UNIVERSITY OF WARWICK

AN ECONOMETRIC MODEL FOR MANUFACTURING STRATEGY FORMULATION AND COMPETITIVENESS IN CHINA

(Innovation Report)

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ABSTRACT

This report summarizes the contents in Submissions 1-4 and divides them into 7 chapters. These are introduction, literature review, methodology, the system dynamics model, the balanced scorecard, multiple regression models, and forecasting models. As this report mainly focuses on the assessment of manufacturing competitiveness in China, findings on the balanced scorecard for manufacturing competitiveness and various key econometric models are discussed in greater detail. On the other hand, the system dynamics model providing support to the development of the balanced scorecard is presented in brief in this report; please refer to Submission 4 for further details if necessary.

Furthermore, this report highlights the main innovation and originality of this study. A two-stage analysis methodology as a novel and original approach to examine the formulation of manufacturing strategy is discussed. The value and significance of this study, in terms of the literature, the manufacturing industry, and the author's company - TTI, are also explained. A concluding chapter is given in the end.

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ABBREVIATIONS AND SYMBOLS

... and -: Not applicable or not available

$ and dollar: US dollars unless otherwise specified

0: Figure is zero or become zero due to rounding

AC: Auto-correlation

ACF: Auto-correlation Function

AIC: Akaike Information Criterion

ADB: Asian Development Bank

ANOVA: Analysis of Variance

APEC: Asia-Pacific Economic Cooperation

AR: Auto-regression

ARIMA: Auto-regressive Integrated Moving Average

ASEAN: Association of Southeast Asian Nations

BSC: Balanced Scorecard

CIS: Commonwealth of Independent States

CPI: Consumer Price Index

DW: Durbin-Watson

EIU: The Economist Intelligence Unit

EU: European Union

FDI: Foreign Direct Investment

FIE: Foreign Invested Enterprise

FOE: Foreign Owned Enterprises

GDP: Gross Domestic Product

H1 and H2: 1st half year and 2nd half year

HKMA: The Hong Kong Management Association

IMF: International Monetary Fund

NAFTA: North American Free Trade Agreement

MA: Moving Average

MNC: Multi-National Corporation

NIE: Newly Industrialized Economy

OECD: Organization for Economic Cooperation and Development

PACF: Partial auto-correlation function

Q1, Q2, Q3 and Q4: 1st quarter, 2nd quarter, 3rd quarter and 4th quarter

RMB: Renminbi or Yuan

SC: Schwarz Criterion

SD: System Dynamics

SSE: Sum of Squared Error

SSR: Sum of Squared Residuals

US: United States

USD: US Dollar

WTO: World Trade Organization

1. Introduction

1.1 An Overview of China’s Manufacturing Industry

In the recent past, due mainly to the low-cost labour markets that are a feature of Asian countries, traditional manufacturing has moved to Asia to take advantage of the low-cost production base the region offers. This has resulted in a “China effect” (Takala *et al*., 2007). Under this “China effect”, many manufacturers have sought to leverage the low cost of labour and materials to improve their competitiveness through low production costs, while various firms have been attracted by the large domestic market China offers and invested in China accordingly. Since the early 1990s, China has allowed foreign investors to manufacture and sell a wide range of goods on the domestic market and authorised the establishment of wholly foreign-owned enterprises. China’s emphasis on channelling foreign direct investment (FDI) into the manufacturing sector has made China the “world’s factory”. China is now the leading recipient of FDI in the world, receiving almost $80 billion in 2005 according to World Bank statistics (2007a). Partly as a result of the strong boost given by FDI, China’s economy has grown vigorously at a rate of around 10% per annum, and its manufacturing industry has expanded robustly. Most things nowadays seem to be made in China. China is widely considered the global centre of manufacturing, whilst its rise in status within Asia and more widely has made China a highly integrated member of the global economy.

In spite of the country’s recent economic progress, commentators have recently expressed concerns about the Chinese economy, RMB appreciation, the shortage of skilled labour, increasing production costs (in terms of both labour and materials), and competition from other emerging economies (including India, Vietnam, Indonesia, Thailand, the Philippines, and

Malaysia). These qualms are supported by the news that 67,000 small and medium-sized enterprises were closed in China in the first half of 2008 (The Epoch Times, 2008). Furthermore, although many global firms have vast facilities in China, some have nevertheless chosen other Asian emerging countries for their latest investments. For example, Intel spent US$350 million building a new factory in Vietnam in 2006, Flextronics, a contract electronics manufacturers, has invested US$110 million in its latest production site in Malaysia to supply goods for Hewlett Packard, and Yue Yuen, a shoemaker for brands including Adidas and Nike, has increased its production output in its Indonesian factory rather than in its Chinese factory (The Economist Newspaper Limited, 2007c). This phenomenon shows that some firms are limiting their investments in China and moving their production sites elsewhere, and appears to show that China is no longer necessarily considered the best production base.

1.2 Challenges to China's Manufacturing Industry

According to FHKI (2007), Hong Kong-funded enterprises have established about 55,200 manufacturing enterprises and 57,500 factories in the PRC, and up to half of the manufacturing enterprises located in the PRC have a Hong Kong connection. These figures indicate that China is considered a suitable manufacturing base for investment with advantages over other countries, a view held especially among Hong Kong-based companies due to the geographical proximity of the mainland. However, as shown by recently voiced concerns about China's overheating economy, there is a worry that these buoyant figures may have peaked. In the first half of 2007, China's GDP growth (11.5%) and CPI (6.5%) reached their highest points for a decade, and the Chinese currency has been appreciating strongly. These developments strongly suggest that China's economy is overcooked. The evidence concerning the key symptoms of this problem in China has been described as follows.

- *Robust Economic Growth*

China's economy has grown at an average rate of 10% per annum since its economic reforms were initiated in 1978, representing the highest growth rate in the world. In more recent years, China’s economic growth rate has accelerated even further. Despite government attempts to cool down the economy, China's GDP grew by 10% in 2003, even faster in 2004 at 10.1%, the growth rate moving inexorably upwards to 10.4% in 2005 and 11.1% in 2006 (EIU, 2007a).

- *An Exceptionally High Inflation Level*

  What seems to be an uncontrollable rise in Chinese inflation is causing concern. In particular, the CPI rose by 3.9% in the period from January-August 2007, exceeding the 3% target set by the central bank for the same year. Worse still, the inflation rate jumped to 6.5% in August 2007, up from just 1.3% in 2006 (ADB, 2007a; The Economist Newspaper Limited, 2007a), and the highest rate for more than a decade. Although some argue that the high inflation rate is mainly due to the rise in food prices, which themselves have been caused by supply-side problems (The Economist Newspaper Limited, 2007b), the exceptionally high rate nevertheless appears to be a symptom of an overheating economy in China. This is because it is difficult for China, given its runaway GDP growth rate, to fight inflation by raising interest rates or appreciating the Chinese currency without causing even more generalised inflationary pressures.

- *Swift RMB Appreciation*

  One notable feature of China’s overheating economy has been the recent sharp appreciation in the RMB. Indeed, RMB appreciation has been a response to rising pressure from the US, which could culminate in extensive measures designed to restrict Chinese exports to the largest economy in the world. According to statistics (EIU, 2007b; The World Bank, 2007a), the rate of RMB appreciation against the US dollar is generally expected to continue at around 4.3-5% in 2007 and 2008, respectively, and will slow to a pace of around 4% in subsequent years.

Due to the pressure it faces from various quarters as a result of its overheating economy, China's government has been taking steps to cool it down; however, the GDP growth and inflation rates remain high, and RMB appreciation seems to be growing out of control. These problems are anticipated to continue beyond 2008 and for a number of years hence. As a result, firms from around the region are likely to be limiting their investments in China, injuring its business sector, manufacturing industry, and trade prospects. Since FDI accounts for a large proportion of investment in the manufacturing industry, manufacturing prospects will probably be hit hard by the overheating economy. Apart from the major symptoms outlined here, Submission 1 identifies other challenges to the manufacturing industry in China.

1.3 Company Background

1.3.1 Corporate Profile of Techtronic Industries Co. Ltd.

Techtronic Industries Co. Ltd. ("TTI" or "the Group") is a market and innovation leader in power equipment products, floor care appliances, and laser and electronic products. TTI has a powerful portfolio of trusted brands which are recognised for setting new standards in innovative design, technical advancements, marketing concepts and speed-to-market. The portfolio of global brands include Milwaukee®, AEG®, Ryobi®, Homelite®, Hoover®, and Stileeto® for power equipment products, and Ryobi®, Dirt Devil®, Regina®, Vax®, and Hoover® for floor care appliances.

TTI products are marketed through home centres, major retailers, full-line tool distributors and other channels in North America, Latin America, Europe, and other selected markets. TTI is also the preferred partner of leading OEM brands and private label retail brands globally.

TTI has moved from being a supplier on an OEM basis to an integrated group that owns leading brands in each of its core businesses as a result of its successful acquisitions and global expansion activities over the years. TTI's main manufacturing base is located in China.

Headquartered in Hong Kong, the Group recorded sales of HK$26.6 billion in 2008.

1.3.2 The Driving Forces Behind TTI

TTI seeks to improve performance in its targeted businesses by delivering consistent value to its customers and shareholders through the four following strategic driving forces.

- *Powerful Brands*

  Leading brands hold the power in the marketplace, so brand investment is required to acquire market power. Time-tested performance delivers brand loyalty, which creates the ability to maintain strong margins and favourable retail placement.

- *Innovative Products*

  Innovation is considered the fuel for sustained profitability and growth. TTI strives to achieve its goal of higher value brands and products through innovative product development focused on creating and matching end user demand.

- *Exceptional People*

  TTI continues to invest in and promote talent. Its people, from those at the senior management level to individuals who work on the factory floor, have the passion, skill, and combined intellectual capital to drive it to the number one position in its target markets.

- *Best Cost*

  Being number one means executing at the highest level, having the most competitive cost structure, and delivering the best value in every aspect of business. TTI is passionate about driving efficiencies at all levels of its business through its continuous improvement programmes (CPI), global procurement activities, and supply chain management.

These strategic focuses contribute to TTI's success, as witnessed by its turnover of US$2.8 billion in 2006 and US$3.2 billion in 2007 and its 12 consecutive years of profit growth.

1.4 Project Objectives

The challenges recently faced by the Chinese manufacturing industry are challenges to which TTI (which is a Hong Kong-based company with a factory located in China) is not immune. This study is designed to address the following four research questions faced by companies considering investing in China and to explore the profitable manufacturing strategies such companies can adopt.

(1) Is China still a favourable and competitive destination for manufacturing investment compared with other Asian countries (including India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam)?

(2) How do investment activities act as a major driving force influencing China's manufacturing growth?

(3) Is China's overheating economy affecting its manufacturing industry? If so, how?

(4) How are the important factors examined in research question (1) likely to play out over the coming five years?

Due to recent interventions by various governments in a number of aspects of the global economy in response to the financial crisis that originated in the US, the author also examines the following research question to adjust the findings of this study (which was initiated before the financial crisis) as necessary and explain the dynamic effect and substantive impact of the financial crisis on China's manufacturing industry.

(5) How does the global financial crisis influence China's manufacturing industry?

This study aims to develop various models to address the above research questions. The results of this study will assist firms to investigate and formulate competitive manufacturing strategies in China through the use of an effective methodology that involves a two-stage analysis. The model development in this project is novel and original that makes this project valuable and innovative. Firms can practically make use of the models developed to strategically manage their manufacturing operations and decision-making processes, particularly for decisions pertaining to plant investment, in an effort to achieve success in what is a highly competitive business environment.

1.5 Outline of this Study

This executive summary is divided into nine chapters that discuss the environment surrounding the manufacturing industry and the formulation of manufacturing strategy.

Chapter 1 introduces the environment surrounding the Chinese manufacturing industry, examines the challenges faced by TTI and other manufacturing firms, describes TTI's background and the objectives of this study, and presents the outline of the rest of this paper.

In **Chapter 2**, the methodology proposed including the study approach, portfolio of research work, data collection method, computer applications, and model development procedures to be used, are described.

Chapter 3 provides evidence on the link between China's economic factors (including the overheating economy) and its industrial activities, discusses the elements of manufacturing strategy and the determinants of investment in China's manufacturing industry, and reviews the economic and manufacturing determinants/variables used in econometric models in the existing literature.

Chapter 4 reveals the results of the system dynamics model constructed. This system dynamics model provides for a better understanding of the economic and manufacturing environment, thereby supporting the identification of factors to be used in developing the balanced scorecard subsequently discussed.

Chapter 5 discusses the key balanced scorecard developed to assess manufacturing competitiveness. This balanced scorecard helps to assess manufacturing competitiveness across key Asian emerging economies, including China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam. The results of the balanced scorecard are analysed and used to support decision-making, particularly for decisions pertaining to plant investment.

Chapter 6 discusses the model estimation and the results and analysis of the four multiple regression models constructed. The causal relationships among economic and manufacturing factors are examined using these econometric models.

Chapter 7 discusses the results of and analyses the five forecasting models, of which four are developed using Holt-Winters exponential smoothing and the other is established through ARIMA analysis. Furthermore, an ARIMA intervention time-series analysis model is constructed. These models are used to predict the growth of China manufacturing activities, and analyse the impact of the financial crisis on China's manufacturing industry.

Chapter 8 highlights the original features and contributions of this study.

Chapter 9 concludes the paper by summarising the key findings of this study and suggesting how it could be extended by further research.

2. Literature Review

2.1 Overview

The literature review presented in this study is divided into two parts.

- *China and Global Economic Review*

  Economic, trade, and manufacturing developments are reviewed from both a global and developing Asia perspective, particularly those relating to China. The review identifies the major factors influencing manufacturing activities and their development.

- *Manufacturing Strategy*

  In this section, the author reviews the generic forms and evolution of manufacturing strategy, as well as the key components and determinants considered in the formulation of manufacturing strategy. This section also outlines the literature on econometric models for manufacturing strategy, system dynamics, and balanced scorecards.

2.2 China and Global Economic Review

2.2.1 Links between Economic Factors and Manufacturing Activities

The statistics cited in the previous chapter clearly indicate that China's overheating economy is likely to remain a problem in coming years. As such, the impact of the unhealthy aspects of the Chinese economy cannot be overlooked, especially when their likely impact on manufacturing growth is considered. This is because economic growth, trade growth, and FDI in China are closely correlated and all have direct relationships with manufacturing activities. Joseph (1999) emphasises that understanding the macro environment in terms of industrial background is an essential and fundamental prerequisite to formulating an appropriate manufacturing strategy. However, the existing literature on the relationship between macro factors and manufacturing strategy is limited. This study seeks to elaborate on and analyse the links between economic factors and manufacturing activities using statistics and the proposed model.

Due to China's surprisingly robust expansion in recent years, many international investors have adjusted their Chinese growth expectations upwards. For instance, in 2007, the National Bureau of Statistics raised its estimate of China's 2006 growth rate from 10.7% to 11.1% (China Daily, 2007). The National Bureau of Statistics also revised its total output estimate for 2006 by $18.8 billion to $2.705 trillion (China Daily, 2007). In the year to the second quarter of 2007, economic and industrial activities in China remained buoyant, with a dizzying growth rate of 11.9% (The Economist Newspaper Limited, 2007a). The similarity of these figures implies that Chinese economic growth and industrial activities are linked.

One factor that has contributed to China's buoyant economy is FDI. Supported by steps taken to liberalise trade and investment policy reforms, foreign-invested firms have been encouraged to invest in China. In 2005, China was the leading recipient of FDI in the world, receiving almost $80 billion (The World Bank, 2007a). Importantly, China's emphasis on channelling FDI into the manufacturing sector has made China the "world's factory". Various economic models show that China's low wages and quality of labour are important determinants of FDI in its manufacturing and trade sectors (Fung *et al.*, 2002a; 2002b). These models further confirm the link between FDI growth and Chinese manufacturing activities.

The massive inflow of FDI China has seen in recent years has coincided with sharp growth in exports of products manufactured by foreign-invested firms. Such exports grew from 12.5% of all Chinese exports in 1990 to 31.5% in 1995 before rising further to 48% in 2000 (Wei and Liu, 2001). China's total trade balance jumped from $32 billion in 2004 to $177.5 billion in 2006

(The World Bank, 2007a). This has not only made China the world's third-largest trading nation after the US and Germany, but has also supported the country's regional rise and its integration into the global economy. China's economy, manufacturing output, and exports have generally grown at a similar pace over the last decade or so, the expansion seen across a broad range of indices ensuring China is now regarded as a global manufacturing base.

The economic factors discussed above, and the overheating problem in particular, have certainly influenced China's manufacturing sector, including its growth, investment levels, output, and exports. Further details on these and other economic factors related to the manufacturing industry are given in Submission 2. Given that the weaknesses of China's economic situation have now been signalled and appear likely to continue in the years to come, it would be valuable for manufacturing firms and investors to identify and gain insights into the likely impact of these weaknesses on the manufacturing industry. This will help them to improve their businesses and fine tune their manufacturing strategies.

2.2.2 The Determinants of Manufacturing Investment in China

Since its accession to the WTO, China has endeavoured to attract FDI through trade liberalisation and investment policy reforms to its manufacturing sector. China has been the leading recipient of FDI in the world since 2005 (The World Bank, 2007a). Fung *et al*. (2002a) demonstrate that direct investment in China, particularly from Hong Kong firms, has largely been attracted by the low wages paid in the mainland. China's booming domestic market has also come to be regarded as an important determinant of FDI as foreign companies seek to expand their trade activities and markets. Furthermore, the geographic proximity of China and the production-sharing network that is particularly pronounced among China, Hong Kong, and Taiwan, have also led to an inflow of direct investment from China's neighbours (Naughton

1997, Roach 2003). As discussed previously, offering a manufacturing capability that is both flexible and innovative should be the long-term competitive priority in the industry; however, most manufacturers in developing countries, including China, are still stuck in the imitation and technology learning stages. To enhance its competitiveness and absorptive capacity, China has lowered its tariff and non-tariff barriers to foreign investors to bring in best practices, technology transfers and readiness, new skills and knowledge, and products of superior quality. Nevertheless, China has to improve the availability of skilled manpower and satisfactory infrastructure to promote its ability to realise technological innovations (Tham, 2001). Infrastructure practices also play an important role in plant competitiveness (Ahmad *et al.*, 2003). These studies indicate that trading conditions and infrastructure (in terms of the regional and international production network) are the determinants of manufacturing investment inflow; this study therefore includes them in its measures of manufacturing competitiveness.

Recent economic studies also support the view that due to the growing importance of intra-regional production in Asia, FDI in China is complementary to direct investments made in the country's neighbouring economies, including Hong Kong, Taiwan, Singapore, Korea, Thailand, Malaysia, the Philippines, and Indonesia (Chantasasawat *et al*., 2003a; 2003b). This implies that China is not only viewed as a low-cost production site, but also as a central region for the development of a global supply chain whereby it imports and exports its products through affiliates. This also facilitates the development of dispersed manufacturing chains in an effort to minimize the global costs of production. Please refer to Submission 2 for further details.

Because FDI is the key driving force behind the manufacturing industry in China and other developing countries, this study will not only measure and compare China's manufacturing competitiveness with six other Asian emerging economies (India, Indonesia, Malaysia, the

Philippines, Thailand, and Vietnam) using a balanced scorecard, but will also investigate how investment activities in China affect its manufacturing growth using multiple regression analysis.

2.3 Manufacturing Strategy

2.3.1 The Elements of Chinese Manufacturing Strategy

Many studies that examine the formulation of manufacturing strategy in China investigate competitive capabilities, strategic choices, manufacturing clusters, generic manufacturing strategies, and similar variables in an effort to explore the key factors influencing strategy. Prior studies recommend that these factors be considered by firms that seek to improve their manufacturing competitiveness in the global market. Skinner (1969; 1974) identifies four important competitive capabilities for manufacturing firms: cost, quality (in terms of conformance and performance), time/speed (of production and delivery), and flexibility (which refers to new product, product mix, volume flexibility, innovation, and technology), suggesting that they be traded off against each other in formulating manufacturing strategy. This approach is widely endorsed in the literature (Hayes and Wheelwright, 1984; Ferdows and DeMeyer, 1990; Schmenner and Swink, 1998; Ward *et al*., 1998). Robb and Xie (2003) have subsequently refined competitive capabilities into value (i.e. cost with a quality objective), speed (production and delivery time), flexibility (function and volume flexibility), and innovation (new product, new product development time, and product mix flexibility). This set of capabilities explicitly indicates that cost on its own does not deliver enhanced competitiveness and that innovation is now regarded as a more significant factor.

Some studies indicate that distinct manufacturing clusters often place an emphasis on competitive capabilities. This may be because aligning competitive capabilities/priorities is a kind of manufacturing attainment, as advocated by Hill and Chambers (1991), Gerwin (1993), and Upton (1995). Figure 1 summarises the findings of several studies, describing the evolution and significance of the different manufacturing clusters suggested. The clusters applicable to manufacturing strategy are formed by different combinations of competitive capabilities. For example, the mass customizer and mass server clusters take quality, time, and flexibility into account; the marketer and market-oriented clusters focus mostly on cost, quality, and time; and the innovator and starter clusters emphasise the capabilities of flexibility and innovation. The studies in which these clusters and their characteristics are identified indicate that the competitive priority of cost is comparatively minor in the manufacturing strategy formulation context, and that quality and time/speed are now the focuses, with flexibility being a long-term capability objective. Chandra (2002) and Huang *et al*. (2005) support the view that improving conformance quality, product reliability, and fast delivery have been the top three competitive priorities of Chinese and Indian firms in recent years and will remain so in the coming five years, while Chryssolouris *et al*. (2008) state that production flexibility and automation are and will be increasingly important to firms, as they allow manufacturers to produce more with less. Tseng *et al.* (1999) explicitly indicate that total quality management is a necessity, especially for the manufacturing industry in China, as it allows firms to make technological changes and adopt innovative strategies. It is widely believed that manufacturing industries, primarily those in developing countries, have to shift from labour-intensive sectors to technology-intensive and capital-intensive sectors in the long term. This shows that R&D and innovation activities are two aspects of manufacturing that should not be overlooked.

	Clusters of Manufacturing Strategy			
Dimensions / Author(s)	Cost → Quality and Time/Speed → Flexibility			
	Significance			
Porter (1985)	Cost leadership	Differentiation		Focus
DeMeyer (1990)	-	Market-oriented group	High performance product group	Manufacturing innovator
Sweeney (1991)	Quick fix	Stretch	Catch up	Breakthrough
Miller and Roth (1994)	Caretaker	Marketeer	-	Innovator
Kathuria (2000)	Do all	Speedy conformer	Efficient Conformer	Starter/First mover
Frohlich and Dixon (2001)	Idler	Designer	Server	Mass customizer
Zhao *et al.* (2006)	Low emphasizer	Specialised contractor	Quality customizer	Mass server

Figure 1 A classification of the clusters of manufacturing strategy

Turning now to generic manufacturing strategies, Stovaugh and Teleslo (1983) classify them into three types: cost-based, market-driven, and technology-driven. These generic manufacturing strategies are extensively adopted by international manufacturing firms (Mills *et al*. 1995). Indeed, they are physically characterised by the competitive capabilities and clusters discussed above. In the “China effect” of the past, which was triggered by the benefits of low-cost production, it is clear that most manufacturing firms investing in China generally adopted a cost-based strategy. This is because it was straightforward for manufacturing firms to execute, particularly with the support of the abundant low-cost labour force in China. In what is nowadays a knowledge-based economy featuring rapid technological acquisition and dynamic customer requirements, manufacturing firms cannot now simply adopt a traditional cost-based strategy and expect to enjoy this low-cost benefit over the long term to maintain their global competitiveness. Instead, firms have to make technological progress and gain insights into market dynamics to pursue a high-value manufacturing capability that encompasses innovation and R&D, international technology transfers, intellectual property protection and licensing, and product customisation. To continuously enhance industrial value, manufacturing firms should formulate their manufacturing strategies using a twofold approach: market and technology. They should attach importance to value, time/speed, flexibility, and innovation and technology, rather than purely to cost. Chang *et al*. (2003) indicate that harmony between manufacturing flexibility (including innovation) and business strategy is critical to business performance. Maintaining manufacturing flexibility is thus regarded as the ultimate strategic goal of manufacturing firms as they strive for a competitive and advantageous position in the global market. This clearly explains why the competitive capability/cluster of cost has become increasingly insignificant, while other clusters, especially flexibility and innovation, have become considerably more necessary and substantial. This is why technology, R&D and innovation form part of the model the author uses to assess manufacturing competitiveness across countries. Furthermore, because market and technological know-how, as well as business efficiency and sophistication, are the essential drivers of expansion in global innovation reach (Fallah and Lechler, 2008), the author does not overlook these factors in this study as the author attempts to measure the full extent of countries' manufacturing competitiveness.

In addition to the above, strategic choices is another research area that has been examined in detail in the manufacturing strategy formulation context. The key extant studies in this area are reviewed and summarised in Figure 2, in which it can be seen that the development of manufacturing strategy has been reshaped through a fundamental stress on the following criteria:

workforce (in terms of labour/staff availability and quality), technology, product development, and market development. These criteria will also be taken into account in the manufacturing competitiveness assessment model. Submission 2 discusses Chinese manufacturing strategy in detail.

Author(s)	Findings on Manufacturing Choices
Skinner (1969)	Indicates the five key strategic choices: ● Plant and equipment ● Production planning and control ● Labour and staffing ● Product design and engineering ● Organisation and management
Hayes and Wheelwright (1985)	Add process and infrastructure to the lists of strategic choices mentioned by Skinner (1969).
Hills (1987)	Emphasises two key strategic choices: ● Structure in terms of operating process and technology ● Infrastructure, including human resources, quality systems, organisational culture, and information technology
Pun *et al*. (2000; 2004)	Explore the determinants of manufacturing strategy formulation for Hong Kong enterprises. The preferred strategic choices are: ● Product/service quality improvements ● Importing new technology ● Importing workforce ● Staff education and training ● New product development ● Production modification ● Market development ● Strengthening R&D

Figure 2 A review of the literature on manufacturing choices

2.3.2 *Econometric Models for Manufacturing Strategy*

A suitable model can reflect the manufacturing strategy under consideration and provide for a prediction of manufacturing capabilities so as to support judgments made in the strategy evaluation process (Baines *et al.*, 1998). The author uses econometric models to gain a better understanding of the links between the economic factors the author refers to earlier in this paper. Econometrics commonly takes account of the application of economic theory, mathematics, and statistical techniques used for testing hypotheses, estimating the coefficients of economic relationships, and forecasting economic phenomena (Salvatore and Reagle, 2001). Econometrics is often viewed as a form of regression analysis; however, time-series methods are supplementary to econometric models. In the present literature, many researchers analyse the performance of econometric models against time-series models (Box and Tiao, 1975; Makridaks and Hibon, 1979; Schmidt, 1979; Zobcr, 1981; Newbold and Granges, 1974; Geurts and Ibranhim, 1975; Hollier *et al.*, 1981; Poulos *et al.*, 1987). Indeed, which econometric method one selects depends on the particular purpose in mind and on the variables and data to be used in the model. Regression analysis is commonly used for studying the causal relationship between variables, whereas the time-series method is appropriate for forecasting time-series data. In addition, the simplest time-series method, exponential smoothing, often performs as well as complex time-series methods, such as Box-Jenkins ARIMA for time series with a trend. Hence, in this study it is better that the author uses the exponential smoothing method, rather than ARIMA, for time series with an obvious trend. However, as discussed by Ip *et al.* (1999), the ARIMA model can provide knowledge and insights into the behaviour of elements considered conducive to better decisions. For this reason, the author also applies the ARIMA model in this study. Please refer to Figure 3 for a comparison of relative strengths and weaknesses of econometric models.

Regression analysis is frequently used to investigate the correlation of variables affecting manufacturing strategy. Some empirical studies show that the growth of GDP, trade, and manufacturing are positively related to each other: higher economic activity at the global level causes acceleration in the expansion of world trade, as well as an increase in manufacturing outputs (Bensidoun *et al.*, 2002; Jeon, 2006). This finding offers substantial support to the above assertion that the symptoms of overheating and other economic factors in China impact China's manufacturing growth to some extent. Figure 4 summarises other literature on econometric models for the Chinese economy and manufacturing. These studies propose that factors such as export growth, the employment rate, GDP growth, the exchange rate, and the inflation rate, be included as determinants or variables in econometric models designed to examine the links between manufacturing and economic factors.

However, these models are incapable of fully investigating how the recent symptoms of an overheating economy in China influence manufacturing industry. This is because (a) the data used in these models is not recent and mostly excludes data from 2006-2007; and (b) the variables examined in most models are limited in number, usually including one dependent and one independent variable only, and thus failing to investigate the interrelationship between variables. Given the clear signals that the Chinese economy is suffering from overheating and the fact that this is raising much concern, this study enables manufacturing firms and would-be foreign investors to gain insights into this problem and formulate a more appropriate manufacturing strategy. For further details, please refer to Submission 2.

	Strengths	Weaknesses
Regression analysis	• Good at studying the causal relationship between variables	• Its forecasting model is considered inaccurate • A random error is often included
Exponential smoothing	• A simple method of adaptive forecasting • Performs well in forecasting time-series data with a trend • An effective way of forecasting when only a few observations are available	• Unable to examine the causal relationship between variables • Forecast based upon pas forecast errors
Box-Jenkins ARIMA	• Good at forecasting time-series data with fluctuations • Can provide knowledge and insights into the behaviour of elements considered conducive to better decisions	• A complex method that requires a certain amount of expertise in determining the most appropriate form of the model • Need a larger volume of data for the model development compared to exponential smoothing • Unable to examine the causal relationship between variables

Figure 3 A comparison of relative strengths and weaknesses of econometric models

Author(s)	Major Findings	Determinants/Variables
Yu (1990)	• Uses regression analysis to study manufacturing growth • National income produced in manufacturing is affected by the average volume of fixed capital in manufacturing, the average amount of labour in manufacturing, and the growth in national income produced in manufacturing with a one-year lag.	• National income produced in manufacturing • Average volume of fixed capital in manufacturing • Average amount of labour in manufacturing • Growth in national income produced in manufacturing with a one-year lag
Young (1991), Chuang (1997), and Rauch and Weinhold (1999)	• Countries that tend to specialise in high-technology skill-intensive goods experience more rapid technological progress and sustain higher rates of economic growth. • The index of specialisation is positively and significantly correlated with manufacturing productivity growth.	• Technology level • Production specialisation • Productivity • Economic growth
Lee (1997)	• Uses a time-series approach to model economic growth in the UK.	N/A
Feenstra and Rose (2000)	• Develop a procedure to order countries according to how soon they export ‘‘sophisticated’’ commodities to the US market. • The sooner a country exports to the US, the faster it grows.	• Exports • Economic growth
Bensidoun *et al.* (2002)	• Countries with an increasing share of international trade grow faster.	• Growth of exports • Growth of GDP

Jeon (2006)	● Uses regression analysis to analyse growth in China. ● A positive correlation between growth of GDP and growth of manufacturing. The faster the growth of manufacturing output, the faster the growth of GDP. ● Secondary industry has played a key role in the overall growth of Chinese GDP.	● Growth of GDP ● Growth rate of labour productivity in manufacturing ● Growth of labour employment in manufacturing
Xing (2006)	● Uses regression for econometric analysis. ● An appreciation of the RMB leads to a reduction in FDI inflows.	● Exchange rate ● Growth of FDI
Christopoulos (2007)	● Studies the impact of openness, terms of trade, human capital, and inflation on efficiency performance. ● The model involves econometric analysis and an indexing approach. ● Trade openness increases the efficiency performance of a country.	● Openness (ratio of exports to GDP) ● Terms of trade ● Inflation rate
Hua (2007)	● Builds an econometric model that uses regression analysis. ● Identifies a negative effect of the real appreciation of the RMB on manufacturing employment.	● Exchange rate ● Growth of employment in manufacturing

Figure 4 A summary of the literature on econometric models in China

2.3.3 System Dynamics and the Balanced Scorecard

System dynamics is a comprehensive and sophisticated approach that involves qualitative modeling and quantitative simulation, and is used to help firms gain a better understanding of their operating conditions, after which an appropriate policy can be designed and established. System dynamics can be used to develop a balanced scorecard using a modeling approach in which the root of the problem is simulated for analysis. In this study, a system dynamics model is built to deliver a better understanding of the interaction of the key economic factors and manufacturing determinants reviewed above. The key determinants and/or indicators related to manufacturing investment are then incorporated into the balanced scorecard the author develops.

3. Methodology

3.1 Study Approach

3.1.1 Research Framework

The author proposes using a ***two-stage modelling approach*** to study the formulation of manufacturing strategy and achieve the research objectives that have been set. This approach consists of two levels:

- *High Level*

  The factors that have an impact on the manufacturing industry are defined with the support of literature reviews and statistics. Their interrelationship is then structured by iThink® using a system dynamics approach. The system dynamics model used provides an overview of the interrelationship among the factors, which later supports the development of the balanced scorecard. A detailed balanced scorecard was developed initially to focus on the manufacturing area to assess a country's manufacturing competitiveness. The approach used to develop a balanced scorecard, which is based on a system dynamics model, is shown in Figure 5. Submission 2 contains a detailed review of the literature on system dynamics and the balanced scorecard.

- *Low Level*

  Further analysis is then carried out using multiple regression models to establish the relationship among various key manufacturing factors in China and gauge the significance of the major factors contributing to competiveness across the different countries. Time-series models such as Holt-Winters exponential smoothing and the Box-Jenkins auto-regressive integrated moving average (ARIMA) model are then developed using the EViews application to predict the major factors determining manufacturing competitiveness.

The framework of the study approach is exhibited in Figure 6, which indicates the aspects of literature reviewed (see Chapter 2 of this document and Submission 2 for more details) and the structure of this study. Submission 3 gives further details on the study approach adopted.

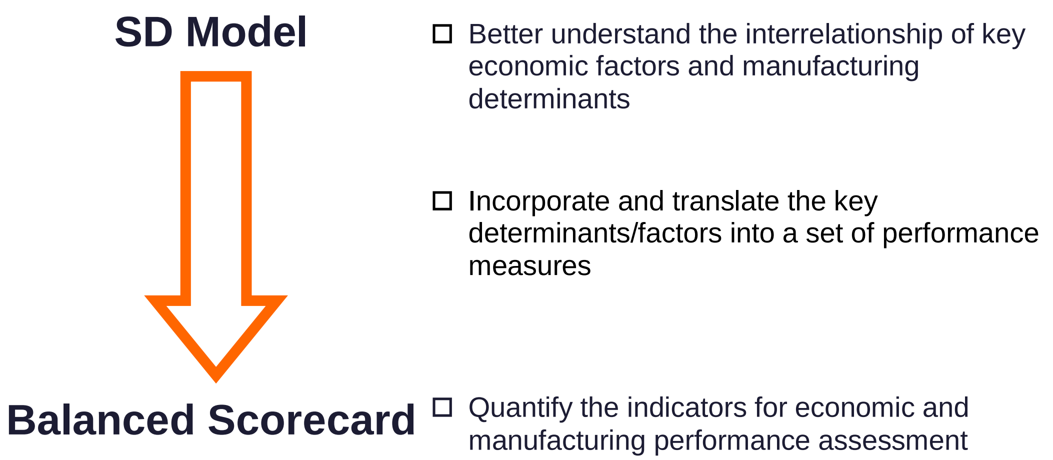

Figure 5 The approach used to develop a balanced scorecard based on a system dynamics mode

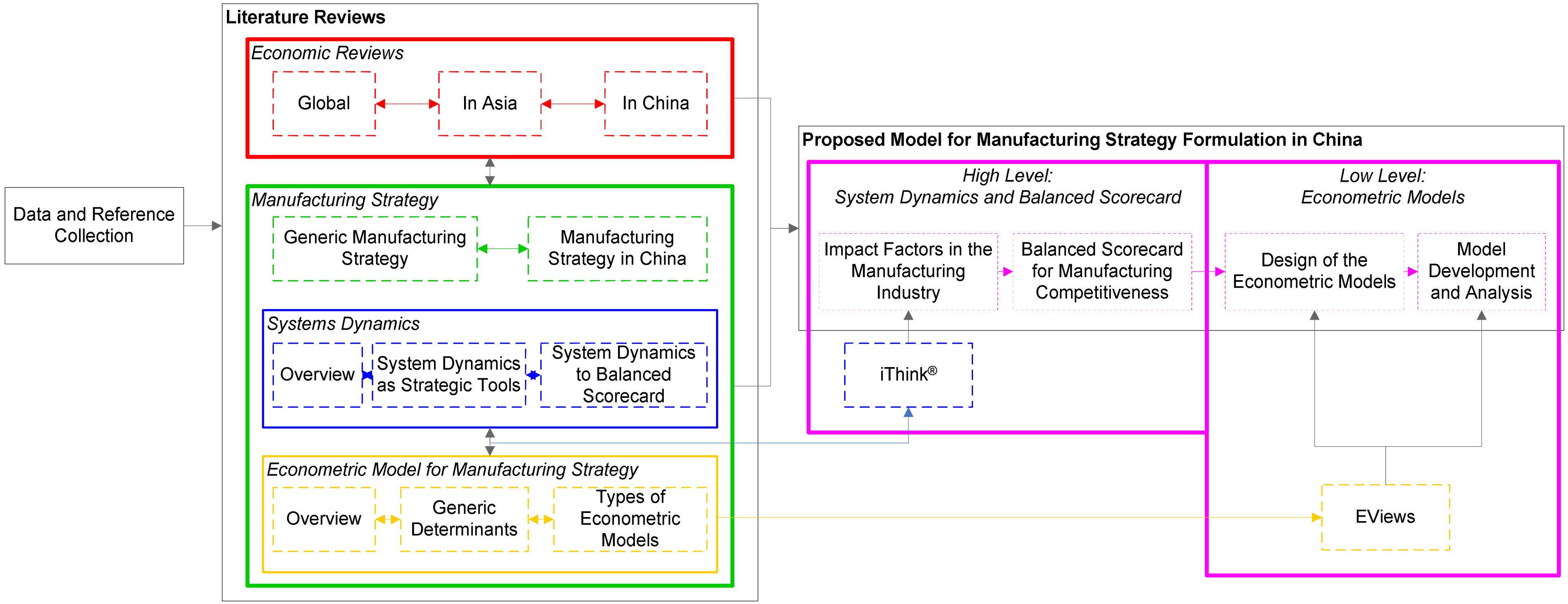

Figure 6 The framework of the study approach

3.1.2 Study Approach to the Research Questions

While a balanced scorecard is used to assess manufacturing competitiveness across different countries (i.e., to investigate research question (1)), the analysis is further developed by using a multiple regression model to establish the relationship among various key manufacturing factors in China and ascertain the significance of the major factor contributing to competitiveness across the different countries (in relation to research question (2)).

As regression analysis is the preferred approach for analysing the causal links between variables, it is also employed to investigate research question (3) in an effort to measure the impact of the recent challenges faced by the Chinese economy, such as RMB appreciation, inflation, and rising production costs in terms of both wages and raw materials, on the competitiveness of the country's manufacturing industry.

Moreover, time-series methods, including Holt-Winters exponential smoothing and ARIMA, are used to forecast the variables examined in the multiple regression models to answer research question (4). A model using ARIMA intervention analysis is also applied to investigate the impact of the global financial crisis on China's manufacturing industry. It is likely that this ARIMA-intervention model can be used to answer research question (5).

3.2 Study Portfolio

This study consists of the following four parts:

(1) An innovation report;

(2) A personal profile;

(3) A project report comprising the four following submissions on the major areas of research work carried out:

- Introduction and background, corporate profile, challenges and opportunities of the manufacturing industry in China, and objectives and project plan;
- Literature reviews on China and global economic review and manufacturing strategy;
- Research methodology covering the research framework, data collection, computer applications, procedures of the model development, and research plan; and
- The results and analysis of the balanced scorecards (for both country and manufacturing competitiveness) and of the econometric and time-series models, including regression models and forecasting models.

(4) 3 journal papers, of which two have been published and the other is currently going through the review process; these papers have been presented at various conferences and meetings.

The overall structure of this study portfolio and the corresponding research schedule are shown in Figure 7.

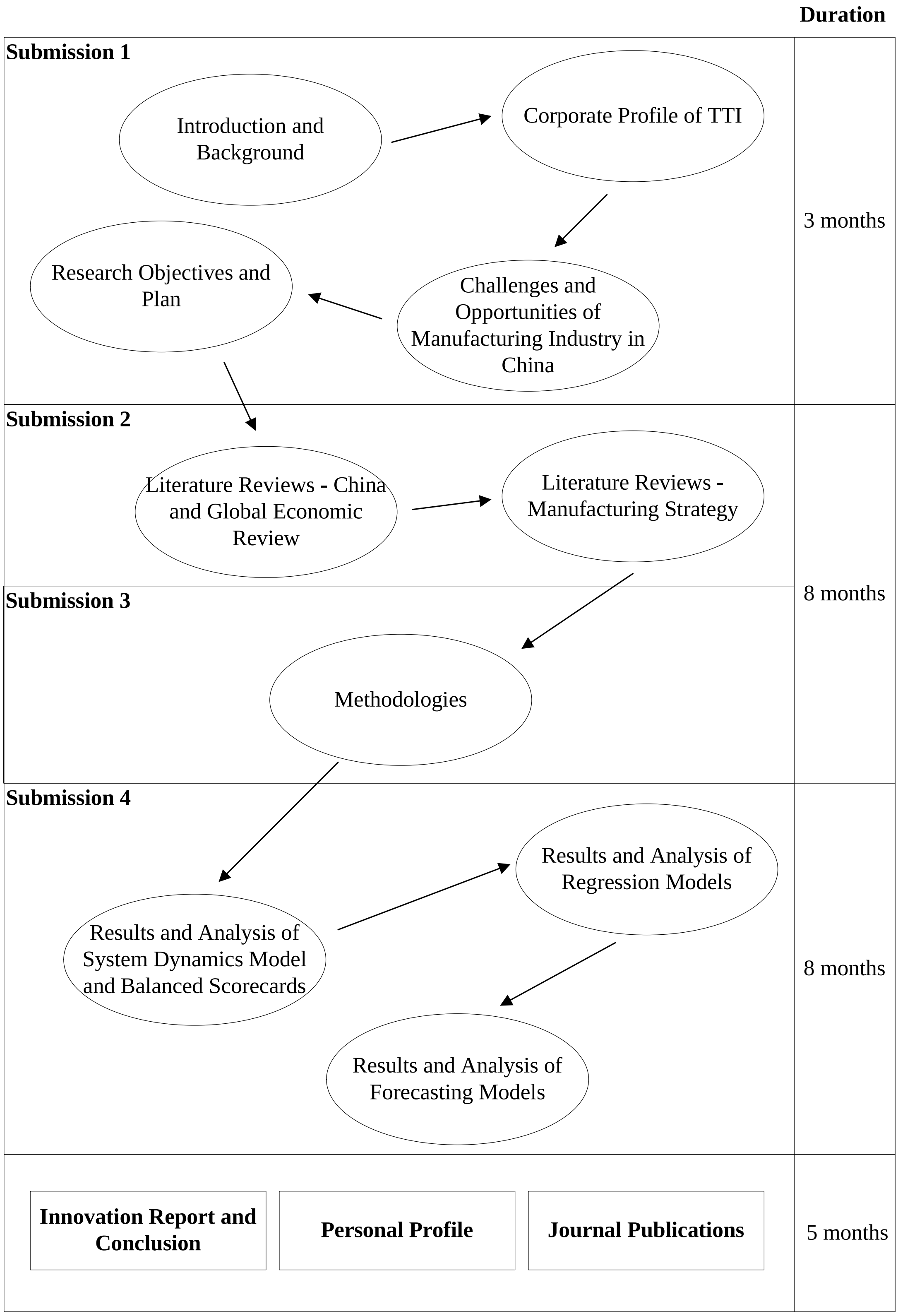

Figure 7 Overall structure of the portfolio

3.3 Data Collection

As the balanced scorecard requires extensive data covering seven countries, the data were collected from several sources, including the Asia Development Bank, Central Intelligence Agency, World Bank, WTO, and World Economic Forum. The empirical study makes use of Chinese historical data from 1950-2007 for the development of econometric models. These data, which relate to the Chinese economy and manufacturing industry, were collected from the China Statistical Databases. These databases include China's statistical yearbooks and national statistics, and are maintained by the University of Michigan in collaboration with the All China Marketing Research Co., Ltd. subject to the authorisation of the National Bureau of Statistics of China. Further details are given in Submissions 3 and 4.

3.4 Computer Applications

This study employs two computer applications, ithink® and EViews. ithink®, a modelling and simulation program, is used to develop a system dynamics model used at the high level, whilst EViews, an econometric program, is used to develop econometric models at the low level. The two applications are well-known and user-friendly that laymen can easily understand and master them and contribute much time to model development and analysis. Owing to these, they are selected to be employed in this study. The features and applications of EViews and ithink® are further discussed in Submission 3.

3.5 Model Development

In the model estimation process, the models are often evaluated and interpreted using various statistical measures, such as R-squared (R^2), p-value, standard error, and sum of squared error (SSE). Submission 3 discusses the statistical measures used for model analysis in detail. The concepts, properties, and relevant equations for the econometric model (regression analysis), as well as the time-series models (exponential smoothing and ARIMA), are reviewed in Submissions 2 and 3. The significance level for all of the econometric and time-series models developed in this study is specified at 5%. The model estimation and prediction procedures are briefly discussed below.

3.5.1 Model Development using Multiple Regression Analysis

This empirical study uses the least squares method with white heteroskedasticity (i.e., with consistent coefficient covariance) to estimate the regression equation, while the combinatorial selection method is applied to select appropriate regressors. The regression analysis is the most appropriate and popular method to study causal relationships among various economic and manufacturing factors in China. Please refer to Submission 2 for its framework, and Submission 3 for the details of the model development process using multiple regression analysis.

3.5.2 Model Development using Holt-Winters Exponential Smoothing

Holt-Winters exponential smoothing is found to be a most effective way of forecasting. This method is appropriate for series with a linear time trend and multiplicative/additive/no seasonal variation. It is thus employed in the model development to predict the growth of the Chinese manufacturing activities. Please refer to Submission 2 for its framework, and Submission 3 for the details of the model development process using exponential smoothing.

3.5.3 Model Development using ARIMA

ARIMA model is powerful and accurate in projecting forecasts for those fluctuated time-series data. It is thus appropriate to be used in this study for such purpose. The framework of the ARIMA modelling approach used in this study is discussed in Submission 3. The criteria used to assess the best ARIMA model, which include statistical measures and the ACF and PACF of the residuals, are also described in Submission 3.

4. The System Dynamics Model

The system dynamics model of the economic and manufacturing environment constructed with the support of the extant literature consists of five sections:

- government policy and investment;
- trade;
- knowledge and skills;
- labour market; and
- R&D, technology, and operations.

The interrelationship of these sectors and the linkages between their components are shown in Figure 8 (the high-level mapping layer) and Figure 9 (the model construction layer). The high-level mapping layer in Figure 8 is the initial stage of the model development while the model construction layer in Figure 9 shows the complete diagram of the economic and manufacturing environment. These pictorial representations together facilitate a better understanding of the economic and manufacturing environment, and inform and support the balanced scorecard developed later in the study. One of the key focuses of this report is on the assessment of manufacturing competitiveness (i.e. the results and analysis of the balanced scorecard), the system dynamic model formulated here is thus presented in brief. Please refer to Submission 4 for further details on the development of the system dynamics model if necessary.

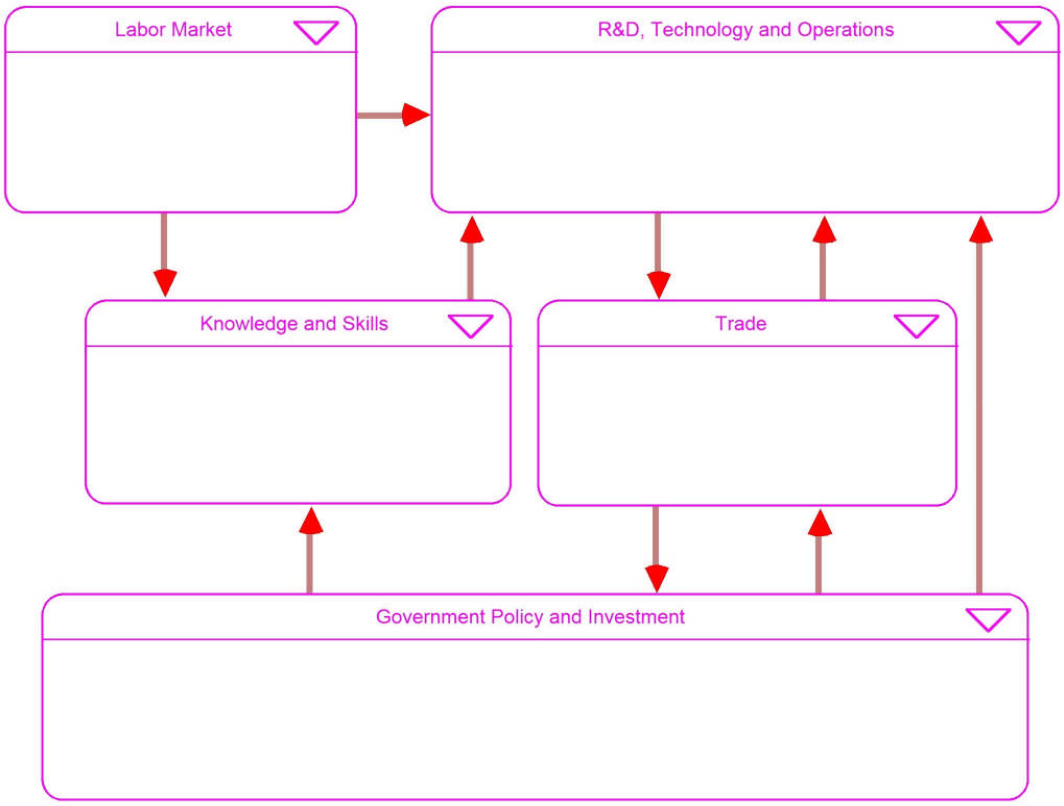

Figure 8 The high-level mapping layer of the iThink® model

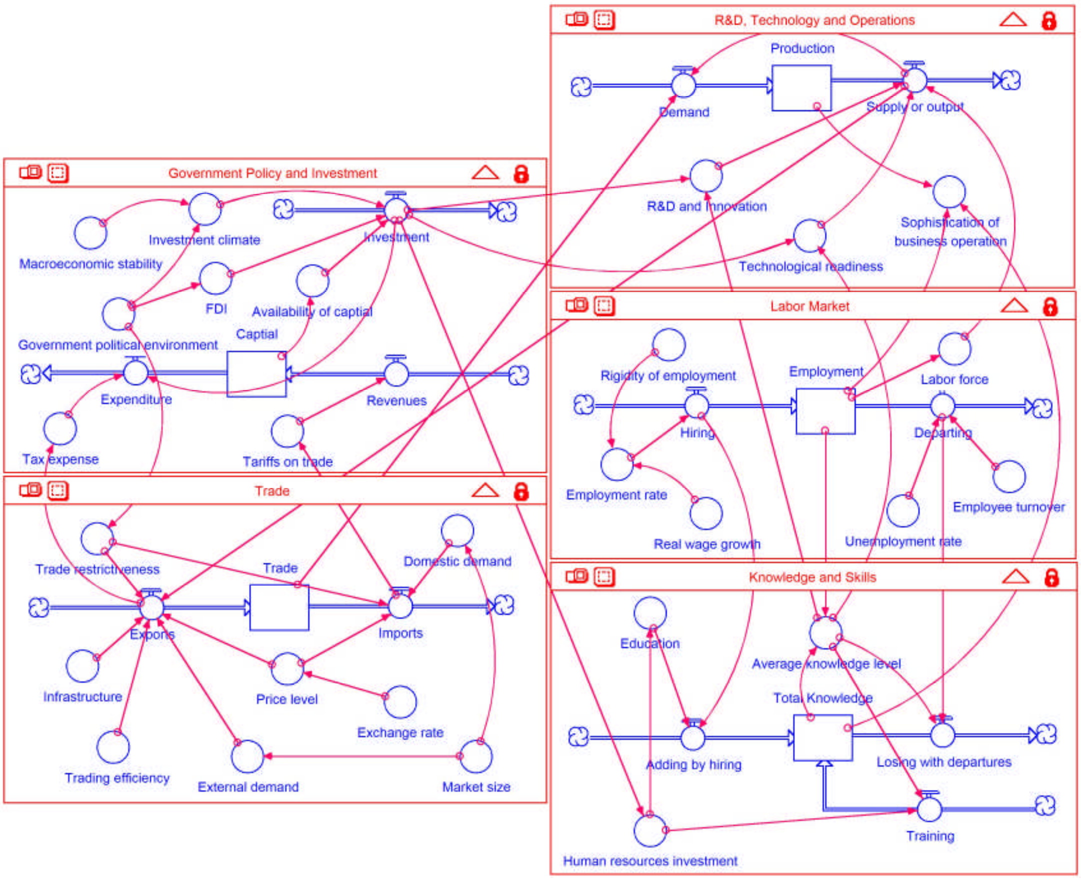

Figure 9 The model construction layer of the iThink® model

5. The Balanced Scorecard

5.1 Overview

Based on the above literature reviews and the system dynamics model of the economic and manufacturing environment, this study designs two balanced scorecards for assessing the following measures across countries including China, India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam:

- Country competitiveness, taking into account both economic and manufacturing factors; and
- Manufacturing competitiveness, focusing on factors affecting the development of the manufacturing industry.

Since the focus of this study is development of the manufacturing industry, the results of the balanced scorecard for manufacturing competitiveness are briefly presented below. The balanced scorecard results for country competitiveness can be found in Submission 4. In this innovation report, the author focuses only on manufacturing competitiveness.

5.2 Dataset and Design of the Balanced Scorecard for Manufacturing Competitiveness

A detailed balanced scorecard focusing on the manufacturing area is developed to assess a country’s manufacturing competitiveness. The balanced scorecard is divided into two categories, basic requirements and manufacturing strengths:

- The basic requirements take account of the following factors:

- infrastructure; and
- investment factors.

- The manufacturing strengths consider the factors of:
  - trade;
  - labour;
  - technology; and
  - R&D and innovation.

As noted previously, the emerging economies in Asia, particularly India, Indonesia, Malaysia, the Philippines, Thailand, and Vietnam, compete strenuously with China to expand their manufacturing sectors. These five factors encompassing 19 indicators serve as the major determinants in measuring manufacturing competitiveness across countries (see Figure 10). Submissions 3 and 4 give a detailed breakdown of these factors and their measurement, such as the dataset used for the indicators.

To consolidate and normalize all the indicators on a zero-to-ten scale to allow a comparison across different countries, all data collected, including hard data, ratings, indices, and scores, are transformed into normalized data as follows:

- for the lower-better indicators: $x_{ij} = (\max_j - v_{ij} / \max_j - \min_j) \times 10$; and
- for the higher-better indicators: $x_{ij} = (v_{ij} - \min_j / \max_j - \min_j) \times 10$,

where v_{ij} is the actual value of indicator j for country i; x_{ij} is the performance ratio; and $\max_j$ and $\min_j$ are the maximum and minimum values of indicator j among all countries. The scoring criteria applied in each of the two situations described above are given in Figure 10.

Factor		Indicator	Data Used	Scoring Criteria
Basic Requirements	Infrastructure	Availability and quality of roadways	Total length of roadways paved (km)	Higher-Better
		Availability of railways	Total length of railways (km)	Higher-Better
		Availability of port and terminals	Total number of ports and terminals	Higher-Better
		Availability and quality of airports	Total number of airports with paved runways	Higher-Better
	Investment	Strength of investor protection	Investor protection index	Higher-Better
		Availability of capital	Gross domestic capital formation ($billion)	Higher-Better
Manufacturing Strengths	Trade	Market size	Domestic and foreign market size	Higher-Better
		Efficiency of trading across borders	Trading across borders ranking	Lower-Better
		Tariff and non-tariff trade barriers	Simple mean tariff rate for manufactured products (%)	Lower-Better
		Availability of trade policy	Total no. of measures in force against anti-dumping	Higher-Better
	Labour	Manufacturing labour force	Labour force employed in manufacturing (thousand)	Higher-Better
		Rigidity of employment	Rigidity of employment index	Lower-Better
		Real wage growth	Real wage rate (%)	Lower-Better
		Quality of higher education and training	Higher education and training index	Higher-Better
	Technology	FDI and technology transfer	Foreign direct investment, net inflow ($million)	Higher-Better
		High-tech exports	High-technology exports (% of manufactured exports)	Higher-Better
	R&D and Innovation	Company spending on R&D	Company spending on R&D	Higher-Better
		Intellectual property protection	Total no. of patents granted and trademarks registered	Higher-Better
		Capacity for innovation	Capacity for innovation	Higher-Better

Figure 10 The components of and scoring criteria for the balanced scorecard for manufacturing competitiveness

5.3 Results and Analysis of the Balanced Scorecard for Manufacturing Competitiveness

The results of the balanced scorecard are presented in Figure 11. Although China's basic requirements, in terms of infrastructure and investment, rank second behind those of India, its manufacturing strengths and overall manufacturing competitiveness are ranked 1st among all the emerging economies analysed. Importantly, China's key competitive advantages are its huge market size, massive labour force, FDI and technology transfers, and capacity for innovation; all of which are ranked first among the countries considered. On the other hand, the balanced scorecard results highlight China's major weaknesses, including strength of investor protection (ranked 5th), company spending on R&D (ranked 5th), and quality of higher education and training (ranked 6th).

It is logical that China, with a population of 1.3 billion, is in a position to provide a labour market that is responsive to the needs of the manufacturing sector and to attract investment from foreign companies that seek to expand and penetrate its large domestic market. As the leading FDI recipient, China has also benefited from an increased level of technological competence and know-how due to input from outsiders, which has enhanced its technological readiness and product development capabilities in terms of quality, design, and innovation. The results of the balanced scorecard show why China is now regarded as the "world's factory" and why the "China effect" has arisen and been reinforced. Furthermore, China's status as a central manufacturing base with the necessary well-established infrastructure has allowed it to play a significant role in international product fragmentation and intra-regional trade in Asia, as well as to host export-oriented manufacturers. China's infrastructure is particularly strong in the area of availability and quality of railways and airports (for which it scores 10), although it ranks behind another Asian giant – India – in terms of basic requirements. Based on the factors and indicators discussed above, China appears to be the most competitive economy among the seven Asian countries assessed for overall manufacturing development; Hong Kong-based firms, in particular can take advantage of their geographical proximity to China's manufacturing sector.

The balanced scorecard results also show that China has certain weaknesses. The scores for China's quality of higher education and training (ranked 6th) and manufacturing labour force (ranked 1st) provide evidence that there may be localised skills shortages in China, but the country's labour surplus has not yet been exhausted, especially given its large population and the steady increase in the size of its labour force at around 1.1% annually from 1990 to 2005 (National Bureau of Statistics of China, 2006). China's scores in these areas do nevertheless show that staff training and education are important areas to address as part of the business strategy for firms that decide to invest there.

Figure 11 also shows that Vietnam offers the cheapest labour force for manufacturing, while Malaysia is ranked highest of the countries assessed in terms of employment rigidity and the quality of the labour force. These areas in which China trails its rivals reflect the rising production and labour costs which have resulted from China's overheating economy and rapid urbanisation and may have prompted foreign firms to seek alternatives to China. China is no longer necessarily viewed as a low-cost production base that can deliver competitive advantage in the manufacturing sector. To overcome this problem, some firms may relocate their factories in other parts of emerging Asia to lower their costs of production. Nevertheless, due to the existence of a number of uncertainties, moving away from a Chinese base may not deliver the superior return on investment such firms expect. It may be unwise to forgo China's advantageous manufacturing conditions to avoid its growing production costs. As an alternative, firms can strategically diversify their operations by moving their manufacturing bases away from China's developed eastern coastal provinces to inland/interior regions where costs are much lower. In this way, firms can not only cut their production costs, but can also benefit from the other favourable aspects of the Chinese manufacturing landscape. Although wages in China have been rising, this can be offset to some extent by the increases seen in labour productivity (The Economist Newspaper Limited, 2007c).

From a long-term manufacturing development perspective, firms ought to place more emphasis on higher-value manufacturing by focusing on product design, quality, innovation, and technology instead of relying solely on cost advantages to maintain or improve their competitive position. The results of the balanced scorecard show clearly that China's technology readiness (ranked 1st) is superior to that of its competitors, whilst it is ranked second behind Malaysia for its R&D and innovation capability. These competencies are precisely those that can allow China to transform itself from an imitator into a creator, and from a manufacturer of low-tech, labour-intensive products into a producer of high-tech, capital-intensive goods. This transition will allow firms to deliver sustainable value to their owners and support business growth over the long term.

Factor		Indicator	China	India	Indonesia	Malaysia	The Philippines	Thailand	Vietnam
Basic Requirements	Infrastructure	Availability and quality of roadways	9.44	10	1.22	0.38	0	0.23	0.14
		Availability of railways	10	8.36	0.75	0.13	0	0.43	0.23
		Availability of port and terminals	8.57	8.57	10	10	7.14	2.86	0
		Availability and quality of airports	10	5.83	3.32	0	1.31	0.79	0.03
	Investment	Strength of investor protection	3.83	5.50	5.00	10	1.67	5.50	0
		Availability of capital	3.84	10	2.30	0.53	0	6.03	0.02
	Results	***Average Score***	***7.61***	***8.04***	***3.76***	***3.51***	***1.69***	***2.64***	***0.07***
		Ranking	***2***	***1***	***3***	***4***	***6***	***5***	***7***
Manufacturing Strengths	Trade	Market size	10	7.21	3.53	0	1.58	2.74	0.70
		Efficiency of trading across borders	6.38	0	6.55	10	3.79	5.00	2.76
		Tariff and non-tariff trade barriers	6.20	0	8.80	7.13	10	5.46	3.33
		Availability of trade policy	4.42	10	0.75	0.60	0.35	1.21	0
	Labour	Manufacturing labour force	10	7.14	1.01	0	0.10	0.36	0.35
		Rigidity of employment	5.88	4.12	0	10	2.65	7.65	5.00

	Real wage growth	9.27	0	1.56	6.15	6.63	5.31	10
	Quality of higher education and training	2.59	5.03	4.15	10	4.29	6.73	0
Technology	FDI and technology transfers	10	2.17	0.49	0.57	0	1.12	0
	High-tech exports	3.94	0	1.67	7.58	10	3.33	0.15
R&D and Innovation	Company spending on R&D	3.09	6.00	5.82	10	1.44	3.81	0
	Intellectual property protection	3.19	8.01	0.43	10	0	1.70	4.33
	Capacity for innovation	10	0.31	0	0.37	0.32	0.55	0.08
Results	***Average Score***	***6.54***	***3.88***	***2.67***	***5.57***	***3.17***	***3.46***	***2.05***
	Ranking	***1***	***3***	***6***	***2***	***5***	***6***	***7***
Overall Results	***Average Score***	***6.88***	***5.19***	***3.02***	***4.92***	***2.70***	***3.20***	***1.43***
	Ranking	***1***	***2***	***5***	***3***	***6***	***4***	***7***

Figure 11 Results of the balanced scorecard for manufacturing competitiveness

6. Multiple Regression Models

6.1 Overview

As multiple regression analysis is a suitable method for studying the causal relationship between variables, it is used in this study to gain a better understanding of how different factors affect the growth of the manufacturing industry, as well as to formulate business and manufacturing strategies that can be applied in a dynamic, competitive market. Four multiple regression models are estimated in the course of the study, the objectives of which are briefly explained as follows. Submission 4 gives further details on the design and objectives of each model.

- *Model I: Impact of economic factors on the manufacturing industry*

  This model examines the impact of economic factors on the manufacturing industry. It can be used to test the theory that there is a connection between the growth of the manufacturing industry and economic factors in China, which has been regarded as a favourable manufacturing centre for some years now and has integrated into the global economy. This indicates a connection between the growth of the manufacturing industry and economic factors in China.

- *Model II: Relationship between the manufacturing industry and investment activities*

  China, now the leading recipient of FDI globally, has channelled FDI into its manufacturing sector, making the country the “world’s factory”. Model II is designed to investigate the relationship between the manufacturing industry and investment activities in an effort to address the question of how investment can best be utilised to develop the manufacturing industry.

- *Model III: Relationship among manufacturing output, labour force, and population growth*

  This model explores the relationship among manufacturing output, labour force, and population growth. Given that the labour force is a vital resource for the manufacturing industry, it should be closely associated with manufacturing output and its growth.

- *Model IV: Impact of overheating economy on the manufacturing industry*

  China's overheating economy has recently focused attention on the impact of RMB appreciation, inflation, and increasing labour and materials costs on the manufacturing industry. This model examines the relationship between the symptoms of overheating in the Chinese economy and investment in the manufacturing industry to investigate whether the flow of investment into the manufacturing industry is likely to be affected by these factors.

6.2 Results and Analysis of Multiple Regression Models I-IV

The results and analysis of model I-IV are briefly presented in Figure 12.

Model	Summary
I	***Objective:*** Impact of economic factors on the manufacturing industry ***Results:*** IND_GDP = -0.16×T_GOVTEXP + 968026730×T_HSEHC + 2.18×MANU_EXPORT - 1.56×T_EXPORT - 370.26 ***Analysis:*** China should maintain its manufacturing position and facilitate GDP growth by producing not only export goods for foreign markets, but also goods for the domestic market to satisfy market demand.
II	***Objective:*** Relationship between the manufacturing industry and investment activities ***Results:*** IND_GDP = 106.1347×INV_INNO + 0.6282×MANU_INV ***Analysis:*** Investing in innovation is more effective and has a greater impact than investing directly in the industry itself to stimulate growth and development in the manufacturing industry
III	***Objective:*** Relationship among manufacturing output, labour force, and population growth ***Results:*** IND_OUTPUT = 35.48×-3.53 + 2.85×MANU_EMPLOYED - 3.53×T_EMPLOYED + 1.79×POP_ACT_D1 ***Analysis:*** An increase in labour force participation in the manufacturing sector can plainly boost manufacturing output and value.
IV	***Objective:*** Impact of overheating economy on the manufacturing industry ***Results:*** MANU_INV = 2.47×MANU_WAGE(-1) + 7.07×CPI(1) + 1.33×T_WAGE + 22.18×EX_RATE ***Analysis:*** EX_RATE, positively related to investment growth in the Chinese manufacturing industry, is more important in explaining the variation in MANU_INV. an appreciation of the RMB will result in reduced investment in manufacturing, particularly where FDI accounts for a large proportion of investment in the manufacturing industry.

Figure 12 A summary of the results and analysis of models I-IV

6.2.1 *Model I: Impact of economic factors on the manufacturing industry*

The dependent and independent variables used for this model are shown in Figure 13. Further details of the variables used in this model are explained in Submission 4.

Dependent variable (RMB 100 million)	**Independent variables** (RMB 100 million)
GDP in the Manufacturing Industry (IND_GDP)	Constant (C), Total Exports (T_EXPORT), Total Imports (T_IMPORT), Exports of Manufactured Goods (MANU_EXPORT), Imports of Manufactured Goods (MANU_IMPORT), Total Government Expenditure (T_GOVTEXP), Total Household Consumption (T_HSEHC), Total Investment in Fixed Assets (T_INV)

Figure 13 The dependent and independent variables in model I

The summary statistics for the best-fit model estimated are shown in Figure 14. This model includes five independent variables: T_GOVREXP, T_HSEHC, MANU_EXPORT, T_EXPORT, and C with p-value < 0.5 in a t-test. This leads to rejection of the null hypothesis that their coefficients = 0, thereby confirming that these five parameters are significant to the model. The results of the ANOVA test shown in Figure 15 explicitly indicate that there is a significant relationship between the dependent variable (IND_GDP) and the independent variables (T_HSEHC, T_GOVTEXP, MANU_EXPORT, T_EXPORT, and C). This is because the p-value in the ANOVA F-test is 0.0001, which is smaller than 0.05 at the 95% confidence level adopted in this study; the null hypothesis is thus rejected.

According to the DW statistic test, there is no correlation among the errors in the model estimated as the DW statistic value is 1.657176, which is absolutely close to 2. Furthermore, the R^2 (0.9998) and adjusted R^2 (0.9998) values are virtually equal to 1, which indicates that the model estimated is a perfect fit. The model estimated also has lower values of SE (393.2262), SSE/SSR (3556416.7667), and AIC (14.9471), and a higher value of SC (15.1850). Furthermore, the values of R^2 and adjusted R^2 are nearly the same, indicating that the regressor(s) added to the model will rarely influence the regression results negatively. The following multiple regression represents the best-fit model for GDP in the manufacturing industry:

$$IND\_GDP = -0.1579 \times T\_GOVTEXP + 968026729.5460 \times T\_HSEHC + 2.1784 \times MANU\_EXPORT - 1.5592 \times T\_EXPORT - 370.2622$$

According to the multiple regression estimated, the positive coefficients of the two independent variables, T_HSEHC (+968026729.5460) and MANU_EXPORT (+2.1784), indicate there is a positive relationship between these variables and the growth of the manufacturing industry in China (measured as the growth in GDP in the manufacturing industry), whereas the negative coefficients of the other three independent variables, T_GOVTEXP (-0.1579), T_EXPORT (-1.5592), and the constant term (-370.2622), indicate that they have a negative relationship with growth in the Chinese manufacturing industry. The higher coefficient value for T_HSEHC implies that total household consumption is more important than the other variables in explaining the variation in GDP in the manufacturing industry. An increase in total household consumption implies an increase in market demand, which prompts an increase in manufacturing industry supply. This thus promotes the growth of the manufacturing industry. To maintain its manufacturing position and facilitate GDP growth, China would be best to adopt a strategy whereby it produces not only export goods for foreign markets, but also goods for the domestic market to satisfy market demand. This may explain why the coefficient of MANU_EXPORT in the regression model is fairly positive (+2.1784). Submission 4 gives further details of this model.

Independent Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
T_GOVTEXP	-0.16	0.06	-2.49	0.02
T_HSEHC	968026729.55	33590491.74	28.82	0.00
MANU_EXPORT	2.18	0.44	4.92	0.00
T_EXPORT	-1.56	0.43	-3.66	0.00
C	-370.26	123.99	-2.99	0.01

R-squared	0.9998	**Mean dependent var.**	27815.80
Adjusted R-squared	0.9998	**S.D. dependent var.**	29284.74
S.E. of regression	393.23	**Akaike info. criterion**	14.95
Sum squared resid.	3556416.77	**Schwarz criterion**	15.19
Log likelihood	-204.26	**Hannan-Quinn criter.**	15.02
F-statistic	37431.31	**Durbin-Watson stat.**	1.66
Prob. (F-statistic)	0.00		

Figure 14 The statistical output of model I

Test for Equality			
Method	**df**	**Value**	**Probability**
Anova F-test	(4,135)	6.55	0.0001

Analysis of Variance			
Source of Variation	**df**	**Sum of Sq.**	**Mean Sq.**
Between	4	11479753269.86	2869938317.46
Within	135	59140211285.28	438075639.150
Total	139	70619964555.13	508057298.96

Figure 15 The results of the ANOVA F-test for model I

6.2.2 Model II: Relationship between the manufacturing industry and investment activities

The dependent and independent variables used for this model are shown in Figure 16. Further details of the variables used in this model are explained in Submission 4.

Dependent variable (RMB 100 million)	**Independent variables (RMB 100 million)**
GDP in the Manufacturing Industry (IND_GDP)	Fixed Asset Investment in Manufacturing Industry (MANU_INV), Government Budgetary Expenditure on Innovation Funds (INV_INNO), Government Budgetary Expenditure on Science and Technology Funds (INV_ST), Total Amount of FDI Actually Utilised (T_INVU), and Constant (C)

Figure 16 The dependent and independent variables for model II

The summary statistics for the best-fit model estimated are shown in Figure 17. This model includes two independent variables: INV_INNO and MANU_INV, with a p-value < 0.5 in a t-test. This leads to rejection of the null hypothesis that their coefficients = 0, thereby confirming that these two parameters are significant to the model. As the p-value in the ANOVA F-test is 0, which is smaller than 0.05 at the 95% confidence level adopted in this study, the null hypothesis is rejected. This suggests that there is a significant relationship between the dependent variable (IND_GDP) and the independent variables (INV_INNO, and MANU_INV). The results of the ANOVA F-test are reported in Figure 18.

The DW statistic test shows no evidence of any correlation among the errors, because the value of the DW statistic is 1.9696, which is absolutely close to 2. Furthermore, the R^2 (0.9952) and adjusted R^2 (0.9946) values are virtually equal to 1, which indicates that the model estimated is almost a perfect fit. The model estimated also has lower values of SE (1844.9059), SSE/SSR (27229424), and AIC (18.0551), and a higher value of SC (18.11562). Furthermore, the values of R^2 and adjusted R^2 are approximately equal; implying that the regressor(s) added to the model will rarely influence the regression results negatively. The following multiple regression represents the best-fit model for the relationship of GDP in the manufacturing industry with significantly related investment activities.

$$IND\_GDP = 106.1347 \times INV\_INNO + 0.6282 \times MANU\_INV$$

According to the multiple regression estimated, a comparatively more positive coefficient of INV_INNO (+106.1347) implies that the correlation between INV_INNO and IND_GDP is more significant than that between MANU_INV (with a coefficient of +0.6282) and IND_GDP. Hence, it can be concluded that where the goal is to stimulate growth and development in the manufacturing industry, investing in innovation is more effective and has a greater impact than investing directly in the industry itself. This may be because innovation often involves the development of new value-added activities, such as product quality improvements and new designs that foster GDP growth in the manufacturing industry. Submission 4 gives further details of this model

Independent Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
INV_INNO	106.13	3.13	33.90	0.00
MANU_INV	0.63	0.08	7.60	0.00
R-squared	0.9952	**Mean dependent var.**	59698.99	
Adjusted R-squared	0.9946	**S.D. dependent var.**	25070.23	
S.E. of regression	1844.91	**Akaike info. criterion**	18.06	
Sum squared resid.	27229423.53	**Schwarz criterion**	18.12	
Log likelihood	-88.28	**Hannan-Quinn criter.**	17.99	
Durbin-Watson stat.	1.96			

Figure 17 The statistical output of model II

Test for Equality			
Method	**df**	**Value**	**Probability**
Anova F-test	(2, 27)	38.87	0.00

Analysis of Variance			
Source of Variation	**df**	**Sum of Sq.**	**Mean Sq.**
Between	2	19461441897.06	9730720948.53
Within	27	6759934534.41	250367945.72
Total	29	26221376431.47	904185394.19

Figure 18 The results of the ANOVA F-test for model II

6.2.3 Model III: Relationship among manufacturing output, labour force, and population growth

The dependent and independent variables used for this model are shown in Figure 19. Further details of the variables used in this model are explained in Submission 4.

Dependent variable (Percentage change)	**Independent variables** (Percentage change)
Growth of Gross Industrial Output Value (IND_OUTPUT)	Growth of Total Number of Employed Persons (T_EMPLOYED), Growth of Number of Staff and Workers Employed in Manufacturing Sector (MANU_EMPLOYED), Growth of Economically Active Population (POP_ACT), Growth of Economically Active Population (with 1st difference) (POP_ACT_D1), Total Permanent Population Growth (T_POP), Growth of Population Density (POP_DENS), Constant (C(3))

Figure 19 The dependent and independent variables in model III

The statistical output of the best-fit model estimated is shown in Figure 20. This model includes four independent variables: MANU_EMPLOYED, T_EMPLOYED, POP_ACT_D1, and C(2), with a p-value < 0.5 in a t-test. This leads to rejection of the null hypothesis that their coefficients = 0, thereby confirming that these four parameters are significant to the model. The results of the ANOVA F-test are shown in Figure 21. The results of the ANOVA test clearly indicate that there is a significant relationship between the dependent variable (IND_OUTPUT), and the independent variables (T_EMPLOYED, MANU_EMPLOYED, and POP_ACT_D1). This is because the p-value in the ANOVA F-test is 0, which is smaller than 0.05 at the 95% confidence level adopted in this study; the null hypothesis is thus rejected.

The DW statistic test shows that there is no correlation among the errors in the estimated model, as the value of the DW statistic is 1.7838, which is absolutely close to 2. Furthermore, the R^2 (0.8755) and adjusted R^2 (0.8415) values are around 1, which indicates that the model estimated is a good fit. This model estimated also has lower values of SE (8.2478), SSE/SSR (748.2859), and AIC (7.2809), and a higher value of SC (7.4698). Furthermore, the R^2 and adjusted R^2 values are almost the same, indicating that the regressor(s) added to the model will rarely influence the regression results negatively. The following multiple regression represents the best-fit model for the growth of gross manufacturing output value.

$$IND\_OUTPUT = 35.4790 \times -3.5326 + 2.8524 \times MANU\_EMPLOYED - 3.5326 \times T\_EMPLOYED + 1.7948 \times POP\_ACT\_D1$$

According to the multiple regression estimated, the positive coefficients of the two independent variables, MANU_EMPLOYED (+2.8524) and POP_ACT_D1 (+1.7948), indicate a positive relationship between these variables and IND_OUTPUT, while the negative coefficient of T_EMPLOYED (-3.5326) demonstrates a negative relationship with IND_OUTPUT. The inclusion of MANU_EMPLOYED in the regression model shows that this is an important factor explaining the variation in IND_OUTPUT. Clearly, labour force is the major resource used for production and growth in the manufacturing industry. An increase in labour force participation in the manufacturing sector can plainly boost manufacturing output and value. In addition, the inclusion of POP_ACT_D1 and rejection of POP_ACT in forming the regression model indicate that growth in the economically active population (with 1st difference), POP_ACT_D1, is more important than POP_ACT in explaining the variation in IND_OUTPUT. Submission 4 gives further details of this model.

Independent Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(3)	35.48	3.41	10.40	0.00
MANU_EMPLOYED	2.85	0.16	17.37	0.00
T_EMPLOYED	-3.53	0.41	-8.62	0.00
POP_ACT_D1	1.79	0.23	7.78	0.00
R-squared	0.88	**Mean dependent var.**		18.05
Adjusted R-squared	0.84	**S.D. dependent var.**		20.72
S.E. of regression	8.25	**Akaike info. criterion**		7.28
Sum squared resid.	748.29	**Schwarz criterion**		7.47
Log likelihood	-50.61	**Hannan-Quinn criter.**		7.28
Durbin-Watson stat.	1.79			

Figure 20 The statistical output of model III

Test for Equality			
Method	**df**	**Value**	**Probability**
Anova F-test	(3,68)	15.30	0.00

Analysis of Variance			
Source of Variation	**df**	**Sum of Sq.**	**Mean Sq.**
Between	3	5253.53	1751.18
Within	68	7784.53	114.48

Total	71	13038.06

Figure 21 The results of the ANOVA F-test for model III

6.2.4 Model IV: Impact of overheating economy on the manufacturing industry

The dependent and independent variables used for this model are shown in Figure 22. In this model, the lead-lag relationship is taken into account to reinforce the significance of the best-fit regression model. The lead and lagged variables are shown in Figure 23. Submission 4 gives further details of the variables included in this model.

Dependent Variable (Percentage change)	**Independent Variables** (Percentage change)
Investment Growth Rate in Manufacturing Industry (MANU_INV)	Total Wage Growth Rate among Staff and Workers (T_WAGE), Total Wages Growth Rate in Manufacturing Industry (MANU_WAGE), Growth of Consumer Price Index (CPI), Growth of Purchasing Price Indices for Raw Materials, Fuel, and Power (PPI), Growth of RMB Exchange Rate to 1 USD (EX_RATE), Constant (C)

Figure 22 The dependent and independent variables for model IV

Lead Independent Variables (Percentage change)	**Lagged Independent Variables** (Percentage change)
T_WAGE(1), MANU_WAGE(1), CPI(1), PPI(1), EX_RATE(1), C(1)	T_WAGE(-1), MANU_WAGE(-1), CPI(-1), PPI(-1), EX_RATE(-1), C(-1)

Figure 23 The lead and lagged variables for model IV

The best-fit model is determined by assessing model accuracy and on the basis of the DW statistic. The estimated output of the best-fit regression model is shown in

Figure 24. The t-test shows that the MANU_WAGE(-1), CPI(1), T_WAGE, and EX_RATE variables are statistically significant, as their p-values are <0.05. The null hypothesis that the variables have zero coefficients is thus rejected. Figure 25 reports the results of the ANOVA F-test. These results clearly indicate a significant relationship between the dependent variable (MANU_INV) and the independent variables (MANU_WAGE(-1), CPI(1), T_WAGE, and EX_RATE). This is because the p-value in the ANOVA F-test is 0.0001, which is smaller than 0.05 at the 95% confidence level; the null hypothesis is thus rejected.

The DW statistic indicates that there is no correlation among the errors in the model estimated, as it has a value of 2.7447, which is close to 2. Furthermore, the R^2 (0.9054) and adjusted R^2 (0.8648) values are virtually equal to 1, indicating that the model estimated is nearly a perfect fit. The model also has lower values for SE (7.9578), SSE/SSR (443.2905), and AIC (7.2615), and a higher value for SC (7.4062). Furthermore, the difference between the R^2 and adjusted R^2 values is minor, indicating that the estimated regression model results are not negatively influenced by the regressors added. The following multiple regression represents the best-fit model for the investment growth rate in the manufacturing industry:

$$MANU\_INV = 2.4724 \times MANU\_WAGE(-1) + 7.0664 \times CPI(1) + 1.3281 \times T\_WAGE + 22.1817 \times EX\_RATE$$

According to this multiple regression estimate, all of the coefficients are positive, including the variables of MANU_WAGE(-1) (+2.4724), CPI(-1) (+7.0664), T_WAGE (+1.3281), and EX_RATE (+22.1817), which indicates that they are positively related to investment growth in the Chinese manufacturing industry. A previous study indicates that an appreciation of the RMB will lead to a reduction in FDI inflows [27]. This study builds on this finding by showing that an appreciation of the RMB will result in reduced investment in manufacturing, particularly where FDI accounts for a large proportion of investment in the manufacturing industry. According to the multiple regression estimated, EX_RATE is more important in explaining the variation in MANU_INV due to its relatively large coefficient value. The positive coefficient of the lagged variable, MANU_WAGE(-1) (+2.4724), shows that investment growth in the manufacturing industry tends to lead wage growth in the industry. Alternatively, the positive coefficient of the lead variable, CPI(-1) (+7.0664), indicates that the consumer price index leads investment growth in the manufacturing industry. Submission 4 gives further details of this model.

Independent Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
MANU_WAGE(-1)	2.47	0.71	3.49	0.01
CPI(1)	7.07	1.77	4.00	0.01
T_WAGE	1.33	0.49	2.71	0.03
EX_RATE	22.18	4.13	5.37	0.00

R-squared	0.91	**Mean dependent var.**	20.93
Adjusted R-squared	0.86	**S.D. dependent var.**	21.64
S.E. of regression	7.96	**Akaike info. criterion**	7.26
Sum squared resid.	443.29	**Schwarz criterion**	7.41
Log likelihood	-35.94	**Hannan-Quinn criter.**	7.17

Durbin-Watson stat.	2.74

Figure 24 The statistical output of model IV

Test for Equality			
Method	**df**	**Value**	**Probability**
Anova F-test	(4,50)	7.40	0.00

Analysis of Variance			
Source of Variation	**df**	**Sum of Sq.**	**Mean Sq.**
Between	4	3416.74	854.18
Within	50	5771.79	115.44
Total	54	9188.53	170.16

Figure 25 The results of the ANOVA F-test for model IV

7. Forecasting Models

7.1 Overview

This study uses the Holt-Winters – no seasonal exponential smoothing method to forecast time-series data, showing a trend with no seasonality. ARIMA analysis is also used to forecast the time-series data, which are likely to fluctuate constantly.

The author proposes four forecasting models that use Holt-Winters exponential smoothing and one forecasting model that uses ARIMA analysis. The objectives of these models are indicated in Figures 26 and 27. Forecasting models V-VIII are used to project the values of each time-series from 2008 to 2012, while forecasting model IX predicts the value of time-series from 2008M7 to 2008M12. For further details of the model objectives and dataset, please refer to Submission 4.

Model	**Objective**	**Time-series**	**Unit**	**Estimation Period**
V	Forecast the growth of the manufacturing industry	IND_GDP	RMB 100million	1952 -2007
VI	Forecast the growth of manufacturing investment	MANU_INV	RMB 100million	1995 -2007
VII	Forecast the growth of total household consumption	T_HSEHC	RMB	1952 -2007
VIII	Forecast the growth of employment	T_EMPLOYED	10000 persons	1952 -2007

Figure 26 Descriptions of forecasting models V-VIII, which use Holt-Winters exponential smoothing

Model	Objective	Data Series	Unit	Estimation Period
IX	Forecast the RMB exchange rate	EX_RATE	percentage change	2005M07 -2008M06

Figure 27 Description of forecasting model IX, which uses ARIMA analysis

7.2 Results and Analysis of Forecasting Models V-VIII

The best-fit model is determined by minimizing the root mean squared error (RMSE) and the sum of the squared errors/residuals (SSE/SSR). The results of models V-VIII are shown in Figure 28. The smoothing parameters used in each model, α and β, are mostly equal to 1, indicating that the dataset series is a random walk where the most recent value is the best value to use in estimating future values.

Model	α	β	RMSE	SSE/SSR	Mean	Trend
V	1	1	982	54049562	1037367	16056
VI	0.95	1	1244	20125255	35348	8977
VII	1	1	69	269471	7016	905
VIII	0.99	0.03	1258	88555736	76994	1003

Figure 28 The results of models V-VIII

Using the smoothing parameters estimated in each model described in Figure 28 allows the model forecast to be produced. The values for the forecasting period following the estimation period for the time-series in models V-VIII are then projected (see Figures 29-32). Figures 29-32 allow for the following observations to be made:

- Model V: the upward trend in GDP growth in the manufacturing industry will be maintained in the coming 5 years without any slowdown;

- Model VI: it is anticipated that the upward trend in investment growth in the manufacturing industry will be maintained in the coming 5 years. Importantly, this implies that China's overheating economy will not have a negative impact on manufacturing investment inflows from 2008-2012;
- Model VII: the upward trend in total household consumption will be maintained in the coming 5 years, and the growth rate is likely to accelerate steeply. This implies that domestic demand in China will remain robust in the coming 5 years.
- Model VIII: the total number of people in employment will steadily increase in the coming 5 years and there will be no labour force shortage in China.

Further details of the results and analysis of models V-VIII can be found in Submission 4.

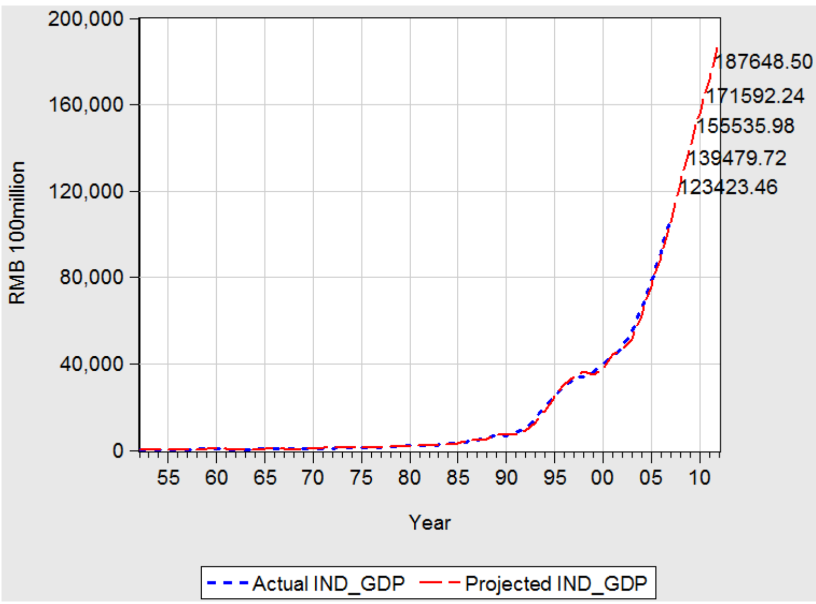

Figure 29 The actual and forecast series for model V

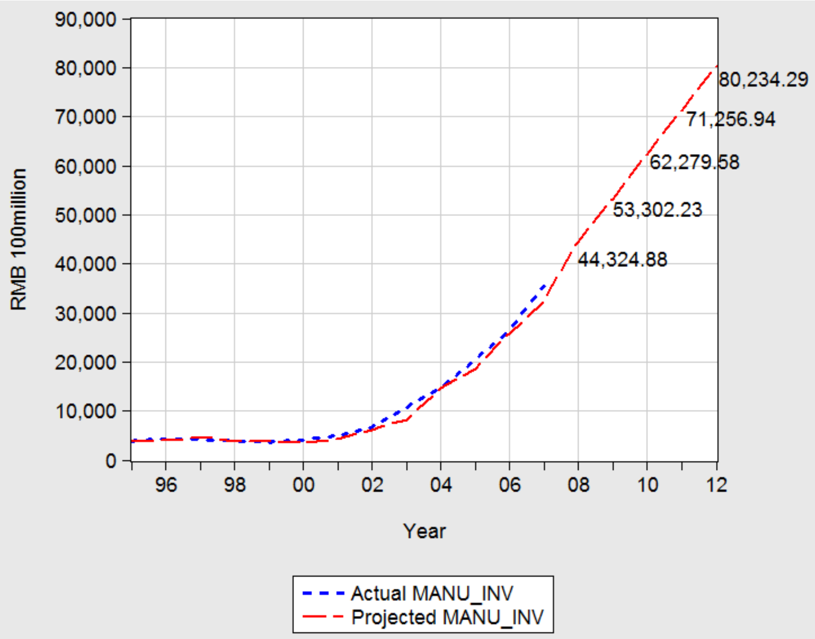

Figure 30 The actual and forecast series for model VI

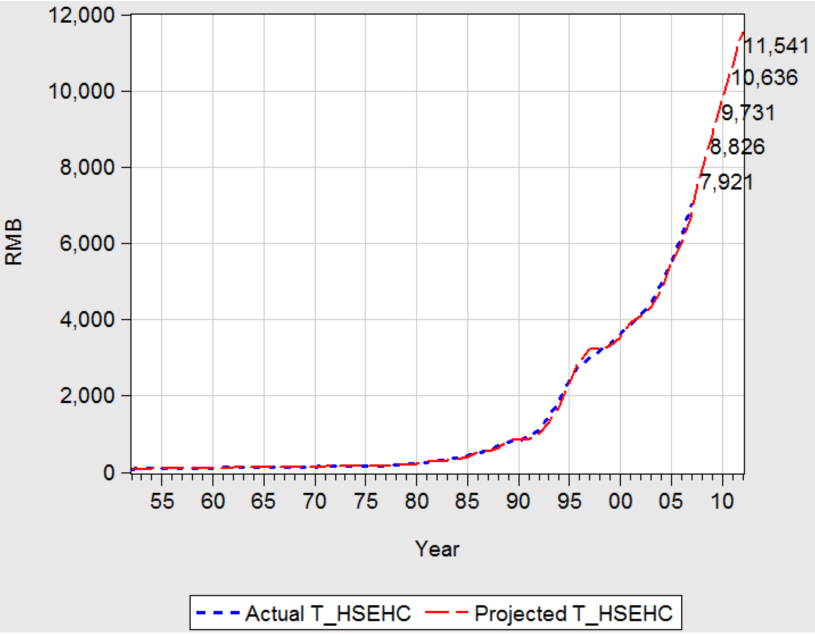

Figure 31 The actual and forecast series for model VII

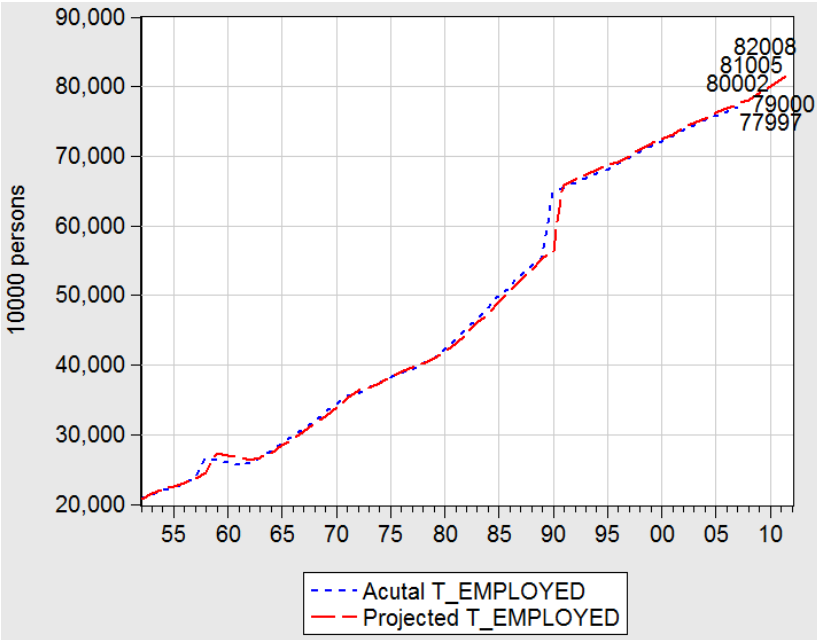

Figure 32 The actual and forecast series for model VIII

7.3 Results and Analysis of Forecasting Models V-VIII

Through an augmented Dickey-Fuller (ADF) test carried out to determine the degree of d and the trial and error procedure undertaken to determine the model components in terms of the degree of p and q, the author determined the best-fit ARIMA (p,d,q) model containing white noise to be ARIMA (0,0,6). The results of the ADF test are reported in Figure 33 and the estimation output is shown in Figure 34. The ARIMA (0,0,6) model is expressed in the following equations:

$$Y_t = (1-\theta_1 B - \theta_2 B^2 - \theta_3 B^3 - \theta_4 B^4 - \theta_5 B^5 - \theta_6 B^6)\varepsilon_t$$
$$Y_t = (1-0.7232B - 0.4296B^2 - 0.3662B^3 - 0.4453B^4 - 0.7022B^5 - 0.9023B^6)\varepsilon_t$$
$$Y_t = \varepsilon_t - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \theta_3\varepsilon_{t-3} - \theta_4\varepsilon_{t-4} - \theta_5\varepsilon_{t-5} - \theta_6\varepsilon_{t-6}$$

$$Y_t = \varepsilon_t - 0.7232\varepsilon_{t-1} - 0.4296\varepsilon_{t-2} - 0.3662\varepsilon_{t-3} - 0.4453\varepsilon_{t-4} - 0.7022\varepsilon_{t-5} - 0.9023\varepsilon_{t-6}$$

where Y_t is the output series, B is the backshift operator, ε_t is the random noise, and θ is the polynomial.

Null Hypothesis: EX_RATE has a unit root

		t-Statistic	Prob.
Augmented Dickey-Fuller test statistic:		-4.45	0.0012
Test critical values:	1% level	-3.63	
	5% level	-2.95	
	10% level	-2.61	

Figure 33 The results of the ADF test on EX_RATE in model IX

Convergence achieved after 15 iterations				
MA Backcast: 2005M01 2005M06				
Variable	**Coefficient**	**Std. Error**	**t-Statistic**	**Prob.**
MA(1)	0.72	0.06	12.59	0.00
MA(2)	0.43	0.10	4.34	0.00
MA(3)	0.37	0.12	2.99	0.01
MA(4)	0.45	0.10	4.31	0.00
MA(5)	0.70	0.07	10.63	0.00
MA(6)	0.90	0.03	33.37	0.00
R-squared	0.57	Mean dependent var.		-0.52
Adjusted R-squared	0.49	S.D. dependent var.		0.49
S.E. of regression	0.35	Akaike info. criterion		0.88
Sum squared resid.	3.63	Schwarz criterion		1.14
Log likelihood	-9.79	Hannan-Quinn criter.		0.97
Durbin-Watson stat.	1.86			
Inverted MA Roots	.73-.67i	.73+.67i	-.20-.96i	-.20+.96i
	-.89+.42i	-.89-.42i		

Figure 34 The estimation output of ARIMA (0,0,6) model IX

The author forecasted time-series for EX_RATE through the equations for the ARIMA(0,0,6) model described above using the static forecasting method. The actual and projected EX_RATE series are plotted in a single graph for illustration (see Figure 35), in which the projected values for the growth of the Chinese exchange rate (EX_RATE) during the period 2008M07-2008M12 are also given.

Figure 35 reveals that the growth rate of the RMB is forecast to slow down from -1.29% in 2008M06 to -0.77% in 2008M07, as well as in subsequent months. This indicates that the rate of appreciation in the RMB against the USD will decelerate in the near future, a conclusion that is consistent with the EIU and World Bank forecasts discussed earlier. Furthermore, the forecast result (i.e., a slowdown in RMB appreciation) provides further evidence supporting and explaining the result of model VI (i.e. that the growth in MANU_INV will not be hindered significantly but will continue in a gradual upward trend). For the detailed results and discussion of this model, please refer to Submission 4.

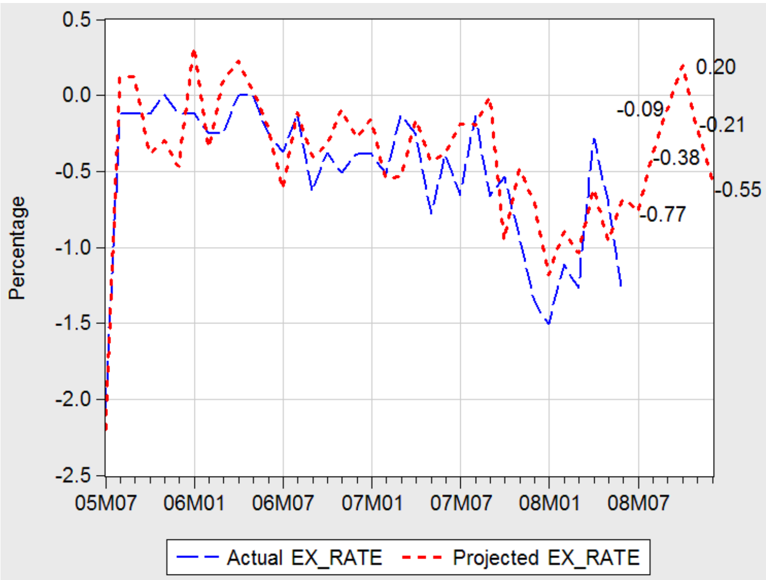

Figure 35 The actual and projected EX_RATE series for model IX

7.4 A Model for Intervention in the Financial Crisis to Support China's Manufacturing Industry

7.4.1 The Financial Crisis

Triggered by the subprime mortgage crisis in the US that began in July 2007, the financial crisis spread rapidly around the globe. It first moved from the US to Europe and subsequently on to the rest of the world, causing the world economy to go into recession. The effect of the crisis on the global economy became even more apparent in September 2008 when stock markets worldwide underwent a dramatic correction in response to the collapse of Lehman Brothers and continued to plunge with an unprecedented level of volatility. China was no exception, suffering a sharp reduction in export and manufacturing sector growth as a result of the global economic slowdown.

According to the International Monetary Fund (2006) and the WTO (2007), China's exports grew at an average rate of 5.7% in the 1980s, 12.4% in the 1990s, and 21.1% between 2000 and 2006. However, China's exports fell by 2.2% from the same month a year earlier in November 2008, and imports plunged by 17.9%, the nation's trade surplus in the first three quarters of 2008 dropping by US$4.7 billion compared with the same period in 2007 (National Bureau of Statistics of China, 2008). It is likely that China's economic growth will continue to slow down in a reflection of trends in trans-Pacific trade and intra-Asian trade, largely as a result of the US and Europe, China's biggest export markets, plunging into economic recession. According to figures from China's National Bureau of Statistics, annual

GDP growth fell from 12.6% in the second quarter of 2007 to 10.6% in the first quarter of 2008, 10.1% in the second quarter, and 9% in the third quarter (The World Bank, 2008). The growth of industrial value added fell even more steeply to 8.2% in the third quarter of 2008 (The World Bank, 2008). These figures for GDP growth and industrial value-added growth are the first single-digit growth rates China has experienced since the economic reforms initiated in 1978 (which have resulted in an average annual growth rate of 10%) and 2001, respectively. These statistical data provide convincing evidence that China is not immune to the US financial crisis, especially in terms of its manufacturing economy. This is because its economy, trade, and manufacturing activities are closely correlated (Chung *et al.*, 2008).

7.4.2 The ARIMA Intervention Time-series Analysis

In light of the ongoing financial crisis and its unexpected severity, this section has been added as a supplement to investigate the impact of the sudden financial crisis on China's manufacturing industry. ARIMA intervention time-series analysis is used to model and analyse the impact of this event and evaluate its pattern and duration. Time-series data on gross industrial output value (IND_OUTPUT) from March 2005 to November 2008 provided by the China Statistical Databases of the National Bureau of Statistics of China are employed for this impact analysis. The time-series data for IND_OUTPUT are depicted in Figure 36 below.

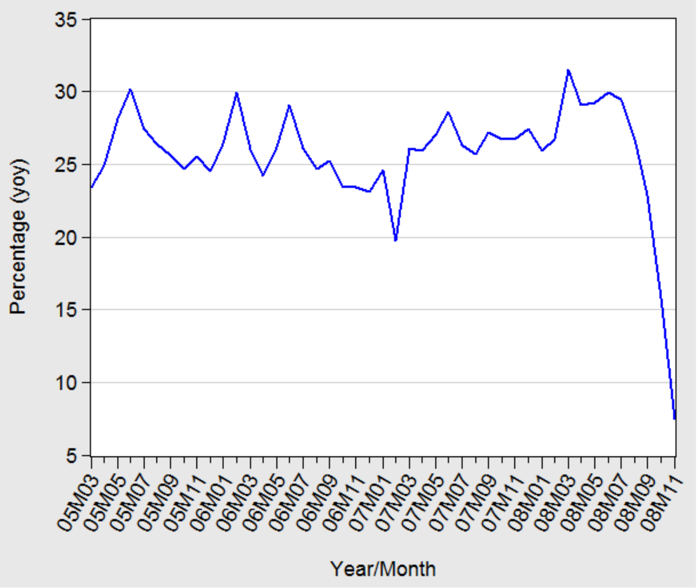

Figure 36 Time-series data for IND_OUTPUT

The author useed ARIMA intervention time-series analysis to explore the impact of including the financial crisis as an intervention in the time-series. Assuming that the global financial crisis first had a serious impact on China in September 2008, the author initiates the intervention, I_t, in that month. The ADF test provides evidence that the time series in the pre-intervention model has no unit root and is stationary, as the t-statistic value of ADF (-3.7577) is smaller than the critical values of (-2.935) at the 5% significance level and (-3.601) at the 1% significance level when $d = 0$. Taking ACF, PACF, SC, AIC, and the adjusted R2 value into account, the ARIMA intervention time-series analysis model can be estimated. The pre-intervention model, ARIMA(1,0,0)(2,0,1) 12, is determined below.

$$Y_t = 27.3263 + \frac{(1-0.9367B^{12})\varepsilon_t}{(1-0.5789B)(1-0.3956B^{12}+0.4663B^{13})}$$

After diagnosing noise and the transfer function, the pre-intervention model, ARIMA(1,0,0)(2,0,1)$_{12}$, is proved to be valid with significant coefficients and white noise, in which the p-value < 0.05 using t-statistics and > 0.14 using Q-statistics. The ARIMA model that includes intervention in the global financial crisis is estimated below, where the noise diagnosis proves that it is a white-noise process and that the estimated model is thus valid.

$$Y_t = \frac{(1+859.4596B)I_t}{(1-0.6898B)} + \frac{(1-0.9367B^{12})\varepsilon_t}{(1-0.5789B)(1-0.3956B^{12}+0.4663B^{13})} + 27.3263$$

The results indicate that as a result of the global financial crisis, China's manufacturing industry may have to withstand a significant negative effect over a period of time, with its gross industrial output value declining continually throughout 2008 and 2009 before reaching a state of equilibrium. The intervention effect is calculated as an asymptotic change of 27.74%, and can be described as temporary but immediate and abrupt. This analysis further confirms that an intervention analysis model can be appropriately applied to explain the dynamics and impact of time-series interruptions in a detailed and precise manner. Further details and discussion can be found in the paper, Chung *et al.*, 2009.

8. Originality and Contributions of this Study

8.1 A New Approach – A Two-stage Analysis Methodology

The major original contribution of this research project is the creation of a two-stage analysis approach to examine the formulation of manufacturing strategy. The overall framework is exhibited in Figure 37. This approach first helps to identify the economic and manufacturing factors that contribute to the development of the manufacturing industry at a high level; a balanced scorecard is thus formulated to assess a country's manufacturing competitiveness for benchmarking purposes. The balanced scorecard developed in this study identifies six major factors encompassing 19 indicators of manufacturing competitiveness (please refer to Figures 10 and 11 for the details or Submission 4 for the details of the factors and indicators). The balanced scorecard allows for a greater emphasis to be placed on important economic and manufacturing factors and enables a better understanding of and greater insight into their effect on manufacturing competitiveness. This facilitates the investigation and formulation of competitive manufacturing strategy via the estimation and projection of a number of econometric models (please refer to chapters 6-7 above or Submission 4 for the details of the variables involved). The major factors considered in the balanced scorecard and econometric models used to formulate manufacturing strategy are summarised in Figure 38 below.

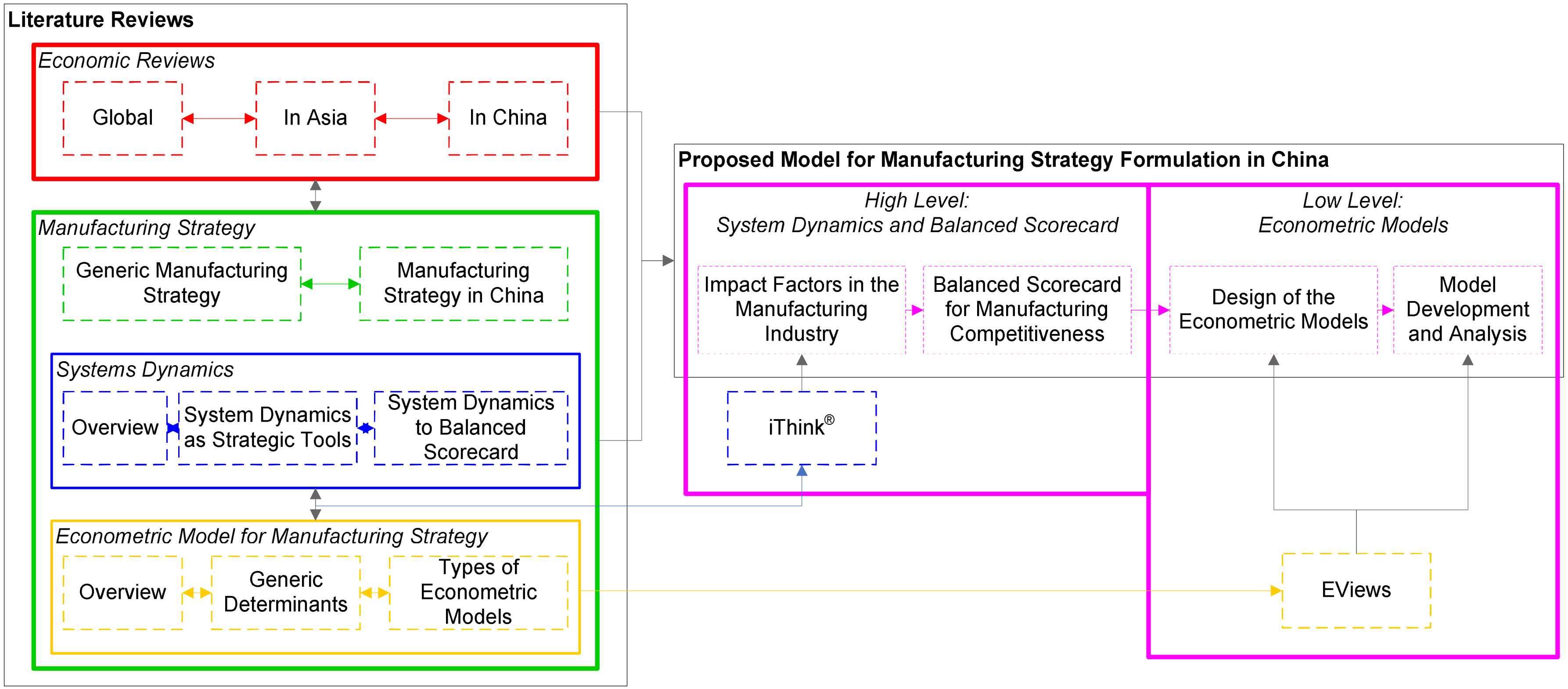

Figure 37 The framework of the approach

Factors	***High Level:*** **Balanced scorecard for manufacturing competitiveness**	***Low Level:*** **Econometric models**			
		I	**II**	**III**	**IV**
Infrastructure	✓				
Investment	✓		✓		✓
Economic		✓			✓
Trade	✓	✓			
Labour	✓			✓	✓
Technology	✓		✓		
R&D and innovation	✓		✓		

Figure 38 Major factors to be considered in formulating a competitive manufacturing strategy

The two-stage analysis methodology proposed in this study is a novel approach to the formulation of manufacturing strategy in that to the best of the author's knowledge, it is the first methodology put forward that fully recognises the impact of macroeconomic variables on domestic manufacturing sector competitiveness and splits the strategic decision-making process into two stages. The results of this study indicate that this new approach is a simple but powerful methodology that can be utilised to gain insights into how best to craft an appropriate and competitive manufacturing strategy.

8.2 Contributions to the Literature

This study makes the following contributions to the literature:

- it introduces a new methodology for the formulation of manufacturing strategy;
- it identifies important economic and manufacturing factors that have a bearing on competitiveness in the manufacturing sector;
- it develops a balanced scorecard and estimates various econometric and time-series models that can be used to make projections;
- it benchmarks China's manufacturing competitiveness against other Asian emerging economies and predicts the path of the Chinese manufacturing sector; and
- it provides a framework that can be used to further develop the measurement of China's global competitiveness in comparison with North American and European countries.

8.3 Contribution to the Manufacturing Industry

The major contribution of this study to the manufacturing industry is that its results give firms an insight into the areas in which China's manufacturing sector is competitive and, more importantly, those in which it is not. The balanced scorecard and econometric models presented in this paper can be used to help manufacturers formulate the manufacturing strategies that will best serve their businesses. This study helps firms not only to gain a better understanding of the manufacturing environment in China and other Asian countries, but also to examine the relationship among economic and manufacturing factors including inflation, RMB appreciation, availability of workforce, and investment activities, and to become aware of the likely level of growth in China’s manufacturing industry. The results and analysis presented in this innovation report allow firms to consider the likely impact of the factors identified in this study that have a major influence on manufacturing strategy. This will enable firms to formulate appropriate and competitive manufacturing and business strategies, particularly those pertaining to plant investment and high-value manufacturing investment, in a manner that supports business sustainability. The two-stage analysis approach proposed in this study is an effective methodology that will allow decision makers to examine and formulate strategy from a number of different perspectives.

8.4 Contribution to TTI

The results of this study show that China remains competitive as a manufacturing base in comparison with other Asian emerging countries. This endorses TTI’s China investment strategy, which assures the firm’s sustainability as a result of the competitive advantages accruing from its decision to locate its factories in China. Based on the results of the balanced scorecard shown in Figure 11, China outperforms other emerging economies, particularly in terms of its huge domestic market, large labour force, active FDI, and capacity for innovation. Applying these factors to TTI, the firm maintains a factory presence in China, employs talented local staff, focuses on developing value-added products, and targets China’s domestic retail market. Although Figure 11 shows that China is no longer the lowest cost economy for production activities, it gives decision makers in TTI an insight into how economies of scale can be used as a successful manufacturing strategy for its Chinese production activities. Furthermore, the regression and forecasting models presented in the study enable decision makers to gain a clear picture of what China’s manufacturing industry will look like in coming years, allowing them to make effective business plans for TTI and sustain its profitability into the future.

9. Conclusions

9.1 Summary of Major Findings

This study reviews China's manufacturing industry environment and, identifies the major economic and manufacturing factors affecting China's competitiveness among Asian countries, as well as accounting for the substantial growth that has taken place in China's manufacturing industry. A two-stage approach to modelling manufacturing competitiveness and strategy is proposed. The empirical analysis conducted in this study leads to the following key conclusions.

- China's rising production costs and burgeoning economy have hampered the inflow of manufacturing investment in recent years; however, this study indicates that China remains competitive. Supported by the results of the balanced scorecard, China provides the most favourable and competitive manufacturing environment among the Asian emerging economies analysed, due the size of its domestic market, its massive labour force, its technological readiness, and its ability to innovate.
- Regression model I shows that although China is regarded as the world's factory, to maintain its manufacturing position and facilitate GDP growth, China should produce not only export goods for foreign markets, but also goods for the domestic market to satisfy market demand.
- Although production costs in China may no longer be the lowest in Asia, firms operating in a global dynamic market should not be fixated by such costs, but should also adopt both market- and technology-driven strategies for high-value manufacturing to enhance firm value and satisfy customer needs. This

conclusion is supported by regression model II, which confirms that investment in innovation, a key component of success in high-value manufacturing, is more significant than direct investment in manufacturing in terms of its contribution to industrial growth.

- With the exception of RMB appreciation, all the symptoms of China's overheating economy have a positive relationship with investment inflows into the manufacturing industry. This is evidenced by regression model IV. This study provides further evidence that RMB appreciation may not only result in a reduction in the FDI inflows noted by Xing (2006), but may also lead to a decline in the growth of investment in the manufacturing industry in China.
- In the coming five years, RMB appreciation is likely to slow down, as shown by the results of forecasting model IX, while based on the results of forecasting models V-VIII, respectively, current trends in manufacturing industry growth, manufacturing investment, total household consumption, and employment will be maintained. However, due to the ongoing financial crisis, which has spread swiftly around the globe and the impact of which became evident in China in September 2008, the global economy has been severely disrupted and entered a deep recession. China is not immune to the financial crisis, especially in terms of its manufacturing economy, which depends on the vitality of export markets. However, it is logical and reasonable to expect that the predictions made in this study will have to be adjusted. Based on the discussion presented in this report on how best to intervene in the financial crisis to support China's manufacturing industry, a deceleration in RMB appreciation is likely to be an appropriate policy response throughout the remainder of 2009. This highlights

that the models developed are robust enough to include the effects of the financial crisis.

- As a result of the global financial crisis, China’s manufacturing industry may have to withstand a significant negative effect over a period of time, with its gross industrial output value declining continually throughout 2008 and 2009 before reaching a state of equilibrium. The intervention effect is described as temporary but immediate and abrupt. Furthermore, the author finds that the ARIMA-intervention model is a more precise tool for explaining and analysing the intervention effect of the financial crisis. This finding is supported by the results of the supplementary intervention model used to assess the impact of the financial crisis on China’s manufacturing industry.

9.2 Research Extension

This study proposes a two-stage analysis approach and indicates that it is an effective methodology for the investigation and formulation of competitive manufacturing strategy. However, there is still room to develop the findings of this study as follows:

- The results of the models estimated in this study could be further validated through the use of updated statistics and hypothesis tests.
- Future research examining the appropriateness of the different weights attached to the manufacturing factors included in the balanced scorecard should be conducted to improve its accuracy. It would be appropriate to incorporate fuzzy AHP into the two-stage modelling approach proposed here.

- This research could also be extended by comparing the competitiveness of China with that of North American and European countries using the two-stage analysis approach the author proposes.

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