	0.4%	0.20%	3.3	7.9	17.7	0.4	0.2	11%	27%	60%	1.3%	0.8%
2010	5769	2465	33151	122	98	14%	6%	80%	0.3%	0.24%	44.4	14.6	276.6	2.6	2.7	13%	4%	81%	0.8%	0.8%
Growth rate	-2%	-63%	297%	58%	128%	-50%	-81%	101%	-20%	16%	1259%	85%	1464%	582%	1043%	17%	-84%	35%	-41%	-1%
Year	**Overall labour productivity in terms of GOV**					**Power of machines per labourer**					**Value of machines per labourer**					**Ratio of net profit to gross output value**				
	Value (Thousand CNY/person)					Value (KW/Person)					Value (Thousand CNY/person)					Value Billion CNY				
	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs	SOEs	COEs	POEs	HMTEs	FFEs
2001	82.9	47.7	72.4	101.7	116.0	6.8	3.9	4.3	4.8	4.8	9.4	5.1	7.1	10.3	13.8	0.6	2.4	2.9	3.7	3.2
2010	271.9	138.6	221.2	192.7	304.9	5.6	4.4	4.6	3.1	3.8	12.5	6.9	9.2	6.4	9.1	2.4	4	3.8	5.8	6.1
Growth rate	228%	191%	206%	89%	163%	-18%	13%	7%	-35%	-21%	33%	34%	31%	-37%	-34%	300%	67%	31%	57%	91%

Table 6-8 The number of employees, total profits, overall labor productivity in terms of gross output value, value of machines per laborer, power of machines per laborer, and ratio of profit to gross output value of the Chinese construction industry in 2001 and 2010

6.6.2 Market structure

Industrial concentration ratio is the most commonly used indicator to measure market structure (Bain, 1951). It may represent 'the market power and the probability of anti-competitive behavior among firms in the market' (Setiawan, *et al.*, 2012). It refers to the proportion of the production factors and/or total output produced in an industry that are accumulated or dominated by a small number of firms. The concentration ratios represent the extent of market control of the largest firms in the industry and illustrate the oligopolistic degree of an industry (Setiawan, *et al.*, 2012).

The concentration ratio is the percentage of market share held by the largest *m* firms in an industry, where m is a specified number of firms. The concentration ratio is often expressed as CR_m. The concentration ratio can be expressed as:

$$CR_m = \sum_{i=1}^{m} s_i = s_1 + s_2 + s_3 + \ldots \ldots + s_m$$

The most common concentration ratios are the CR_4 and the CR_8, which means the market share of the four and the eight largest firms in an industry. Concentration ratios range from 0 to 100 percent. Bain (1951) first applied the concentration ratio for analysing industrial competition and monopolisation degree and classified the levels (refer to Table 6-9).

Classification	**CR_4 (%)**	**CR_8 (%）**	**Total sum of the enterprises**
Monopolisation I	Up 75%	—	20
Monopolisation II	65%~75%	Up 85%	20~100
Monopolisation III	50%~65%	75%~85%	many
Monopolisation IV	35%~50%	45%~75%	more
Monopolisation V	30%~35%	40%~45%	most
Competition	Below 30%	Below 40%	redundant

Table 6-9 Classification with industrial competition and monopolisation degree

Source: Bain, J. S., 1951, 'Relation of profit rate to industry concentration: American manufacturing, 1936–1940', Quarterly Journal of Economics, Vol.65, pp. 293–325.

In order to calculate the concentration ratio of the Chinese construction industry, the gross output value of the Chinese construction industry and the total revenue of the top Chinese construction enterprises should be sourced. The gross output value of the Chinese construction industry was obtained from the Statistical Yearbook of China and the China Construction Industry Statistical Yearbook. The top Chinese construction enterprises in relation to the total revenue can be identified based on the top 225 global construction contractors, which is provided by Engineering News Record every year and ranks the top construction contractors in the international market based on their total revenue.

According to the formula of concentration ratio and the data sources from Statistical Yearbook of China, China Construction Industry Statistical Yearbook and the top 225 global construction contractors list, this section presents the results of the concentration ratio CR_4, CR_8 and CR_{12} of the Chinese construction industry from 2001 to 2010, and is shown in Figure 6-2.

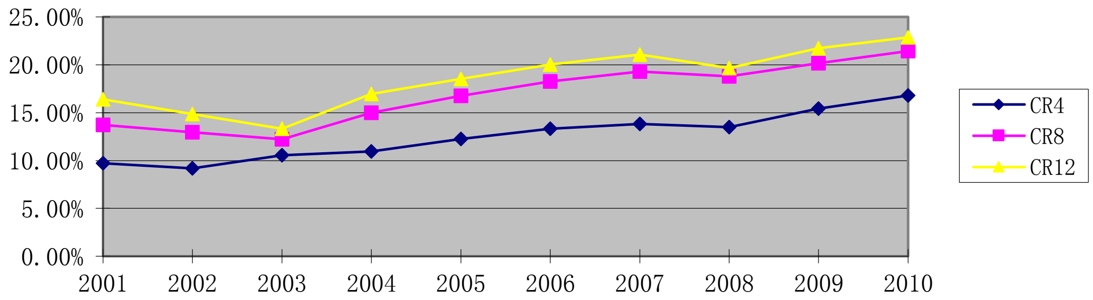


Figure 6-2 Concentration ratio CR_4, CR_8 and CR_{12} of the Chinese construction industry from 2001 to 2010

From Figure 6-2, the concentration ratio of the Chinese construction industry declined from 2001 to 2003, but the overall trend is that CR_4, CR_8 and CR_{12} are increasing in these ten years. The market share of the top Chinese construction enterprises is increasing. The value of the ratio indicates that the dominance of large-scale Chinese construction enterprises' in the market is still low and they probably won't influence market price and competition unduly. By 2010, the Concentration ratio CR_4, CR_8 and

CR_{12} of the Chinese construction industry is 16.81%, 21.44% and 22.89% respectively. They are still in the 'Competition' level, according to Bain's classification. The Chinese construction industry is considered to be competitive, with a number of other firms competing, with few owning a very large proportion of the market.

6.7 Activities of Multinational Enterprises

Dunning (1993) states that as very important participants of the international economy, the multinational enterprises (MNEs) may help their home countries to achieve many advantages. Therefore, Dunning suggested the element of activities of multinational enterprises should be included in the industrial competitiveness model. This research develops a 'reformative OLI model' (ROLI Model) to measure the degree of internationalisation of construction enterprises at both firm and industry level by a combination of Low and Jiang's improvement and a removal of the S-ISF concept in Chapter 3 Section 3.4.7. The indexes included in the ROLI Model and their measurements have been discussed in Chapter 4 Section 4.8.4, and are summarised in Table 6-10.

Indexes	**Measurement**
O-IRTR	The ratio of international revenue to total revenue
L-IBD	International business distribution (L-IBD), measured in terms of the ratio of the number of countries in which the firm has worked in a particular period to the number of countries in which the firm may have the potential to work.
I-OMS	Overseas management structure (I-OMS), measured in terms of the ratio of the number of overseas subsidiaries and associates to the total number of such affiliates.
OII	Overall internationalisation index for a firm, measured by the sum of O-IRTR, L-IBD and I-OMS.
A-O	The level of O-IRTR for a country, measured by the average of O-IRTR of all the firms of a country.
A-L	The level of L-IBD for a country, measured as the average of L-IBD of all the firms of a country.
A-I	The level of I-OMS for a country, measured as the average of I-OMS of all the firms of a country.
T-DOI	The degree of internationalisation in country level, and measured in the

	sum of A-O, A-L and A-I.

Table 6-10 ROLI Model Indexes

In order to identify the impact of the activities of multinational enterprises on industrial competitiveness, the relationship between the degree of internationalisation and a firm's financial performance and the relationship between degree of internationalisation and the construction industry performance in the international market at the country level will be discussed in this section. After that, the improvement of the degree of internationalisation of the Chinese construction industry will be explored.

6.7.1 Relationships

Firstly, the relationship between the degree of internationalisation and a construction firm's financial performance will be discussed. This research adopts the Spearman Rank Correlation Coefficient to analyse the relationship between the degree of internationalisation and a construction firm's performance. According to the data availability and the period of the financial year, 25 international construction firms' performance was analysed and selected from the ENR top 225 international constructors list 2010 (Reina & Tulacz, 2010). These companies originated from 6 countries, including: China, Brazil, Italy, France, German and Spain. Their financial performance was measured by using Return on Assets (ROA), which was sourced in their annual report. Their 'degree of internationalisation' was calculated by the formula provided in Chapter 3. In this part, only O-IRTR, L-IBD, I-OMS and OII in 2009 were calculated. OII is the degree of internationalisation (DOI) for a firm. The DOI of the 25 firms and their ROA are calculated and listed in Table 6-11.

Country	Company	ROA	DOI	Rank of ROA	Rank of DOI
Italy	Saipem	11.28 %	2.0852	1	1
Brazil	Camargo Correa	6.93%	0.3875	2	20
Spain	Tecnicas Reunidas	6.53%	0.8963	3	11
Spain	Grupo Acs,	4.69%	0.577	4	14
China	Shanghai Electric Group Co. Ltd	3.88%	0.8283	5	12
China	China Wu Yi Co. Ltd	3.51%	0.5474	6	16
Spain	Abeinsa Sa,	3.46%	0.9237	7	10
Italy	Maire Tecnimont Spa	3.35%	1.4061	8	3
China	China Communications Construction Group	3.32%	0.9745	9	7
Germany	Hochtief Ag,	3.32%	0.9381	10	9
France	Vinci	3.06%	1.3181	11	4
China	China Nonferrous Metal Indus. Frgn. Eng'g & Constr.	2.78%	1.1937	12	6
China	China Railway Construction Corp. Ltd	2.68%	0.2594	13	22
China	China Metallurgical Group Corp	2.56%	0.2378	14	23
France	Technip	2.46%	2.013	15	2
China	Dongfang Electric Corp	2.39%	0.2181	16	25
Spain	Sacyr Vallehermoso	2.09%	0.4407	17	19
Italy	Astaldi Spa	2.01%	0.9596	18	8
Germany	Bilfinger Berger Ag,	1.90%	1.3006	19	5
China	Shanghai Construction (Group) General Co	1.74%	0.2886	20	21
China	Shanghai Tunnel Engineering Co. Ltd.	1.67%	0.2284	21	24
Spain	Fcc, Fomento De Constr. Y Contratas Sa	1.60%	0.777	22	13
Spain	Grupo Isolux Corsan Sa	1.18%	0.5388	23	17
France	Eiffage	0.74%	0.4513	24	18
Spain	Ferrovial Agroman Sa	0.01%	0.5531	25	15
Spearman Rank Correlation Coefficient	$\rho = 1 - \frac{6 \sum d_i^2}{n(n^2 - 1)}.$ = 0.33				

Table 6-11 ROA and DOI of 25 Firms

The Spearman Rank Correlation Coefficient ρ is 0.33. It means there is a weak positive relationship between the degree of internationalisation and a construction firm's financial performance. With the increase of a firm's degree of internationalisation, a firm can achieve a slightly better Return on Assets.

For the relationship between degree of internationalisation and the construction industry performance in the international market at the country level, this research analysed sixteen countries' construction industries, which were selected according to the numbers of construction multinational enterprises listed in the ENR top 225 international constructors list in 2010. Only the countries which have more than three construction multinational enterprises in this list were selected. The countries are China, Turkey, Italy, the U.S., Japan, Korea, Span, France, UK, German, Australia, Canada, Egypt, U.A.E., Brazil and India. The International Advanced Index is adopted to measure the construction industry performance in the international market at the country level. The ROLI-Model was used to calculate the degree of internationalisation of these 16 countries. The indexes of A-O, A-L, A-I and T-DOI were generated. The results are summarized in Table 6-12.

Country	DOI	IAI	Rank of DOI	Rank of IAI	Spearman Rank Correlation Coefficient
Germany	1.1664	2.5640	2	1	$\rho = 1 - \frac{6\sum d_i^2}{n(n^2-1)}.$ = 0.55
Australia	0.9213	0.9169	5	8	
U.K.	1.1124	1.4762	3	4	
France	1.2260	2.3900	1	2	
Egypt	0.8113	0.3238	9	15	
U.A.E.	0.2961	0.1234	16	16	
Canada	0.6168	1.0005	14	7	
Spain	0.7077	1.5678	11	3	
Italy	0.5277	0.6814	15	12	
S. Korea	0.6718	0.6272	13	13	
Turkey	1.0184	0.5072	4	14	
USA	0.8153	1.1297	8	6	
Japan	0.8593	0.8046	6	10	
China	0.6970	0.8071	12	9	
Brazil	0.8271	1.2624	7	5	
India	0.7561	0.7279	10	11	

Table 6-12 Spearman Rank Correlation Coefficient between DOI and International Advanced Index of construction industry in selected countries

The Spearman Rank Correlation Coefficient ρ between DOI and International Advanced Index of construction industry in these sixteen countries is 0.55. There is a moderate positive relationship between the degree of internationalisation of a certain country's construction industry and the construction industry's performance at the country level. With the increase of the degree of internationalisation, the International

Advanced Index of a certain country's construction industry can be improved significantly.

6.7.2 Improvement

The annual report on the top 225 international contractors provided by Engineering News Record (ENR) is used in this section, because it is the most comprehensive data set currently available. In order to calculate the I-OMS and A-I, Dun and Bradstreet (D&B)'s 'Who Owns Whom (WoW)' ownership tree structure database, annual reports, finance reports, company brochures and company websites will be used as well.

It is difficult to track the changes of the number of overseas subsidiaries and the total number of such affiliates for all the multinational enterprises listed in the ENR's Top 225 international constructors from 2001 to 2010, especially for the Chinese enterprises as they are not listed companies and their information is very limited. Low and Jiang (2003) adopted the same measurement to calculate the I-OMS of the top 35 Chinese international contractors listed in the top 225 construction contractors. Therefore, this section will only compare the degree of internationalisation of the Chinese multinational construction enterprises in 2000 and 2010. The results are provided in Table 6-13.

Index	2000	2010
A-O	0.48	0.53
A-L	0.44	0.1
A-I	0.41	0.09
T-DOI	1.33	0.72

Table 6-13 The degree of internationalisation of the Chinese multinational construction enterprises in 2000 and 2010

From 2000 to 2010, the degree of internationalisation of the Chinese construction enterprises at the country level declined from 1.33 to 0.72. The average of L-IBD (A-L) and the average of I-OMS (A-I) declined dramatically from 0.44 and 0.41 in 2000 to 0.1 and 0.09 in 2010 respectively. Only the average of O-IRTR (A-O) has increased slightly from 0.48 to 0.53 beterrn 2000 and 2010. The degree of internationalisation of the Chinese construction enterprises after entry into the WTO did not increase as the Chinese government and many scholars expected. With the development of globalisation, more countries open their market for international enterprises. However, the Chinese construction enterprises did not seem to seize these opportunities and broaden their international market. It is also very difficult for the Chinese construction enterprises to spread their business to the developed countries. And in their traditional markets, like the Middle East, Asia and Africa, they are facing increasing competition (refer to Table 5-7 in Chapter 5 Section 5.4).

The decrease of A-I, A-L and T-DOI may be explained by the large growth in the domestic market and the difficulties of entry into the international market. As a developing country and emerging economy of the world, China is on the way to modernisation and urbanisation. Infrastructure and residential building have always been a major concern of by the Chinese government. During the financial crisis of 2009, much more investment in infrastructure was made by Chinese governments at all levels to sustain economic growth. Therefore, the Chinese construction enterprises have more opportunities in the domestic market and their willingness to go abroad is weak. In addition, regulations and standards are different in different countries, and this may affect the Chinese construction enterprises entering into the international market.

6.7.3 Conclusion

There are positive relationships between the degree of internationalisation and a construction firm’s financial performance and between the degree of internationalisation and the construction industry performance in the international market at the country level. Especially, a moderate positive relationship exists between the degree of internationalisation of a certain country’s construction industry and construction industry's performance at the country level. This result indicates that the performance of the construction industry in the international market could be improved significantly, with the increase of the degree of internationalisation. These results also support the statements of Dunning (1993, 2003) and Cho and Moon (2000), that is, the activities of the multinational enterprises would be included in international competiveness and be a determinant.

In addition, the degree of internationalisation of the Chinese construction enterprises at the country level declined from 2000 to 2010. This is unexpected by the Chinese government and many scholars and the decrease may be caused by the large growth in the domestic market and the difficulties of entry into the international market.

6.8 Related and supporting industries

The development of the related and supporting industries is essential for the improvement of an industry's competitiveness (Porter, 2000). This section will identify the related and supporting industries of the Chinese construction industry by adopting the input-output analysis. Three indexes will be discussed including: Direct Consumption Coefficient, Total Consumption Coefficient and Influence Coefficient. After identifying the related and supporting industries of the Chinese construction industry, these industries will be studied briefly and the productivity changes will be explored as well.

6.8.1 Identification

6.8.1.1 Direct and Total Consumption Coefficient

The latest input-output table of China is the 2007 version. This research will adopt the basic data of 2007 China 42 × 42 sectors input-output table to calculate the Direct Consumption Coefficient and Total Consumption Coefficient of the Chinese construction industry to the 42 sectors based on Leontief's theory, which is provided in Chapter 4 Section 4.8.1. The results are provided in Table 6-14 and Table 6-15.

Sector	Construction Industry	Ratio %	Accumulation	Rank
Manufacture of Non-metallic Mineral Products	0.212 6	27.66	27.66%	1
Smelting and Pressing of Metals	0.156 5	20.36	48.02%	2
Transport and Storage	0.075 3	9.80	57.82%	3
Manufacture of Electrical Machinery and Equipment	0.041 7	5.42	63.24%	4
Chemical Industry	0.039 1	5.09	68.34%	5
Manufacture of Metal Products	0.036 2	4.71	73.05%	6
Manufacture of General and Special Purpose Machinery	0.029 2	3.80	76.85%	7
Wholesale and Retail Trades	0.023 4	3.04	79.89%	8
Processing of Petroleum, Coking, Processing of Nuclear Fuel	0.020 2	2.63	82.53%	9

Table 6-14 Closely related industries of the Chinese construction industry in terms of Direct Consumption Coefficient

Sector	Construction Industry	Ratio %	Accumulation	Rank
Smelting and Pressing of Metals	0.400 5	16.10	16.10%	1
Manufacture of Non-metallic Mineral Products	0.278 7	11.21	27.31%	2
Chemical Industry	0.217 9	8.76	36.07%	3
Production and Supply of Electric Power and Heat Power	0.158 3	6.36	42.44%	4
Transport and Storage	0.148 8	5.98	48.42%	5
Processing of Petroleum, Coking, Processing of Nuclear Fuel	0.118 4	4.76	53.18%	6
Manufacture of General and Special Purpose Machinery	0.117 3	4.72	57.89%	7
Manufacture of Electrical Machinery and Equipment	0.088 2	3.55	61.44%	8
Manufacture of Metal Products	0.082 0	3.30	64.74%	9
Extraction of Petroleum and Natural Gas	0.081 5	3.28	68.02%	10
Mining and Processing of Metal Ores	0.066 8	2.69	70.70%	11
Wholesale and Retail Trades	0.063 8	2.57	73.27%	12

Table 6-15 Closely related industries of the Chinese construction industry in terms of Total Consumption Coefficient

The construction industry has extensive relationships with other industries. The total direct consumption coefficient of the Chinese construction industry to all the 42 sectors is 0.7686. The sum of the total consumption coefficient is 2.4869. It means that if the Chinese construction industry increased one unit of output, 0.7686 units of direct demand will be generated for the 42 sectors. The sum of direct and indirect demand for the 42 sectors is 2.4869 units. The difference between the total consumption coefficient and direct consumption coefficient reflects the indirect consumption by the Chinese construction industry in the 42 sectors. Because the difference is larger than the direct consumption coefficient, the indirect demand-pull effect of the Chinese construction industry on the 42 sectors is higher than the direct demand-pull effect.

The average direct and total consumption coefficient of the Chinese construction industry to the 42 sectors is 0.0183 and 0.0592 respectively. If the direct/total consumption coefficient of the Chinese construction industry to a sector is higher than the average level, this sector could be called the closely related industries of the Chinese construction industry in terms of direct/total consumption coefficient. These sectors are listed in Table 6-14 and Table 6-15 based on the order of 'closeness' to the Chinese construction industry.

6.8.1.2 Influence Coefficient

Influence coefficient indicates the increasing degree of all the sectors' production demand when a certain sector increases one unit of final use. The sectors with a higher influence coefficient have a stronger ability to influence the national economy. By conducting Equation 29 in Chapter 4 Section 4.8.1 and using the data from the 2007 input-output table of China, the influence coefficient is calculated and the value is 1.2856. It indicates that the driving ability and influence of the Chinese construction industry on all sectors and on the national economy is higher than the average level of influence of all the 42 sectors. If the government wants to improve the performance of the Chinese economy, it is a good choice to pay more attention to the construction industry.

6.8.1.3 Conclusion

The industries closely related to the Chinese construction industry in terms of direct/total consumption coefficient have been provided in Table 6-14 and Table 6-15. The closely related industries of the Chinese construction industry in terms of the direct consumption coefficient are all included in the closely related industries of the Chinese construction industry in terms of the total consumption coefficient. Only the rank is slightly different. The top two industries from both of them are the same, which are Smelting and Pressing of Metals and Manufacture of Non-metallic Mineral Products. This study will only discuss these two related and supportive industries of the Chinese construction industry.

6.8.2 Analysis of related and supporting industries

The top two related and supporting industries of the Chinese construction industry are Smelting and Pressing of Metals industry and Manufacture of Non-metallic Mineral Products industry. The Smelting and Pressing of Metals industry will be studied from 2005 to 2010, because of the changes in the statistical method of the China Statistical Yearbook and data availability. The panel data is provided in Table 6-16. Except the number of firms and the total profits in 2009, all the indicators increased significantly from 2005 to 2010. The Return on Assets (ROA) of the Smelting and Pressing of Metals sector increased from 2005 to 2007 and declined from 2007 to 2009. Though the ROA climbed from 4.31% in 2009 to 6.09% in 2010, it is still lower than 2005, which is 6.59%. The results indicate that the abilities of asset utilisation, corporate profitability and management of the Chinese Smelting and Pressing of Metals industry did not substantially increase from 2005 to 2010.

When the total factor productivity changes (TFPC) of the Chinese Smelting and Pressing of Metals industry from 2005 to 2010 is calculated, the number of annual average employees and the Gross Output Value (GOV) of the Chinese Smelting and Pressing of Metals industry are inputs and the Gross Value-added (GVA) is output. The mean of the TFPC is 0.834. This indicates the average level of the total factor productivity of the total factor productivity changes the Chinese Smelting and Pressing of Metals industry from 2005 to 2010 decreased. It increased in 2005-2006, 2006-2007 and 2008-2009. From 2007 to 2008, there was a 6.6% decrease. The most significant drop is from 2009 to 2010 with a decrease rate of 69.5%. The bailout investment initiatives of the Chinese government in 2009-2010, such as the 4 trillion CNY investment plan, stimulated the economic development and reduced the impact of the economic crisis. However, for some industries, these initiatives lead to the decrease in the efficiency of utilising resources.

Year	No. of Firms	Total Assets (BIL CNY)	Total Profits (BIL CNY)	Input		Output	ROA %	TFPC
				No. of Employees (MIL)	GOV (BIL CNY)	GVA (BIL CNY)		
2005	11812	2552.01	149.43	4.18	2940.89	770.66	6.59	N/A
2006	12862	3168.05	224.48	4.33	3834.03	1020.25	7.85	1.139
2007	13862	4050.46	326.45	4.60	5173.49	1348.48	9.04	1.104
2008	16212	4932.79	242.15	4.99	6567.67	1477.41	5.39	0.934
2009	15814	5746.54	230.05	5.01	6320.34	1638.25	4.31	1.128
2010	16081	6628.24	376.97	5.37	79952.6	1837.37	6.09	0.305
							Mean	0.834

Table 6-16 Smelting and Pressing of Metals

Table 6-17 summarised the performance of the Chinese Manufacture of Non-metallic Mineral Products industry from 2005 to 2010. All the indicators of the Chinese Manufacture of Non-metallic Mineral Products industry, including total number of firms, total assets, total profits, annual average employees, gross output value and gross value-added increased from 2005 to 2010. The return on assets is increased from 4.4% in 2005 to 12.35% in 2010. The total factor productivity changes of the

Manufacture of Non-metallic Mineral Products industry increased from 2005 to 2010, with an average growth rate of 5.5% in these 6 years, except the 4.5% decrease in 2007-2008. These results indicate a better asset utilisation efficiency of enterprises, increasing of corporate profitability and improvement of management capability of the Chinese Manufacture of Non-metallic Mineral Products industry.

Year	No. of Firms	Total Assets (BIL CNY)	Total Profits (BIL CNY)	Input		Output	ROA %	TFPC
				No. of Employees (MIL)	GOV (BIL CNY)	GVA (BIL CNY)		
2005	20111	10370.69	420.35	418.18	9195.24	2807.92	4.40	N/A
2006	21936	11937.18	618.59	426.39	11721.52	3656.20	5.55	1.142
2007	24278	13971.51	1037.19	448.41	15559.44	4849.19	8.01	1.123
2008	30524	17927.36	1480.55	498.73	20943.45	5668.70	9.28	0.955
2009	32544	20820.55	1856.59	508.91	24843.90	6502.00	9.58	1.043
2010	34793	25567.37	2858.59	544.61	32057.26	7821.91	12.32	1.024
							Mean	1.055

Table 6-17 Manufacture of Non-metallic Mineral Products

6.8.3 Conclusion

This section identified the related and supporting industries of the Chinese construction industry by adopting the input-output analysis. Direct Consumption Coefficient, Total Consumption Coefficient and Influence Coefficient were discussed. The closely related industries of the Chinese construction industry in terms of Direct/Total Consumption Coefficient were identified. The top two related and supportive industries were discussed in detail, including: the Smelting and Pressing of Metals industry and Manufacture of Non-metallic Mineral Products industry. Most of the indicators of these industries show a gradual increase in recent years. However, the total factor productivity of the Smelting and Pressing of Metals industry didn’t perform well from 2005 to 2010.

6.9 Government

The government element is not new and has been included in Porter’s Diamond

Model as an auxiliary element. In the Internationalisation Sustainable Development Competitiveness Model, the government element has been modified to be a determinant. The total factor productivity changes of the Chinese government in relation to the construction industry from 2001 to 2010 will be analysed.

Firstly, when input is the administrative expenses, the total factor productivity changes of the Chinese government in relation to the construction industry (TFPCg) from 2001 to 2006 and 2007 to 2010 could be summarised in Table: 6-18. The results of the two inputs' measurement from 2008 and 2009 are provided in Table 6-19. The original data of the input and output are provided in Table 6-20.

Year	TFPCHg
2001-2002	0.995
2002-2003	1.012
2003-2004	0.987
2004-2005	0.903
2005-2006	0.969
Mean	**0.972**
2007-2008	0.973
2008-2009	1.105
2009-2010	1.078
Mean	1.051

Table 6-18 Total factor productivity changes of the Chinese government in relation to the construction industry from 2001 to 2006 and 2007 to 2010 – Signal input

Year	TFPCg
2008-2009	1.092
2009-2010	1.106
Mean	1.099

Table 6-19 Total factor productivity changes of the Chinese government in relation to the construction industry from 2008 to 2010 – Two inputs

Year	Output 1	Output 2	Output 3	Input 1	Input 2
	No. of persons with a non-school qualification per thousand people	No. of construction companies	GOV of non-State Owned construction enterprises (Billion CNY)	Administrative expenses (Billion CNY)	The number of civil servants ’000
2001	34.49125	45893	999.875	351.249	N/A
2002	43.76355	47820	1294.432	410.132	N/A
2003	51.12256	48688	1702.364	469.126	N/A
2004	54.10995	59018	2169.584	552.198	N/A
2005	50.97739	58750	2612.007	651.234	N/A
2006	58.3619	60166	3233.86	757.105	N/A
2007	61.54255	62074	4041.281	1221.568	N/A
2008	62.96937	71095	4980.515	1409.64	6597
2009	68.28449	70817	6161.769	1415.924	6789
2010	89.3	71863	7788.255	1512.408	6894

Table 6-20 Inputs and outputs of total factor productivity changes of the Chinese government in relation to the construction industry

Except for 2002-2003, the productivity of the Chinese government in relation to the Chinese construction industry decreased from 2001 to 2006. The average decrease rate is 2.8%. From 2007 to 2008, productivity declined as well, with a decrease rate of 2.7%.

From 2008 to 2010, both the signal and double input measurements show a similar trend of increasing the productivity of the Chinese government in relation to the Chinese construction industry. For the single input, the average growth rate in these three years is 9.15%. For the double inputs measurement, the average growth rate reached 9.9%. It could be speculated that from 2008 the Chinese government by expending the same amount of resources (capital or/and labour) could enhance the increase of advanced factors, the competition situation of the domestic market and the performance of non-State Owned construction enterprises of China to a greater extent, compared with the previous years.

6.10 Sustainable Development Index

A new sustainable development index system has been generated in Chapter 3. All the indicators could be grouped into three categories and four aspects. The three categories are Economic Sustainability, Social Sustainability and Environmental Sustainability, and the four aspects are Resource Consumption and Environmental Benefits, Development Potential, Development Efficiency and Development Level. Firstly, this section will discuss the development of each indicator from 2001 to 2010. Next, the degree of coordination analysis will be conducted to explore the relationship between the Economic Sustainability, Environmental Sustainability and Social Sustainability of the Chinese construction industry from 2001 to 2010.

6.10.1 Improvements of sustainability

Data was sourced from the China Statistical Yearbook and the Chinese Construction Industry Yearbook. The results are summarised in Table 6-21.

Year	Economic Sustainability					Social Sustainability		Environmental Sustainability	
	GOV (BIL CNY)	Labour productivity in terms of value-added (CNY/Person)	Profit margin (%)	GDP (BIL CNY)	Gross fixed capital formation (BIL CNY)	Per capita disposable income per year CNY	No. of persons with a non-school qualification per thousand people	Construction Waste / GOV (Ton/MIL CNY)*	Energy Consumption / GOV (Tons of SCE /MIL CNY)
2001	153.62	17621	1.9	10966	3775.5	(CNY)	34.49125	30.69	9.46
2002	185.27	15715	2	12033	4363.2	6859.98	43.76355	25.79	8.69
2003	230.84	17476	2.3	13582	5349.1	7702.8	51.12256	22.53	7.68
2004	290.21	20817	2.2	15988	6511.8	8472.2	54.10995	18.70	11.23
2005	345.52	23427	2.6	18494	7423.3	9421.61	50.97739	15.78	9.85
2006	415.57	25741	2.9	21631	8795.4	10493.03	58.3619	12.50	9.05
2007	510.44	28853	3.1	26581	10394.9	11759.45	61.54255	10.43	8.09
2008	620.37	32444	3.5	31405	12808.4	13785.81	62.96937	8.71	6.15
2009	768.08	37640	3.5	34090	15668	15780.76	68.28449	7.17	5.94
2010	960.31	40319	3.5	40120	18234	17174.65	89.3	5.76	6.48

Table 6-21 Developments of the sustainable development indicators of the Chinese construction industry

* Construction Waste / GOV: there is no public data of the construction waste. A widely acceptable measurement for the construction waste is that it accounts about 30% to 40% of the consumption wastes. This research adopts 35% to measure the construction waste from consumption wastes.

According to this table all the indicators increased gradually from 2001 to 2010, except the energy consumption for per million gross output value (GOV) of the Chinese construction industry and the ratio of profit before tax to GOV. (Construction waste generated per million GOV decreased.) The energy consumption for per million CNY GOV of the Chinese construction industry reduced from 9.46 tons of standard coal equivalent (SCE) in 2001 to 6.48 tons of SCE in 2010. However, its development track is not flat, but declining unevenly. From 2001 to 2003, the energy consumption for per million CNY GOV of the Chinese construction industry was decreasing. There is a big increase in 2004. It then decreased from 2005 to 2009. In 2010, it had a 9.16% growth. The profit margin climbed from 1.9% in 2001 and peaked at 3.5% in 2008. After that, the profit margin did not change and was stable at 3.5% from 2008 and 2010.

6.10.2 Degree of coordination

In order to explore the degree of coordination between Economic Sustainability, Environmental Sustainability and Social Sustainability in the Chinese construction industry from 2001 to 2010, date of all the indicators will firstly be processed dimensionless by using the min-max normalisation method. The average of the value of the indicators after dimensionless in each category, named economic sustainability index, environmental sustainability index and social sustainability index, will be adopted to discuss the degree of coordination among economic sustainability, environmental sustainability and social sustainability of the Chinese construction industry by conducting Equation 34, which is provided in Chapter 4. The average of all the indicators in the sustainable development index (SDI) after dimensionless will be used to explore the development of the sustainability of the Chinese construction industry from 2001 to 2010. The results are provided in Table 6-22.

Year	Economic Sustainability						Social Sustainability			Environmental Sustainability			DOC	SDI
	GOV	Labour productivity in terms of value-added	Profit margin	GDP	Fixed asset investment	Average	Per capita disposable income per year	No. of persons with a non-school qualification per thousand people	Average	Construction Waste / GOV	Energy Consumption / GOV	Average		
2001	0.0000	0.0775	0.0000	0.0000	0.0000	0.0155	0.0000	0.0000	0.0000	0.0000	0.3350	0.1675	0.2325	0.0458
2002	0.0392	0.0000	0.0625	0.0366	0.0407	0.0233	0.0688	0.1692	0.1190	0.1967	0.4800	0.3383	0.6986	0.1215
2003	0.0957	0.0716	0.2500	0.0898	0.1088	0.1032	0.1316	0.3034	0.2175	0.3275	0.6718	0.4996	0.8370	0.2278
2004	0.1693	0.2074	0.1875	0.1723	0.1893	0.1976	0.2091	0.3579	0.2835	0.4808	0.0000	0.2404	0.9855	0.2193
2005	0.2379	0.3134	0.4375	0.2582	0.2523	0.2924	0.2966	0.3008	0.2987	0.5982	0.2608	0.4295	0.9840	0.3284
2006	0.3247	0.4075	0.6250	0.3658	0.3472	0.3891	0.4000	0.4355	0.4178	0.7297	0.4121	0.5709	0.9878	0.4497
2007	0.4423	0.5340	0.7500	0.5356	0.4578	0.5139	0.5654	0.4936	0.5295	0.8126	0.5942	0.7034	0.9911	0.5762
2008	0.5786	0.6799	1.0000	0.7011	0.6247	0.7169	0.7283	0.5196	0.6239	0.8817	0.9610	0.9214	0.9864	0.7417
2009	0.7617	0.8911	1.0000	0.7932	0.8225	0.8337	0.8421	0.6166	0.7293	0.9435	1.0000	0.9717	0.9932	0.8523
2010	1.0000	1.0000	1.0000	1.0000	1.0000	0.9800	1.0000	1.0000	1.0000	1.0000	0.8971	0.9486	0.9997	0.9886

Table 6-22 Degree of coordination of the Chinese construction from 2001 to 2010

The economic sustainability index and the social sustainability of the Chinese construction industry increased from 2001 to 2010. The environmental sustainability index increased from 2001 to 2003. There is a significant fall in 2004. After that, from 2005 to 2009, the environmental sustainability index of the Chinese construction industry keeps climbing. However, there is another fall in 2010.

The degree of coordination (DOC) among the economic sustainability, environmental sustainability and social sustainability of the Chinese construction industry was only 0.2325 in 2001, which is ‘extremely maladjusted’. It is the most maladjusted time during these ten years. In 2002 and 2003, the DOC increased to 0.6986 and 0.8370, which means weakly coordinated and coordinated respectively. After that, despite fluctuations, the DOC of the Chinese construction industry is all above 0.98, which is located in the group of ‘well-coordinated’. Therefore, it could be said that the development level and trend among the economic sustainability, environmental sustainability and social sustainability of the Chinese construction industry is under the process of moving from ‘uncoordinated’ to ‘coordinated’ from 2001 to 2010.

The sustainable development index of the Chinese construction industry from 2001 to 2010 is increasing dramatically, except for the slight drop in 2004. The average increase rate in these ten years is 47%. It represents the sustainability of the Chinese construction industry has been improved dramatically from 2001 to 2010.

6.11 Conclusion

The productivity of the Chinese construction industry has increased from 2001 to 2010. Most of the elements of the industrial competitiveness of the Chinese construction industry have developed continuously from 2001 to 2010. The important change in the factor conditions is that China pays increasing attention to the development of the advanced factors. The proportion of R&D expenditure in the Chinese GDP is increasing gradually. The proportion of R&D expenditure of the

Chinese construction industry in its gross output value is also rising significantly.

The size of the domestic market for the Chinese construction industry is very large with a high growth rate. It would benefit the demand conditions element. For the concentration ratio, CR_4, CR_8 and CR_{12} have increased significantly. However, they are all still lower than 25%. The capital structure of the Chinese construction industry has changed as well. The changes are:

a) The dominant position of SOEs and COEs in the Chinese construction industry has been replaced by POEs;
b) The performance of the non-public ownership enterprises including POEs, HMTEs and FFEs is better than the public ownership enterprises, including SOEs and COEs. The Chinese construction industry is transforming from being dominated by public ownership enterprises to being dominated by non-public ownership enterprises.
c) Chinese domestic construction enterprises have developed rapidly. The gap between Chinese domestic construction enterprises and foreign enterprises has narrowed, substantially so in relation to labour productivity. However, from the perspective of profit margins, the distance between them has not been reduced.

There are positive relationships between the degree of internationalisation and a construction firm's financial performance and between the degree of internationalisation and the construction industry performance in the international market at the country level. It is appropriate to include the activities of the multinational enterprises in international competeiveness, and to consider this a determinant. However, the degree of internationalisation of the Chinese construction industry in 2010 is even lower than 2000. This was not expected by the Chinese government or scholars, and the decrease may be caused by the large growth in the domestic market and the difficulties of entry into the international market.

Next, the closely related and supporting industries of the Chinese construction industry are identified. The top two are discussed in detail, including: the Smelting and Pressing of Metals industry and Manufacture of Non-metallic Mineral Products industry. Most of the indicators of these industries show a gradually increase in recent years. However, the total factor productivity of the Smelting and Pressing of Metals industry doesn’t perform well from 2005 to 2010.

In addition, both the single and two inputs productivity of the Chinese government in relation to the Chinese construction industry have improved to a certain extant in recent years.

Finally, for the sustainable development element, all the indicators increased to a certain degree. The sustainability of the Chinese construction industry from 2001 to 2010 has improved. The three sub-indexes: Economic Sustainability, Social Sustainability and Environmental Sustainability are discussed as well. The degree of coordination among them is increasing from 2001 to 2010. They are well-coordinated in recent years.

Chapter 7 Australian construction industry analysis

7.1 Introduction

As a traditional developed country, the Australian economy plays an important role in the Asia Pacific area, even the world. Australia's economy is the third freest in the 2013 Index of Economic Freedom (Heritage, 2013). Australia is the world's twelfth largest economy and has the fifth highest per capita GDP (nominal) and it is ranked second in the United Nations 2011 Human Development Index and first in Legatum's 2008 Prosperity Index (United Nation, 2011). In addition, all of Australia's major cities received good results in global comparative livability surveys. For example, Melbourne reached first place on The Economist's 2011 world's most livable cities lists, followed by Sydney, Perth, and Adelaide in sixth, eighth, and ninth place respectively (The Economist, 2011).

The Australian construction industry plays an important role in Australia's economy. The construction industry was the fourth largest contributor to Gross Domestic Product (GDP) in the Australian economy during 2008-09 in current price terms, and plays a major role in determining economic growth. In chain volume terms, the construction industry accounted for 6.8% of GDP in 2008-09. The construction industry also provides infrastructure for other sectors, including '(a) parts of the manufacturing, wholesale and retail trade and finance industries, in supplying components, fittings and furnishings, and in financing building and construction, and (b) parts of the professional services industry, such as the architectural and engineering professions for design and erection methods embracing both proven and advanced innovative technological methods and products' (ABS, 2010). As at May quarter 2009 the construction industry employed 984,100 persons, which is 9.1% of the Australian workforce, making it Australia's fourth largest industry.

The Australian construction industry has also made remarkable achievements and development in both domestic and international markets in recent years. This Chapter will discuss the domestic and international performance of the Australian construction industry from 2001-02 to 2010-11. In addition the productivity changes of the Australian construction industry in these ten years will be explored. Furthermore, the industrial competitiveness of the Australian construction industry will be analysed.

7.2 Domestic market performance

The Australian construction industry operates in both the private and public sectors and is made up of two sub-divisions –general construction and construction trade services. General construction consists of three broad areas:

- Residential building (houses, flats, etc.),
- Non-residential building (offices, shops, hotels, etc.), and
- Engineering construction (airports, bridges, water and sewerage, highways, etc.).

Residential building is dominated by the private sector. Non-residential building and engineering construction are undertaken by both the private and public sectors and the public sector plays a key role especially for the activities relating to health and education. Some major public infrastructure projects are increasingly delivered through private-public partnerships. Construction trade services are composed by five groups, including:

- Preparation services
- Building structure services
- Installation trade services
- Building completion services and

- Other construction services

The value of construction work done by the Australian construction industry has increased from AU$87.5 billion in 2001-2002 to AU$173.7 billion in 2010-2011 (refer to figure 7-1), with an average growth rate of 7.97%. The proportion of three broad areas of construction – residential building, non-residential building and engineering construction in the total construction work done of the Australian construction industry has changed significantly over time (refer to Figure 7-2) .

From 2000-01 to 2010-11, residential building and non-residential building increased slightly. However, engineering construction activity has grown steadily. In 2005-06, it exceeded the value of residential building activity and became the largest among these three areas. In addition the difference between the value of engineering construction activity and the other two activities became larger (refer to Figure 7-2).

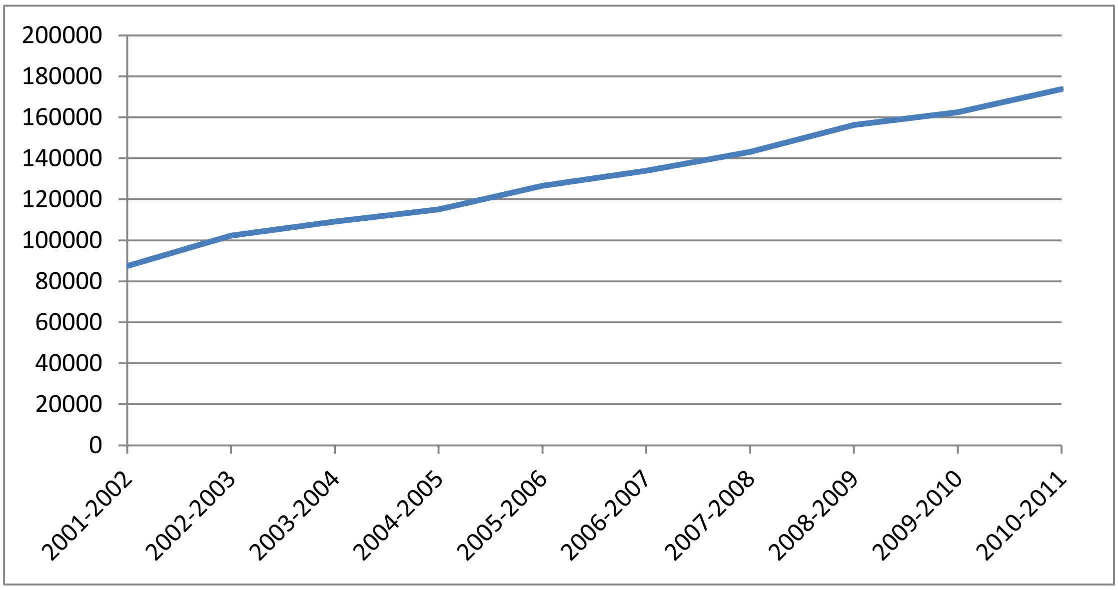
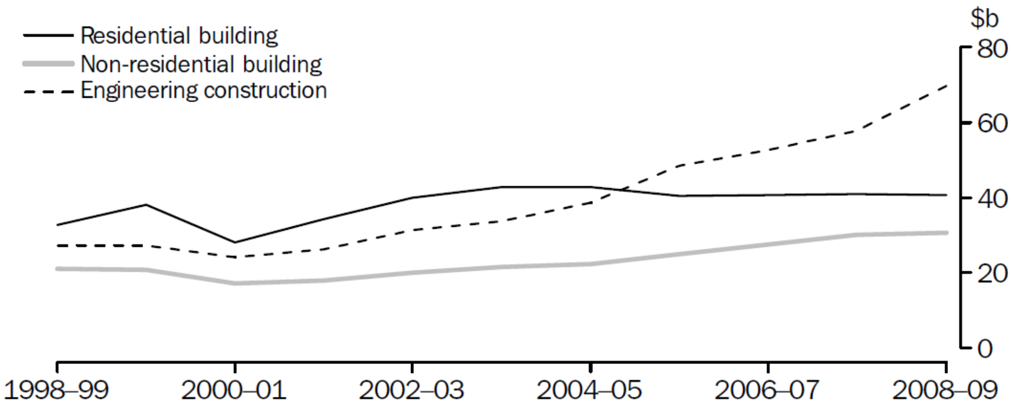


Figure 7-1 Value of construction work done by the Australian construction industry (AU$m)

Source: Australia Year Book, Australian Bureau of Statistics



(a)Volume measure. Reference year is 2006-2007. (b) Resident building includes alterations and addtions

Figure 7-2 Value of work done (a), by type of activity (b) of the Australian construction industry

Source: Construction Work Done, Australia, Preliminary 98755.0, Australia Year Book 2012

Table 7-1 provides some other key indicators of the Australian construction industry. The gross value added of the Australian construction industry increased from AU$59518 million in 2001-02 to AU$98539 in 2008-09. After a small drop in 2009-10, the gross value added of the Australian construction industry reached AU$ 103760 in 2010-11. The average increase rate of the Australian construction industry from 2001-02 to 2010-11 was 6.45%.

Year	Gross Value added AU$m	No. of firms	Operating profit before tax AU$m	Margin rate	Employee (000) (quarter average)
2001-2002	59518	344561	11232	9.3	670.4
2002-2003	69461	339982	13078	9.5	692.95
2003-2004	73901	365781	15935	10.1	717.65
2004-2005	77318	383517	16930	9.9	773.7
2005-2006	83447	407188	19485	9.9	832.85
2006-2007	88624	316029	33283	14.3	877.575
2007-2008	94103	323071	24508	9.7	943.3
2008-2009	98539	273276	23280	8.9	971.5
2009-2010	98293	238530	35615	12.6	1001.725
2010-2011	103760	213352	30393	10.2	1003.75

Table 7-1 key indicators of the Australian construction industry

Source: Australia Year Book, Australian Bureau of Statistics

Though there is fluctuation in the number of Australian construction firms from 2001-

02 to 2010-11, the total trend decreased and it declined from 344561 in 2001-02 to 213352 in 2010-11, with an average decrease rate of 4.62%. The profits of the Australian construction firms increased from AU$11232 million in 2001-02 to AU$33283 million in 2006-07. After that, it declined to AU$23280 in 2008-09. After a significant increase in 2009-10, it dropped to AU$30393 in 2010-11. The average increase rate of the profits of the Australian construction firms from 2001-02 to 2010-11 is approximately 15.26%. The margin rate did not have significant change and the average margin rate is 10.44% from 2001-02 to 2010-11.

As the fourth largest industry in relation to the workforce, the Australian construction industry provides a large number of job opportunities. The number of employees in the construction industry rose from 670400 in 2001-02 to 1003750 in 2010-11, which is calculated by the average of quarter data from the Australian Bureau of Statistics. The average increase rate is 4.62% from 2001-02 to 2010-11.

7.3 International market performance

In the international construction market, Australian construction enterprises have been very active and occupied a certain degree of market share. There are four Australian construction enterprises listed in the ENR top 225 international contractors in 2010, up from two in 2001. The total international revenue of the Australian construction enterprises in the top 225 international contractors list climbed dramatically from US$856 million in 2001 to US$20431.5 million in 2010. The share of these Australian construction enterprises in the total international revenue of the top 225 international contractors increased from 0.8% in 2001 to 3.3% in 2007. After that, it dropped to 2.7% in 2010 (refer to Table 7-2).

Year	No. of firms in Top 225	International revenue US$ m	% in the total international revenue
2001	2	856	0.8
2002	2	975.6	0.84
2003	2	943.5	0.67
2004	4	1534.3	0.92
2005	3	1260.3	0.67
2006	3	1737.9	0.8
2007	4	10115	3.3
2008	4	12123.5	3.1
2009	4	12011.2	3.1
2010	4	10431.5	2.7

Table 7-2 International market performance of the Australian construction industry from 2001 to 2010

Table 7-3 summarises the performance of the Australian construction enterprises in the top 225 international contractors list in the regional international construction market from 2007 to 2010. The top three regional international markets for the Australian construction enterprises are Asia, the U.S. and Europe.

Regions	Indicators	2007	2008	2009	2010
Middle East	International revenue (US$ m)	258.8	939.3	1502.7	1246
	Growth rate of international revenue (%)	N/A	262.94	59.98	-17.08
	% in the total international revenue of this area	0.4	1.2	1.9	1.7
	% in the total international revenue of the Australian construction firms in top 225	2.56	7.75	12.51	11.94
Asia	International revenue (US$ m)	1963	2410.6	3894.6	3827.5
	Growth rate of international revenue (%)	N/A	22.80	61.56	-1.72
	% in the total international revenue of this area	3.5	3.5	5.3	5.0
	% in the total international revenue of the Australian construction firms in top 225	19.41	19.88	32.42	36.69
Africa	International revenue (US$ m)	0	0	0	0
	Growth rate of international revenue (%)	0	0	0	0
	% in the total international revenue of this area	0	0	0	0
	% in the total international revenue of the Australian construction firms in top 225	0	0	0	0
Europe	International revenue (US$ m)	2944.6	3240.2	2051.8	1656.4
	Growth rate of international revenue (%)	N/A	10.04	-36.68	-19.27
	% in the total international revenue of this area	3.1	2.8	2	1.8
	% in the total international revenue of the Australian construction firms in top 225	29.11	26.73	17.08	15.88
U.S.	International revenue (US$ m)	4806.2	5384.2	4436.3	3406.6
	Growth rate of international revenue (%)	N/A	12.03	-17.61	-23.21
	% in the total international revenue of this area	13	12.9	12.7	10.4
	% in the total international revenue of the Australian construction firms in top 225	47.52	44.41	36.93	32.66
Canada	International revenue (US$ m)	140.6	123	125.8	223.7
	Growth rate of international revenue (%)	N/A	-12.52	2.28	77.82
	% in the total international revenue of this area	1.7	0.9	0.9	1.7
	% in the total international revenue of the Australian construction firms in top 225	1.39	1.01	1.05	2.14
South America & Caribbean	International revenue (US$ m)	2.0	26.2	0	71.3
	Growth rate of international revenue (%)	N/A	1710	0	N/A
	% in the total international revenue of this area	0	0.1	0	0.2
	% in the total international revenue of the Australian construction firms in top 225	0.02	0.22	0	0.68

Table 7-3 Performance of the Australian construction enterprises in the top 225 international contractors list in the regional international construction market from 2007 to 2010

In the Middle Eastern market, the international revenue of Australian construction enterprises increased from 2007 to 2009 and dropped in 2010. The average increase rate was 102% from 2007 to 2009. Australian construction enterprises' share in the Middle Eastern international construction market increased from 0.4% to 1.7%. These results indicate that the influence of Australian construction enterprises is improving in the Middle Eastern international construction market. The international revenue from this area accounted for 11.94% of the total international revenue of the Australian construction enterprises in the top 225 list, which increased from 0.4% in 2007.

The performance of Australian construction enterprises in the Asian international construction market is similar to the Middle East. Both the international revenue and their share in the Asian international construction market improved from 2007 to 2010. The international revenue from this market has accounted 36.69% of the total international revenue of the Australian construction enterprises in the top 225 list, raised from 19.41% in 2007. These results represent the increasing importance of the Asian international construction market for the Australian construction industry.

Europe and the U.S. are two traditional international construction markets for the Australian construction industry. However, from 2007 to 2010, the international revenue of the Australian construction enterprises listed in the top 225 has decreased significantly from both markets. In 2010, nearly 50% of the international revenue of the Australian construction firms in the top 225 was from the U.S. and European markets, and 10.4% of the total international revenue of all the top 225 international construction enterprises in the U.S. market belonged to Australian construction enterprises. It represents the status of Australian construction enterprises in the U.S. international construction market. The decrease in these 4 years may have been caused by the economic crisis from 2008-2009 and the development of emerging markets.

In the remaining of three regional markets, the Australian construction enterprises do not have many activities. They may need to think about the possibility of spreading their business to the emerging market, for example Africa and South America & Caribbean. Both of these two markets are providing more opportunities for construction enterprises, details have been discussed in Chapter 2.

7.4 International Advanced Index

In order to explore the status and level of the Australian construction industry, the data collected in 2001 and 2010 about the Australian construction industry was used to calculate the International Advanced Index and the sub-indexes, including Width Index, Height Index and Depth Index. The annual report about the top 225 international contractors provided by Engineering News-Record (ENR) was adopted. By using the formulas generated and presented in Chapter 3 Section 4.6.1, the International Advanced Index, Width Index, Height Index and Depth Index of the Australian construction industry were calculated and are summarised in Table 7-4.

WI		HI		DI		IAI		M*	
2001	**2010**	**2001**	**2010**	**2001**	**2010**	**2001**	**2010**	**2001**	**2010**
0.3333	0.9167	0.013	0.0246	0.008	0.027	0.3543	0.9683	0	2

M= The total number of each country's firms listed in the top 10 of the ten construction fields

Table 7-4 The International Advanced Index of the Australian construction industry

The International Advanced Index of the Australian construction industry has risen from 0.3543 in 2001 to 0.9683, which is a huge increase of 173.3%. The Width Index, Height Index and Depth Index all increased significantly from 2001 to 2010 and their increase rates are 175%, 189% and 237.5% respectively. There were two Australian construction firms listed in the top 10 of the ten construction fields in 2010, while there were no firms listed in 2001. Therefore, the status and level of the Australian construction industry in the international market increased from 2001 to 2010. In the international market, the Australian construction industry had higher influence in more fields of construction and shared more international revenue. The quantity and quality of the Australian top construction firms increased as well.

7.5 Productivity

Productivity is a core index in economics (Latruffe, 2010). The general calculation method uses the ratio of output performance indicators to input performance indicators. Partial Factor Productivity and Total Factor Productivity are the two types of measurement for productivity. A single input will be used in the Partial Factor Productivity. The most popular two Partial Factor Productivity measurements are labor productivity (output/labor) and capital productivity (machine hours or dollars invested). Total Factor Productivity (TFP) is generated and plays an important role in economics and industry sectors. TFP measurement adopts multi-input indicators and multi-outputs indicators.

This section adopts total factor productivity to understand the changes in productivity of the Australian construction industry from 2001-02 to 2010-11. The Malmquist total factor productivity changes measurement will be adopted. The DEAP Version 2.1 was used to calculate the Malmquist total factor productivity changes. The explanation of the results from the DEAP Version 2.1 for the Malmquist Malmquist total factor productivity changes could be summarised as:

1) TFPCH <1: The productivity decreased from last year to the observation year;
2) TFPCH=1: No change on the productivity in these two years;
3) TFPCH>1: The productivity increased from last year to the observation year;
4) The increase/decrease rate = TFPCH-1

7.5.1 Input and output variables in total factor productivity

This study sources data from the Australian Bureau of Statistics to evaluate productivity changes. The Total Factor Productivity measurement conducted in this study is based on two inputs including; the construction work done and the number of employees in construction sector, and one single-output variable which is the construction industry gross value added. The analysed period is from 2001-02 to 2010-11.

Table 7-5 presents the descriptive statistics of the Australian construction industry on the construction work done, the number of employees and the gross value added. The trends of the construction work done and the number of employees have been discussed in Chapter 7 Section 7.2. For the gross value-added (GVA) of the Australian construction industry, except the decrease in 2007-08, it increased from AU$33381 millon in 2001-02 to AU$92759 million in 2009-10. However, the GVA declined slightly in 2010-11, down to AU$92107 million. The average growth rate is approximately 7.97% from 2001-02 to 2010-11.

Year	Construction work done AU$ m	NO. of Employees '000	Gross Value-Added AU$ m
2001-02	87508.041	670.4	33381
2002-03	102214.609	692.95	37918
2003-04	109156.119	717.65	45957
2004-05	115109.384	773.7	49536
2005-06	126559.415	832.85	57240
2006-07	133954.439	877.575	75463
2007-08	143221.423	943.3	75255
2008-09	156334.705	971.5	78899
2009-10	162440.336	1001.725	92759
2010-11	173661.024	1003.75	92107

Table 7-5 The construction work done, the number of employees and the gross value added of the Australian construction industry

7.5.2 Malmquist Total Factor Productivity changes

To calculate the Malmquist total factor productivity changes (MTFPC) of the

Australian construction industry, the DEAP Version 2.1 is adopted. The results of the Malmquist total factor productivity changes of the Australian construction industry from 2001-02 to 2010-11 is summarized in Table 7-6.

Year	EFFCH	TECHCH	PECH	SECH	MTFPC
2001-02/2002-03	1	1.034	1	1	1.034
2002-03/2003-04	1	1.152	1	1	1.152
2003-04/2004-05	1	1.011	1	1	1.011
2004-05/2005-06	1	1.062	1	1	1.062
2005-06/2006-07	1	1.248	1	1	1.248
2006-07/2007-08	1	0.930	1	1	0.930
2007-08/2008-09	1	0.989	1	1	0.989
2008-09/2009-10	1	1.136	1	1	1.136
2009-10/2010-11	1	0.959	1	1	0.959
Mean	1	1.054	1	1	1.054

Table 7-6 The Malmquist total factor productivity changes of the Australian construction industry from 2001 to 2010

The Malmquist total factor productivity changes of the Australian construction industry from 2001-02/2002-03 to 2005-06/2006-07 and 2008-09/2009-10 are all above 1. The total factor productivity of the Australian construction industry is increasing in these years. However, the Malmquist total factor productivity changes index are only 0.930 and 0.989 in 2006-07/2007-08 and 2007-08/2008-09 respectively. This indicates the decrease of the Total Factor Productivity of the Australian construction industry. The decrease rate is 7% and 1.1%. Though from 2008-09 to 2009-10 the Malmquist total factor productivity changes index of the Australian construction industry came back to more than 1, it went down to 0.959 in 2009-10/2010-11. It represents a decrease of 4.1% from 2009-10 to 2010-11. The mean of the Malmquist total factor productivity changes index of the Australian construction industry is 1.054. The average growth rate of the total factor productivity of the Australian construction industry from 2001-02 to 2010-11 is 5.4%.

7.6 Industrial competitiveness

The Internationalisation Sustainable Development Competitiveness Model (ISDC

Model) has been developed in Chapter 2. It is composed of eight elements including factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of Multinational Enterprises and sustainable development. Chance is the only external element, all the others are determinants. The measurements and indicators for these eights elements have been discussed in Chapter 4.

This chapter will adopt the calculation formulas and measurement methods generated in Chapter 3 and Chapter 4 to discuss the performance of the elements of the Internationalisation Sustainable Development Competitiveness Model of the Australian construction industry in recent years. Firstly, factor conditions, demand conditions, firm strategy, structure and rivalry, and activities of multinational enterprises will be explored. Next, the related and supporting industries element will be studied by a two step approach. The two steps are: 1) identifying which industries are the related and supporting industries for the Australian construction industry by adopting the input-output analysis (refer to Chapter 4); 2) briefly describing the current development of these industries, and explore their productivity changes.

In addition, the government element will be analysed by adopting the Malmquist productivity index to explore the total factor productivity changes in these ten years. Similar to the analysis on the Chinese construction industry, the inputs are administrative expenses and the number of civil servants in Australia. The outputs include:

(1) Producing high level factors – reflected by the number of persons with a non-school qualification per thousand people;
(2) The competitive nature of the domestic market –reflected by the number of construction companies; and
(3) The performance of private sectors –indicated by the construction work done by the provided construction sectors.

In addition, as the new added element, sustainable development of the industrial competitiveness of the Australian construction industry will be discussed. The indicators and variables in the different categories, including Economic Sustainability, Social Sustainability and Environmental Sustainability, will be calculated and compared one by one between 2002-03 and 2009-10.

7.6.1 Factor conditions

There are two types of factors, including basic factors and advanced factors (Porter 1977). Basic factors refer to natural resources, climate, geographical location, non-skilled workers and capital. Advanced factors include modern communications, information, transportation infrastructure, manpower with high education and research institutes. With regard to improving competitive advantage, the advanced factors are much more important than the basic factors (Porter, 1977)

For the basic factors, the examples of the natural resources of Australia is provided in Table 7-6 and Table 7-7, and the resources summary of human resources are shown in Table 7-7. Australia comprises a land area of almost 7.7 million square kilometers. The holding of many kinds of mineral resources in Australia is at the highest level in the world (refer to Table 7-7 and Table 7-8). For example, the holdings of recoverable black Coal and Lead are the highest in the world in 2009 (ABS, 2012).

Mineral	Quantity	Australia	World	Australia's percentage of world EDR	Australia's ranking in world holding of EDR-2009
Bauxite	Gt	6	27	23	2nd
Black coal					
In situ	Gt	61	na	na	na
Recoverable	Gt	80	148 (a)	25	1st
Copper (b)	Mt	10	596	13	2nd
Diamond					
Gem and near gem (c)	Mc	105	na	na	na
Industrial	Mc	109	594	18	3rd
Gold (b)	t	7399	47000	16	2nd
Iron ore	Gt	28	168	17	2nd
Lead (b)	,Mt	31	85	36	1st
Lithium (b)	kt	607	9927	6	na
Manganese ore	Mt	181	1420	13	4th
Mineral sands					
Hemenite	Mt	200	1252	16	2nd
Rutile	Mt	23	46	50	1st
Zircon	Mt	40	88	46	1st
Nicke (b)	Mt	24	69	35	1st
Sliver (b)	kt	70	438	16	2nd
Tantalum (b)	kt	51	116	44	2nd
Uranium (b) (d)	kt	1223	2577 (d)	47	1st
Zinc (b)	Mt	58	235	25	1st

na not available

(a) Geoscience Australia estimate.

(b) Quantity measured in contained metal.

(c) Detailed data are not available on world resources of gem/near gem diamond but Australia has one of the largest stocks for this category.

(d) From OECD Nuclear Energy Agency and International Atomic Energy Agency(OECD/NEA&IAEA)(2009).Compiled from the most recent data for resources recoverable at <US$80per kilogram of uranium..

Table 7-7 Economic demonstrated resources (DRE) of major minerals – December 2009

Source: Geoscience Australia, Australia's Identified Mineral Resources,2010.

	Crude Oil		Condensate		LPG		Sales Gas
	gigalitres	million barrels	gigalitres	million barrels	gigalitres	million barrels	billion cubic meters
			Economic Demonstrated Resources				
2006	171	1078	258	1624	214	1348	2434
2007	161	1010	239	1504	207	1298	2446
2008	162	1020	230	1447	192	1206	2365
2009	188	1181	343	2156	177	1113	3158
2010	170	1067	340	2141	166	1042	2984
			Subeconomic Demonstrated Resources				
2006	95	599	146	917	78	488	1884
2007	95	595	150	945	78	489	2084
2008	81	507	208	1305	77	486	2313
2009	45	284	98	614	60	379	1505
2010	45	286	94	592	60	379	1506

(a) Mckelvey classification estimates (according to the resource's geological certainty and economic feasibility).

Table 7-8 Oil and gas resources(a), as at 1 January

Source: Geoscience Australia, Oil and Gas Resources of Australia, 2010.

For human resources, the population of Australia has increased from 19.275 million in 2001 to 22.032 million in 2010 (refer to Table 7-9). The average growth rate is 1.50% in these ten years. The increase of population could benefit the industry by providing more labour force and increasing the consumer market. The increasing number of migrants in Australia is the driving force for the increase of Australia's population and economy. The average increased rate of net immigrants is 7.4% from 2001 to 2010.

People aged between 15 and 64 years are referred to as the working-age population. The working-age population in Australia has climbed to 14.846 million in 2010 from 12.895 million in 2001. However the proportion of working-age population in the total population of Australia did not have significant change in the period. The population of children and elderly people in Australia both increased from 2001 to 2010. However, the proportion of the population of children and elderly people in the total population of Australia decreased from 20.55% to 19.06% and increased from 12.55% to 13.56% respectively from 2001 to 2010. This trend will cause social issues and affect the demand of goods and services.

In addition, the children dependency ratio refers to the ratio of the population of children (aged 0-14) to the population of the working-age population (aged 15-64). This ratio indicates the number of children fostered per 100 working-age people. The children dependency ratio in Australia drops from 30.71% in 2001 to 28.28% in 2010. It is caused by the decrease of the proportion of children population in the total population of Australia. The elderly dependency ratio refers to the ratio of the population of elderly people (aged 65 and over) to the population of the working-age population (aged 15-64). It indicates the number of elderly people that are borne per 100 working-age people. The elderly dependency ratio increased from 418.76% in 2001 to 20.12% in 2010, which is caused by the increase of the proportion of elderly people in the total population of Australia. The gross dependency ratio refers to the ratio of the population of non working-age people (both aged 0-14 and aged 65 and over) to the population of working-age people (aged 15-64). It is expressed with percentage. It indicates how many non working-age people are supported by per 100 working-age people. The gross dependency ratio slightly declines from 49.47% in 2010 to 48.4% in 2010. It means two Australian working-age people have to support three people, including themselves.

Year	Total Population MIL	Migrant (a) 000	Aged 0-14		Aged 15-64		Aged 65 and Over		Children Dependency Ratio	Elderly Dependency Ratio	Gross Dependency Ratio
			Population Persons	Proportion	Population Persons	Proportion	Population Persons	Proportion			
Jun.2001	19.275	135.7	3960233	20.55%	12895398	66.90%	2419070	12.55%	30.71%	18.76%	49.47%
Jun.2002	19.495	110.6	3964606	20.34%	13064935	67.02%	2465669	12.65%	30.35%	18.87%	49.22%
Jun.2003	19.721	116.5	3969669	20.13%	13239741	67.14%	2511327	12.73%	29.98%	18.97%	48.95%
Jun.2004	19.933	100	3974224	19.94%	13399641	67.22%	2558857	12.84%	29.66%	19.10%	48.76%
Jun.2005	20.177	123.8	3983391	19.74%	13581574	67.31%	2611879	12.94%	29.33%	19.23%	48.56%
Jun.2006	20.451	146.7	4002387	19.57%	13784515	67.40%	2664064	13.03%	29.04%	19.33%	48.36%
Jun.2007	20.828	232.7	4046861	19.43%	14044151	67.43%	2736610	13.14%	28.82%	19.49%	48.30%
Jun.2008	21.249	277.4	4100896	19.30%	14343136	67.50%	2805167	13.20%	28.59%	19.56%	48.15%
Jun.2009	21.692	299.8	4158040	19.17%	14643047	67.51%	2890566	13.33%	28.40%	19.74%	48.14%
Jun.2010	22.032	196.1	4198698	19.06%	14846377	67.39%	2986675	13.56%	28.28%	20.12%	48.40%

(a) The sum of quarterly data.

Table 7-9 Population information of Australia

Advanced factors are considered to be much more important than the basic factors, because they can only be achieved through sustainable investment of substantial human resources and capital. As discussed in Chapter 3, the advanced factors can be indicated by the investment in R&D activities (including: R&D expenditure, the R&D expenditure/gross output value, and the R&D person years of effort (PYE)—also named as personnel full-time equivalent) and people's level of education.

The R&D expenditure in Australia is divided into four sectors including business, government, higher education and private non-profit. The date is available on the Australian Bureau of Statistics. However, their statistical time intervals are different. Therefore, the data from the 2012 Australia Year Book will be adopted, which only has the data for every two financial years from 2000-01 to 2008-09. For the national data, the gross output value is GDP. The summary of the investment in R&D activities by Australia is provided in Table 7-10.

The R&D expenditure of Australia increased from AU$ 10417 million in 2000-01 to AU$ 28146 million in 2008-09. The average growth rate is 28.33% in this period. The proportion of the R&D expenditure within the GDP also increased from 1.47% to 2.24%. The human resources in R&D reached 136696 PYE in 2008-09 from 95620 PYE in 2000-01, with the average growth rate of 9.36%.

Year	**R&D expenditure**			**Human resources in R&D**	
	AU$m	Growth Rate	Proportion in GDP	PYE	Growth Rate
2000-01	10417	N/A	1.47%	95620	N/A
2002-03	13212	26.83%	1.65%	107210	12.12%
2004-05	15969	20.87%	1.73%	116194	8.38%
2006-07	21777	36.37%	2.01%	126702	9.04%
2008-09	28146	29.25%	2.24%	136696	7.89%

Table 7-10 Investment in R&D activities of Australia

For the construction industry, the data of R&D expenditure and person years of effort are from *Australian Bureau of Statistics: 8104.0 – Research and Experimental*

Development, Businesses, Australia. The gross output value is measured by the construction work done. The information on R&D in the Australian construction industry is shown in Table 7-11.

Year	**R&D expenditure**			**Human resources in R&D**	
	AU$000	**Growth Rate**	**Proportion in GOV**	**PYE**	**Growth Rate**
2000-01	47873	N/A	0.09%	190	N/A
2001-02	94577	97.56%	0.16%	275	44.7%
2002-03	196794	108.08%	0.27%	675	145.5%
2003-04	219971	11.78%	0.27%	735	8.9%
2004-05	316740	43.99%	0.34%	911	23.9%
2005-06	401898	26.89%	0.38%	900	-1.2%
2006-07	485088	20.70%	0.40%	1174	30.4%
2007-08	754738	55.59%	0.55%	1939	65.2%
2008-09	934668	23.84%	0.60%	2482	28.0%
2009-10	868176	-7.11%	0.54%	2175	-12.4%
2010-11	994890	14.60%	0.57%	2484	14.2%

Table 7-11 R&D of the Australian construction industry

The R&D expenditure of the Australian construction industry has increased from AU$47.9 million in 2000-01 to AU$ 994.9 million in 2010-11. The average increasing rate in the period is 39.59%. Hereinto, the average increase rate from 2000-01 to 2008-09 is 48.6%, which is much higher than the national level for all the sectors. The proportion of the R&D expenditure of the Australian construction industry in the construction work done has increased from 0.09% to 0.57% from 2000-01 to 2010-11. At the same time, the human resources in R&D of the Australian construction industry increased dramatically from 190 PYE in 2000-01 to 2482 PYE in 2010-11, with the average growth rate of 34.7%. It indicates the Australian construction industry has realised the importance of investing in R&D activities. However, compared with the proportion of the R&D expenditure in GDP of Australia, the proportion of the R&D expenditure of the Australian construction industry in the construction work done is very low. This means that compared with other sectors, the Australian construction industry should pay more attention to R&D activities.

For the education level of the population, there is no particular data for the Australian construction industry. However, the national data could be collected from the Australian Bureau of Statistics. Table 7-12 provides the number of persons with a non-school qualification per thousand people aged 15-64 (NPNSQ/TP 15-64) from 2001-02 to 2010-11. It increased from 472 in 2001-02 to 557 in 2010-11. The average increasing rate is 1.82%. It represents the increase of educated labours, which could bring efficiency and competitiveness to sectors.

Year	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09	2009-10	2010-11
NPNSQ/TP 15-64	472	482	491	509	515	524	526	539	550	557
Growth Rate %	N/A	2.12	1.87	3.67	1.18	1.75	0.38	2.47	2.04	1.27

Table 7-12 Number of persons with a non-school qualification per thousand people aged 15-64 in Australia

Australia is vast in territory and rich in resources. However, advanced factors are much more critical in relation to the improvement of competitiveness. Australia increased the investment in R&D activities in the last decade. The Australian construction industry has also realised the importance of R&D activities. Various indicators in relation to the R&D in the Australian construction industry have been improved significantly. However, compared with the average level of all the sectors, the Australian construction industry should be doing more in this area.

7.6.2 Demand conditions

The size of the domestic market, and the demand growth rate in the domestic market are used in the research to measure the domestic demand element, which is considered as one of the drivers for industrial development (Rodrik，2007). The size of the domestic market could be reflected by construction work done. The demand growth rate in the domestic market could be represented by the growth rate of the construction work done. These two indicators have been discussed in this Chapter, Section 7.2. The details are provided in Figure 7-1. The value of construction work done by the Australian construction industry has increased from AU$87.5 billion in 2001-2002 to AU$173.7 billion in 2010-2011 (refer to figure 7-1), with an average growth rate of 7.97%. The engineering construction sector developed rapidly in this period and has been the largest sector among the three broad areas including residential building, non-residential building and engineering construction.

7.6.3 Firm strategy, structure and rivalry

Firm strategy, structure and rivalry refers to the firm's organisation structure and management situation, and the performance of competitors in the domestic market Porter (1977). It will be measured by the capital structure and market structure of the Australian construction industry in this research.

7.6.3.1 Capital structure

Based on the capital structure, the Australian construction industry could be divided into two sectors, the private sector and public sector. The development of both sectors is provided in Table 7-13. The private sector is the main driver of the Australian construction industry. Its value of work done accounts 70%-80% of the total construction work done in Australia. The value of construction work done by the private sector has increased dramatically from AU$54 billion in 2000-01 to AU$124.5 billion in 2010-11, besides the drop from 2008-09 to 2009-10. The growth rate from 2000-01 to 2001-02 and from 2001-02 to 2002-03 are both more than 20%. The average growth rate in this period is 8.96%.

For the public sector, the value of construction work done has increased from AU$22.7 billion in 2000-01 to AU$49.1 billion in 2010-11. The average growth rate is 8.47% during this period, which is quite similar to the private sector.

Year	Private sector			Public sector			Total sectors
	AU$b	Proportion	Growth rate	AU$b	Proportion	Growth rate	AU$b
2000-01	54.0	70.2%	N/A	22.7	29.6%	N/A	76.9
2001-02	65.2	74.5%	20.66%	22.3	25.4%	-2.10%	87.5
2002-03	80.1	78.4%	22.98%	22.1	21.6%	-0.93%	102.2
2003-04	87.6	80.3%	9.35%	21.5	19.7%	-2.44%	109.2
2004-05	91.2	79.3%	4.14%	23.9	20.7%	10.87%	115.1
2005-06	98.8	78.1%	8.30%	27.8	21.9%	16.40%	126.6
2006-07	105.7	78.9%	6.97%	28.3	21.1%	1.80%	134.0
2007-08	112.4	78.5%	6.33%	30.9	21.5%	9.12%	143.2
2008-09	120.0	76.8%	6.79%	36.3	23.2%	17.77%	156.3
2009-10	114.9	70.7%	-4.24%	47.5	29.3%	30.80%	162.4
2010-11	124.5	71.7%	8.35%	49.1	28.3%	3.40%	173.7

Table 7-13 Capital structure of the Australian construction industry: value of work done - chain volume measures by sectors

7.6.3.2 Market structure

As discussed in Chapter 4, the concentration ratios will be adopted to analyse the market structure in this study. The most common concentration ratios are the CR4 and the CR8, which means the market share of the four and the eight largest firms in an industry. From 1998-99 to 2000-01, the Australian Bureau of Statistics generated three issues of Industry Concentration Statistics, which shows the proportions of Sales of Goods and Services, Persons Employed and Industry Value Added that are concentrated among the 20 largest enterprise groups operating in each industry (ABS, 2002). The largest enterprises are identified by their sales of goods and services. However, after the 2000-01 issue, the Industry Concentration Statistics stopped updating.

The Engineering News Record (ENR) provides the list of the Top 225 Global Contractors every calendar year based on the total revenue of the construction enterprises worldwide. In 2010, there are four Australian construction enterprises in this list. Therefore, this section will adopt the data from the 2000-01 Industry

Concentration Statistics and the Top 225 Global Contractors in 2010 to understand the changes of the market structure of the Australian construction industry from 2000-01 to 2010 based on the concentration ratios CR_4. For the CR_4 in 2010, the total revenue of the largest four Australian construction enterprises was US$ 29837 million. The average exchange rate of the Australian dollar to US dollar in 2010 was 0.91972, which can be calculated by using ABS table of *the Australian Economic Indicators July 2012, Table 12 Table 8.6-Exchange rates, Monthly*. Therefore, the total revenue of the largest four Australian construction enterprises is AU$ 32441.51 million. CR_4 of the Australian construction industry was 19.79% in 2010 and it was 6.5% in 2000-01 (ABS, 2002).

7.6.4 Activities of multinational enterprises

The 'reformative OLI model' (ROLI Model) has been generated in Chapter 3 to measure the degree of internationalisation of construction enterprises both at firm and industry levels by a combination of Low and Jiang's modification and the removal of the S-ISF concept. The annual report on the top 225 international contractors provided by Engineering News-Record (ENR) will be adopted in this section. For the I-OMS and A-I, Dun and Bradstreet (D&B)'s 'Who Owns Whom (WoW)' ownership tree structure database, annual reports, finance reports, company brochures and company webpages will be used as well. The number of overseas subsidiaries and the total number of such affiliates for all the multinational enterprises listed in the ENR's Top 225 international constructor from 2001 to 2010 is difficult to track. Low and Jiang (2003) adopted the same measurement to calculate the I-OMS of the top 225 international contractors in 2000. This section will only compare the degree of internationalisation of the Australian multinational construction enterprises in 2000 and 2010. The results are shown in Table 7-14.

Index	2000	2010
A-O	0.48	0.35
A-L	0.09	0.09
A-I	0.55	0.62
T-DOI	1.12	1.06

Table 7-14 The degree of internationalisation of the Australian multinational construction enterprises in 2000 and 2010

The average of O-IRTR (A-O) declined from 0.48 in 2000 to 0.35 in 2010. It means the proportion of the international revenue of the Australian construction enterprises in their total revenue decreased. The average of I-OMS (A-I) reached at 0.62 in 2010 from 0.55 in 2000. This indicates that the proportion of the international subsidiaries of the Australian construction industry in their total subsidiaries increased slightly. In addition, the average of L-IBD (A-L) does not change from 2000 to 2010. Furthermore, from 2000 to 2010, the degree of internationalisation of the Australian construction enterprises at the country level declined from 1.12 to 1.06. The rise of emerging economies in the construction sector could seize the construction market share of the developed countries. Also, the economic crisis begun in 2008 could be another reason for the decrease of the degree of internationalisation of the Australian construction enterprises.

7.6.5 Related and supporting industries

The development of related and supporting industries is essential for the improvement of an industry's competitiveness (Porter, 2000). This section will identify the related and supporting industries of the Australian construction industry by adopting the input-output analysis. The Direct Consumption Coefficient (Indirect Allocation of Imports) will be adopted to identify the related and supporting industries of the Australian construction industry. After the related and supporting industries are identified, these industries will be studied briefly and the productivity changes of these industries will be explored as well.

7.6.5.1 Identifying industries

The latest input-output table for Australia is the 2012-13 version. This research will adopt the basic data of 2012-13 Australia 114 × 114 sectors input-output table to calculate the Direct Consumption Coefficient (Indirect Allocation of Imports) of the Australian construction industry. The data of the Australian construction industry consists of residential building construction, non-residential construction, heavy and civil engineering construction and construction services. The results are provided in Table 7-15.

Sector	Construction Industry	Rank
Construction industry	0.06776	1
Professional, Scientific and Technical Services	0.05231	2
Finance	0.03301	3
Employment, Travel Agency and Other Administrative Services	0.02454	4
Non-Residential Property Operators and Real Estate Services	0.02390	5
Wholesale Trade	0.01891	6
Telecommunication Services	0.01545	7
Computer Systems Design and Related Services	0.01455	8
Auxiliary Finance and Insurance Services	0.01367	9
Transport Support services and storage	0.01237	10
Petroleum and Coal Product Manufacturing	0.00982	11
Road Transport	0.00911	12
Retail Trade	0.00875	13
Rental and Hiring Services (except Real Estate)	0.00747	14
Building Cleaning, Pest Control and Other Support Services	0.00640	15
Structural Metal Product Manufacturing	0.00568	16
Air and Space Transport	0.00506	17
Polymer Product Manufacturing	0.00499	18
Public Administration and Regulatory Services	0.00487	19
Professional, Scientific, Computer and Electronic Equipment Manufacturing	0.00469	20
Publishing (except Internet and Music Publishing)	0.00459	21
Food and Beverage Services	0.00441	22

Table 7-15 Related and supporting industry of the Australian construction industry in terms of Direct Consumption Coefficient (Indirect Allocation of Imports)

The construction industry has extensive relationships with other industries. The total direct consumption coefficient (Indirect Allocation of Imports) of the Australian construction industry to all the 114 sectors is 0.4672. This means that if the Australian construction industry increase one unit of output, 0.4672 unit of direct demand will be generated for the 114 sectors. The average direct consumption coefficient (Indirect Allocation of Imports) of the Australian construction industry to the 114 sectors is 0.00421. Twenty-two industries' direct consumption coefficients (Indirect Allocation of Imports) are higher than 0.00421. Therefore, these 22 industries are the closely related and supporting industries of the Australian construction industry.

The top two related and supporting industries of the Australian construction industry are the construction industry and the professional, scientific and technical services industry. Because the first one is construction, this section will discuss the professional, scientific and technical services industry only.

7.6.5.2 Analysis of related and supporting industries

Because of the changes of classification, the data of Professional, Scientific and Technical Services industry is only available from 2004-05 in ABS. The developments of the Australian Professional, Scientific and Technical Services industry from 2004-05 to 2011-12 are summarised in Table 7-16.

Year	Total income AU$m	Operating profit before tax AU$m	EBITDA AU$m	Gross Value Added AU$m	Employees '000	Gross value added per person $'000
2004–05	104252	14,310	8,804	66608	655.23	101.656
2005–06	133294	22,201	14,303	69268	715.05	96.872
2006–07	150468	25,703	17,524	70842	743.93	95.227
2007–08	166888	29,816	18,599	73064	784.93	93.083
2008–09	186463	37,205	19,748	76420	784.38	97.427
2009–10	177634	34,503	22,551	82683	833.95	99.146
2010–11	194065	40,935	24,072	88881	861.03	103.226
2011–12	210976	52,670	29,966	92945	890.18	104.411

Table 7-16 Developments of the Australian Professional, Scientific and Technical Services from 2004-05 to 2011-12

Source: Australia Year Book, Australian Bureau of Statistics

The number of people working in the Australian Professional, Scientific and Technical Services industry has increased continuously from 2004-05 to 2011-12, and there was a slight drop in 2008-09. All the other selected indicators increased gradually in this period, including total income, operating profit before tax, earnings before interest, tax, depreciation and amortisation and gross value added.

The labour productivity of the Australian Professional, Scientific and Technical Services industry could be measured by the gross value added per person and it declined from AU$101656 per person in 2004-05 to AU$93.083 per person 2007-08. After that, it went up to AU$104411 per person in 2011-12. However, the average growth rate from 2004-05 to 2011-12 is only 0.43%.

7.6.5.3 Summary

This section identified the related and supporting industries of the Australian construction industry by adopting the input-output analysis. The total direct consumption coefficient (Indirect Allocation of Imports) of the Australian construction industry was discussed. The closely related industries of the Australian construction industry were identified. The Professional, Scientific and Technical Services industry was discussed further. The productivity of the Professional, Scientific and Technical Services industry only improved a little bit in recent years. The ability of providing sustainably increasing power and support to the Australian construction industry by the Professional, Scientific and Technical Services industry is limited.

7.6.6 Government

In the Internationalisation Sustainable Development Competitiveness Model, the government element is a determinant. In this section, the productivity changes of government in recent years will be analysed.

Due to the data availability, the total factor productivity changes of the Australian government in relation to the Australian construction industry from 2007-08 to 2010-11 will be analysed. The inputs are the administrative expenses and the number of civil servants. The former could be found from the Australian government budget website (http://www.budget.gov.au), named *general government services*. The number of civil servants is available at *Employment and Earnings, Public Sector, Australia, 2011-12* in ABS, named public service employees. The outputs are: 1) the number of persons with a non-school qualification per thousand people; 2) the number of construction companies; and 3) the construction work done by the Australian private construction firms.

By conducting the Malmquist total factor productivity changes method, the result is provided in Table 7-17. The number of civil servants and the administrative expenses increased gradually from 2007-08 to 2010-11. However, the total factor productivity of the Australian government in relation to the construction industry declined continuously. The average decrease rate was 20.7%, which is significant.

Year		**2007–08**	**2008–09**	**2009–10**	**2010–11**
Input	No. of civil servants '000	1751.4	1807.4	1844.0	1894.6
	Administrative expenses AU$m	32232	79270	80478	92862
Output	No. of persons with a non-school qualification per thousand people	539	550	557	565
	No. of construction firms	323071	273276	238530	213352
	Construction work done of private sector AU$b	112.4	120	114.9	124.5
TFPCH		N/A	0.597	0.924	0.904

Table 7-17 Total factor productivity changes of the Australian government in relation to the construction industry from 2007-08 to 2010-11

Source: Australia Year Book, Australian Bureau of Statistics

7.6.7 Sustainable Development Index

There are three categories included in the sustainable development index system: Economic Sustainability, Social Sustainability and Environmental Sustainability. The development of the indicators of the sustainable development index of the Australian construction industry from 2002-03 to 2009-10 are summarised in Table 7-18. For the economic sustainability of the Australian construction industry, all the indicators increased significantly from 2002-03 to 2009-10. The growth rates of construction work done, labour productivity in terms of construction industry gross value added and gross fixed capital formation of Australia are all higher than 50%. The growth rates of profit margin of the Australian construction industry and GDP of Australia from 2002-03 to 2009-10 is 32.63% and 23.76% respectively.

Similar to economic sustainability, the indicators of social sustainability of the Australian construction industry climbed from 2002-03 to 2009-10. However, the growth rate of equivalised disposable household income per week of Australia which is 66.27% is more significant than number of persons with a non-school qualification per thousand people, which is only 13.44%. The increase of disposable income could improve the demand on goods and service, including goods and services from construction sectors, for example, buying a new house, or the repair, renovation and expansion of an old building. More educated labour could lead to the increase of efficiency and productivity in sectors.

For the environmental sustainability of the Australian construction industry, the decrease rate of the construction waste generated per million dollars of construction work done is 15.46% from 2002-03 to 2009-10. However, the energy consumption per million dollars of construction work done increased dramatically from 0.274 pj to 0.886 pj. It could be caused by the increasing use of machinery. However, the construction sector should consider ways of reducing energy consumption without reducing the level of technology and mechanisation.

Year	Economic Sustainability					Social Sustainability		Environmental Sustainability	
	Construction work done AU$m	Labour productivity in terms of gross value-added AU$'000	Profit margin (%)	GDP AU$ m	Gross fixed capital formation AU$m	Equivalised disposable household income per week AU$	No. of persons with a non-school qualification per thousand people	Construction Waste/ Constrcution work done (Ton/AU$m)*	Energy Consumption/ Construction work done (pj / AU$b)
2002-03	102214.609	54.72	9.5	1107424	235011	510	491	120.45	0.274
2009-10	162440.336	92.60	12.6	1370540	358787	848	557	101.83	0.886

Table 7-18 Developments of the sustainable development indicators of the Australian construction industry

* Construction Waste / GOV: the data of construction waste in 2009-10 is available at *Waste Account, Australia, Experimental Estimates* in ABS. The only available issue is released at 19 February, 2013. There is no other public data about the construction waste generated in Australia. The proportion of the construction waste in consumption wastes is measured as 38 in 2006-07 according to ABS. The data for construction waste in Australia in 2002-03 is estimated by the consumption wastes of construction in 2002-03 multiplied by 38%.

7.7 Conclusion

As an important part of the world economy, the Australian economy has made remarkable achievements in recent years. The Australian construction industry has also progressed well in both the domestic and international market. By using the International Advanced Index, the results show that the status and level of the Australian construction industry in the international market increased from 2001 to 2010. The Australian construction industry had higher influence in more fields of construction in the international market. The Australian construction industry shared more international revenue in the international market, and the quantity and quality of the Australian top construction firms increased as well.

The total factor productivity of the Australian construction industry fluctuated from 2001-02 to 2010-11. The average growth rate was 5.4%. For industrial competitiveness, the Australian construction industry has a good position on the basic factors. At the same time, the investment in the advanced factors improved gradually, including R&D expenditure and human resources in R&D. The number of persons with a non-school qualification per thousand people increased from 2002-03 to 2009-10. In addition, with the development of the Australian economy, the size of the domestic construction market increased, which could bring increasing demand for the Australian construction industry.

For the firm strategy, structure and rivalry, the private sector dominated the Australian construction industry. CR_4 of the Australian construction industry increased from 6.5% in 2000-01 to 19.79% in 2010. The influence of the top companies increased. In addition, the degree of internationalisation of the Australian international enterprises declined from 1.12 in 2011 to 1.06 in 2010. This decrease could be caused by the improvement of the developing countries and emerging economies in the international market and the economic crisis.

By conducting the input-output analysis, the related and supporting industries are identified. The top two closely related and supporting industries of the Australian construction industry, including; the construction industry and the Professional, Scientific and Technical Services industry. The Professional, Scientific and Technical Services industry made limited improvement in recent years. Therefore, increasing support and promotion to be obtained from this industry for the Australian construction industry is limited.

Furthermore, the total factor productivity of the Australian government in relation to the construction industry declined continuously from 2007–08 to 2010-2011. The Australian government should take this issue seriously. Moreover, for the sustainable development index, all indicators increased from 2002-03 to 2009-10 except for the energy consumption per $billion construction work done.

Chapter 8 Comparison between the Chinese and the Australian construction industries

8.1 Introduction

As one of the emerging economies, the Chinese economy has made significant achievements since the implementation of the reform and opening-up policy in 1978. The role of the Chinese economy in the regional and world economy is increasingly important. The Chinese construction industry plays an important role in the development of the Chinese economy and society. The development of the Chinese construction industry could be beneficial for solving many issues in the development of China. With the development of the Chinese economy and its deeper involvement in the process of internationalisation and globalisation in the last decades, significant achievements have been gained by the Chinese construction industry. In the domestic market, many indicators such as the gross output value, gross value added and technology level all increased gradually. In recent years, the productivity of the Chinese construction industry has increased, and most of the elements of the industrial competitiveness of the Chinese construction industry have improved. In the international market, the performance of Chinese construction enterprises is significant. For example, the number of Chinese construction enterprises listed in the top 225 international constructors by Engineering News Record (ENR) has increased from 35 in 2000 to 51 in 2010 (Reina & Tulacz, 2011). The International Advanced Index, which indicates the level and status of a country's construction industry in the world, has increased from 0.6126 in 2001 to 0.8593 in 2010 (refer to Chapter 5).

Although these results are encouraging, the differences with the construction industries of developed countries still exist and they are worth identifying. This could help the policymakers to clearly understand the current situation of the Chinese construction industry and formulate future development strategies. This chapter will compare the current level of the Chinese and Australian construction industry based on the International Advanced Index, total factor productivity and industrial competitiveness. Because of the difference in financial year system and date availability，the development level of the Chinese construction industry in 2010 will be compared with the development level of the Australian construction industry in 2009-10. In addition, this chapter will utilise multivariate cointegration analysis to explore the interaction among the Economic Sustainability, Social Sustainability and Environmental Sustainability of the Chinese construction industry.

8.2 International Advanced Index

The comparison between the Chinese construction industry and the Australian construction industry in the International Advanced Index is summarised in Table 8-1.

	WI		**HI**		**DI**		**IAI**	
	2001	**2010**	**2001**	**2010**	**2001**	**2010**	**2001**	**2010**
China	0.4	0.5076	0.1566	0.2027	0.056	0.149	0.6126	0.8593
Australia	0.3333	0.9167	0.013	0.0246	0.008	0.027	0.3543	0.9683

Table 8-1 The International Advanced Index of the Chinese and the Australian construction industries in 2001 and 2010

Table 8-1 indicates that all indicators of the Chinese construction industry and the Australian construction industry in the International Advanced Index increased from 2001 to 2010. The International Advanced Index and Width Index of the Australian construction industry were lower than the Chinese construction industry in 2001. However, these two indictors of the Australian construction industry were higher than the Chinese construction industry in 2010. Therefore, the Chinese construction industry could make more efforts in widening participation in construction fields (diversification) or improving the level of the activity in each involved field (specialisation).

The results which were generated by using the International Advanced Index and the previous one-dimensional financial methods are different. If adopting the one-dimensional financial method, it could find the financial performance of the Chinese construction industry in the international market in 2010 was better than the Australian construction industry. However, the difference in the situation of involvement in construction fields could not be identified. Hence, the targeted suggestions could not be provided. Therefore, the International Advanced Index is more comprehensive to reflect the status and level of a country's construction industry in the international market. Moreover, the data which were used for the International Advanced Index are easier to collect, which is an advantage compared with the previous complex methods.

8.3 Productivity comparison

The total factor productivity of the Chinese construction industry has increased from 2001 to 2010. The average growth rate is 3.3% in this period. Also, the total factor productivity of the Australian construction industry improved considerably from 2001-02 to 2010-11. The average growth rate is 5.4%, which is even higher than the Chinese construction industry. The discussion details about the total factor productivity changes of the Chinese and Australian construction industry are provided in Chapter 6 and Chapter 7 respectively. So, which country's productivity is higher between the Chinese and the Australian construction industry? This section will explore the answer for this question first.

The Malmquist productivity index is used to explore the total factor productivity changes of the Chinese and Australian construction industry in recent years. This section will adopt the Malmquist productivity index again to compare the two construction industries' total factor productivity in 2010 (2009-2010). The total factor productivity of the Chinese construction industry in 2010 will be considered as Year 1. The total factor productivity of the Australian construction industry in 2009-10 will be considered as Year 2. The Malmquist productivity index will be used to find out the total factor productivity from Year 1 to Year 2. Similar to the explanation about the results of the Malmquist productivity index in Chapter 6 and Chapter 7:

(1) If the value of the Malmquist productivity index is bigger than 1, the total factor productivity is increasing from Year 1 to Year 2. It indicates the total factor productivity of the Australian construction industry is better than the Chinese construction industry. The degree of the better of the total factor productivity of the Australian construction industry than the Chinese construction industry is the value of the Malmquist productivity index minus 1.
(2) If the value of the Malmquist productivity index is 1, the total factor productivity from Year 1 to Year 2 does not change. It means the total factor productivity of the Australian construction industry is equal to the Chinese construction industry.
(3) If the value of the Malmquist productivity index is smaller than 1, the total factor productivity is decreasing from Year 1 to Year 2. It indicates the total factor productivity of the Chinese construction industry is better than the Australian construction industry. The degree of the better of the total factor productivity of the Chinese construction industry than the Australian construction industry is 1 minus the value of the Malmquist productivity index.

The inputs are construction work done and the number of employees in the construction industry. The output is the gross value added. The construction work done and gross value added of the Chinese construction industry will be converted to

Australian dollars based on the average exchange rate in 2010, which is available in the China Statistical Yearbook 2011. The data and results are provided in Table 8-2.

Chinese construction industry			Australian construction industry			MTFPC
Input		Output	Input		Output	
Construction work done Au$m	No. of employees '000	Gross value added Au$m	Construction work done Au$m	No. of employees '000	Gross value added Au$m	
1546146.1	41604	305643.86	162440.336	1001.725	92759	6.034

Table 8-2 Comparison of the total factor productivity of the Chinese and Australian construction industry

The construction work done, the number of employees in the construction industry and the gross value added of the Chinese construction industry in 2010 are all much higher than the Australian construction industry in 2009-10. It could have benefited from the size of the Chinese economy and population. However, when the total factor productivity is discussed, the Australian construction industry in 2009-10 is 503.4% higher than the Chinese construction industry in 2010. This result indicates that the gap is large between the Chinese and Australian construction industries in relation to the total factor productivity. In addition, because the average growth rate of the Australian construction total factor productivity changes from 2001-02 to 2010-11 is higher than the Chinese construction industry from 2001 to 2010 (refer to Chapter 6 and Chapter 7), the gap might become larger in the future. Therefore, the policymakers should consider this situation and find a way to reverse it.

The previous studies on the Chinese construction industries mainly focus on exploring the development in total factor productivity and identifying the differences between different regions (Xue *et al.*, 2008 and Wang *et al.*, 2013). They stated that the development of the Chinese construction industry in productivity is dramatic. However, few of them conducted international comparisons in productivity, in particular between the Chinese and the Australian construction industries. This study fills this gap and identifies the differences with a developed country – the Australian construction industry. The results warn policymakers and industry participants that despite significant progress made by the Chinese construction industry, there is still a large gap with the developed countries.

8.4 Industrial competitiveness comparison

Porter's Diamond Model has been developed to be the Internationalisation Sustainable Development Competitiveness Model (ISDC Model) in this study. The ISDC Model is composed of eight elements including factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of Multinational Enterprises and sustainable development. Only chance is an external element, all the others are determinants. The measurement for each element has been provided in Chapter 3. Most of the elements of the industrial competitiveness of both the Chinese and the Australian construction industries improved in the recent years. This section will compare the performance of the Chinese and the Australian construction industries in relation to industrial competitiveness to explore the differences and similarities in each element.

8.4.1 Factor conditions

According to Table 7-10 in Chapter 7, from the total amount point of view, the R&D expenditure in Australia has reached AU$ 28146 million in 2008-09. This is the most recently available date. The average growth rate of the R&D expenditure in Australia is 28.33% from 2000-01 to 2008-09. For China, the R&D expenditure has climbed to AU$108733 million in 2009. The average growth rate is 24% from 2001 to 2009 (refer to Table 6-6 in Chapter 6). Because of the difference in economies of scale, the R&D expenditure of China is much higher than Australian. However, the average growth rate of the R&D expenditure in Australia is slightly higher than China in the recent year. Moreover, the proportion of the R&D expenditure in the Australian GDP increased from 1.47% in 2000-01 to 2.24% in 2008-09. For China, it has gone up to

1.70% in 2009 from 0.95% in 2001. However, it is still much lower than Australia.

For the human resources in R&D, Australia reached 136696 PYE in 2008-09, up from 95620 PYE in 2000-01, with an average growth rate of 9.36%. For China, it increased from 0.957 million PYE in 2001 to 2.291 million PYE in 2009. The average growth rate is 11.6%.

In addition, the number of persons with a non-school qualification per thousand people in China was 89.3 in 2010. For Australia, it reached 550 in 2009-10. There is a big difference between China and Australia in this indicator. The average growth rate of China in the number of persons with a non-school qualification per thousand people was 11.7% from 2001 to 2010. For Australia, the average growth rate is only 1.82% from 2001-02 to 2010-11. Therefore, it could be speculated that the gap in educated labour between China and Australia will be narrowed in the future.

For the construction industry, the human resources invested in R&D of China in 2009 is 63432 PYE which is 2.77% in total human resources invested in R&D of China. In the Australian construction industry it is 2175 PYE in 2009-10. The R&D expenditure of the Chinese construction industry in 2009 is AU$2532.31 million, which is much higher than the Australian construction industry in 2009-10. In addition, although the proportion of the R&D expenditure in the gross output value of the Chinese construction industry increased from 0.03% in 2000 to 0.18% in 2009, it is still much lower than the Australian construction industry which is 0.54% and 0.57% in 2009-10 and 2010-11 respectively. The current level of the proportion of the R&D expenditure in the gross output value of the Chinese construction industry is only slightly higher than the level of Australia in 2001-02, which is 0.16%. Compared with the Australian construction industry, the Chinese construction industry needs to improve the proportion of the R&D expenditure in GOV.

8.4.2 Demand conditions

The size of the domestic market and the demand growth rate in the domestic market are used in the research to measure the domestic demand element. The size of the domestic market could be reflected by the construction work done. The demand growth rate in the domestic market could be represented by the growth rate of the construction work done.

The value of construction work done by the Chinese construction industry in 2010 is AU$1546 billion. The growth rate from 2009 to 2010 is 25%. The value of construction work done by the Australian construction industry in 2009-10 is AU$157 billion, which is about 10% of Chinese construction. The growth rate from 2008-09 to 2009-10 is only 1.77%. Therefore, the demand conditions of the Chinese construction industry is much better than the Australian construction industry.

8.4.3 Firm strategy, structure and rivalry

Firm strategy, structure and rivalry are measured by the capital structure and market structure in this research. Based on the perspective of the industrial capital structure, the classification of firms in Chinese construction industry has changed from three categories to five categories. The three categories were State Owned Enterprises (SOEs), Urban and Rural Collectives (URCs) and Rural Construction Teams (RCTs). The five categories that have existed since China's entry into the WTO are State Owned Enterprises (SOEs), Collective Owned Enterprises (COEs), Private Owned Enterprises (POEs), Enterprises founded by Hong Kong, Macao and Taiwan (HMTEs), and Foreign Founded Enterprises (FFEs). The development of the capital structure of the Chinese construction industry from 2001 to 2010 can be summarised as:

1) The dominant position of SOEs and COEs in the Chinese construction industry has been replaced by POEs;

2) The performance of the non-public ownership enterprises including POEs, HMTEs and FFEs is better than the public ownership enterprises, including SOEs and COEs, as the nature of them is the same. The Chinese construction industry is converting from being dominated by public ownership enterprises to non-public ownership enterprises.
3) The Chinese domestic construction enterprises have made rapid development and significant progress. The gap between the Chinese domestic construction enterprises and foreign enterprises was narrowed substantially in relation to labour productivity. However, from the perspective of profit margins, the distance between them has not reduced. Therefore, it urgently needs to find a way to narrow the gap in the future.

For the Australian construction industry, there are two sectors including; private sector and public sector. Both of them are developing gradually. The private sector is the main part of the Australian construction industry. The value of work done of the private sector accounts 70%-80% of the total construction work done in Australia. The average growth rate of the private sector and public sector’s construction work done is 8.96% to 8.47% respectively from 2000-01 to 2010-11. They are very similar. Therefore, the position of the private and public sectors in the Australian construction industry is stable. The private sector dominates the construction market. The public sector plays a supporting role. The Chinese construction industry is moving to this state.

For the market structure, industrial concentration ratio is adopted in the research. The CR_4 of the Chinese and Australian construction industry in 2010 was 16.81% and 19.79% respectively. They are quite similar and both located in the group of ‘Competition’.

8.4.4 Activities of multinational enterprises

This research develops a ‘reformative OLI model’ (ROLI Model) to measure the degree of internationalisation of construction enterprises at both firm and industry level. The degree of internationalisation of the Chinese and Australian multinational construction enterprises in 2000 and 2010 is provided in Table 8-3.

Index	Chinese multinational construction enterprises		Australian multinational construction enterprise	
	2000	2010	2000	2010
A-O	0.48	0.53	0.48	0.35
A-L	0.44	0.1	0.09	0.09
A-I	0.41	0.09	0.55	0.62
T-DOI	1.33	0.72	1.12	1.06

Table 8-3 The degree of internationalisation of the Chinese and Australian multinational construction enterprises in 2000 and 2010

Both the degree of internationalisation of the Chinese and Australian construction enterprises decreased from 2000 to 2010, which could be caused by more construction enterprises from different countries involved in the international construction industry under the context of internationalisation and globalisation, especially developing countries. In 2000, the degree of internationalisation of the Chinese construction enterprises was higher than the Australian construction enterprises. However, by 2010, the degree of internationalisation of the Australian multinational construction enterprises surpassed the Chinese ones at the country level and this is caused by the difference in A-I, which is the average of I-OMS. I-OMS is defined as overseas management structure (I-OMS), and measured in terms of the ratio of the number of overseas subsidiaries and associates to the total number of such affiliates. The Australian construction enterprises set up more overseas subsidiaries and associates in order to improve their influence in the host country. This may be a result of the limited domestic market. In contrast, because of the huge domestic market with its high growth rate, the driving force for the Chinese construction industry would be much lower than the Australian construction industry.

In addition, the A-O of the Chinese multinational construction enterprises in 2010 is higher than the Australian multinational construction enterprise. A-O is defined as the level of O-IRTR for a country, and measured by the average of O-IRTR of all the firms of a country. O-IRTR is the ratio of international revenue to total revenue. The lower A-O would be caused by the lower increase rate of international revenue than the domestic revenue. For the Australian multinational construction enterprises, Europe and the U.S. are two major markets. However, both of these regional markets shrank in recent years (refer to Chapter 2). In rapidly increasing markets including the Middle Eastern and the African markets, the performance of the Australian multinational construction enterprises did not improve. In contrast, the Middle East and Africa are the major markets for Chinese multinational construction enterprises. Therefore, it is easy to understand the difference in A-O between the Chinese and Australian multinational construction enterprises in 2010.

Furthermore, the A-I index is quite similar between the Chinese and Australian multinational construction enterprises. This result shows that the average number of countries in which the Chinese and Australian multinational construction enterprises has worked in 2010 are quite similar.

Compared with Low and Jiang's (2003) OLI-S model, the ROLI Model believes that both the diversification strategy and the specification strategies may offer a better opportunity for enterprises to develop and be involved in the international market. The results generated from ROLI Model avoided being misled.

8.4.5 Related and supporting industries

The top two related and supportive industries of the Chinese construction industry are the smelting and pressing of metals industry and the manufacture of non-metallic mineral products industry. The mean of the total factor productivity of the smelting and pressing of metals industry from 2005 to 2010 is 0.834. This result indicates the total factor productivity changes of the Chinese smelting and pressing of metals industry from 2005 to 2010 decreased. Especially from 2009 to 2010, the decrease rate was nearly 70%. This could seriously affect its stimulating effect in supporting the construction industry. The total factor productivity changes of the manufacture of non-metallic mineral products industry increased from 2005 to 2010, with an average growth rate of 5.5% in these six years; however, there was a 4.5% decrease in 2007-

2008

The top two related and supporting industries of the Australian construction industry are the construction industry and the professional, scientific and technical services industry. This result shows that the stimulating effect of the Australian construction industry on its own demand is significant. This is very different with the Chinese construction industry. The average growth rate of the labour productivity of the Australian professional, scientific and technical services industry from 2004-05 to 2011-12 is only 0.43%.

These results indicate that the closely related and supporting industries of the Chinese and Australian construction industries did not perform well in recent years. Their capability of providing sustainably increasing support to the Chinese and the Australian construction industries is limited.

8.4.6 Government

The government element is considered as a determinant in the Internationalisation Sustainable Development Competitiveness Model. The total factor productivity analysis is adopted to study the Chinese and Australian construction industry in this research. The inputs are the administrative expenses and the number of civil servants. The outputs are the number of persons with a non-school qualification per thousand people, number of construction companies and construction work done by the non-state owned/private construction enterprises.

The total factor productivity changes of the Chinese and Australian governments in relation to their construction industry were analysed using the Malmquist productivity index in Chapter 6 and Chapter 7. In order to compare the total factor productivity between the Chinese and Australian government in relation to their construction industry, this section will adopt the Malmquist productivity index. The total factor productivity changes of the Chinese government in relation to the Chinese construction industry will be considered as Year 1. The total factor productivity changes of the Australian government in relation to the Australian construction industry will be considered as Year 2. The Malmquist productivity index could be calculated from Year 1 to Year 2.

(1) If the value of the Malmquist productivity index is bigger than 1, the total factor productivity is increasing from Year 1 to Year 2. It indicates the total factor productivity of the Australian government in relation to the Australian construction industry is better than the Chinese government. The degree of the better of the total factor productivity of the Australian government in relation to the Australian construction industry than the Chinese government is the value of the Malmquist productivity index minus 1.
(2) If the value of the Malmquist productivity index is 1, the total factor productivity from Year 1 to Year 2 does not change. It means the total factor productivity of the Australian government in relation to the Australian construction industry is equal to the Chinese government.
(3) If the value of the Malmquist productivity index is smaller than 1, the total factor productivity is decreasing from Year 1 to Year 2. It indicates the total factor productivity of the Chinese government in relation to the Chinese construction industry is better than the Australian government. The degree of the better of the total factor productivity of the Chinese government in relation to the Chinese construction industry than the Australian government is 1 minus the value of the Malmquist productivity index.

The administrative expenses and construction work done of the non-state owned/private construction enterprises of the Chinese construction industry will be converted to Australian dollars based on the average exchange rate in 2010, which is available in the China Statistical Yearbook 2011. The data and results are provided in Table 8-4.

<table>
<tr><th colspan="5">Chinese government (2010)</th></tr>
<tr><th colspan="2">Input</th><th colspan="3">Output</th></tr>
<tr><td>Administrative expenses Au$m</td><td>No. of civil servants ’000</td><td>No. of persons with a non-school qualification per thousand people</td><td>Construction work done of the non-state owned/private construction enterprises Au$b</td><td>No. of construction companies</td></tr>
<tr><td>243504.74</td><td>6894</td><td>89.3</td><td>1253.9454</td><td>71863</td></tr>
<tr><th colspan="5">Australian government (2009-2010)</th></tr>
<tr><th colspan="2">Input</th><th colspan="3">Output</th></tr>
<tr><td>Administrative expenses Au$m</td><td>No. of civil servants ’000</td><td>No. of persons with a non-school qualification per thousand people</td><td>Construction work done of the non-state owned/private construction enterprises Au$b</td><td>No. of construction companies</td></tr>
<tr><td>80478</td><td>1844</td><td>557</td><td>114.9</td><td>238530</td></tr>
<tr><td>MTFPC</td><td colspan="4">2.543</td></tr>
</table>

Table 8-4 Comparison of the total factor productivity of the Chinese and Australian government in relation to their construction industry

The Malmquist productivity index is 2.543. This result indicates the total factor productivity of the Australian government in relation to the Australian construction industry is better than the Chinese government. The degree of the better of the total factor productivity of the Australian government in relation to the Australian construction industry than the Chinese government is 154.3%. However, the total factor productivity of the Chinese government in relation to the Chinese construction industry gradually increased from 2001 to 2010 (refer to Table 6-19, Table 6-20. Table 6-21 and Chapter 6 Section 6.6). For the Australian construction industry, the total factor productivity of the Australian government decreased from 2007-08 to 2010-11 (refer to Table 7-17 in Chapter 7 Section 7.6.6). Therefore, the gap between the total factor productivity of the Chinese and Australian government in relation to their construction industry would be narrowed in the future if the trend does not change.

8.4.7 Sustainable Development Index

Sustainable development is a new element of industrial competitiveness. A new sustainable development index system was generated in Chapter 3. The indicators are grouped in three categories including Economic Sustainability, Social Sustainability and Environmental Sustainability.

For the Chinese construction industry, all the indicators of the sustainable development index increased gradually (Construction Waste/Construction work done and Energy Consumption/Construction work done decreased). For the Australian construction industry, Construction work done, Labour productivity in terms of gross value added, Profit margin, GDP, Gross fixed capital formation, Equivalised disposable household income, the number of persons with a non-school qualification per thousand people and Construction Waste/Construction work done all increased from 2002-03 to 2009-10 (Construction Waste/Construction work done decreased). However, the energy consumption per AU$ billion of construction work done increased from 0.274 in 2002-03 to 0.886 in 2009-10 and it will reduce the Environmental Sustainability and overall Sustainable Development Index of the Australian construction industry.

In order to explore the difference in sustainability between the Chinese and Australian construction industries, this section will compare the sustainable development index of the Chinese construction industry in 2010 with the Australian construction industry in 2009-10 due to data availability. All monetary indicators of the Chinese construction industry will be converted to Australian dollars. Tons of Standard Coal Equivalent (SCE) will be transformed to be petajoule (pj).

The indicators in the sustainable development index of the Australian construction industry in 2009-10 will be considered as the ‘base’ and the value is 1. The value of indicators in Economic Sustainability and Social Sustainability of the Chinese construction industry in 2010 divided by the value of indicators in Economic Sustainability and Social Sustainability of the Australian construction industry in 2009-10 will be considered as the index value of the Chinese construction industry for each indicator in Economic Sustainability and Social Sustainability in 2010. However, for Environmental Sustainability, the smaller value of the indicators is the better. The index value of the indicators in Environmental Sustainability will be measured by 2 minus the value of indicators in Environmental Sustainability of the Chinese construction industry in 2010 divided by the value of indicators in Environmental Sustainability of the Australian construction industry in 2009-10. In addition, the value of sustainable development index and the sub-indices including economic sustainability index, social sustainability index and environmental sustainability index will be expressed by the average of the value of indicators included in each index. The result is provided in Table 8-5.

Indicators		Australian construction industry (2009-10)		Chinese construction industry (2010)		Difference in index value
		Original value	Index value	Original value	Index value	
Economic Sustainability	Construction work done (CWD) AU$m	162440.336	1	1546146	9.518239361	8.518239361
	Labour productivity in terms of value-added AU$'000	92.6	1	6.49	0.070086393	-0.929913607
	Profit margin (%)	12.6	1	3.5	0.277777778	-0.722222222
	GDP AU$ m	1370540	1	6459540	4.713134969	3.713134969
	Gross fixed capital formation AU$m	358787	1	2935765.577	8.182474775	7.182474775
	Average	N/A	1	N/A	4.552342655	3.552342655
Social Sustainability	Per capita disposable income per year AU$	17117	1	2765.1988	0.16154693	-0.83845307
	No. of persons with a non-school qualification per thousand people	557	1	89.3	0.16032316	-0.83967684
	Average	N/A	1	N/A	0.160935045	-0.839064955
Environmental Sustainability	Construction Waste / CWD (Ton/AU$m)	101.83	1	35.8	1.648433664	0.648433664
	Energy Consumption / CWD (pj / AU$b)	0.886	1	1.178	0.670428894	-0.329571106
	Average	N/A	1	N/A	1.159431279	0.159431279
Sustainable development index		N/A	1	N/A	2.822493991	1.822493991

Table 8-5 Comparison of the sustainable development index between the Chinese and Australian construction industry

The value of the sustainable development index of the Chinese construction industry is 2.8. It shows that the degree of the sustainability of the Chinese construction industry is nearly three times the Australian construction industry's sustainability. For the sub-index, the economic sustainability index of the Chinese construction industry is approximately 4.55. This result indicates the huge advantages of the Chinese construction industry in economic sustainability. The construction work done, GDP and gross fixed capital formation are all higher than the Australian construction industry. This is caused by China's economic aggregate and the continuous growth of the Chinese economy and demand for construction products. However, the level of labour productivity in terms of value added and profit margin of the Chinese construction industry is much lower than the Australian construction industry. Therefore, compared with the Australian construction industry, the development style of the Chinese construction industry is still extensive. The efficiency of the Chinese construction industry still needs to be improved. The intensive development strategies should be generated and implemented well.

The environmental sustainability index of the Chinese construction industry is about 1.16 which is 16% higher than the Australian construction industry. This should be attributed to the higher level in construction waste per AU$ million of construction work done than the Australian construction industry. However, the energy consumption per AU$ billion of construction work done still needs to be improved, compared with the Australian construction industry.

The social sustainability index of the Chinese construction industry is approximately 0.161. This result means the degree of the social sustainability of the Chinese construction industry is only equivalent to 16.1% of the Australian construction industry. Therefore social sustainability needs the most attention.

In order to promote the overall progress of the whole system, many scholars and policymakers will identify the elements, indicators or sub-systems with bad performance and then formulate strategies or policies to enhance the improvement of those elements, indicators or sub-systems directly. Most of the previous studies on the Chinese construction industry adopt the same logic (Du, 2007; Sha *et al.,* 2008; Yang, *et al.,* 2010; Zhao & Shen, 2009; Gong & Cheng, 2000 and Zhang, 2002) and this logic may be useful in the short term.

However, as a unified whole, a dynamic and complex interrelationship exists among the various components or sub-systems within the system. In this sense, Systems thinking is necessary and critical. In particular, the interactivity principle of systems thinking needs to be used. The influence level and direction between the sub-systems may change in the long term. The multivariate cointegration analysis can be utilised to explore the dynamic and complex interrelationship among elements, indicators or sub-systems in the long term. Therefore, in order to find the appropriate strategy to improve the social sustainability of the Chinese construction industry, the interaction between the Economic Sustainability index, Social Sustainability index and Environmental Sustainability index will be discussed by using the multivariate cointegration analysis.

8.5 Multivariate cointegration analysis

More than 20 years of data is required to conduct a multivariate cointegration analysis for the sustainable development of the Chinese construction industry. In this section, the date from 1988 to 2010 is collected. The first step is to conduct a dimensionless process for the data by using the min-max normalisation method, and calculate the economic sustainability index, environmental sustainability index and social sustainability index. This was explained in detail in Chapter 4, Section 4.8.2. The results are summarised in Table 8-6.

Year	Economic Sustainability						Social Sustainability			Environmental Sustainability		
	GOV	Labour productivity in terms of value added	Profit margin	GDP	Fixed asset investment	Average	Per capita disposable income per year	No. of persons with a non-school qualification / ’000 people	Average	Construction Waste / GOV	Energy Consumption / GOV	Average
1988	0.0001	0.0248	1.0000	0.0000	0.0016	0.2053	0.0000	0.0000	0.0000	0.1630	0.0556	0.1093
1989	0.0024	0.0239	0.6207	0.0050	0.0000	0.1304	0.0107	0.0916	0.0512	0.1737	0.0656	0.1196
1990	0.0000	0.0298	0.2414	0.0094	0.0023	0.0566	0.0184	0.0954	0.0569	0.0000	0.0000	0.0000
1991	0.0036	0.0000	0.2069	0.0175	0.0093	0.0474	0.0289	0.0996	0.0643	0.0400	0.1127	0.0763
1992	0.0144	0.0149	0.3103	0.0308	0.0230	0.0787	0.0471	0.0861	0.0666	0.2930	0.3565	0.3247
1993	0.0377	0.0959	0.2759	0.0525	0.0500	0.1024	0.0779	0.0904	0.0841	0.5667	0.6803	0.6235
1994	0.0610	0.1725	0.1241	0.0859	0.0725	0.1032	0.1291	0.0949	0.1120	0.6585	0.7938	0.7261
1995	0.0803	0.2255	0.0276	0.1185	0.0925	0.1089	0.1730	0.1687	0.1708	0.7106	0.8561	0.7834
1996	0.0673	0.2307	0.0345	0.1454	0.1103	0.1176	0.2040	0.1711	0.1875	0.6548	0.7949	0.7249
1997	0.0763	0.2507	0.0000	0.1656	0.1211	0.1227	0.2219	0.2289	0.2254	0.6862	0.8761	0.7812
1998	0.0862	0.2842	0.0000	0.1796	0.1357	0.1372	0.2367	0.2349	0.2358	0.7104	0.8211	0.7657
1999	0.0978	0.3134	0.0690	0.1933	0.1467	0.1640	0.2606	0.2648	0.2627	0.7405	0.8856	0.8131
2000	0.1121	0.3526	0.1034	0.2180	0.1654	0.1903	0.2844	0.3592	0.3218	0.7640	0.9019	0.8330
2001	0.1426	0.3975	0.2414	0.2450	0.1874	0.2428	0.3168	0.3397	0.3282	0.7848	0.9376	0.8612
2002	0.1762	0.3470	0.2759	0.2727	0.2204	0.2584	0.3638	0.4514	0.4076	0.8271	0.9512	0.8892
2003	0.2247	0.3937	0.3793	0.3128	0.2758	0.3172	0.4067	0.5400	0.4734	0.8553	0.9692	0.9122
2004	0.2878	0.4824	0.3448	0.3751	0.3412	0.3662	0.4596	0.5760	0.5178	0.8883	0.9061	0.8972
2005	0.3465	0.5516	0.4828	0.4400	0.3924	0.4427	0.5194	0.5383	0.5288	0.9135	0.9306	0.9221
2006	0.4210	0.6131	0.5862	0.5212	0.4695	0.5222	0.5900	0.6273	0.6086	0.9418	0.9448	0.9433
2007	0.5218	0.6957	0.6552	0.6494	0.5594	0.6163	0.7031	0.6656	0.6843	0.9597	0.9619	0.9608
2008	0.6387	0.7910	0.7931	0.7743	0.6951	0.7384	0.8143	0.6828	0.7485	0.9745	0.9963	0.9854
2009	0.7957	0.9289	0.7931	0.8438	0.8558	0.8435	0.8921	0.7468	0.8194	0.9878	1.0000	0.9939
2010	1.0000	1.0000	0.7931	1.0000	1.0000	0.9586	1.0000	1.0000	1.0000	1.0000	0.9903	0.9952

Table 8-6 Economic sustainability index, environmental sustainability index and social sustainability index of the Chinese construction industry from 1988 to 2010

The economic sustainability index, environmental sustainability index and social sustainability index from 1988 to 2010 generated in Table 8-6 will be named as EC_t, SO_t and EN_t. Their first differences and second differences are named as DEC_t, DSO_t and DEN_t respectively. Their values are calculated by Eviews 6.0 and summarised in Table 8-7.

EC_t	**SO_t**	**EN_t**	**DEC_t**	**DSO_t**	**DEN_t**
0.2053	0.0000	0.1093	N/A	N/A	N/A
0.1304	0.0512	0.1196	-0.0749	0.0512	0.0104
0.0566	0.0569	0.0000	-0.0738	0.0057	-0.1196
0.0474	0.0643	0.0763	-0.0092	0.0074	0.0763
0.0787	0.0666	0.3247	0.0313	0.0024	0.2484
0.1024	0.0841	0.6235	0.0237	0.0175	0.2987
0.1032	0.1120	0.7261	0.0008	0.0279	0.1027
0.1089	0.1708	0.7834	0.0057	0.0588	0.0572
0.1176	0.1875	0.7249	0.0087	0.0167	-0.0585
0.1227	0.2254	0.7812	0.0051	0.0379	0.0563
0.1372	0.2358	0.7657	0.0145	0.0104	-0.0154
0.1640	0.2627	0.8131	0.0268	0.0269	0.0473
0.1903	0.3218	0.8330	0.0263	0.0591	0.0199
0.2428	0.3282	0.8612	0.0525	0.0064	0.0282
0.2584	0.4076	0.8892	0.0156	0.0794	0.0280
0.3172	0.4734	0.9122	0.0588	0.0658	0.0231
0.3662	0.5178	0.8972	0.049	0.0445	-0.0150
0.4427	0.5288	0.9221	0.0765	0.0110	0.0249
0.5222	0.6086	0.9433	0.0795	0.0798	0.0213
0.6163	0.6843	0.9608	0.0941	0.0757	0.0175
0.7384	0.7485	0.9854	0.1221	0.0642	0.0247
0.8435	0.8194	0.9939	0.1051	0.0709	0.0085
0.9586	1.0000	0.9952	0.1151	0.1806	0.0013

Table 8-7 Basic statistical description of EC_t, SO_t, EN_t DEC_t, DSO_t, and DEN_t

8.5.1 Unit Root Test

The timing diagram of EC, SO and EN is generated as Figure 8-1. It shows that there is an increasing or similar trend of series EC, SO and EN, and there are unstable factors in these sequences.

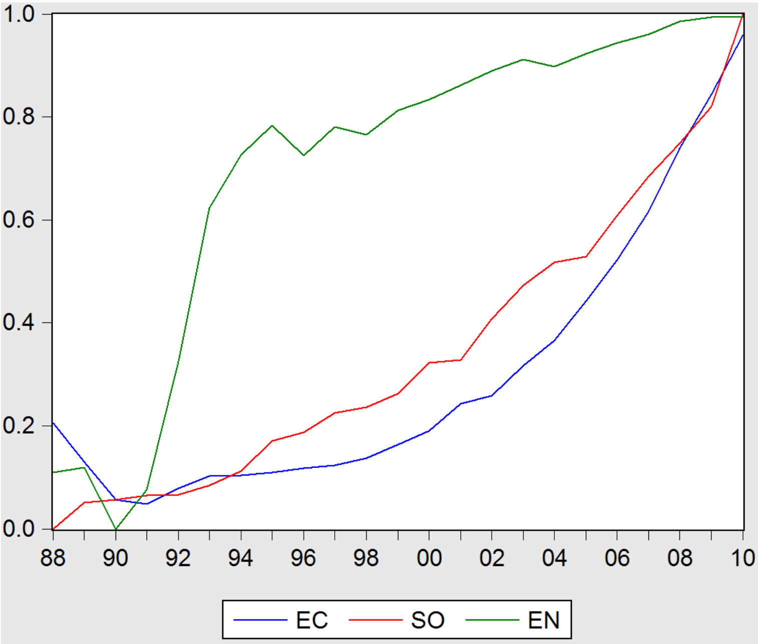


Figure 8-1 Timing Diagram of EC, SO and EN

In order to conduct the ADF test to the unit root of ECt, SOt and ENt, the selection of test equations is determined by the corresponding data graphs. The lag coefficient will be decided by using Akaike Information Criterion (AIC). This research will adopt the test equation which includes the trend and intercept. By using Eviews, the test result is provided in Table 8-8. The ADF test statistic of ECt and SOt are all higher than the test critical values in the levels of 0.01, 0.05 and 0.1. The null hypothesis cannot be rejected. ECt and SOt have time trends and unit root. Both of them are non-stationary. The ADF test statistic of ENt is lower than the test critical values in the levels of 0.01. The null hypothesis can be rejected. ENt does not have unit root and it is stationary.

Then the DECt amd DSOt are tested. The results show that the DECt and DSOt are smaller than the test critical values in the levels of 0.01, 0.05 and 0.1. The null hypothesis could be rejected. DECt and DSOt are stationary.

Variable	Test type (C，T，K)*	ADF	Prob	Test critical values			Result
				1%	5%	10%	
EC_t	(C，T，4)	-0.077389	0.9918	-4.440739	-3.632896	-3.254671	Non-stationary
SO_t	(C，T，4)	1.502197	0.9999	-4.440739	-3.632896	-3.254671	Non-stationary
EN_t	(C，T，4)	-8.269312	0.0000	-4.571559	-3.644963	-3.286909	Stationary
DEC_t	(C，T，4)	-3.571748	0.0586	-4.498307	-3.658446	-3.268973	Stationary
DSO_t	(C，T，4)	-3.725104	0.0430	-4.467895	-3.644963	-3.261452	Stationary

** (C，T，K) represents that the unit root test equation includes intercept, time trend and lags. 0 means the test equation does not include intercept or time trend.*

Table 8-8 ADF test result of EC_t, SO_t, EN_t DEC_t, and DSO_t

When two variables are used in a cointegration test, their order of integration must be the same. If there are three or more variables, each variable’s order of integration can be different. However, the variables with a higher order of integration must be cointegrated, and the number of their non-equilibrium error sequence’s order should be the same as the order of the lower-order variables. In this case, the cointegration relationship may not be unique. The order of explained variable must not be higher than the order of explanatory variables.

8.5.2 Johansen cointegration test

After the ADF test, the order of integration of ECt, SOt and ENt has been identified. In order to explore the long-term dynamic equilibrium among them, the Johansen cointegration test is conducted by using Eviews 6.0 and adopting ENt, ECt and SOt. The result is shown as Table 8-9.

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.813381	49.67738	29.79707	0.0001
At most 1	0.372973	14.42500	15.49471	0.0720
At most 2 *	0.197592	4.622901	3.841466	0.0315

Trace test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.813381	35.25239	21.13162	0.0003
At most 1	0.372973	9.802096	14.26460	0.2252
At most 2 *	0.197592	4.622901	3.841466	0.0315

Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegrating Coefficients (normalized by b'*S11*b=I):

EN	EC	SO
-6.653105	-11.55541	0.100969
-2.970924	-16.78018	34.26417
-2.597411	10.41253	-7.549150

Unrestricted Adjustment Coefficients (alpha):

D(EN)	0.044193	0.014492	0.014397
D(EC)	0.005216	0.010243	0.002340
D(SO)	-0.016839	-0.002624	0.009781

1 Cointegrating Equation(s): Log likelihood 152.3510

Normalized cointegrating coefficients (standard error in parentheses)

EN	EC	SO
1.000000	1.736845	-0.015176
	(0.34029)	(0.60136)

Adjustment coefficients (standard error in parentheses)

D(EN)	-0.294023
	(0.07549)
D(EC)	-0.034704
	(0.02953)
D(SO)	0.112031
	(0.03963)

2 Cointegrating Equation(s): Log likelihood 157.2520

Normalized cointegrating coefficients (standard error in parentheses)

EN	EC	SO
1.000000	0.000000	5.099500
		(1.05676)
0.000000	1.000000	-2.944808
		(0.54340)

Adjustment coefficients (standard error in parentheses)

D(EN)	-0.337077	-0.753845
	(0.07835)	(0.21909)
D(EC)	-0.065136	-0.232162
	(0.02642)	(0.07387)
D(SO)	0.119826	0.238609
	(0.04314)	(0.12062)

Table 8-9 Result of Johansen cointegration test

This research aims to find the long-term relationship between economic sustainability, environmental sustainability and social sustainability. The equation can be expressed as:

$$ENt = -1.736845ECt + 0.015176SOt$$

It indicates that if ECt increases one unit, ENt will decrease 1.736845 unit; if SOt increased one unit, ENt will increase 0.015176 unit.

8.5.3 Granger causality test

Based on the result of the Johansen cointegration test, there is a long-term equilibrium relationship among ECt, SOt and ENt. However the Granger causality among these three variables needs to be studied further by utilising the time difference and lag-effects of variables coming into play. Because of the high sensitivity on lag orders of the Granger causality test, this research will successively test several log orders from 1-7, which depends on the sample size. From log 8, the Granger causality test couldn't be run in Eviews 6.0. The results of Granger causality test among ECt, SOt and ENt are summarised in Table 8-10.

Lags	Null Hypothesis:	F-Statistic	Prob.	Result
1	EC does not Granger Cause EN	0.21485	0.6483	Accept
	EN does not Granger Cause EC	7.92398	0.0111	Reject
	SO does not Granger Cause EN	0.02612	0.8733	Accept
	EN does not Granger Cause SO	0.01492	0.9041	Accept
	SO does not Granger Cause EC	30.9372	0.00002	Reject
	EC does not Granger Cause SO	6.71946	0.0179	Reject
2	EC does not Granger Cause EN	13.5250	0.0004	Reject
	EN does not Granger Cause EC	1.17888	0.3330	Accept
	SO does not Granger Cause EN	3.76051	0.0458	Reject
	EN does not Granger Cause SO	0.26643	0.7694	Accept
	SO does not Granger Cause EC	2.57565	0.1072	Accept
	EC does not Granger Cause SO	1.74554	0.2062	Accept
3	EC does not Granger Cause EN	11.9486	0.0005	Reject
	EN does not Granger Cause EC	1.10208	0.3835	Accept
	SO does not Granger Cause EN	1.17842	0.3559	Accept
	EN does not Granger Cause SO	0.97907	0.4326	Accept
	SO does not Granger Cause EC	3.44754	0.0486	Reject
	EC does not Granger Cause SO	1.98392	0.1662	Accept
4	EC does not Granger Cause EN	5.71521	0.0117	Reject
	EN does not Granger Cause EC	0.62579	0.6549	Accept
	SO does not Granger Cause EN	1.82959	0.1998	Accept
	EN does not Granger Cause SO	0.88300	0.5080	Accept
	SO does not Granger Cause EC	4.36791	0.0267	Reject
	EC does not Granger Cause SO	2.48186	0.1111	Accept
5	EC does not Granger Cause EN	4.80681	0.0317	Reject
	EN does not Granger Cause EC	0.47572	0.7847	Accept
	SO does not Granger Cause EN	3.64318	0.0608	Reject
	EN does not Granger Cause SO	0.72022	0.6289	Accept
	SO does not Granger Cause EC	3.08372	0.0871	Reject
	EC does not Granger Cause SO	1.47454	0.3085	Accept
6	EC does not Granger Cause EN	4.58009	0.0812	Reject
	EN does not Granger Cause EC	0.53494	0.7649	Accept
	SO does not Granger Cause EN	0.80266	0.6151	Accept
	EN does not Granger Cause SO	1.04505	0.5065	Accept
	SO does not Granger Cause EC	1.22757	0.4405	Accept
	EC does not Granger Cause SO	0.33658	0.8870	Accept
7	EC does not Granger Cause EN	1.33563	0.5844	Accept
	EN does not Granger Cause EC	3.71531	0.3801	Accept
	SO does not Granger Cause EN	2.66308	0.4406	Accept
	EN does not Granger Cause SO	9.63099	0.2433	Accept
	SO does not Granger Cause EC	10.1919	0.2368	Accept
	EC does not Granger Cause SO	0.45308	0.8190	Accept

Table 8-10 Results of Granger causality test among EC_t, SO_t and EN_t

According to Table 6-34, there is unidirectional and/or bidirectional Granger causality among ECt, SOt and ENt. In log 1, EN and SO are the Granger cause of EC with the explanatory ability of 98.89% and 99.998%. EC is the Granger cause of SO with the explanatory ability of 98.21%. The results from log 2 to log 7 could be explained in the same way. However, The EN does not have any impact on SO from log 1 to log 7.

8.5.4 Vector Error Correction Model

According to the cointegration theory, once short-term fluctuations deviate from the long-run equilibrium, the error correction mechanism can correct this bias to make the relationship among ECt, SOt and ENt cointegrated. In order to explore the detailed interaction between variables, the vector error correction model should be set up to reflect the short-term dynamic equilibrium between ECt, SOt and ENt. The results using Eviews 6.0 are provided in Table 8-11:

Cointegrating Eq:	CointEq1		
EN(-1)	1.000000		
DEC(-1)	-4.784759 (0.79439) [-6.02316]		
DSO(-1)	4.379566 (1.87711) [2.33315]		
C	-0.738520		
Error Correction:	D(EN)	D(DEC)	D(DSO)
CointEq1	-0.318803 (0.05494) [-5.80295]	-0.080420 (0.02171) [-3.70357]	-0.039503 (0.05498) [-0.71856]
D(EN(-1))	0.129750 (0.12149) [1.06798]	-0.232209 (0.04802) [-4.83573]	0.044115 (0.12157) [0.36287]
D(DEC(-1))	-0.224117 (0.49747) [-0.45052]	-0.370983 (0.19662) [-1.88677]	-0.543962 (0.49780) [-1.09273]
D(DSO(-1))	0.700994 (0.36243) [1.93416]	0.524765 (0.14325) [3.66330]	-0.484346 (0.36267) [-1.33549]
C	0.045413 (0.01129) [4.02331]	0.022418 (0.00446) [5.02484]	0.012189 (0.01130) [1.07916]

Table 8-11 Result of Vector Error Correction

This table could be expressed by the following equations:

D(EN) = - 0.318802811697*(EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322) + 0.129750062898*D(EN(-1)) - 0.224117425016*D(DEC(-1)) + 0.700994397811*D(DSO(-1)) + 0.0454132459717 (1)

D(DEC) = - 0.0804202923815*(EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322) - 0.23220888857*D(EN(-1)) - 0.370982823341*D(DEC(-1)) + 0.524764592128*D(DSO(-1)) + 0.0224177617477 (2)

D(DSO) = - 0.0395027100196*(EN(-1)-4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322) + 0.0441150476728*D(EN(-1)) - 0.543961818182*D(DEC(-1)) - 0.484345560828*D(DSO(-1)) + 0.0121892858276 (3)

EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 is the error correction term (ecm_{t-1}), which reflects the mechanism of error correction model to correct Misaligned error.

Equation 1 describes the effect of equilibrium error on the short-term dynamic of the Environmental Sustainability index. The modulus of ecm_{t-1} is - 0.318802811697. It indicates reverse correction mechanism and the adjustment of trends in long-run equilibrium's error correction term is about 31.88%. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 >0, ecm_{t-1} can reduce the growth of Environmental Sustainability. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 <0, ecm_{t-1} plays a catalytic role in the growth of Environmental Sustainability. Based on the VEC model, the short-term dynamic equilibrium among Environmental Sustainability, Social Sustainability and Economic Sustainability could be described as:

- If the Environmental Sustainability index of last year changes one unit, the Environmental Sustainability of the current year will change 0.129750062898 units in the same direction. When the Economic Sustainability index of last year changes one unit, the Environmental Sustainability index of the current year will change 0.224117425016 units in the opposite direction. When the Social Sustainability index of the last year changes one unit, the Environmental Sustainability index of the current year will change 0.700994397811 units in the same direction.

Equation 2 describes the effect of equilibrium error on the short-term dynamic of the Economic Sustainability index. The modulus of ecm_{t-1} is - 0.0804202923815. It indicates reverse correction mechanism and the adjustment of trends in long-run equilibrium's error correction term is about 8.04%. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 >0, ecm_{t-1} can reduce the growth of the Economic Sustainability index. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 <0， ecm_{t-1} could increase the growth of the Economic Sustainability index. Based on the VEC model, the short-term dynamic equilibrium among Environmental Sustainability, Social Sustainability and Economic Sustainability could be described as:

- If the Environmental Sustainability index of the last year changes one unit, the Environmental Sustainability of the current year will change 0.23220888857 units in the opposite direction. When the Economic Sustainability index of the last year changes one unit, the Economic Sustainability index of current year will change 0.370982823341 units in the opposite direction. When the Social Sustainability index of last year changes one unit, the Economic Sustainability index of the current year will change 0.524764592128 units in the same direction.

Equation 3 describes the effect of equilibrium error on the short-term dynamic of Social Sustainability index. The modulus of ecm_{t-1} is - 0.0395027100196. It indicates reverse correction mechanism and the adjustment of trends in long-run equilibrium's error correction term is about 3.95%. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 >0, ecm_{t-1} can reduce the growth of the Social Sustainability index. When EN(-1) - 4.78475935738*DEC(-1) + 4.37956552471*DSO(-1) - 0.738519665322 <0， ecm_{t-1} could increase the growth of the Social Sustainability index. Based on the VEC model, the short-term dynamic equilibrium among Environmental Sustainability, Social Sustainability and Economic Sustainability could be described as:

- If the Environmental Sustainability index of last year changes one unit, the Social Sustainability of the current year will change 0.0441150476728 units in the same direction. When the Economic Sustainability index of the last year changes one unit, the Social Sustainability index of current year will change 0.543961818182 units in the opposite direction. When the Social Sustainability index of the last year changes one unit, the Social Sustainability index of the current year will change 0.484345560828 units in the opposite direction.

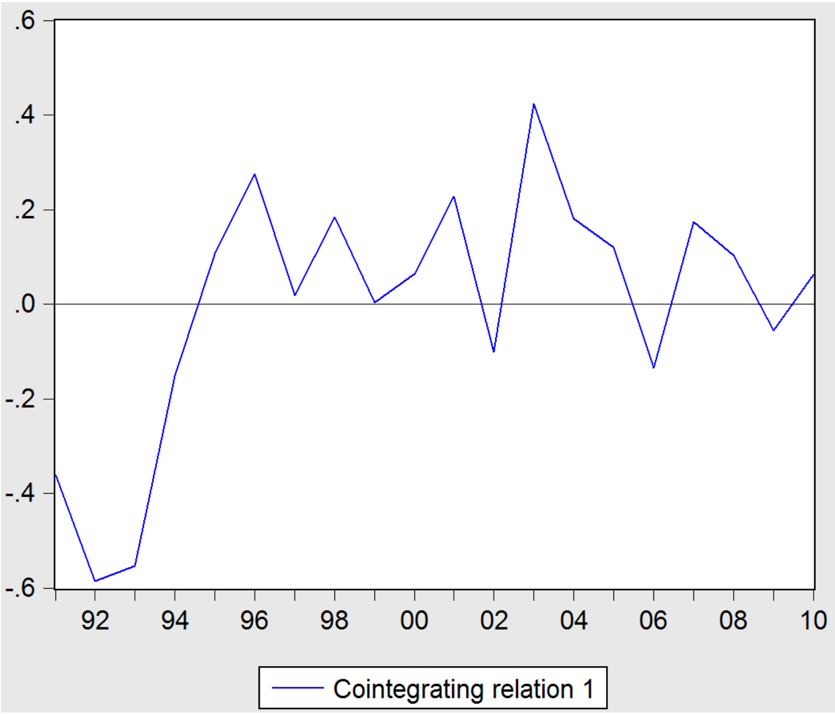


Figure 8-2 Cointegrating relation

In Figure 8-2, zero line represents the stable long-run equilibrium relationship among the variables. The absolute value of the error correction term in 1992 and 2003 are the largest two. This indicated that the extent of short-term fluctuations deviated from long-run equilibrium in these two years is big. For the rest of the year, it is relatively small.

8.5.5 Impulse response functions and variance decomposition forecast

Based on the VER model, this section will adopt impulse response functions and variance decomposition forecast to discuss the interaction of the Environment Sustainability index, Social Sustainability index and Economic Sustainability index of the Chinese construction industry from 1988 to 2010.

8.5.5.1 Impulse response functions

This section will discuss their reflection on the impulse of one standard deviation innovations from the hysteresis value of other variables including themselves when EN, DEC and DSO is considered as the dependent variable respectively, and the trends of the influence. The results are provided in Figure 8-3 and Table 8-12. The horizontal axis represents the trace periods of the response function. The vertical axis represents responsiveness of the dependent variable on the explanatory variables. Tracking periods of the response function is set to 10 years.

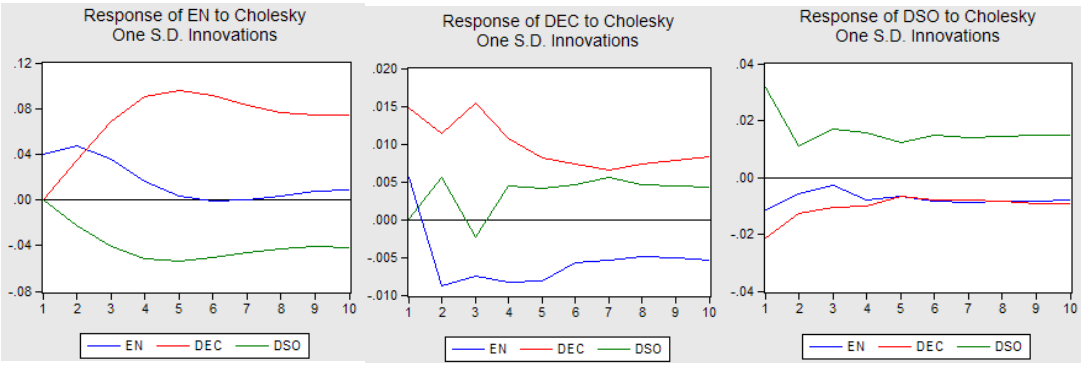


Figure 8-3 Response for one standard deviation innovations of EN, DEC and DSO

Response of EN:

Period	EN	DEC	DSO
1	0.039967	0.000000	0.000000
2	0.047577	0.034133	-0.022097
3	0.035104	0.069462	-0.040634
4	0.016563	0.090510	-0.051396
5	0.003857	0.096236	-0.054009
6	-0.001246	0.091118	-0.050463
7	-0.000127	0.082970	-0.046011
8	0.003725	0.076614	-0.042608
9	0.007240	0.073783	-0.041227
10	0.009203	0.074000	-0.041519

Response of DEC:

Period	EN	DEC	DSO
1	0.005534	0.014796	0.000000
2	-0.008862	0.011307	0.005485
3	-0.007497	0.015341	-0.002331
4	-0.008320	0.010752	0.004475
5	-0.008079	0.008173	0.004056
6	-0.005671	0.007389	0.004604
7	-0.005412	0.006542	0.005487
8	-0.004899	0.007329	0.004519
9	-0.005018	0.007870	0.004512
10	-0.005421	0.008283	0.004203

Response of DSO:

Period	EN	DEC	DSO
1	-0.011457	-0.021402	0.031783
2	-0.005706	-0.012585	0.010891
3	-0.002892	-0.010486	0.017077
4	-0.007851	-0.010169	0.015725
5	-0.006688	-0.006682	0.012358
6	-0.008465	-0.007816	0.014863
7	-0.008698	-0.007916	0.013801
8	-0.008190	-0.008438	0.014499
9	-0.008201	-0.009075	0.014866
10	-0.007792	-0.009043	0.014662

Table 8-12 Response for a standard shock of EN, DEC and DSO

When EN is the dependent variable,

1) the response of the Environmental Sustainability index of the Chinese construction industry to the impulse of its own one standard deviation innovations increases from 0.039967 in the first year to 0.047577 in the second year and decreases gradually to -0.001246 in the sixth year. After that, it starts to increase until the tenth year and it is back up to positive number in the eighth year. It indicates the Environmental Sustainability index of the Chinese construction industry has a positive response to its own one standard deviation innovations from the first year to the fifth year and from the eighth year to the tenth year. However, there is negative response in the sixth and seventh year.

2) the response of the Environmental Sustainability index of the Chinese construction industry to the impulse of one standard deviation innovations of the Economic Sustainability index is 0 in the first year and increases to 0.096236 in the fifth year and then falls to 0.073783 in the ninth year. After that, there is a slight increase in the tenth year. It shows that there is a positive relationship between the Environmental and Economic Sustainability indices of the Chinese construction industry. According to Figure 8-3, the degree of the response of the Environmental Sustainability index of the Chinese construction industry to the impulse of one standard deviation innovations of Economic Sustainability index is the highest among these three indices from the third year.

3) the response of the Environmental Sustainability of the Chinese construction industry to the impulse of one standard deviation innovations of the Social Sustainability index is 0 in the first year and decreases gradually from the second year to the fifth year. After a slight increase in the sixth year, it stays relatively stable under -0.041. This means there is a negative relationship between the Environmental and Social Sustainability index of the Chinese construction industry. The other two variables could be analysed in a similar way.

8.5.5.2 Variance decomposition forecast

This section decomposes the prediction variance of each variable to distinguish the relative importance of the impulse in dynamic changes of the EN, DEC and DSO. The results are shown in Figure 8-4 and Table 8-13.

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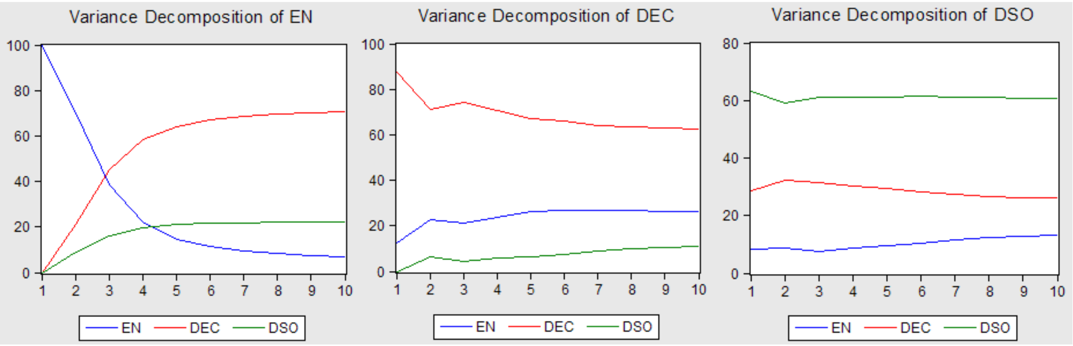

Figure 8-4 Variance decomposition forecast of EN, DEC and DSO

Variance Decomposition of EN:				
Period	S.E.	EN	DEC	DSO
1	0.039967	100.0000	0.000000	0.000000
2	0.074258	70.01750	21.12799	8.854508
3	0.114990	38.51898	45.30142	16.17960
4	0.155983	22.06088	58.28933	19.64979
5	0.191112	14.73670	64.18694	21.07636
6	0.217657	11.36471	67.01094	21.62435
7	0.237435	9.550207	68.52280	21.92699
8	0.253129	8.424347	69.45005	22.12560
9	0.266965	7.647312	70.07623	22.27646
10	0.280277	7.045970	70.54891	22.40512
Variance Decomposition of DEC:				
Period	S.E.	EN	DEC	DSO
1	0.015797	12.27093	87.72907	0.000000
2	0.022046	22.45922	71.35158	6.189204
3	0.027982	21.11872	74.34545	4.535827
4	0.031430	23.74581	70.63152	5.622664
5	0.033710	26.38605	67.27820	6.335750
6	0.035275	26.68130	65.82932	7.489381
7	0.036695	26.83181	64.01157	9.156627
8	0.038009	26.67064	63.38133	9.948022
9	0.039397	26.44606	62.98294	10.57099
10	0.040839	26.37391	62.72906	10.89703
Variance Decomposition of DSO:				
Period	S.E.	EN	DEC	DSO
1	0.039994	8.206868	28.63680	63.15633
2	0.043693	8.581419	32.29011	59.12847
3	0.048156	7.425168	31.32336	61.25147
4	0.052262	8.561071	30.38071	61.05822
5	0.054529	9.368449	29.40851	61.22304
6	0.057681	10.52633	28.11850	61.35517
7	0.060464	11.64896	27.30392	61.04712
8	0.063280	12.31012	26.70576	60.98412
9	0.066143	12.80467	26.32582	60.86951
10	0.068792	13.12031	26.06522	60.81447

Table 8-13 Variance decomposition forecast of EN, DEC and DSO

For the Environmental Sustainability index of the Chinese construction industry:

a. The contribution rate of the Environmental Sustainability index of the Chinese construction industry to its own is 100% in the first year and decreases to 70% in the second year, and then keeps dropping gradually until the tenth year. The contribution rate of the tenth year is only about 7%. It indicates that in the first year, all the contribution is from itself. With the increase of lag period, the contribution from the Economic Sustainability index and Social Sustainability index becomes bigger. From the fifth year, the contribution from the Environmental Sustainability index of the Chinese construction industry itself is becoming the smallest among these three indexes.
b. The contribution rate of Economic Sustainability index to Environmental Sustainability index of the Chinese construction industry is 0 in the first year and then increases rapidly and reaches 70.55% in the tenth year. From the third year, the contribution from the Economic Sustainability index of the Chinese construction industry is becoming the largest among these three indexes.
c. The contribution rate of Social Sustainability to Environmental Sustainability of the Chinese construction industry is 0 in the first year and then increases to 1.37% in the second year. It keeps slightly decreasing for the rest of the years and is lower than 1%. The contribution rate of Social Sustainability to Environmental Sustainability of the Chinese construction industry is the lowest among these three variables.

For the Economic Sustainability index of the Chinese construction industry:

a. The contribution rate of the Economic Sustainability of the Chinese construction industry to its own is 87.73% in the first year and decreases to 71.35% in the second year. After the increase in the third year with the contribution rate of 74.35%, from the fourth year, it starts to decrease gradually to 62.73% in the tenth year. From the first year, the contribution rate of the Economic Sustainability to itself is the always the highest among these three variables.
b. The contribution rate of the Social Sustainability index to the Economic Sustainability index of the Chinese construction industry is 0 in the first year and then increases to 6.19% in the second year. After a drop in the third year, it keeps

increasing for the rest of the years and reaches 10.9% in the tenth year. The contribution rate of the Social Sustainability index to Environmental Sustainability index of the Chinese construction industry is the lowest among these three variables from the first year.

c. The contribution rate of the Environmental Sustainability index to the Economic Sustainability index of the Chinese construction industry is 12.27% in the first year and increases to 22.46% in the second year. After a drop in the third year, it keeps relatively stable in the rest of the years. The contribution rate of the Environmental Sustainability index to the Economic Sustainability index of the Chinese construction industry is higher than the Social Sustainability index and it is lower than Economic Sustainability index itself.

For the Social Sustainability index of the Chinese construction industry:

a. The contribution rate of the Social Sustainability index of the Chinese construction industry to its own is 63.16% in the first year. Except in the second with the contribution rate of 59.13%, it is more than 60% in the rest of years and it is slightly decreasing. The contribution rate of the Social Sustainability index to itself is the highest among these three variables in the ten year period.
b. The contribution rate of the Economic Sustainability index to Social Sustainability index of the Chinese construction industry is 28.64% in the first year and then increases to 32.29% in the second year. After that, it keeps decreasing for the rest of the years. The contribution rate of the Economic Sustainability index to the Social Sustainability index of the Chinese construction industry is higher than Environmental Sustainability index and it is lower than Social Sustainability index to itself.
c. The contribution rate of the Environmental Sustainability industry to the Social Sustainability index of the Chinese construction industry is 8.2% in the first year. Except for a decline in the third year, it increases slightly in the rest of years. The contribution rate of Environmental Sustainability index to Social Sustainability index of the Chinese construction industry is the lowest one among these three variables.

8.5.5.3 Long-term influence theory

By conducting the multivariate cointegration analysis, the interaction among these three sub-indexes is explored. In this research, the performance of the sustainable development of the Chinese and the Australian construction industries has been compared in Section 8.4 of Chapter 8. Compared with the Australian construction industry, the economic and environmental sustainability of the Chinese construction industry performed better in recent years. However, the social sustainability of the Chinese construction industry is very much behind the Australian construction industry. Therefore social sustainability needs to be paid more attention.

From the results of the multivariate cointegration analysis among the Economic Sustainability index, Social Sustainability index and Environmental Sustainability index in this section, it can be found that there are negative relationships between the Environmental and Social Sustainability indices of the Chinese construction industry and between the Economic and Social Sustainability indices of the Chinese construction industry. Only the relationship between the Social Sustainability index and itself is positive. In addition, by conducting the variance decomposition forecast, the contribution rate of the Social Sustainability index of the Chinese construction industry to its iyself is the highest among these three variables in the ten year period. Therefore, the improvement of the Social Sustainability index of the Chinese construction industry is the priority. This result seems to be the same with the previous research with the logic of ‘if an element of the system does not perform well, this element should be improved directly’.

However, if the environmental sustainability of the Chinese construction industry needs to be improved in the long term, the strategies and policies of directly improving environmental sustainability may be unscientific and unreasonable. There is a positive relationship between the Economic and Environmental Sustainability index. Moreover, the response of the Environmental Sustainability index of the Chinese construction industry to the impulse of one standard division innovations of the Economic Sustainability index is the highest among these three indices from a long term perspective (refers to Figure8-3 and Table 8-11). In addition, by variance decomposition forecast of Environmental Sustainability index in a ten year period, although in the first two years the contribution rate of the Environmental Sustainability index of the Chinese construction industry to itself is the highest among these three indexes, from the third year, the contribution rate of the Economic Sustainability index of the Chinese construction industry to the Environmental Sustainability index becomes the highest among these three indices and keeps the position in the rest of years. In this sense, in the long term, if the Environmental Sustainability index needs to be improved, the best way is to improve the Economic Sustainability index, not the Environmental Sustainability index itself.

A dynamic and complex interrelationship exists among the indicators/sub-systems within a system. The influence level and direction between the indicators/sub-systems may be different in the long term. In order to improve the performance of an indicator/sub-system in a system for a long term point of view, stimulating the indicator/sub-system directly may be not the best way and it may be better to improve the other indicators/sub-systems in the long term. This analysis method is named as the long-term influence theory.

8.6 Conclusion

Significant achievements have been made by the Chinese construction industry in recent years. In order to help the policymakers to generate the appropriate development strategy for the Chinese construction industry, this Chapter compares the productivity and industrial competitiveness between the Chinese and Australian construction industry.

By using the International Advanced Index (IAI), the Chinese construction industry and the Australian construction industry were compared. The IAI and Width Index of the Australian construction industry were higher than the Chinese construction industry in 2010. The Chinese construction industry could make more efforts in widening participation in construction fields (diversification) or improving the level of the activity in each involved field (specialisation). Compared with the previous one-dimensional financial methods, the International Advanced Index is more comprehensive to reflect the status and level of a country’s construction industry in the international market. Moreover, the data which were used for the International Advanced Index is easier to collect and this is the advantage compared with the previous complex methods.

For the total factor productivity, the Australian construction industry in 2009-10 is 503.4% higher than the Chinese construction industry in 2010. It represents the gap between the Chinese and Australian construction industries in relation to the total factor productivity is large. In addition, because of the average growth rate of the Australian construction total factor productivity changes from 2001-02 to 2010-11 is higher than the Chinese construction industry in 2010 (refer to Chapter 6 and Chapter 7), the gap might become bigger in the future. Therefore, despite the Chinese construction industry improving horizontally in recent years, the gap with the construction industry of Australia is still large.

For industrial competitiveness, firstly there is significant gap in the investment in the advanced factors between the Chinese and Australian construction industry. The gap between China and Australian in educated labour could be narrowed in the future. Compared with the Australian construction industry, the Chinese construction industry needs to improve the proportion of the R&D expenditure in the gross output value of the Chinese construction industry.

Next, the Chinese construction industry has much better demand conditions than the Australian construction industry. Moreover, the capital structure of the Chinese construction industry has shown a lot of new trends and characteristics from 2001 to 2010. The Chinese construction industry is moving to the status of 1) the private sector dominates the construction market and 2) the public sector plays a supporting role. For the market structure, the CR_4 of the Chinese construction industry and the Australian construction industry in 2010 are quite similar and both located in the 'Competition' group.

In addition, both the degree of internationalisation of the Chinese and Australian construction enterprises decreased from 2000 to 2010, which could be caused by more construction enterprises from different countries involved in the international construction industry under the context of internationalisation and globalisation, especially from developing countries. In 2000, the degree of internationalisation of the Chinese construction enterprises is higher than Australian construction enterprises. However, by 2010, the degree of internationalisation of the Australian multinational construction enterprises has surpassed the Chinese ones at the country level, which could be caused by the significant decrease of the A-L and A-I. The possible reasons are discussed. Compared with the previous models, the ROLI Model concerns the characteristics of the construction industry and recognises the benefits of both the diversification strategy and the specification strategies. The results generated from the ROLI Model avoided being misled by the significance of diversification unilaterally.

Furthermore, the performance of the closely related and supporting industries of the Chinese and the Australian construction industries are studied. The closely related and supporting industries of the Chinese and the Australian construction industries did not perform well in recent years. Their capability of providing sustainably increasing support to the Chinese and Australian construction industry is limited.

For the government element, the total factor productivity of the Australian government in relation to the Australian construction industry is much higher than the Chinese government. However, if the growth rate trend of the total factor productivity of the Chinese and Australian governments in relation to their construction industries is considered, the gap between the Chinese and Australian governments would be narrowed in future.

Finally, the sustainable development index of the Chinese construction industry is 182.25% higher than the Australian construction industry. The economic sustainability index and environmental sustainability index of the Chinese construction industry is higher than the Australian construction industry. The social sustainability index of the Chinese construction industry is lower than the Australian construction industry. Based on systems thinking, the multivariate cointegration analysis is conducted to explore the interaction among the Economic Sustainability index, Social Sustainability index and Environmental Sustainability index of the Chinese construction industry. The improvement of the Social Sustainability index of the Chinese construction industry should be considered as the priority. This result seems to have the same logic as the previous research.

However, if the environmental sustainability of the Chinese construction industry needs to be improved in the long term, the result shows the best way is to improve the Economic Sustainability index, not the Environmental Sustainability index itself. Therefore, this study proposed the long-term influence theory, which is

> *In order to improve the performance of an element/sub-system in a system in the long term, stimulating the element /sub-system directly may be not the best way. It may be better to improve the other elements/sub-systems, because a dynamic and complex interrelationship exists among the elements/sub-systems within a system and the influence level and direction between the elements/sub-systems may be different in the long term.*

Chapter 9: Summary and conclusion

9.1 Introduction

The key findings of the dissertation will be presented in this chapter. It offers a discussion of how this PhD study addressed the research questions and attempts to answer them. Furthermore, the contributions and limitations of this study are outlined and there are suggestions for avenues of further research.

9.2 Research Question 1

> *What is the performance of the Chinese and the Australian construction industries in the international market from 2001 to 2010?*

Research Question 1 was answered in Chapter 5, Chapter 7, Section 7.2-7.4 and Chapter 8, Section 8.2. The development of the Chinese construction industry from 1949 to 2001 was divided into four periods by Jiang in 2006, including Creation Time, Frustrated Time, Rehabilitation Time and Development Time. The time after the entry into the WTO could be considered as the fifth phase and called 'Post WTO Time'. Chapter 5 Section 5.3 explored the development of the Chinese construction industry in the Post WTO Time from five perspectives including market conditions, employment, level of technology, classification of firms and industrial organisation structure. Chapter 5 Section 5.4 then discussed the development phases of the Chinese construction industry in the international market including, Economic and Technical Aid Time, Emergence Time, Towards Multinational Time and WTO Time. In addition, Chapter 7, Sections 7.2 and 7.3 explored the development of the Australian construction industry in both the domestic and international markets.

Moreover, the status and level of the Chinese and the Australian construction industries in the international market in 2001 and 2010 was analysed by using the International Advanced Index in Chapter 5, Section 5.5 and Chapter 7 Section 7.4. The results indicate that the status and level of both the Chinese and the Australian construction industries in the international market increased dramatically from 2001 to 2010. In the international market, the Chinese and the Australian construction industries had higher influence in more fields of construction and shared more international revenue in the international market. The quantity and quality of the Chinese and the Australian top construction firms increased as well.

Next, Chapter 8, Section 8.2 compared the Chinese and the Australian construction industries based on the International Advanced Index. The results indicate that though all indicators of the Chinese and the Australian construction industries in the International Advanced Index increased from 2001 to 2010, the International Advanced Index and Width Index of the Australian construction industry were higher than the Chinese construction industry in 2010. The Chinese construction industry could make more efforts in widening participation in construction fields (diversification) or improving the level of the activity in each involved field (specialisation).

If the previous one-dimensional financial methods were adopted to analyse the status and level of the Chinese and the Australian construction industries, the results must be that the Chinese construction industry performance was better than the Australian construction industry. The International Advanced Index produces different the results. In addition, one-dimensional financial methods could not provide comments on how to improve the performance. For example, the difference in the involvement level in the construction fields could not be identified. Hence, the targeted suggestions could not be provided. Therefore, the International Advanced Index is more comprehensive to reflect the status and level of a country's construction industry in the international market. Moreover, the data which were used for the International Advanced Index are easier to collect and this is an advantage compared with the previous complex methods. Furthermore, the data for different counties has the same standard and it could be compared internationally. Therefore, the International Advanced Index can be applied widely.

9.3 Research Question 2

> *What are the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries and how can sustainability of the Chinese construction industry be improved in the long term?*

Research Question 2 is answered in Chapter 6, Chapter 7 Section 7.5 & 7.6, and Chapter 8 Section 8.3-8.5.

9.3.1 Productivity

Chapter 6 Section 6.2 discussed the total factor productivity changes of the Chinese construction industry from 2001 to 2010 by conducting the Malmquist productivity index. The key finding is the total factor productivity of the Chinese construction industry has increased from 2001 to 2010, with the average growth rate of 3.3%.

Chapter 7 explored the total factor productivity changes of the Australian construction industry from 2001-02 to 2010-11. The total factor productivity changes of the Australian construction industry from 2001-02/2002-03 to 2005-06/2006-07 and 2008-09/2009-10 are all increasing. However, it declined in 2006-07/2007-08, 2007-08/2008-09 and 2009-10/2010-11. The average growth rate of the total factor productivity of the Australian construction industry from 2001-02 to 2010-11 is 5.4%.

Chapter 8 compared the total factor productivity of the Chinese construction industry in 2010 with the Australian construction industry in 2009-10. Although the construction work done, the number of persons employed in the construction industry and the gross value added of the Chinese construction industry in 2010 are all much higher than the Australian construction industry in 2009-10, the total factor productivity of the Australian construction industry in 2009-10 is 503.4% higher than the Chinese construction industry in 2010. This shows that the gap between the Chinese and Australian construction industry in relation to the total factor productivity is huge. Furthermore, because of the average growth rate of the Australian construction total factor productivity changes from 2001-02 to 2010-11 is higher than the Chinese construction industry from 2001 to 2010, the gap will become bigger in the future. This is a noteworthy problem for the policymakers and industry participants.

9.3.2 Industrial competitiveness

Chapter 6 Section 6.3–6.10 and Chapter 7 Section 7.6 elaborated the development of the Chinese and the Australian construction industries in relation to industrial competitiveness, element by element. Chapter 8 Section 8.4 compared the industrial competitiveness of the Chinese construction industry in 2010 with the Australian construction industry in 2009-2010.

9.3.2.1 Factor conditions

Firstly, for the factor conditions, there are two types of factors including basic factors and advanced factors (Porter 1990 and 2000). For the basic factors, both China and Australia are rich in natural resources. The population of China is the largest in the world, much more than Australia. However, the advanced factor is more important than the basic factors, because a high level of production factors is difficult to obtain from the outside and advanced factors can only be achieved through sustainable investment of substantial human resources and capital.

China has paid increasing attention to the development of the advanced factors. The proportion of R&D expenditure in the Chinese GDP increased gradually from 2001 to 2010. The proportion of R&D expenditure of the Chinese construction industry in its gross output value also increased significantly in these ten years.

For Australia and the Australian construction industry, the investment in the advanced factors improved gradually as well, including R&D expenditure and human resources in R&D. In addition, the number of persons with a non-school qualification per thousand people increased in recent years.

Because of the difference in economies of scale, the R&D expenditure of China was much higher than Australian. However, the average growth rate of the R&D expenditure in Australia was slightly higher than China in recent years. Moreover, although the proportion of the R&D expenditure in both the Chinese and Australian GDP increased in recent years, China is still much lower than Australia. In addition, the number of persons with a non-school qualification per thousand people in China was 89.3 in 2010. For Australia, it has reached 550 in 2009-10. There was a large gap between China and Australia in this indicator. The average growth rate of China in the number of persons with a non-school qualification per thousand people was 11.7% from 2001 to 2010. For Australia, the average growth rate was only 1.82% from 2001-02 to 2010-11. Therefore, it could be speculated that the gap between China and Australia in educated labour will be narrowed in the future.

The R&D expenditure of the Chinese construction industry in 2009 was much higher than the Australian construction industry in 2009-10. Although the proportion of the R&D expenditure in the construction work done of the Chinese construction industry increased from 0.03% in 2000 to 0.18% in 2009, it was still much lower than the Australian construction industry in 2009-10, which is 0.54%. Compared with the Australian construction industry, the Chinese construction industry needs to improve the proportion of the R&D expenditure in construction work done.

9.3.2.2 Demand conditions

Chapter 6 Section 6.5 discussed the demand conditions of the Chinese construction industry from 2001 to 2010. The value of construction work done by the Chinese construction industry climbed to 9603.1 billion CNY in 2010 from 1536.2 billion CNY in 2001, with the average growth rate of 23% from 2001 to 2010. The size of the Chinese domestic construction market is extremely large and the demand growth rate in the Chinese domestic construction is very significant.

Chapter 7 Section 7.6.2 provided the details of the demand conditions of the Chinese construction industry from 2001-02 to 2010-2011. The value of construction work done by the Australian construction industry increased from 2001-2002 to 2010-2011. The average growth rate from 2001-02 to 2010-11 was 7.97%. In addition, the engineering construction sector developed rapidly in this period and has been the largest sector among the three broad areas including residential building, non-residential building and engineering construction.

Chapter 8 Section 8.4.2 compared the size of the domestic construction market and the demand growth rate in the Chinese construction industry in 2010 with the Australian construction industry in 2009-10. The value of construction work done by the Chinese construction industry in 2010 was AU$1546 billion. The growth rate from 2009 to 2010 was 25%. The value of construction work done by the Australian construction industry in 2009-10 was AU$157 billion, which was about 10% of the Chinese construction. The growth rate from 2008-09 to 2009-10 was only 1.77%. Therefore, the demand conditions of the Chinese construction industry are much better than the Australian construction industry.

9.3.2.3 Firm strategy, structure and rivalry

According to Porter (1990), firm strategy, structure and rivalry refers to the firm's organisation structure and management situation, and the performance of competitors in the domestic market. In this research, this element was measured by the capital structure and market structure.

Chapter 6 Section 6.6 discussed the developments of the capital structure of the Chinese construction industry from 2001 to 2010 first. They are:

1) The dominant position of SOEs and COEs in the Chinese construction industry has been replaced by POEs;
2) The performance of the non-public ownership enterprises including POEs, HMTEs and FFEs is better than the public ownership enterprises, including SOEs and COEs, as the nature of them is the same. The Chinese construction industry is converting from being dominated by the public ownership enterprises to the non-public ownership enterprises.
3) The Chinese domestic construction enterprises have achieved rapid development and significant progress. The gap between the Chinese domestic construction enterprises and foreign enterprises was narrowed substantially in relation to labour productivity. However, from the perspective of profit margins, the distance between them has not been reduced. Therefore, there is an urgent need to find ways to narrow the gap in the future.

For the concentration ratio, CR_4, CR_8 and CR_{12} have increased significantly. However, they are all still lower than 25%.

Chapter 7 Section 7.6.3 describes the capital structure and market structure of the Australian construction industry in recent years. The private sector dominates the Australian construction industry. CR_4 of the Australian construction industry has increased from 6.5% in 2000-01 to 19.79% in 2010.

By the comparison between the Chinese and Australian construction industry in relation to their developments in the capital structure and market structure, Chapter 8 Section 8.4.3 provided the findings as:

1) The Chinese construction industry is moving to the status of the private sector dominates the construction market and the public sector plays a supporting role.
2) For the market structure, the CR_4 of the Chinese construction industry and the Australian construction industry in 2010 are quite similar and both located in the 'Competition' group.

9.3.2.4 Activities of Multinational Enterprises

The ROLI model was utilised in this research to analyse the degree of the internationalisation of the Chinese and Australian construction industries, which is used to measure the activities of the multinational construction enterprises in the international construction market.

Chapter 6 Section 6.7 explored the relationships between the degree of internationalisation and a construction firm's financial performance and between the degree of internationalisation and the construction industry performance in the international market at the country level. This result indicates that the performance of the construction industry in the international market could be improved significantly, with the increase of the degree of internationalisation. Therefore, the activities of the multinational enterprises could be included in the international competiveness and is considered a determinant factor.

In addition, it is found that the degree of internationalisation of the Chinese multinational construction enterprises at the country level declined from 1.33 in 2000 to 0.72 in 2010. The average of L-IBD (A-L) and the average of I-OMS (A-I) declined dramatically from 0.44 and 0.41 in 2000 to 0.1 and 0.09 in 2010 respectively. Only the average of O-IRTR (A-O) increased slightly from 0.48 to 0.53 from 2000 to 2010. This was not expected by the Chinese government and scholars, and the decrease may be caused by the large growth in the domestic market and the difficulties of entry into the international market.

Chapter 7 Section 7.6.4 studied the activities of the Australian construction multinational enterprises at the country level in 2000 and 2010. The degree of internationalisation of the Australian multinational construction enterprises at the country level declined from 1.12 in 2000 to 1.06 in 2010. The average of O-IRTR (A-O) declined from 0.48 in 2000 to 0.35 in 2010. It means the proportion of the international revenue of the Australian construction enterprises in their total revenue decreased. The average of I-OMS (A-I) reached 0.62 in 2010 from 0.55 in 2000. It represents that the proportion of the international subsidiaries of the Australian construction industry in their total Subsidiaries increased slightly. In addition, the average of L-IBD (A-L) did not change from 2000 to 2010.

Chapter 8 Section 8.4.4 compared the activities of the Chinese construction multinational enterprises with the Australian construction multinational enterprises at the country level in 2000 and 2010. Both of them declined from 2000 to 2010, which could be caused by more construction enterprises from different countries being involved in the international construction industry under the context of internationalisation and globalisation, especially developing countries. In 2000, the degree of internationalisation of the Chinese construction enterprises was higher than the Australian ones. However, by 2010, the degree of internationalisation of the Australian multinational construction enterprises surpassed the Chinese multinational construction enterprises at the country level. It is caused by the difference in A-I. The Australian construction enterprises set up more overseas subsidiaries and associates in order to extend their business and improve their influence in the host country. It may be caused by the limited domestic market compared with the Chinese construction market. Because of the large domestic market with high growth rate, the driving force for the Chinese construction industry would be much lower than the Australian construction industry.

For the A-O index, the Chinese multinational construction enterprises in 2010 were higher than the Australian multinational construction enterprises. The lower growth rate of international revenue compared to domestic revenue could lead to the lower A-O. Europe and the U.S. are two major markets of the Australian multinational construction enterprises. However, both of them are shrinking in recent years. In addition, the performance of the Australian multinational construction enterprises didn't improved in the rapidly increasing markets including the Middle Eastern and African markets. In contrast, the Middle East and Africa are the major markets for the Chinese multinational construction enterprises. Therefore, the difference in A-O between the Chinese and Australian multinational construction enterprises in 2010 can be easily understood. For the A-I index, the Chinese and Australian multinational construction enterprises were similar. It shows that the average number of countries in which the Chinese and Australian multinational construction enterprises worked in 2010 was quite similar.

9.3.2.5 Related and supporting industries

An industry's competitiveness could be affected by the development of related and supporting industries (Porter, 2000). Chapter 6 Section 6.8 identified the closely related and supporting industries of the Chinese construction industry by conducting the input-output analysis including: Direct Consumption Coefficient, Total Consumption Coefficient. The top two related and supporting industries of the Chinese construction industry are the Smelting and Pressing of Metals industry and the Manufacture of Non-metallic Mineral Products industry.

Chapter 7 Section 7.6.5 identified the closely related and supporting industries of the Australian construction industry by conducting the input-output analysis. The construction industry itself lists in the first place of the closely related and supporting industries. It shows the significant stimulating effect of the Australian construction industry on the demand of itself. The second closely related and supporting industry is the Professional, Scientific and Technical Services industry.

The productivity changes of the top related and supporting industries of the Chinese and the Australian construction industries are analysed and compared between these two countries. The closely related and supporting industries of the Chinese and the Australian construction industries did not perform well in recent years. Their capability of providing sustainable support to the Chinese and the Australian construction industries is limited.

9.3.2.6 Government

Chapter 6 Section 6.9 explored the total factor productivity changes of the Chinese government in relation to the construction industry from 2001 to 2010. Both the single and two inputs productivity of the Chinese government in relation to the Chinese construction industry were improved to a certain extent in recent years.

Chapter 7 Section 7.6.6 analysed the total factor productivity changes of the Australian government in relation to the Australian construction industry from 2007-08 to 2010-11. The total factor productivity of the Australian government in relation to the construction industry declined continuously. The average decreasing rate was 20.7% in these years.

Chapter 8 Section 8.4.6 compared the total factor productivity of the Chinese government in relation to the construction industry in 2010 with the Australian government in 2009-10. The total factor productivity of the Australian government in relation to the construction industry was much better than the Chinese government. In addition, because the total factor productivity of the Chinese government in relation to the Chinese construction industry increased and the total factor productivity of the Australian government in relation to the Australian construction industry decreased in recent years, the total factor productivity of the

Chinese and Australian governments in relation to their construction industries will narrow in the future.

9.3.2.7 Sustainable Development Index

Chapter 6 Section 6.10 discussed the developments of sustainability and the degree of coordination of the Chinese construction industry from 2001 to 2010. The sustainable development index of the Chinese construction industry from 2001 to 2010 increased dramatically, except the slight drop in 2004. The average increase rate in these ten years was 47%. It shows that the sustainability of the Chinese construction industry improved dramatically from 2001 to 2010. In addition, the degree of coordination (DOC) among the Economic Sustainability, Environmental Sustainability and Social Sustainability of the Chinese construction industry increased from 0.2325 in 2001 to 0.9997 in 2010, which is located in the group of 'well-coordinated'. Therefore, it could be said that the development speed and trend among the Economic Sustainability, Environmental Sustainability and Social Sustainability of the Chinese construction industry was under the process of moving from 'uncoordinated' to 'coordinated' from 2001 to 2010.

Chapter 7 Section 7.6.7 explored the developments of the sustainable development indicators of the Australian construction industry from 2002-03 to 2009-10.,All indicators of the sustainable development index increased from 2002-03 to 2009-10, except the energy consumption per billion dollars of construction work done.

Chapter 8 Section 8.4.7 compared the sustainable development index of the Chinese construction industry in 2010 with the sustainable development index of the Australian construction industry in 2009-10. The sustainable development index of the Chinese construction industry was 182.25% higher than the Australian construction industry. The economic sustainability index and environmental sustainability index of the Chinese construction industry was higher than the Australian construction industry. The social sustainability index of the Chinese construction industry was lower than the Australian construction industry.

By conducting the Degree of Coordination and Multivariate Cointegration analysis, it indicated the three sub-elements of sustainability are interdependent and they interact and the Social Sustainability Index should be considered as the priority to be improved. However, it was also found that for the long term, if the Environmental Sustainability index needs to be improved, the best way is to improve the Economic Sustainability index, not the Environmental Sustainability index itself, which proved the importance of the interactivity principle of systems thinking. As a result, the Long-Term Influence Theory is proposed as:

> *In order to improve the performance of an element/sub-system in a system in the long term, stimulating the element /sub-system directly may be not the best way and it may be better to improve the other elements/sub-systems. This is because a dynamic and complex interrelationship exists among the elements/sub-systems within a system and the influence level and direction between the elements/sub-systems may be different in the long term.*

9.4 Contributions of this study

This PhD study contributes to the body of knowledge on the construction industry in several ways. A number of theoretical and practical contributions will result from this research.

9.4.1 Theoretical contributions

Firstly, a new method for measuring a certain country's construction industry development level and position in the international market is proposed. It is named the International Advanced Index (IAI). It includes three sub-indexes and they are Depth Index (DI), Height Index (HI) and Width Index (WI). IAI overcomes the problems in unidimensional and complex measurements successfully. This study compared the status and level of the Chinese and the Australian construction industries by using the IAI and proposed that the Chinese construction industry should be involved in a greater number of construction fields (diversification) or improve the level of activity in each involved field (specialisation). Compared with the previous models, this study illustrated that the IAI is more comprehensive in reflecting the status and level of a country's construction industry in the international market. The index also provides a method to access and use data that is more readily available yet is still rigorous and robust.

Secondly, a new method for measuring industrial competitiveness is introduced in this research. As the most internationally recognised Multi-factor comprehensive evaluation methods for industrial competitiveness, Porter's Diamond Model has been debated by many researchers since it was first proposed. Some concerns are addressed by various scholars. In order to solve the problems, some scholars provide two types of suggestion for revising Porter's Diamond Model including: modify the elements within the model and double the diamond. Dunning (1993) and Cho and Moon (2000) state the activities of multinational enterprises should be included in the industrial competitiveness model. However, it has not been tested quantitatively. This study tested it by exploring the relationship between the degree of internationalisation and the performance at a construction firm and a country level. The results indicated that the activities of the multinational enterprises could be included in the international competiveness model and is considered a determinant factor.

In addition, in order to test 'the activities of multinational enterprises' a new method for measuring the degree of internationalisation is proposed in this research. The early researchers adopted unidimensional measurement methods. The concerns of this type of measurement can be summarised in terms of the method's lack of rigor in the specification and operationalisation of the concept of internationalisation. There have been various attempts to develop a multidimensional measurement for internationalisation. Most of the methods developed have been used for measuring a firm's degree of internationalisation in various industries in a generic manner. However, different industries have different and unique characteristics, and for this reason it is more beneficial to generate a measurement method which is tailored to suit the unique characteristics of the construction industry. Low and Jiang (2003) refined the Dunning's (1977, 2000) 'Eclectic paradigm' through simplification and quantification based upon the nature of international construction activities to generate an OLI-S model to determine a firm's degree of internationalisation. Low and Jiang's OLI-S model states that the diversification strategy may offer a better opportunity for enterprises to develop and be involved in the international market. However, both the diversification and specification strategies may help enterprises occupy more market share and achieve increased profits in both domestic and international markets. Through a combination of Low and Jiang's improvement and a removal of the S-ISF concept, this research developed a 'reformative OLI model' (ROLI Model) to measure the degree of internationalisation of construction enterprises at a firm level. The Average O-IRTR (A-O), Average L-IBD (A-L), Average I-OMS (A-I) and Total DOI (T-DOI) indices were also generated to measure the degree of internationalisation of construction enterprises at a country level.

Moreover, a very important element, sustainable development, has been missed in discussion of industrial competitiveness until now. By elaborating the concept of sustainable development and analysing the relationship between sustainable development and industrial competitiveness, the researcher believes sustainable development should be added into Porter's Diamond Model as a determinant factor. After reconsidering the development of other scholars in this field, this research re-formed Porter's model to reflect the current requirements and development of the world, and generated a new model to measure industrial competitiveness, called the Internationalized Sustainable Industrial Competitiveness Model (ISIC Model). There are eight elements in this model including: factor conditions, demand conditions, firm strategy, structure and rivalry, related and supporting industries, government, chance, activities of multinational enterprises and sustainable development. Seven of them are the determinants. Chance is the only external element.

Furthermore, a new method for measuring sustainable development was generated in this research. A number of sustainability assessment frameworks have been used to evaluate a firm's performance. However, these frameworks cannot be used to measure the industry or country level performance in sustainability. Some countries and international organisations also develop indicators for measuring sustainable development. However, some of the indicators in these index systems are difficult to locate. At times it may require several years and a large amount of information gathering. In addition, the fundamental target of the construction industry is to achieve sustainability as well as to play a key role as an economic driver for the society. However, some of the indicators mainly focus on the environmental and social issues. Furthermore, these indicators should be revised according to different industry characteristics. A sustainable development index system was generated to measure the construction sector by Zhang and London in 2011, which considered the nature of the construction industry, data availability and other performance indicator systems which have been proposed previously. The sustainable development index system is composed of three sub-elements including economic sustainability, social sustainability and environmental sustainability.

By conducting the Degree of Coordination and Multivariate Cointegration analysis, it indicated the three sub-elements of sustainability are interdependent and they interact. In the long term, if the Environmental Sustainability Index needs to be improved, the best way is to improve the Economic Sustainability index, not Environmental Sustainability index itself, which proved the importance of the interactivity principle of systems thinking and the Long-Term Influence Theory is proposed.

9.4.2 Practical contributions

Firstly, this research reviewed the phases of the Chinese construction industry in both the domestic and international markets and identified that the gap between the Chinese construction industry and the Australian construction industry is the Width Index by using the International Advanced Index. Therefore, the strategies for the Chinese construction industry is proposed, that is involvement in a greater number of construction fields (diversification) or improving the level in each involved field (specialisation).

Next, this research discussed the performance of the Chinese and Australian construction industries and analysed its development in productivity and industrial competitiveness in recent years. By comparison between these two countries, the aspects of the Chinese construction industry that lagged behind the Australian construction industry are identified. It points out the direction for formulating future strategies, without being confused by the achievements identified by the horizontal comparison.

In addition, based on the interactivity principle of systems thinking, by conducting the multivariate cointegration analysis and compared with the Australian construction industry, the direction of improving the sustainability of the Chinese construction industry is identified, which is the Social Sustainability Index.

9.5 Limitations and further study

Although this research has reached its aims and achieved the research objectives, there are unavoidable limitations and shortcomings because of the time limit and data availability. Firstly, when the relationship between degree of internationalisation and a construction firm's financial performance was explored, 25 multinational construction enterprises from six countries were analysed. One of the key reasons to select them is the issue of the period of the financial year. The U.S. companies performed well in the international market, however, they were not included in this analysis because of the period of financial year. Moreover, the period of the financial year is different in China and Australia. For the same reason, when conducting the comparison between the Chinese and the Australian construction industries in productivity and industrial competitiveness, this research adopted the data of the Chinese construction industry in 2010 and the data of the Australian construction industry in 2009-10.

Next, because some data are not available, this research estimated the reasonable amount, which could be different with the real amount. For example, there is no public data for construction waste in China. A widely acceptable measurement for the construction waste is that it accounts for about 30% to 40% of consumption waste. This research adopts 35% to measure the construction waste from consumption waste.

Moreover, the data sourced from Engineering News Record (ENR) was adopted in this study. The quality of the data depends on the willingness of firms who wish to participate in the ENR's survey. If some firms do not wish to participate, the data will be different. For example, because the British contractors Trafalgar House PLG in 1996 and Kvaener Groupand Bovis Construction Ltd in 1999 did not participate in the ENR survey, the data changed dramatically. In addition, the authenticity of data depends on the firms' honesty. The country that the construction enterprise is attributable to is determined by the construction company's registration places. However, because changes in equity, joint ventures, and mergers and acquisitions occur frequently in the international market, the data from ENR may not reflect these activities timely and comprehensively.

In addition, because of the research aims and objectives, this research only identified the difference in productivity and industrial competitiveness between the Chinese and the Australian construction industries in recent years and the problems which should be paid more attention to and the general direction of the future development of the Chinese construction industry. However, specific strategies and policies need to be further explored. For example, improving the Social Sustainability Index was identified to be the priority for improving the sustainability of the Chinese construction industry in the long term. The strategies to improve this index should be explored in the future.

Furthermore, the performance of the Chinese and the Australian construction industries is similar in some aspects. It does not mean that the Chinese construction industry can 'sit back and relax', because this result is only achieved by comparison with the Australian construction industry. These similar aspects are also worthy of further study. For example, when the market structure (industrial concentration ratio) was discussed, the CR_4 of the Chinese and Australian construction industry in 2010 is 16.81% and 19.79% respectively.

They are quite similar and both located in the group of 'Competition'. The higher concentration ratio indicates the higher level of monopoly. Monopolisation could cause the reduction of competition and efficiency of the industry, and it is not conducive to the development of the industry. However, the low industry concentration ratio is not always a good thing for the Chinese construction industry (Li, *et al.*, 2001; Liu, 2000; Qiu, 2010 and Yang & Li, 2008). According to Qiu (2010), many disadvantages could be caused by the low industry concentration ratio for the Chinese construction industry including:

1) The low industry concentration ratio is not conducive to reduce production costs and develop economies of scale.
2) The low industry concentration ratio is not conducive to the optimal allocation of resources.
3) The low industry concentration ratio could reduce the dominance of the Chinese construction industry in the international business cooperation.
4) The low industry concentration ratio is not conducive to the role of national macro-control.
5) The low industry concentration ratio cannot improve the general contracting capability of the Chinese construction enterprises.

Therefore, it is a meaningful future research topic to explore the relatively suitable industry concentration ratio for the Chinese construction industry.

9.6 Final concluding remarks

This research developed theories in relation to a certain country's construction industry development level and status in the international market and the industrial competitiveness of the construction industry. Some new models were generated, including International Advanced Index, ROLI Model, the Internationalized Sustainable Industrial Competitiveness Model and Sustainable Development Index. The importance of the interactivity principle of systems thinking is proved and the Long-Term Influence Theory is proposed.

This research explored the performance of the Chinese and the Australian construction industries in both the domestic and the international markets. Next, the developments of the Chinese and the Australian construction industries in productivity and industrial competitiveness were explored and compared. In addition, the differences in productivity and industrial competitiveness between the Chinese and the Australian construction industries in recent years were identified. Furthermore, the possible way to increase the sustainability of the Chinese construction industry compared with the Australian construction industry in the long term was explored. The improvement of the Social Sustainability Index of the Chinese construction industry should be considered as the priority.

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