THE PRODUCTIVITY SPILLOVERS OF FOREIGN DIRECT INVESTMENT IN CHINA: A COMPUTABLE GENERAL EQUILIBRIUM MODEL

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ABSTRACT

One of the most important aspects of foreign direct investment (FDI) is that it embodies advanced technologies and business practices which can spill over to domestic firms via various channels, e.g. labour mobility, input-output linkages, export of multinational affiliates, demonstration and competition.

This research combines computable general equilibrium (CGE) modelling and econometric techniques to quantify FDI productivity spillovers. The research is conducted in the context of the Chinese economy.

A static 101-sector CGE model is constructed to measure the endogenous productivity spillovers of FDI. Spillover effects are analyzed under three different market structure assumptions, namely perfect competition, monopolistic competition with homogeneous firms, and monopolistic competition with heterogeneous firms.

The research results show that the presence of FDI productivity spillovers can generally improve the productivity and output level of domestic enterprises in China. Spillovers make foreign firms' total output decrease. But collectively, spillovers exert positive impact on national aggregate variables, i.e. GDP, total output and welfare. The market structure assumptions of monopolistic competition and firm heterogeneity provide more perspectives (e.g. product variety and scale) for this research than the assumption of perfect competition does.

A removal of preferential corporate income tax treatment on foreign enterprises can increase the output level of domestic enterprises and promote national welfare. From a dynamic perspective, it could also promote the productivity spillovers from foreign firms.

A LIST OF PUBLISHED PAPERS

- Adam Blake; Ziliang Deng; Rod Falvey. "How Does the Productivity of Foreign Direct Investment Spill over to Local Firms in Chinese Manufacturing?" *Journal of Chinese Economic and Business Studies* (by Routledge). Vol. 7(2): pp. 183-197. 2009.
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THE WISDOM OF "PRODUCTIVITY SPILLOVERS"

"When I walk along with two others, they may serve me as my teachers. I will select their good qualities and follow them, their bad qualities and avoid them."

The Analects, Confucius (551 - 479 BC)

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LIST OF ABBREVIATIONS

BL	backward linkages
CES	constant elasticity of substitution
CET	constant elasticity of transformation
CGE	computable general equilibrium
CIESY	*China Industrial Economy Statistical Yearbook*
CSY	*China Statistical Yearbook*
EXCO	export concentration of foreign-invested enterprises
FDI	foreign direct investment
FIEs	foreign-invested enterprises
FL	forward linkages
GAMS	General Algebraic Modeling System
GE	general equilibrium
HMT	Hong Kong, Macau and Taiwan
HZDS	horizontal demonstration by foreign-invested enterprises
I/O	*Input-output Table of China*
MMU	mining, manufacturing and utilities sectors
MNEs	multinational enterprises
MOFCOM	Ministry of Commerce of China
MPSGE	Mathematical Programming System for General Equilibrium Analysis
NBS	National Bureau of Statistics of China
PE	partial equilibrium
Private	all domestic enterprises except SOEs
RMB	Renminbi, the currency of the People's Republic of China
SAM	social accounting matrix
SHEs	state-holding enterprises
SOEs	state-owned enterprises

TFP total factor productivity

TNCs trans-national corporations

UNCTAD United Nations Conference on Trade and Development

CHAPTER 1: INTRODUCTION

1.1. INTRODUCTION

Foreign direct investment (FDI) inflows to China increased dramatically from US$0.9 billion in 1983 to US$78.3 billion in 2007. China has been the largest FDI host countries among developing countries in the world for 15 years. The potential benefit which Chinese indigenous enterprises can obtain from connections with foreign-invested enterprises is enormous. This PhD research aims to find the magnitude of such benefit with a computable general equilibrium model.

This Chapter introduces what are FDI and their productivity spillovers, the current status of FDI to China, factors governing FDI productivity spillovers from FDI in China, research questions and thesis structure.

1.2. FOREIGN DIRECT INVESTMENT AND THE CHANNELS OF PRODUCTIVITY SPILLOVER

Foreign direct investment (FDI) is the movement of capital across borders in a manner that grants the investors a control over the acquired assets. FDI is different from portfolio investment in that the latter does not offer such a control. There are two forms of FDI – *greenfield investment* which initiates direct investment to new assets and *merger and acquisition* in which a foreign firm acquires part (or all) of the assets of an existing host firm. The firms that conduct FDI activities are called multinationals enterprises (MNEs) or trans-national corporations (TNCs). FDI plays an increasingly significant role in the global economy.

One of the most important aspects of FDI is that it embodies advanced technologies and business practices which can be transferred to the host economics. Domestic firms can improve their productivity through their connections with MNEs. This externality is named FDI "**productivity spillovers**" or equivalently, "technology diffusions" in the recent economic literature (Blomström and Kokko, 1998; Görg and Greenaway, 2004; Görg and Strobl, 2001; Keller, 2004). Productivity spillovers do *not* include contract-based transfer or illegal acquisition of intellectual property rights, know-how, or any kind of technology. Productivity spillovers are a relatively intangible and intractable phonomenon and can take place through four channels, namely, labour mobility, vertical linkages, export of MNE affiliates, and horizontal effects.

Labour mobility: the employees trained by MNE's affiliates will benefit from the production knowledge and management expertise they have acquired after they flow to the domestic firms or establish their own enterprises (Fosfuri, Motta and Ronde, 2001; Görg and Strobl, 2005; Markusen and Trofimenko, 2009);

Vertical linkages: MNE's affiliates help upstream and downstream domestic firms to set up production facilities, provide them with technical assistance and training in management and organization. Besides, the presence of MNEs may also trigger competition among their upstream and downstream firms (Girma and Gong, 2008a; Girma, Görg and Pisu, 2008; Javorcik, 2004;

Markusen and Venables, 1999);

Exports of MNE affiliates: MNEs transfer and relocate their manufacturing centres to export-oriented economies which are relatively labour-abundant, *e.g.* China and Vietnam, and export assembled product to third markets. This can help domestic firms gain access to international markets and promote their productivity (Aitken, Hanson and Harrison, 1997; Clerides, Lach and Tybout, 1998; Greenaway and Kneller, 2008; Greenaway, Sousa and Wakelin, 2004);

Demonstration and competition: MNEs usually possess an advantage in technology (Dunning, 1977, 1981; Markusen, 2002b) and exert a strong demonstration effect on the domestic firms in host countries. In observing the market activities of MNE affiliates and competing with MNE affiliates, local firms can imitate MNE technology and make corresponding innovations (Findlay, 1978; Koizumi and Kopecky, 1977; Wang and Blomström, 1992).

Productivity spillovers are beneficial not only to domestic firms in the host countries, but may also benefit the multinational affiliates by fostering a more productive economic environment in the host market.

1.3. IMPORTANCE OF FDI TO CHINA

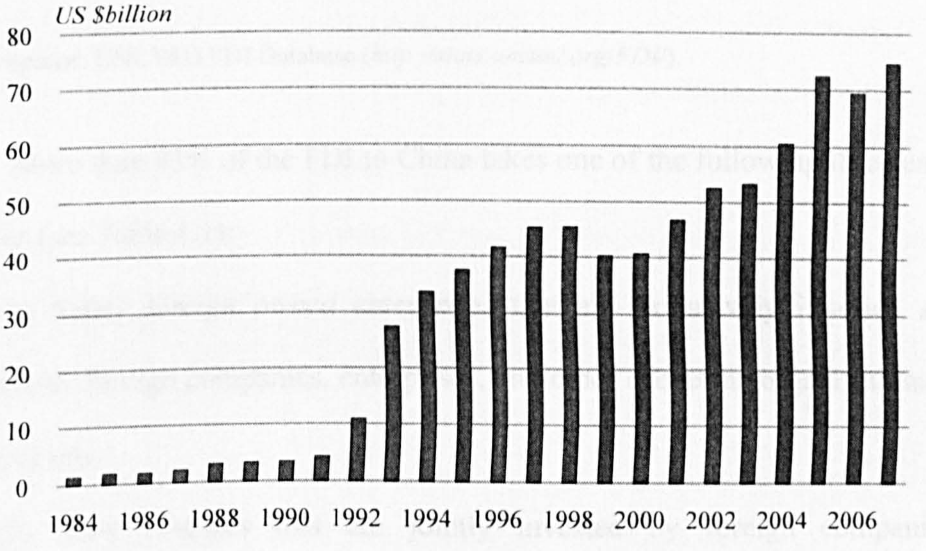
In the late 1970s Chinese ended its closure to the outside world and started implementing a "reform and opening-up" strategy. With its enormous labour supply and low labour cost (Ceglowski and Golub, 2007), stable political and economic environment, and pro-FDI policies, China has become an attractive FDI destination. As a result, FDI inflows[1] to China increased

[1] About one quarter of its FDI inflow is speculative "hot money" and "round-tripping" capital.

dramatically from US$0.9 billion in 1983 to US$78.3 billion in 2007, as shown in Figure 1.1.

Since 1993, China has been the largest FDI recipient among the developing countries, and in 2003 it was the largest FDI recipient in the world. In 2007, China was still the world's fourth largest destination for FDI, second only to the United States, United Kingdom and France. As the majority of FDI flows into developed countries (see Figure 1.2), it is amazing that China, as a relatively backward country, holds such a strong attraction for foreign capital.

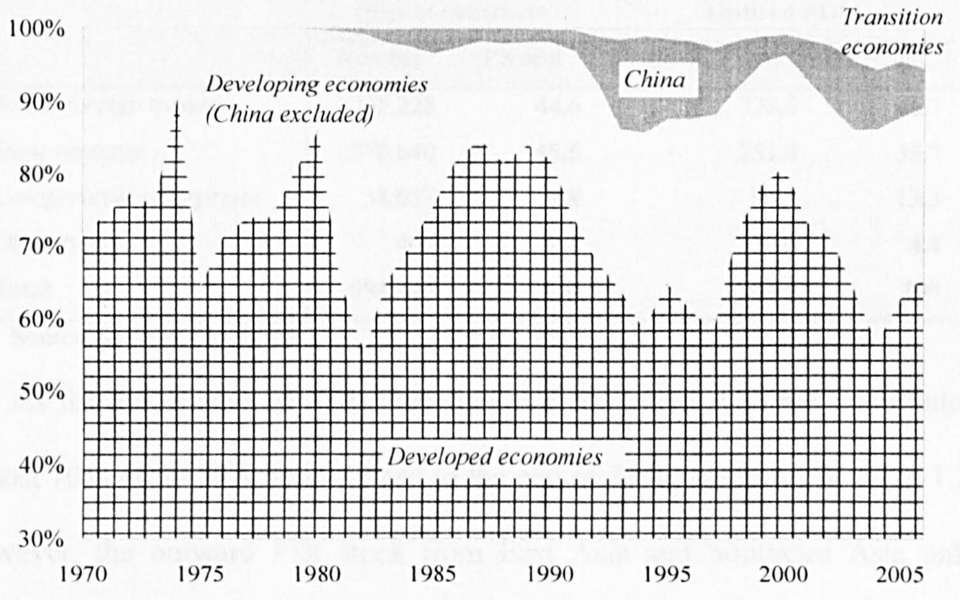
Figure 1.1: FDI Inflow to China, 1984-2007



Note: In current prices unless otherwise stated. The same rule applies to all data used throughout the thesis.
Source: Investment in China, Ministry of Commerce of China (http://www.fdi.gov.cn/).

"Round tripping" FDI refers to cross-border investment motivated by the more favourable treatment of foreign as opposed to domestic capital. Domestic investors can transfer their capital out of, and then invest back into, the domestic market in the new form of "FDI". (United Nations Conference on Trade and Development, 2003, pp. 45)

Figure 1.2: FDI Inflows, Global and by Group of Economies, 1970-2006



Source: UNCTAD FDI Database (*http://stats.unctad.org/FDI/*).

More than 95% of the FDI to China takes one of the following three entry modes (see Table 1.1):

(1) *Solely foreign owned enterprises* that are exclusively invested and owned by foreign companies, enterprises, and other economic organizations or individuals;

(2) *Joint ventures* that are jointly invested by foreign companies, enterprises, and other economic organizations or individuals and Chinese companies, enterprises, and other economic organizations. The latest *Law on Chinese-Foreign Joint Ventures* (2001) states in Article 4 that "the proportion of the investment contributed by the foreign partner(s) should not be less than 25% of the registered capital of a joint venture";

(3) *Co-operative enterprises* that are established based on cooperative terms and conditions agreed upon by foreign companies, enterprises, and other economic organizations or individuals and their Chinese counterparts.

Table 1.1: Proportions of FDI Entry Modes, Cumulated to the End of 2006

	Signed contracts		Utilized FDI	
	Number	Percent	Amount ($bn)	Percent
Solely foreign owned	265,228	**44.6**	328.5	**46.7**
Joint ventures	270,640	**45.5**	251.4	**35.7**
Co-operative enterprises	58,057	**9.8**	93.5	**13.3**
Other types	460	**0.1**	30.6	**4.4**
Total	**594,445**	**100**	**704.0**	**100**

Source: same as Figure 1.1.

As for the sources of FDI, East Asia and Southeast Asia has contributed almost 70% of the FDI accumulated to the end of 2006, as shown in Table 1.2. However, the outward FDI stock from East Asia and Southeast Asia only accounts for 12% of the world total outward FDI stock by the end of 2006, while the outward FDI from the Europe and North America accounts for 80% of world total outward FDI stock.

Table 1.2: Top 10 Sources of FDI to China, Cumulated to the End of 2006

	Signed contracts		Utilized FDI	
	Number	Percent	Amount ($bn)	Percent
Hong Kong	269,555	45.3	279.8	**39.7**
Japan	37,714	6.34	58.0	**8.2**
Virgin Islands	16,616	2.8	57.2	**8.1**
United States	52,211	8.8	54.0	**7.7**
Taiwan	71,847	12.1	43.9	**6.2**
South Korea	43,130	7.3	35.0	**5.0**
Singapore	15,556	2.6	30.0	**4.3**
United Kingdom	5,359	0.9	13.9	**2.0**
Germany	5,338	0.9	13.4	**1.9**
Cayman Islands	1,843	0.3	10.8	**1.5**
Others	75,495	12.7	108.4	15.4
Total	**594,445**	**100**	**704.0**	**100**

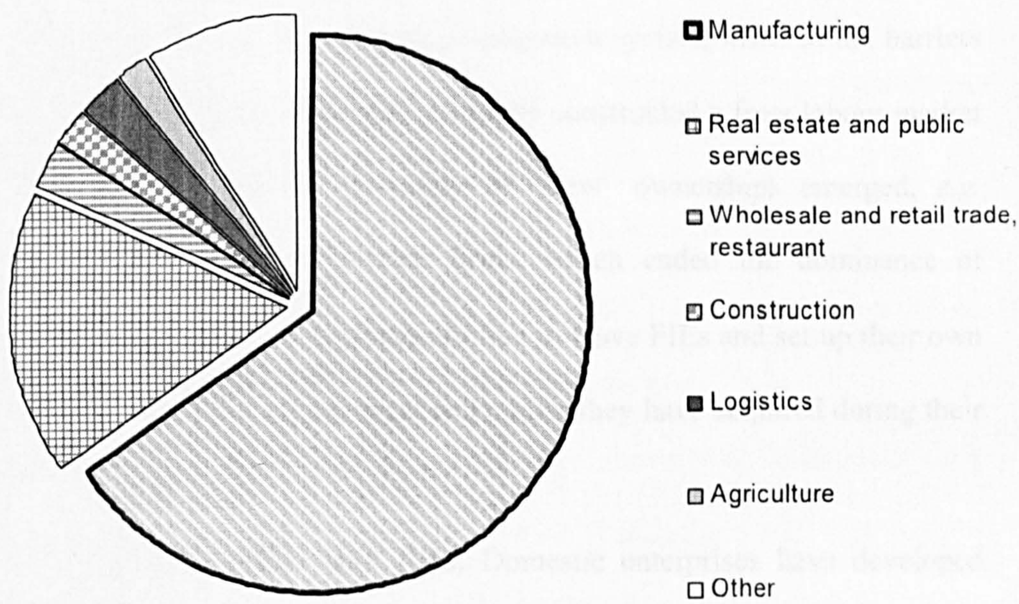
Source: same as Figure 1.1.

Note: [1] "China" in the whole thesis refers to the People's Republic of China *i.e.* China Mainland unless stated otherwise. In China Mainland, direct investment from Hong Kong, Macau and Taiwan enjoys the same favourable treatment as FDI from other sources.

There are many factors leading to the unusually large-scale Asian FDI to

China. First is the "Chinese connections" which includes, *inter alia*, ethnic Chinese networks, similar languages and culture, and geographic proximity (Zhang, 2005). Second is the perfect match between the relocations of *export-oriented* manufacturing sectors from Asian newly industrial economies (due to their rising labour cost) and China's national strategy of *export orientation*. By transferring manufacturing centres to China, the resource-seeking FDI helps multinationals maintain their cost advantage in the international market (Deng, Guo and Zheng, 2007).

Figure 1.3: Industry Distribution of Contract FDI Inflow in China, Accumulated from 1978 to 2006



Source: same as Figure 1.1

In terms of industry distribution, 67% of accumulated FDI flows to the manufacturing sectors in China (see Figure 1.3). This ratio is much higher than the proportion of manufacturing in China's total GDP, which has been maintaining within a relatively narrow band between 37% and 44% since 1978. By transferring manufacturing and assembly centres to China, FDI is viewed to have brought significant technology spillover to these sectors (Buckley, Clegg and Wang, 2002, 2004, 2007; Girma and Gong, 2008a; Liu, 2008).

1.4. FACTORS GOVERNING PRODUCTIVITY SPILLOVERS OF FDI IN CHINA

The potential of the foreign capital inflow attracted by preferential FDI policies, low labour cost, and improved infrastructure to bring positive productivity spillovers to Chinese indigenous enterprises has been strengthened by the following factors:

(1) *Freer labour market.* During the process of marketisation, the Chinese government abandoned the life-long employment system, lowered the barriers between rural and urban areas, and gradually constructed a freer labour market (Knight and Yueh, 2004). A variety of "new" ownerships emerged, *e.g.* foreign-invested firms and private firms, which ended the dominance of state-owned enterprises. Employees are free to leave FIEs and set up their own private firms using the management techniques they have acquired during their work experience.

(2) *Stronger linkages with FIEs.* Domestic enterprises have developed quickly in the past three decades and their product quality has also improved. FIEs in China are more willing to source *locally* from those qualified domestic firms, creating the opportunity for backward productivity spillovers via input-output linkages (Long, 2005; Farrell, Gao and Orr, 2004).

(3) *Learning to export by observation.* The extraordinary export performance of FIEs provided examples for domestic firms to learn to enter overseas markets. They have also familiarised the world with Chinese exports.

Both can effectively lower the entry cost of domestic firms to exporting. (Kneller and Pisu, 2007)

(4) *Increased but moderate competition.* The competition caused by the increased foreign presence has stimulated domestic firms to improve their productivity and performance. At the same time, the competition in most industries is not so fierce as to force a mass exit of domestic firms. The Chinese domestic market is growing sufficently fast that domestic firms have the opportunity to find their own niche (Long, 2005).

However FDI productivity spillovers are neither free nor automatic. In fact, there have been debates over whether spillovers really occur, and if so, their magnitude. The following factors influence the size of the spillovers:

(1) *Low absorptive capacity.* For domestic enterprises with low absorptive capacity due to a lack of R&D activity or absence of employee skills, the foreign presence could lead to no spillovers at all (Buckley, Clegg and Wang, 2002; Girma and Gong, 2008a, 2008b). Less qualified domestic firms can be forced to exit even before starting to absorb spillover benefits.

(2) *Limited scope of spillovers.* Evidence shows that firms in Chinese cities take advantage of FDI spillovers not only from local FDI inflows, but also from FDI inflows to *adjacent* cities (Madariaga and Poncet, 2007). However, due to the inter-*regional* trade barriers imposed by local governments, the inter-regional linkages are restricted (Young, 2000). Given that by the end of 2006 85% of the accumulated FDI flowed to 11 eastern and costal provinces, little inter-regional spillover from FDI will be received by the other 20 technologically backward inland provinces which host 61% of China's population and contribute 40% of total GDP (Girma and Gong, 2008b).

managers and salesmen from SOEs and other domestic firms. Evidence shows that SOEs with little care for the human capital development of their employees (*i.e.* little labour training expenditure) face a high possibility of losing talent and incurring negative spillovers (Girma and Gong, 2008a).

(6) *Indigenous technological capability suppressed.* Technological transfer through FDI may substitute for domestic technologies in production (Fan and Hu, 2007), and thus discourage indigenous R&D activities (Long, 2005). For example, in 1985 when Volkswagen established a joint venture with Shanghai Automobile, it introduced an outdated model Santana into the Chinese automobile market, and this model continued to be produced with little improvement for 20 years. At the same time the cars produced based on indigenous intellectual property struggled for a small market share (22% in 2007).

In brief, the roles of spillover channels are heavily dependent on a range of factors, and when investigating how FDI productivity spillovers occur, it is important to take these factors into consideration where possible.

1.5. RESEARCH QUESTIONS

Although the productivity spillovers of FDI are appreciated in the literature and favourable FDI policies have been a common policy practice worldwide (United Nations Conference on Trade and Development, 2006, pp. 23-24), it is still debated how to quantitatively measure the productivity spillover and whether favourable FDI policies are necessary for host countries to pursue this benefit.

This thesis aims at answering the following **research questions** which concern the nature of FDI productivity spillover, the costs and benefits of preferential FDI policies, and theory and methodology to address FDI productivity spillover:

(a) Can we examine the effects of FDI productivity spillovers in China at the macro rather than the micro level using sector and national variables, e.g. sector output, value added and GDP?

(b) In the economics literature, there have been alternative market structure assumptions, e.g. perfect competition, monopolistic competition with homogeneous firms, and monopolistic competition with heterogeneous firms. These assumptions form distinct market environments wherein the FDI productivity spillovers may take place. How do different market structure assumptions affect the ways in which FDI productivity spills over to domestic enterprises and the magnitude of such spillovers?

(c) In 2008, the Chinese government abolished its preferential corporate tax treatments for foreign-invested enterprises in China. How has this tax harmonisation impacted on the FDI productivity spillover effects?

This research constructs a static computable general equilibrium (CGE) model to quantify the productivity spillover from FDI. This research is conducted in the context of the Chinese economy in that China has been the largest FDI host country as a developing economy since 1993, and FDI productivity spillovers in China as a technologically backward country are potentially important.

This research makes three contributions. First, the productivity improvement in manufacturing sectors caused by productivity spillover is captured as an *endogenous* phenomenon by linking the spillover effects to spillover channels in a CGE model. Second, it compares the FDI productivity spillover effects in three different market structures, namely perfect competition, monopolistic competition with homogeneous firms (Dixit and Stiglitz, 1977), and monopolistic competition with firm heterogeneity (Melitz, 2003). Third, it assesses how China's 2008 corporate income tax reform has affected the FDI productivity spillover effects.

1.6. THESIS STRUCTURE

This Chapter has discussed the stylized facts of FDI inflow to China. FDI to China has been increasing dramatically, which has potentially important productivity spillover effects on domestic enterprises via labour market mobility, industrial linkages, export of FIEs, demonstration and competition. However there also exist various factors which constrain FDI productivity spillovers, such as absorptive capacity, geographic scope of spillovers, technology intensity of FIEs, short-term learning cost, cherry-picking effect in labour market, and potentially oppressed indigenous technology advancement ability. These factors influence the sign of the overall spillover effects.

Chapter 2 reviews the literature on the origin and channels of FDI productivity spillover, factors governing FDI productivity spillover effects, and empirical methodologies to address FDI productivity spillovers.

The theories constructed in the paradigm of "ownership, location, internalisation" assume that firms engaging in FDI activities are homogeneous and more productive than their domestic rivals in a host economy so that they can overcome the cost disadvantages of overseas business operations. The latest theories built on the assumption of "firms with heterogeneous productivity" find that firms engaging in FDI are more productive than firms which only export, while the latter are more productive than firms which serve the domestic market only. The above two generations of FDI theories both imply that multinational enterprises are the most productive in a host economy, implying the possibility of FDI productivity spillovers.

The review also shows that possible channels of FDI productivity spillovers include labour mobility and vertical input-output linkages between multinational affiliates and domestic enterprises, export of MNEs, demonstration, increased competition, and resource reallocation.

Various factors determine the effects of FDI productivity spillovers. They include FDI intensity, technology intensity, geographic proximity to multinational affiliates, absorptive capacity of domestic enterprises, legal environment on intellectual property rights in host countries, and learning cost.

Available empirical methodologies include econometric models and computable general equilibrium models. The former are more widely adopted for firm-level and industry-level analysis, while the latter are more suitable for economy-wide analysis.

Chapter 3 introduces the theoretical foundation and construction of a typical CGE model. CGE modelling involves designing a large-scale general equilibrium model across all the industries and implementing computer-based simulations of counterfactual scenarios.

CGE models are a class of models that explore the overall economic impact of policy, technology or other external "shocks". The microeconomic foundation for CGE models is Walrasian general equilibrium theory. A CGE model consists of (1) a series of equations of production, consumption, utility and so on, which cover the whole economy including the activities of all industries, governments, and households; and (2) a detailed database consistent with the model equations.

As a *general-equilibrium* model, a CGE model is inappropriate for the analysis of small-scale, sector-specific changes, but is well tailored to the investigation of broadly based policy innovations where inter-region and inter-industry feedbacks and interdependences are important. Most of the applications of CGE fall into the categories of tax and trade policy research and more recently, resource and environment research.

The simulation work in a CGE model is based on a social accounting matrix (SAM) or input-output table in a base year. A SAM expands a cross-industry input-output table by incorporating non-production sectors, (*e.g.* households and government) in a more comprehensive way. A SAM or input-output table statistically represents flows of all economic transactions that take place within an economy.

GAMS provides a tailored and powerful higher-level coding platform for CGE modellers. MPSGE as a subsystem of GAMS is specially designed for a mix of complementarity problems that are most frequently met in general equilibrium models. CGE modelling provides a convincing structural research framework on the topic of FDI productivity spillovers and the associated FDI policy assessment. A CGE model can decompose FDI spillovers effects into benefit obtained through different channels, namely vertical linkages, export of MNEs and horizontal demonstration. However, due to the data constraint and the only option of a single year as the benchmark year, the reliability of CGE modelling is subject to sensitivity tests.

Chapter 4 provides data sources used in this research and discusses the data compilations. The transformation of the original input-output table involves a complex data manipulation process, which mainly involves **three types of work**: (1) aggregating the original 122 by 122 input-output table into a 39 by 39 one; (2) disaggregating 39 by 39 one into a 101 by 101 one with information on different ownerships, which enables the CGE model constructed on this input-output table to address issues regarding ownership (*i.e.* spillovers from foreign-invested enterprises to domestic enterprises); (3) data balancing and consistency check.

Data employed are mainly from *China Statistical Yearbook 2003*, *China Industry Economy Statistical Yearbook 2003* and *China Input-Output Table 2002*. Data of several sectors are aggregated to reconcile different statistical standards. Data of agriculture, construction, and services are also aggregated to a great extent to cater for the data availability of FDI inflows. By doing so, we can obtain a 39 by 39 sector input-output table. With data estimated for FIEs, SOEs, and Private enterprises, 31 out of the 39 sectors can be further disaggregated into $31 \times 3 = 93$ ownership-sectors. Data balancing techniques are used to make the transformed input-output table balanced. In the process of data manipulations, three rounds of data consistency checks are conducted.

Chapter 5 constructs a CGE model tailored for this research on FDI productivity spillover in China. Theoretical models for three market structures are also discussed, namely perfect competition, monopolistic competition, and firm heterogeneity.

A benchmark CGE model for the Chinese economy will be presented with the original forms and "calibrated duality forms" of CES functions. The model contains blocks of value-added production, output production, CET transformation into export and domestic consumption, labour and capital disaggregation, Armington aggregation, export and import, representative domestic agent, representative agent for multinational enterprises, and government. Equations for equilibria of factor marks, Armington markets, aggregate export and import will also be presented.

This model will then be extended to incorporate FDI productivity spillovers under perfect competition. Chinese industry-level data during 2001 and 2006 will be employed to estimate the coefficients of four spillover channels. Forward linkages and horizontal demonstration are found to be the most significant channels via which spillovers take place.

FDI productivity spillovers will be modelled in an alternative market structure, namely monopolistic competition with homogeneous firms. In this scenario, the markup rate of a representative firm of each sector is derived, which is essential to extending a CGE model to incorporate monopolistic competition. A CGE model to study FDI spillovers under monopolistic competition can also reflect the changes of product varieties and quantities caused by the spillovers.

Finally FDI productivity spillovers will be modelled in another alternative market structure, *i.e.* monopolistic competition with heterogeneous firms. This market structure is a newly explored one in the literature, and is potentially important in explaining the productivity change of domestic firms. A CGE model under firm heterogeneity is composed of a general equilibrium module and a partial equilibrium module. The former is a model with FDI spillovers under perfect competition. The latter deals with firm heterogeneity, assuming a virtual "quasi-representative" firm and "summarising" the distribution of firm productivity in each sector. The CGE model in this scenario can provide alternative perspective to the effects of spillovers by examining productivity improvement under FDI productivity spillovers in a more direct way.

Chapter 6 discusses how an FDI shock to the benchmark economy, together with productivity spillovers, affects economic performance. Simulations are conducted under three different market structures, namely, perfect competition, monopolistic competition, and firm heterogeneity.

Results show that (1) in terms of national aggregate indicators, an FDI shock is beneficial to the economy, and FDI productivity spillovers are followed by positive spillover premiums under the three market structures; (2) for domestic enterprises (including SOEs and Private enterprises), FDI productivity spillovers promote their performance and always outweigh the negative impact of an FDI shock; (3) for foreign-invested enterprises, FDI productivity spillovers cause resources to be attracted away by their rivals that are more productive thanks to the FDI spillovers, thus making the increase in foreign-invested enterprises' total output *lower* than otherwise. This finding also applies to all the three market structures; (4) product variety and production scale per variety can both be improved by an FDI shock, and FDI productivity spillovers can exert positive "spillover premiums" under certain conditions; and (5) the experiments under monopolistic competition assumption show that FDI productivity spillovers are more prominent in an industry with a lower initial degree of competition.

Chapter 7 simulates the impact of corporate income tax reform in 2008 on the FDI productivity spillover effect in China.

It introduces the major tax incentives to attract FDI in China, and discusses the cost and benefit of such preferential FDI treatment. The results of the tax reform simulations show that the original dual corporate income tax system was indeed good for the FDI productivity spillovers to occur in that it helped strengthen the foreign presence which is vital for FDI productivity spillovers.

A higher corporate income tax levied on foreign-invested enterprises alone distorts the economy's structure and lowers total output, welfare, and GDP. However an integrated tax reform formula can do a better job by increasing the output level of domestic enterprises and by promoting national welfare. Under firm heterogeneity, the spillover benefit of integrated reform is even more prominent, because the reform can lift up the average productivity of all existing enterprises, and raise the possibility of productivity spillovers and the absorptive capacity of domestic enterprises. This is more beneficial to the productivity spillovers from foreign-invested firms to domestic enterprises.

Neither single-sided reform nor integrated reform can increase the proportion of the productivity spilt over from foreign firms to domestic firms in total productivity of domestic enterprises. Taking into consideration the changing pattern of productivity under firm heterogeneity, the tax reform will only temporarily lower the FDI productivity spillover effects, however it may promote the speed and magnitude of spillovers later.

Chapter 8 summarises the methodologies, contributions and main findings of the whole thesis and discusses possible directions for future research.

CHAPTER 2: A REVIEW ON FOREIGN DIRECT INVESTMENT AND PRODUCTIVITY SPILLOVERS

2.1. INTRODUCTION

This Chapter will review the literature on the origin (Section 2.2) and channels of FDI productivity spillover (Section 2.3), factors governing FDI productivity spillover effects (Section 2.4), and empirical methodologies to address FDI productivity spillovers (Section 2.5).

2.2. THEORIES OF FDI

2.2.1. Theories of MNEs in Dunning's Paradigm

Multinational affiliates can compete with local firms in host countries due to their advantage in productivity. Without productivity advantage, multinational affiliates can never survive in competition with local firms as the former face extra cost in doing business in overseas markets, including communication cost, a higher pay for stationing employees overseas, and barriers of languages and culture (Hymer, 1976).

Dunning (1977; 1981) conceptualises this productivity advantage and attributes it to three factors of a multinational firm which outweigh the cost disadvantages of producing in an host country:

(1) *Ownership advantage* which represents both tangible (*e.g.* special equipment) and intangible assets (*e.g.* know-how, patent, trade mark), neither

of which is easily replicable to host firms;

(2) *Location advantage* which includes the benefit which a multinational can get by circumventing tariffs and transportation costs incurred in trade, and by getting closer access to consumers in local markets;

(3) *Internalisation advantage* which means that profitable production processes can be fully exploited by multinationals in setting up overseas subsidiaries rather than licensing them out.

Markusen (2002b) proposes the concept of "*knowledge capital*" which denotes the firm-level R&D activities shared by headquarters and subsidiaries. Markusen argues that knowledge capital offers foundations for ownership, location and internationalization advantages of multinational enterprises proposed by Dunning (1977; 1981). He constructed a "knowledge capital model", which owes the origin of vertical and horizontal FDI to the knowledge capital of multinationals. The theoretical hypotheses drawn from this model fit well with the results of econometric studies.

2.2.2. Theories of MNEs with Heterogeneous Productivity

The implicit assumption of the above theories is that all firms in a country have identical productivities and every firm is *productive enough* to go abroad and engage in more costly and risky overseas production. However, this assumption contradicts with the prevailing evidence that multinationals are typically more productive than those national firms that only engage in domestic business (Tomiura, 2007; Yasar and Paul, 2007; e.g. Girma, Kneller and Pisu, 2005). This contradiction has been largely solved by the latest development of FDI theories, namely the theory of *firm heterogeneity* (Helpman, Melitz and Yeaple, 2004) and theory of *incomplete contracts*

(Antràs and Helpman, 2004). Both theories have predicted that only the most productive firms can engage in FDI, implying the possibilities of FDI productivity spillover in host countries.

Firm heterogeneity model

Helpman *et al* (2004) emphasise the role of *productivity differences* across firms in determining the sales of MNEs relative to the exports of national enterprises (NEs). They find that only the most productive firms can afford the high fixed costs of setting up foreign subsidiaries, whereas less productive firms remain as NEs and may serve foreign markets by exporting. The least productive firms can only serve the domestic market.

The model of Helpman *et al* (2004) is supported by many empirical studies. With firm-level data of U.K. manufacturing sectors, Girma, Kneller and Pisu (2005) find that the cumulative productivity distribution of British MNEs lies to the right of that of non-MNEs in the level, *i.e.* the productivity of MNEs is generally higher than non-MNEs. Similarly, the productivity distribution of exporters lies to the right of that of non-exporters.

With firm-level panel data of Japanese industries, Kimura and Kiyota (2006) also find evidence supporting the prediction of Helpman *et al* (2004), *i.e.* productivity is indeed an important factor explaining the decision to engage in FDI as well as export. They also find that the highest productivity firms export *as well as* engage in FDI. This does not contradict with Helpman *et al* (2004), as for a multi-product firm operating in a several countries different in sizes and wages, it is possible that the firm will adopt both exports and FDI as complementary rather than substitute strategies, as discussed by Girma *et al* (2005).

In their model with heterogeneous multinational firms, Falvey, Greenaway and Yu (2007) assume that unit cost of a multinational subsidiary is *jointly* determined by the parent firms' cost in its home country and a random cost drawn from a distribution that is common to all indigenous entrants in the host country. They find that a subsidiary is less likely to shut down when its parent firm's productivity is higher and the counterpart domestic firm's productivity is relatively lower.

Nocke and Yeaple (2007) further differentiate FDI activities into cross-border merger & acquisitions (M&A) and greenfield FDI, and find that for R&D-intensive industries where the heterogeneous productivity at firm level mainly originates from firms' technological know-how, firms engaging in either M&A or greenfield FDI are more productive than firms engaging in exporting only.

The technological superiority of greenfield FDI is supported by an empirical study of U.S. multinational firms (Nocke and Yeaple, 2008). It is found that U.S. parent firms that choose greenfield FDI are systematically more productive than those firms that choose M&A. This stylized fact has been generalized as a theoretical proposition in a general equilibrium model of the world economy (Nocke and Yeaple, 2008).

Incomplete contract model

Antràs and Helpman (2004) model how a firm sources abroad either through foreign outsourcing or FDI with the notion of "*incomplete contract*". An "incomplete contract" denotes a contract of an intermediate product between its supplier and user, which however can not specify the legal consequences of every possible state of the intermediate product the supplier sells to the user. In their model, the high-productivity firms source overseas by engaging in FDI; the low-productivity firms acquire intermediates only within the home country; and the firms with medium productivity choose foreign sourcing.

Tomiura (2007) finds evidence supporting the theoretical propositions of Antràs and Helpman (2004) and Helpman *et al* (2004). With a firm-level dataset of 118,300 Japanese firms, Tomiura documents how the firm productivity varies as firms engage in different internationalisation modes. Foreign outsourcers and exporters tend to be more productive than domestic firms, but less productive than the firms active in FDI or in multiple globalization modes. This productivity hierarchy is robust to the inclusion of control variables, *i.e.* firm size, factor intensity, and industry dummy.

In brief, Section 2.2 has reviewed the theories of FDI. The theories constructed in Dunning's paradigm of "ownership, location, internalisation" assume that firms engaging in FDI activities are homogeneous and more productive than their domestic rivals so that they can overcome the cost disadvantages of overseas business operations. The latest theories built on the assumption of "firms with heterogeneous productivity" find that firms engaging in FDI are more productive than firms which only export, while the latter are more productive than firms which serve the domestic market only. The above two generations of FDI theories both imply that multinational enterprises are the most productive, which give rise to the possibility of FDI productivity spillovers.

2.3. CHANNELS OF FDI PRODUCTIVITY SPILLOVERS

In investing overseas, the advanced technology of multinationals will inevitably spill over to the domestic firms in the host countries via a variety of channels, such as labour mobility, vertical input-output linkages, exports, and horizontal effects. In the past decade, there has been emerging literature scrutinizing the spillovers by examining the spillover channels at micro level.

2.3.1. Labour Mobility

Productivity spillovers could take place when workers or managers in foreign-invested firms move to domestic firms or set up their own enterprises. In this process, the workers or managers will apply their knowledge legally acquired while working for multinationals in their new domestic firm and exert a positive impact on its productivity. Fosfuri, Motta and Ronde (2001) construct a two period model where a multinational trains a local worker to run its subsidiary in the first period, then in the second period the multinational and a local firm compete to employ the trained worker. Only if the MNE pays a higher wage can it stop the worker from moving to the local firm. Regardless of whether the worker moves to the local firm, the domestic economy can always benefit from the FDI presence. When the informed worker is hired by the local firm, a *technological* spillover takes place, while if the informed worker is retained by the multinational subsidiary at a higher wage, then a *pecuniary* benefit arises. These technological spillover and pecuniary benefits are echoed by Glass and Saggi (2002) who build a model with multiple host and source firms.

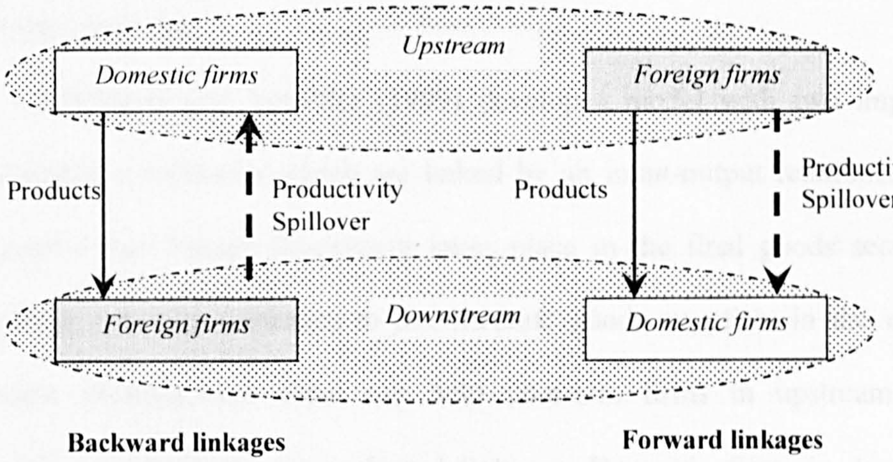
Markusen and Trofimenko (2009) situate the issue of FDI productivity spillover via labour mobility in a general equilibrium (rather than partial equilibrium) framework. When the analysis is applied to Colombian firm-level data, the paper confirms that the inter-ownership mobility of workers with skills acquired from contacts with foreign experts have substantial and persistent positive effects (though not always immediate) on the value added per worker of domestic firms.

Görg and Strobl (2005) investigate FDI spillovers through the channel of labour mobility using detailed firm-level data for a sample of manufacturing firms in Ghana. Specifically, the authors have data on whether the entrepreneurs of the domestic firms in the sample have worked for a foreign multinational or have taken professional training in an MNE before they joined or established their current companies. They control for the underlying capability of entrepreneurs, using years of schooling and previous experience in the same industry. This avoids potential ambiguity in the causality between the productivity of the firms and the labour mobility: firstly, foreign firms might hire or provide training to more skilled workers as they already demonstrate a stronger capability, possibly through higher education; secondly, better domestic firms may attract better workers and managers. The econometric analysis shows that the FDI spillovers via labour mobility are significant and industry-specific.

2.3.2. Vertical Input-output Linkages

MNEs affiliates may help upstream and downstream domestic firms to set up production facilities, and provide them with technical assistance and training in management and organization (Girma and Gong, 2008a; Girma, Görg and Pisu, 2008; Javorcik, 2004; Markusen and Venables, 1999). Vertical input-output linkages include backward linkages and forward linkages as illustrated in Figure 2.1.

Figure 2.1: Backward and Forward Linkages as Spillover Channels



Backward linkages result in backward feedback from multinational affiliates in downstream sectors to upstream indigenous firms. Sourcing locally can effectively reduce the production cost of multinational affiliates and thus is a natural choice for them. This can trigger competition among upstream domestic firms. Moreover, multinationals usually set high technical standards for their intermediate inputs and it is likely that downstream foreign firms need to transfer necessary techniques to the upstream domestic firms (Javorcik, 2004), improving the latter's technological capacity in the process. Thus the competition effect and high standards together with the knowledge transfer, all as a result of *backward linkages*, act as a channel of FDI productivity spillover.

Forward linkages promote the forward transfer of knowledge from multinational affiliates in upstream sectors to downstream indigenous firms. Domestic firms can improve their productivity via forward linkage in two ways. First by purchasing high-quality intermediate products from multinational firms. Similar spillover effects via forward linkages in international trade have been widely acknowledged in the literature (Falvey, Foster and Greenaway, 2004; Keller, 2004). Second, in becoming a product distributor of a multinational firm, a domestic company often has to make a series of improvements, *e.g.* employee training, to meet the standards to be a retailer for the multinational.

Markusen and Venables (1999) develop a model with two imperfectly competitive industries which are linked by an input-output relationship. It is assumed that foreign investment takes place in the final goods sector, thus creating backward linkages to intermediate goods suppliers in the upstream sector. Multinational firms can help domestic firms in upstream sectors improve productivity via backward linkages. Domestic firms in downstream sectors can then also benefit from the improved intermediate products supplied by domestic suppliers. This benefit can *outweigh* the competition effect (in the product and factor markets) which multinational firms impose on their rival domestic firms, therefore leading to the development of local industry.

With firm-level data for Lithuania, Javorcik (2004) finds evidence of positive backward spillover from FDI via the nexus between multinational firms and their local upstream suppliers. The specification for backward linkage is as follows:

$$Backward_{j,t} = \sum_{k \text{ if } k \neq j} \alpha_{j,k,t} \left[\sum_{i} ForeignShare_{i,k,t} * \frac{Y_{i,k,t}}{\sum_{i} Y_{i,k,t}} \right] \quad (2.1)$$

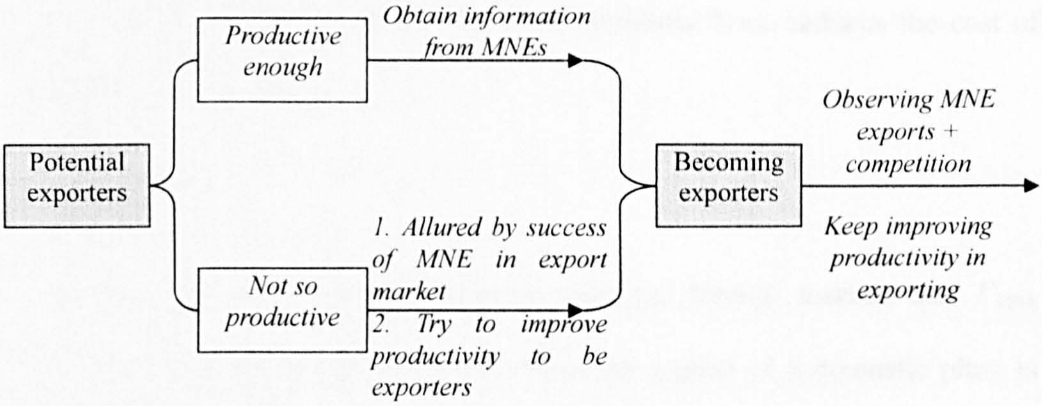
where $\alpha_{j,k,t}$ is the proportion of sector j's output supplied to sector k at period t calculated from input-output matrix. $Y_{i,k,t}$ denotes the output of the ith firm in the kth sector at period t. $ForeignShare_{i,k,t} \times \frac{Y_{i,k,t}}{\sum_{i} Y_{i,k,t}}$ measures the foreign equity participation of the ith firm in the kth sector, weighted by each firm's share in sectoral output.

Jacorcik's specification of backward linkages has been widely employed to examine backward productivity spillover in various studies (Girma and Gong, 2008a; Girma, Görg and Pisu, 2008; Kneller and Pisu, 2007; Bitzer, Geishecker and Görg, 2008).

2.3.3. Export of MNEs

To export involves sunk costs incurred for market research, advertisement, distribution networks etc., which might deter entry. Trade models with heterogeneous firms predict, and evidence from firm level data sets confirm, that entry into exporting is a *self-selection* process in which more productive firms become exporters while less productive firms serve domestic markets only (Melitz, 2003; Clerides, Lach and Tybout, 1998). But even when some domestic firms are *productive enough* to enter export markets, they may lack information of overseas markets and foreign consumers may be unfamiliar with products manufactured abroad. As large multinationals have well established international trade networks and have extensive knowledge of international markets, their presence can help lower information barriers facing domestic firms and help acquaint foreign consumers with products manufactured in the host country (Aitken, Hanson and Harrison, 1997; Greenaway and Kneller, 2008).

Figure 2.2: Productivity Spillover of MNE Exports



For domestic export candidates which are not currently productive enough to find exporting profitable, the success of multinational firms in international markets can stimulate domestic candidates to emulate them (Alvarez and López, 2005). To achieve this goal, they have to improve their productivity and product quality to meet international standards.

There is little evidence of exporting itself improving firm productivity in developed countries (e.g. Greenaway and Kneller, 2004, 2007). However this does not necessarily imply that such productivity improvements may not occur in *emerging* markets, such as China. FDI from the East Asian economies have transferred their labour-intensive, export-oriented assembly centres to the coastal provinces in China (Deng, Guo and Zheng, 2007), and the exports of foreign-invested firms accounts for more than 50% of national total export volume in the past ten years. During 1980-2006, the commodity export volume of China has increased dramatically (53.5 fold), while in the same period, the commodity export volumes of the U.K. and U.S. have only increased by 3.9 fold and 4.7 fold, respectively.[2]

With panel data of Mexican manufacturing plants, Aitken, Hanson and

[2] Author's calculations based on data from United Nations Commodity Trade Statistics.

Harrison (1997) finds that the information externalities associated with export activity of multinational firms rather than domestic firms reduces the cost of exporting of other firms:

$$\frac{\partial m_f}{\partial \Gamma_{MNE}} \leq 0$$

where m_f denotes the distribution cost for foreign market, and Γ_{MNE} denotes the export activity of MNEs. Thus the export of a domestic plant is positively affected by contacts with multinational firms.

Greenaway, Sousa and Wakelin (2004) investigate export spillover effects from multinationals to domestic firms in the UK. They find that exports of multinational affiliates can help increase domestic firms' export propensity, and domestic firms can improve their productivity by increasing exports.

The evidence found by Kneller and Pisu (2007) also supports productivity spillover via export of MNEs. With British firm-level data, they find that the decisions of domestic British firms concerning how much to export are positively influenced by the presence of foreign multinationals in the same, upstream or downstream industries. Both export-oriented and domestic market-oriented multinationals appear to generate positive and significant export spillovers, but those from the former are stronger. This suggests that the leakage of specific information about foreign markets from established foreign exporters is important in improving domestic exporters' productivity. Once a firm becomes an exporter, it is possible that its productivity will be boosted due to learning and competition effects.

Girma, Görg and Pisu (2008) confirm that the degree of export orientation of both domestic and multinational enterprises is relevant to FDI productivity spillover. Using a panel data set of British companies, they find positive horizontal spillovers from export-oriented multinationals only, yet domestic-market-oriented MNEs generate positive spillovers through backward linkages for both domestic exporters and non-exporters.

2.3.4. Horizontal Effects: Demonstration, Competition and Resource Reallocation

Demonstration is probably the "most evident" spillover channel (Crespo and Fontoura, 2007, pp. 411), especially in transition economies such as China which are transforming from a centrally planned economy, dominated by SOEs, into a market economy with a variety of ownerships in a short time span. Foreign-invested firms with technological and managerial advantages open a fresh "window" of high productivity, and showcase their superior practices in production, management, and services to their indigenous counterparts. Domestic firms can thus imitate the production of foreign firms through "reverse engineering" (Das, 1987).

Increased competition in a host economy created by the entry of MNEs constrains the market power of monopolistic domestic firms, forcing them to make a more efficient use of existing resources.

Resource reallocation is a channel via which FDI presence can help the host economy relocate resources towards the most productive firms and increase industry-level and national productivity. The entry of foreign firms can intensify the competition for labour resources in host countries. Even for large transition economies with a huge hidden surplus labour supply like China (Fu and Balasubramanyam, 2005), the price of non-skilled labour in export-intensive sectors will inevitably rise (Ceglowski and Golub, 2007) due to the factor price convergence effect of international trade (Falvey and

Kreickemeier, 2005). The rising labour cost will make the least productive domestic firms unprofitable and drive them out of market. Then resources will be relocated to more productive firms, allowing them to increase in production scale. Therefore the industry-level and aggregate-level productivity can be raised. This resource reallocation effect driven by FDI is consistent with that effect driven by trade which is modelled by Melitz (2003). This spillover via resource reallocation does *not* necessarily improve the productivity of any individual firm. But it helps explain why industry-level econometric analyses of FDI productivity spillovers tend to generate significantly positive results.

2.4. DETERMINANT FACTORS OF FDI PRODUCTIVITY SPILLOVERS

2.4.1. FDI Intensity and Technology Intensity

It is found that there exists a threshold effect in FDI productivity spillovers, *i.e.* if the FDI volume is too low, the productivity spillover will be limited (Aitken and Harrison, 1999). It is also generally acknowledged that the more FDI in an industry, the higher will be the possibility of productivity spillovers. However, the spillover effect also depends on the technology intensity of FDI. For foreign firms with mature and standardised rather than state-of-the-art technologies, their productivity spillover effect exhibits an inverted U curve trajectory as their presence becomes higher.

Koizumi and Kopecky (1977) were the first to explicitly specify the spillover effect of foreign capital. In their model, the total capital stock K in a host country is divided into K_F and K_N, (*i.e.* $K = K_F + K_N$), which represent the portion owned by foreigners and domestic nationals, respectively. K_F and K_N

are heterogeneous in that the former can trigger technology spillover.

The production function of the only domestic commodity *X* is:

$$X = \psi(K_F / L) * G[(K_F + K_N), L]$$

$\psi(K_F/L)$ is the technology transfer function and K_F/L denotes foreign capital per capita. It is assumed that a host country always experiences technological improvement from the contact with foreigners so that $\psi(K_F/L)$ is greater than unity for any $K_F/L>0$.

Then technology spillover is denoted in partial differentiations:

$$\frac{\partial X}{\partial K_N} = \psi G_K, \quad \frac{\partial X}{\partial K_F} = \psi G_K + (\frac{\partial \psi}{\partial K_F})G$$

Therefore the marginal product of foreign capital is greater than that of domestic capital by $(\partial\psi/\partial K_F)G$ which represents the *productivity spillover* embodied in foreign capital. When $\partial^2\psi/\partial K_F^2 > 0$, $(\partial\psi/\partial K_F)G$ is an *increasing* function of K_F. By linking domestic production to foreign capital intensity, the model indicates the importance of foreign capital in influencing the path of economic development.

In a dynamic model, Findlay (1978) hypothesises that the rate of technical efficiency change in the backward countries is an increasing function of the technology gap between advanced and backward regions.

The ratio of foreign capital stock $K_f(t)$ to domestic capital stock $K_d(t)$ is used to measure foreign presence at period *t*. $A(t)$ and $B(t)$ represent the levels of technical efficiency in the advanced and backward regions at period *t*, respectively:

$$x \equiv \frac{B(t)}{A(t)}; \; y \equiv \frac{K_f(t)}{K_d(t)}$$

$\partial \dot{x} / \partial y$ is assumed to be positive, *i.e.* the technological gap between the relatively backward and advanced countries will decrease as foreign capital intensity in the relatively backward country increases. The model shows, that under this assumption, (x, y) can converge to a long-term steady state (x^*, y^*).

Das (1987) examines the optimal behaviour of a multinational firm's subsidiary in a host country when technology spillover takes place between it and its local rivals. Let parameter A denote the productivity of *local* firms, then the advancement of A in any period is positively and linearly correlated with Q_m, the amount of output of the MNE's subsidiary during that period:

$$\dot{A} = \alpha Q_m, \ \alpha > 0$$

This will intensify the competition and lower the price of MNEs' products. Assuming MNEs need to maximise their discounted sum of profit, the model also finds out that the best response of MNEs is to lower the increase rate of domestic enterprises ($\dot{A}$) by lowering their own production scale (Q_m).

Buckley, Clegg and Wang (2002; 2007) emphasizes how the technology intensity of foreign investment affects the productivity spillover effect. In China Mainland, the enterprises invested by FDI from overseas Chinese in Hong Kong, Macau, and Taiwan (HMT) tend to engage in labour-intensive manufacturing with standardised rather than state-of-the-art technologies. Their studies show that the spillover from HMT FDI falls beyond a certain critical point of foreign presence as the productivity spillover is mitigated by the competition with domestic enterprises for limited resources. The findings of Buckley *et al* (2002; 2007) are echoed by Wei and Liu (2006), who find that OECD-invested firms play a much greater role in inter-industry spillovers than overseas Chinese firms from HMT.

2.4.2. Proximity and Participation

Geographic **proximity** matters in FDI productivity spillovers due to the limited spatial scope of labour mobility and the importance of face-to-face communication (Halpern and Murakozy, 2007). Similarly, the entry modes of FDI *i.e.* M&A or greenfield, also matter. Joint ventures involve a higher degree of local **participation** and a higher possibility of linkages with local firms, which could generate more productivity spillover.

Using data of Hungarian manufacturing firms, Halpern and Murakozy (2007) examine the role of geographic distance between where foreign-invested firms are located and domestic firms in productivity spillovers. They weigh the spillover variables with functions of distance of foreign firms to domestic firms so that the spillover variables will be larger when the distance is smaller. For example one of the weighing functions they employ is: $f(d_{i,m}) = 1/(1+d_{i,m}/100)$, where $d_{i,m}$ denotes the distance of the ith indigenous firm to the mth multinational affiliate. Their econometric analysis results show a significantly negative relationship between the distance between foreign firms and domestic firms and the spillover.

Their conclusion is consistent with those of Greenaway and Kneller (2008). As industrial or locational agglomeration might offer opportunities for lowering sunk costs, industrial or locational proximity to export-oriented multinational firms can help non-exporters become exporters. With firm-level data of U.K. manufacturing sectors, they find that exporters have a strong positive and significant impact on the export decision of potential exporters in the same industry, and similarly, from the same region. No significant impact is found on entry from exporting firms located in other regions or industries.

With Romanian firm-level data, Javorcik and Spatareanu (2008) find M&A FDI has a greater productivity spillover effect on domestic firms than greenfield FDI does. First, affiliates in the form of joint ventures are likely to face lower costs of finding local suppliers of intermediates. Thus they should be more likely to source inputs locally, which in turn leads to more vertical productivity spillover to firms in upstream sectors, *i.e. backward spillover* (Javorcik, 2004). Second, multinational headquarters tend to transfer medium advanced technologies to their partially owned affiliates and transfer state-of-the-art technologies to wholly owned subsidiaries. The medium advanced technologies could be easier to be absorbed after they spill over to domestic firms.

2.4.3. Absorptive Capacity

Absorptive capacity includes both *macro-level* characteristics including infrastructure, economic development and human capital, and *micro-level* indicators *e.g.* R&D expenditure, education of employees, employee training and flexibility of labour turnover. Theoretical models have shown that a firm with a stronger absorptive capacity can reap more benefit from FDI productivity spillover (Lai, Peng and Bao, 2006; Keller, 1996).

Aitken and Harrison (1999) find that the economy of Venezuela is not sufficiently developed to accommodate the positive externalities of FDI. Their appreciation of macro-level absorptive capacity is echoed by research on the productivity spillover of international trade (e.g. Falvey, Foster and Greenaway, 2007)

The studies of China also justify absorptive capacity as a necessary condition of FDI productivity spillover. With industrial survey data of 1995, Buckley *et al* (2002) find SOEs could reap no spillover from the presence of foreign firms while non-SOEs could get positive benefit from FDI spillover. This is not unusual as Chinese SOEs were tightly controlled by the government, and operated "bureaucratically mandated plans" in the 1990s (Buckley, Clegg and Wang, , pp. 641).

Girma and Gong (2008a) examine the adjustment of Chinese SOEs' total factor productivity (TFP) to the presence of multinational firms using the following empirical model:

$$TFP_{it} = \alpha_i + \boldsymbol{\beta}' \boldsymbol{X}_{it} + \gamma_1^{'} \boldsymbol{RFDI}_{it} + \gamma_2^{'} \boldsymbol{OUTFDI}_{it} + \boldsymbol{\delta}' \boldsymbol{D}_{it} + \varepsilon_{it}$$

where i and t index SOEs and time respectively, ε represents a random error term and $\boldsymbol{X}$ is a vector of variables measuring *absorptive capacity* (employee training, market share, intangible assets, and exporting activity) hypothesized to impact on SOEs' TFP. ***RFDI*** and ***OUTFDI*** are two vectors consisting of variables capturing foreign presence in the firm's region and outside the region, respectively. The vector $\boldsymbol{D}$ consists of the full set of time, sectoral and regional dummies. These dummies control for economy-wide productivity shocks and the fact that FDI flow is endogenous in the sense of being partly determined by sectoral and regional productivity levels. They find that foreign presence is generally *negatively* associated with TFP level of SOEs. However, there is a positive effect of FDI on SOEs that export, invest in human capital or R&D, or have prior innovation experience. These findings confirm that absorptive capacity is indeed a necessary condition of FDI spillover.

2.4.4. Protection of Intellectual Property Rights

How the protection of intellectual property right (IPR) affects FDI productivity spillover is largely dependent on the channels via which the spillover takes place.

On the one hand, knowledge of multinational affiliates spills over, via *labour mobility* and *demonstration*, to domestic enterprises more quickly in a host country where the IPR protection system is not well established. Suppose know-how is protected as a patent in the U.K., however it is very time-consuming to apply for a patent for this know-how in a host country. Then, as the employees in the host country know the details of the patent, there exist risks that these employees will join local companies, taking with them this sensitive technology. This technology spillover is not illegal as the know-how has not been protected in the host country.

However a poor IPR protection environment usually discourages FDI, especially in the form of joint ventures (Gattai and Molteni, 2007; Falvey, Foster and Memedovic, 2006; Saggi, 2002). This will decrease the *magnitude* of productivity spillover.

On the other hand, a better protection of IPR can promote transfer of technology from multinational headquarters to overseas affiliates and also increase the local R&D expenditures of multinational affiliates (Branstetter, Fisman and Foley, 2006). This will possibly help FDI productivity spillover take place in a larger magnitude via *vertical input-output linkages*, although the chances of spillover via *labour mobility* or *demonstration* is greatly restricted. Furthermore, a legal reform on IPR in host country will also stimulate indigenous R&D activities, which can enhance domestic firms' capacity of absorbing FDI productivity spillover.

2.4.5. Learning Cost

Spillover is neither free nor automatic due to numerous reasons. First, regression can be applied interchangeably with another similar type of model that replaces the dependent variable with value added ($Y_{i,j,t}$) of local firms and add labour ($L_{i,j,t}$) and capital ($K_{i,j,t}$) inputs to the right hand side of the above equation:

$$Y_{i,j,t}=\alpha_2+\beta_2K_{i,j,t}+\beta_3L_{i,j,t}+\beta_4FDI_{j,t}+\boldsymbol{\delta V}_{j,t}+\zeta_{i,j,t}$$

The above two regressions can be run with either firm-level, or industry-level data (by suppressing firm index *i*).

As for **variable selections**, *foreign presence* can be measured by total FDI, proportion of foreign firms' output or employment, total output or employment of foreign firms; *backward and forward linkage* can be measured by either equation (2.1) or sectoral FDI weighted by input-output coefficients; *absorptive capacity* can be measured by local firm's R&D expenditure or labour training hours; various *dummy variables* are usually adopted to control for the factors related to industry, time, and export status.

Capital (*K*) is usually measured as the value of fixed assets deflated by industry (or GDP) deflator (e.g. Javorcik and Spatareanu, 2008), or by constructing a capital stock from investment data using a certain depreciation rate (e.g. Aitken and Harrison, 1999). Various measures of labour input (*L*) have been employed in the literature, including (a) with the total number of employees which is the most straightforward and most commonly adopted measure (e.g. Girma and Gong, 2008a; Girma, Görg and Pisu, 2008; Javorcik and Spatareanu, 2008; Liu, 2008), (b) employees broken down into skilled labour and unskilled labour (e.g. Aitken and Harrison, 1999), (c) employees broken down into production workers and non-production workers (e.g. Lóez, 2008), (d) with efficiency units which are calculated by dividing total wages by to do the same" (pp. 149). Therefore, another specification is constructed to capture these intra-ownership externalities among domestic firms. Suppose there are n identical domestic firms and each of them is engaged to a learning investment I_i, i=1, 2, ..., n. Let E_i be the *effective* learning investment in firm i:

$$E_i = I_i + \sum_{j \neq i}^{n} \beta I_j, \quad \beta \in (0,1)$$

where β is intra-ownership externality coefficient. Therefore equation (2.2) can be transformed to capture both an inter-ownership and an intra-ownership productivity spillover:

$$d\left(\frac{A_f}{A_i}\right) \Big/ dt = \left[I_f - \phi(E_i)\left(\frac{A_f}{A_i}\right)\right]\left(\frac{A_f}{A_i}\right)$$

Sembenelli and Siotis (2008) employ Spanish firm-level panel data and examine how FDI affects the mark-ups of domestic firms as a proxy of firm performance. Their research shows that FDI has a positive long-run effect on the mark-ups of domestic firms in R&D intensive sectors. However, foreign presence dampens the mark-ups of domestic firms in the short-run. This contrast reflects the negative and significant effect of short-run learning cost.

2.5. EMPIRICAL METHODOLOGIES

2.5.1. Econometric Methodologies

Almost all empirical research on FDI productivity spillover is conducted with econometric models. A **typical econometric model** of FDI productivity spillovers regresses productivity of individual local firms against FDI presence in the local market, and a vector of control variables (V):

$$TFP_{i,j,t} = \alpha_I + \beta_I FDI_{j,t} + \gamma V_{j,t} + \varepsilon_{i,j,t}$$

where i, j, t index firm, industry, and time respectively. If it is assumed that the production of value added takes a Cobb-Douglas technology, then this domestic firms need to pay a higher salary to attract employees with work experience in MNE affiliates. Second, domestic enterprises need to make extra investments to improve their product standard to become qualified supplier candidates of MNE affiliates (Wang and Blomström, 1992). Third, after observing the success of MNE affiliates in exportations, domestic firms also need to do costly overseas market investigation in preparing for export. Thus it is often found that perceived effect of spillovers over a short time span is often negative, although the long-term productivity growth induced by FDI spillover is positive (Liu, 2008).

Wang and Blomstrom (1992) acknowledge the cost of transferring technology within a MNE and the cost that native firms incur in learning from MNE affiliates. The technology capability of MNE, A_f, is augmented by resources (I_f) devoted to transferring technology: $\dot{A}_f = I_f A_f$.

The technology level of a domestic firm is an increasing function of its *learning* investment (I_d) and the investment exhibits a diminishing return as it increases. υ depicts the rate of costless (*i.e.* when I_d=0) technology spillover. Thus,

$$\dot{A}_d = \phi(I_d)A_f$$
$$\phi' > 0, \phi'' < 0, \phi(0) = \upsilon > 0$$

Then the transfer-absorption process can be derived:

$$d\left(\frac{A_f}{A_d}\right)\Big/dt = \left[I_f - \phi(I_d)\left(\frac{A_f}{A_d}\right)\right]\left(\frac{A_f}{A_d}\right) \quad (2.2)$$

Wang and Blomstrom also note that the externalities among the learning efforts of domestic firms *themselves*: "once a domestic firm has adopted or modified foreign technologies, it is generally easier and cheaper for other firms the minimum wage (e.g. Javorcik, 2004), or if high-quality data are available, (e) with human capital constructed by weighing workers in different categories with their relative wages to adjust for quality (e.g. Kugler, 2006).

It is found that how the FDI presence variables are defined affects the results. For example, empirical studies with either the share of employment in foreign-owned firms or the share of output produced by these firms to proxy the foreign presence tends to get a higher spillover effect than those with other measures (e.g. the share of foreign equity participation), *ceteris paribus*. (Görg and Strobl, 2001)

Data: panel data analyses are preferred to cross-section analysis when it is necessary to control for time-invariant effects and to permit investigation of the development of domestic firm's productivity over a period of time rather than at a fixed point of time.

It is found that on the basis of firm-level studies, the empirical results of the FDI spillover effects are controversial, while with industry-level data, empirical studies usually support the view that the FDI spillover promotes the productivity of host countries (Saggi, 2002). One reason is that sector-level analyses also include the effects of resource allocation triggered by FDI, as discussed in Section 2.3.4.

2.5.2. Computable General Equilibrium Modelling

FDI productivity spillover is a *nation-wide and cross-industry* phenomenon. It can be captured by computable general equilibrium (CGE) models which attach due importance to the interdependency between industries, government and household activities. Therefore, a CGE model can also be tailored to evaluating FDI policies with respect to its productivity spillovers.

Currently there is little literature of CGE models on FDI spillover. Several CGE models are constructed with trade-embodied technology spillover (Robinson, Wang and Martin, 2002; van Meijl and van Tongeren, 1998; Das, 2007), but no FDI spillover is incorporated in these models.

Robinson, Wang and Martin (2002) build a ten-region, eleven-sector global CGE model that focuses on the services sectors. Links between trade performance and total factor productivity are introduced into the model by connecting a region's TFP growth with its imports of capital and technology-intensive products and professional services, especially from advanced industrial countries:

$$ITFP_{ir} = 1 + ims_{ir} \times \frac{NX_{ir}}{NX_{ir} + VA_{ir}} \times \left(\left[\frac{\sum_{j \in IM} \sum_{s \in R} X_{jsr}}{\sum_{j \in IM} \sum_{s \in R} X0_{jsr}} \right]^{\sigma} - 1 \right)$$

where $ITFP_{ir}$ denotes the TFP shift variable. ims_{ir} is the share of imported products and services that are embodied with advanced technology used as firms' intermediate inputs in total imports of such products and services. NX_{ir} and VA_{ir} are intermediate inputs and value added respectively. $X0_{jsr}$ and X_{jsr} are the base year and current trade flows, respectively. IM is the subset referring to those products embodied with advanced technology. R is the subset referring to those technologically backward countries. σ is an exogenous parameter.

They compare the effects of trade liberalization under two assumptions on the source of advanced technology, namely imports of intermediate and durable manufactures, and imported service intermediate inputs. They found that under the former assumption, service sector liberalization has only a limited impact on each region's TFP growth, and such growth is relatively concentrated in the intermediate and durable sectors. However, under the second assumption, the impacts are quite significant and spread to more sectors through forward linkages.

van Meijl and van Tongeren (1998) also employ a global CGE model to address international technology spillovers. Their spillover hypothesis is summarized as:

$$\frac{a_{jis}}{a_{jir}} = E_{jirs}^{1-\delta_{irs}}\text{, where } 0 \le \delta_{irs} \le 1; 0 \le E_{jirs} \le 1; \delta_{irs} = \delta_{irs}(H_{irs}, D_{irs})$$

where a_{jir} *and* a_{jis} denote input-specific productivity growth rates of input j in activity i in the regions of origin r and destination s, respectively, and δ_{irs} indicates the effectiveness of this amount of knowledge. It is a function of an absorption capacity index H_{irs}, and an index of structural similarity D_{irs}. E_{jirs} is an index of the amount of knowledge embodied in commodity j which is used in activity i:

$$E_{jirs} = \frac{X_{jirs}/Y_{is}}{Y_{jir}^{d}/Y_{ir}}$$

where X_{jirs} represents the bilateral trade flows of input j that are used in sector i and which are exported from the source country r to the destination country s, Y_{is} production of sector i in country s, and Y_{jir}^{d} domestic inputs of sector j delivered to sector i in country of origin r.

The potential benefits from trade liberalization with the above embodied technology spillovers are analyzed by taking Chinese barriers against North American imports as a case study. The results show that its negative impact on the welfare of China (measured by equivalent variation) can be more than counterbalanced by the gains from technology spillovers.

Very similar specifications are employed by Das (2007) to explore the role of absorptive capacity and socio-institutional factors for the capture of information technology and biotechnology. Das finds that regions perform better with higher human capital, better governance, and superiour technological expertise.

Lejour, Rojas-Romagosa and Verweij (2008) explicitly incorporate FDI productivity spillover into a world CGE model with FDI supplies and demands endogenised. Suppose a sectoral production function is $y=Af(k^F, k^D, l)$, where A, k^F, k^D and l denote TFP, foreign capital, domestic capital and total labour, respectively. Then FDI productivity spillovers can be modelled as an externality:

$$A_t = A_0\left(1+\mu^{TFP}\right)^t e^{\gamma\frac{k_{t-1}^F}{k_{t-1}^F+k_{t-1}^D}}$$

where μ^{TFP} is exogenous TFP growth rate, γ is productivity spillover coefficient obtained from estimations in literature. The results show that opening up services market to FDI in European countries with the above productivity spillovers can lead to twice marginal GDP growth (*e.g.* with an extra 0.8%) as much as the case without productivity spillovers (*e.g.* with an extra 0.4%). Lejour et al. allow the magnitude of the spillover to vary with the size of FDI. However they take the value of the key parameter γ from the literature to link the FDI presence and its influence on the economy, and γ was not particularly estimated for the European Union economies in question, but for the US economy.

2.6. CONCLUSIONS

This Chapter has reviewed the literature on the origin and channels of FDI productivity spillover, factors governing FDI productivity spillover effects, and empirical methodologies to quantify FDI productivity spillovers.

The theories constructed in the paradigm of "ownership, location, internalisation" assume that firms engaging in FDI activities are homogeneous and more productive than their domestic rivals so that they can overcome the cost disadvantages of overseas business operations. The latest theories built on the assumption of "firms with heterogeneous productivity" find that firms engaging in FDI are more productive than firms which only export, while the latter are more productive than firms which serve domestic market only. The above two generations of FDI theories both imply that multinational enterprises are the most productive, implying the possibility of FDI productivity spillovers.

The review also shows that possible channels of FDI productivity spillovers include labour mobility and vertical input-output linkages between multinational affiliates and domestic enterprises, export of MNEs, demonstration, increased competition, and resource reallocation.

Various factors determine the effects of FDI productivity spillovers. They include FDI intensity and technology intensity, geographic proximity to multinational affiliates, absorptive capacity of domestic enterprises, legal environment on intellectual property rights in host countries, and learning costs.

Available empirical methodologies include econometric models and computable general equilibrium models. The former are more widely adopted for firm-level and industry-level analysis, while the latter are more suitable for economy-wide analysis.

CHAPTER 3: COMPUTABLE GENERAL EQUILIBRIUM MODELLING

3.1. THEORETICAL FOUNDATIONS OF COMPUTABLE GENERAL EQUILIBRIUM MODELLING

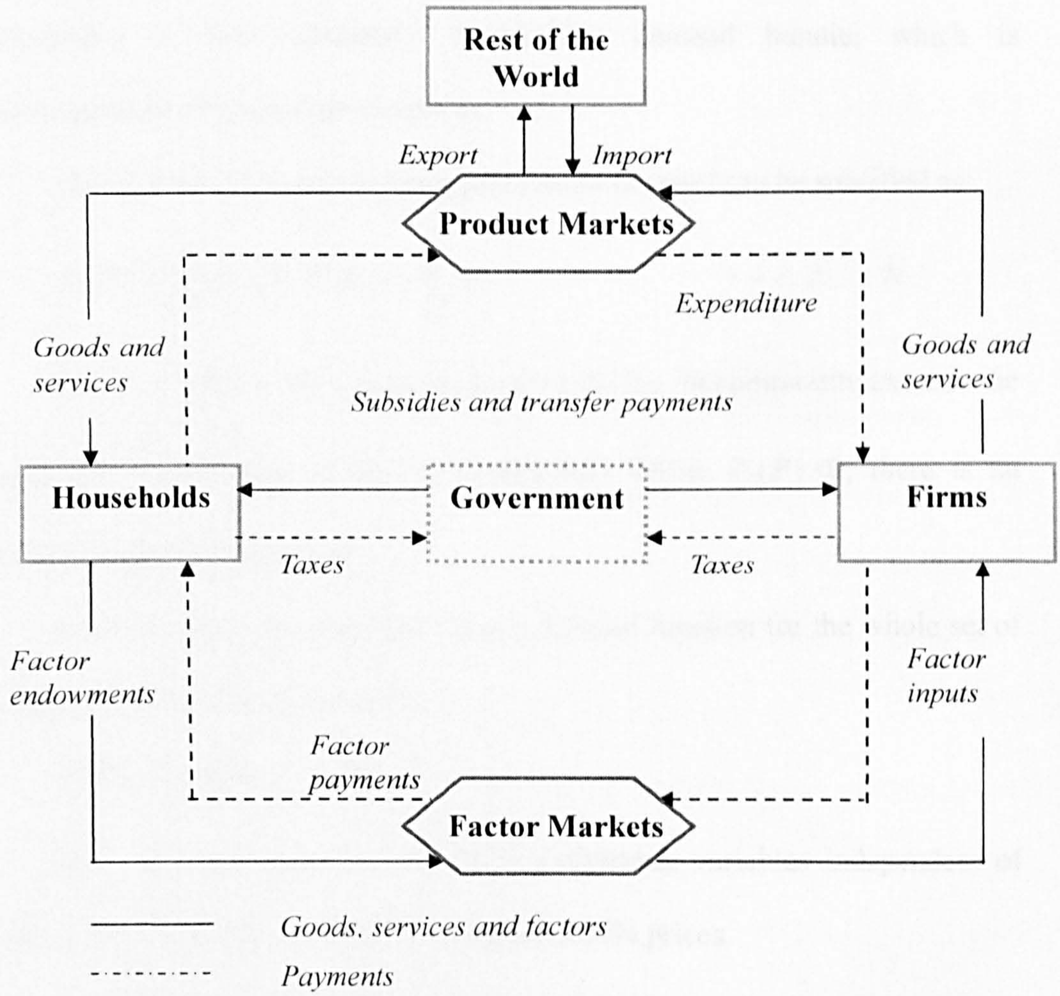
3.1.1. Basics of General Equilibrium

The theory underpinning computable general equilibrium (CGE) modelling is Walrasian general equilibrium theory, which shows that the demand and supply in an economy can achieve a general equilibrium with the interaction and interdependence of individual markets and agents. Compared to general equilibrium theory, a partial equilibrium analysis considers the determination of prices for some products only, assuming that the prices for other products are constant.

A general equilibrium in an open economy can be depicted by the circular flow of the goods, services, factors and payments as shown in Figure 3.1.

There are three types of active agents in the economy, namely, firms, households and government. Firms employ the endowment of households in factor markets, and produce goods and services, which will be bought by households in the product markets. The income of households comes from the rental of their endowments including labour, capital and land. The government collects taxes from households and firms and disburses the tax revenue to firms and households in the forms of subsidies and transfer payments.

Figure 3.1: Circular Flows of an Open Economy



Source: Sue Wing (2004), Dervis, de Melo and Robinson (1982).

3.1.2. An Exchange Economy with Walrasian General Equilibrium

In a pure exchange economy, a Walrasian general equilibrium is characterised by a vector of prices that makes the *excess demand* for each good in the economy zero.

Suppose there are D consumers and N types of goods in the economy. The consumer agent needs to solve a utility maximization problem:

$$\max\ U_d(\boldsymbol{X}_d) \quad \text{s.t. } \boldsymbol{P}\cdot\boldsymbol{X}_d \le \boldsymbol{P}\cdot\boldsymbol{E}_d \qquad d = 1, 2, \ldots, D$$

where $\boldsymbol{P}$ is the price vector; $\boldsymbol{X_d}$ is the vector of demand for goods; and $\boldsymbol{E_d}$

denotes the vector of goods (endowments) of the dth consumer. The solution $X(P, P \cdot E_d)$ to this utility maximization problem subject to the income constraint is the consumer's Marshallian demand bundle, which is homogeneous of degree zero in prices.

Then for the ith good, the aggregate excess demand can be specified as:

$$Z_i(P) = \sum_{d=1}^{D} X_{i,d}(P, P \cdot E_d) - \sum_{d=1}^{D} E_{i,d} \qquad i = 1, 2, \ldots, N$$

When $Z_i(P) > 0$, the aggregate demand for the ith commodity exceeds the aggregate endowment of the ith commodity. When $Z_i(P) < 0$, there is an excess supply of commodity i.

In vector form, the aggregate excess demand function for the whole set of commodities can be specified as:

$$Z(P) = (Z_1(P), \ldots, Z_N(P))$$

Since the endowment vector E_d is exogenous variables independent of prices, $Z(P)$ is also homogenous of degree zero in prices.

Walrasian general equilibrium occurs when the aggregate excess demand for each commodity in the whole economy is zero. That is to say, a price vector P^* is called a **Walrasian general equilibrium** price vector if $Z(P^*) = \mathbf{0}$. Furthermore, the aggregate excess demand function must satisfy **Walras' Law**: for any price vector P, we have $P \cdot Z(P) = 0$.

The existence of a general equilibrium in the economy has been controversial until it was proved by McKenzie (1954) and Arrow and Debreu (1954) with fixed points theorems. The general equilibrium is named after Walras only because "Walras was the first to attempt to an answer to the question of existence by reducing it to a question of whether simultaneous equations of market supply and market demand have a solution"(Jehle and Reny, 2001, pp. 191-192).

Since the aggregate excess demand function is homogeneous of degree zero in commodity prices, then if $\boldsymbol{P}_0^*=[P_1, P_2, \ldots, P_N]$ is a solution, then $\boldsymbol{P}_1^*=[1, (P_2/P_1) \ldots, (P_N/P_1)]$ is also a solution to this exchange equilibrium, *i.e.* equilibrium determines relative prices, so we can choose the price of one good as numéraire.

3.1.3. A Closed Economy with Competitive General Equilibrium

The pure exchange economy can be extended to a competitive market with firms and production but no government. Now the general equilibrium in this economy have four important properties, namely, *good market clearance*, *factor market clearance*, *zero profit*, and *income balance*.

Suppose there are N representative producers, each producing an idiosyncratic type of good or service. Suppose that there exists a single representative household owning F types of endowments. The household rents his/her endowments E_f and consume goods and services X_j. Let indices $j=\{1,2,\cdots,N\}$ denote the set of producers and their associated commodities, $f=\{1,2,\cdots,F\}$ denote the set of primary inputs. $\boldsymbol{P}=(P_1,P_2\ldots,P_N)$ is the vector of market prices for goods, services, and $\boldsymbol{R}=(R_1,R_2\ldots,R_F)$ is the vector of market prices for endowments.

Market Clearance

Firstly, an equilibrium of economic flows implies that any product produced in a certain industry should be exhausted by firms in other industries as intermediate products, or consumed by households as final products, *i.e.* *commodity market clearance*; and all the endowments of households are fully employed by firms, *i.e. factor market clearance*.

Commodity market clearance implies that the supply of the *j*th commodity Y_j must be equal to the sum of the *i*th producer's demand for this commodity $G_{j,i}$ indexed by $i = 1, 2, ..., N$, and the consumer's demand of this commodity X_j:

$$Y_j = \sum_{i=1}^{N} G_{j,i} + X_j \tag{3.1}$$

In a similar way, factor market clearance implies that the quantity of the *f*th endowment is equal to sum of this particular endowment employed by the *N* industries:

$$E_f = \sum_{j=1}^{N} E_{f,j} \tag{3.2}$$

Zero Profit

Another property of general equilibrium is that every representative firm makes zero profit. The reason for this property in competitive market is that otherwise firms would enter the profit-making industries so that we can not be in *equilibrium*. This implies that the revenue of gross output of the *j*th sector, $P_j Y_j$, should be equal to the sum of the total cost of the intermediate inputs plus the total cost of the primary factors which are employed for the production of the *j*th industry:

$$P_j Y_j = \sum_{i=1}^{N} P_i G_{j,i} + \sum_{f=1}^{F} R_f E_{j,f} \tag{3.3}$$

Income Balance

The income balance implies that for the representative household, all of his/her income M should come from the return to his/her primary inputs into the production of goods and services:

$$M = \sum_{f=1}^{F} R_f E_f \tag{3.4}$$

All the income of the consumer should exhaust in consuming the goods and services to satisfy his/her demand:

$$\sum_{i=1}^{N} P_i X_i = M = \sum_{f=1}^{F} R_f E_f \tag{3.5}$$

3.2. MODEL CONSTRUCTION

3.2.1. Constant Elasticity of Substitution Functions

CGE modelling uses standard functional forms to solve the production and consumption decisions which are captured by nonlinear optimality conditions. Most widely adopted forms of functions for production and utility are **constant elasticity of substitution (CES) functions** and their special cases, namely, Cobb-Douglas, Leontief and constant elasticity of transformation (CET) functions. Various combinations of these four functional forms are employed in different scenarios in CGE modelling to capture different production technologies and consumption preferences. The choice of functional forms largely depends on availability of the parameter data, and the also on the amount of effort the modeller is willing to invest in econometric estimation (Ginsburgh and Keyzer, 1997).

A constant elasticity of substitution (CES) function has a form of:

$$Y_j = A_j \left[\sum_{i=1}^{N} \delta_{j,i} X_{j,i}^{\rho_j} \right]^{1/\rho_j} \tag{3.6}$$

To derive the elasticity of substitution of this production function, *technical rate of substitution* (TRS) between two inputs needs to be found first.

$$\partial Y_j / \partial X_{j,s} = A_j \cdot \frac{1}{\rho_j} \cdot \left[\sum_{i=1}^{N} \delta_{j,s} X_{j,s}^{\rho_j} \right]^{\frac{1}{\rho_j}-1} \cdot \delta_{j,s} \cdot \rho_j \cdot X_{j,s}^{\rho_j - 1}$$

$$\partial Y_j / \partial X_{j,t} = A_j \cdot \frac{1}{\rho_j} \cdot \left[\sum_{i=1}^{N} \delta_{j,t} X_{j,t}^{\rho_j} \right]^{\frac{1}{\rho_j}-1} \cdot \delta_{j,t} \cdot \rho_j \cdot X_{j,t}^{\rho_j - 1}$$

$$TRS_{j,s,t} = -\frac{\partial Y_j / \partial X_{j,s}}{\partial Y_j / \partial X_{j,t}} = -\frac{\delta_{j,s}}{\delta_{j,t}} \left(\frac{X_{j,s}}{X_{j,t}} \right)^{\rho_j - 1}$$

The logarithm of the technical rate of substitution is derived:

$$\ln \left| TRS_{j,s,t} \right| = \ln\left(\frac{\delta_{j,s}}{\delta_{j,t}}\right) + (\rho_j - 1) \cdot \ln\left(\frac{X_{j,s}}{X_{j,t}}\right)$$

Finally, the value of the elasticity of substitution (hereafter σ) can be calculated:

$$\sigma_j = \frac{d \ln(X_{j,t} / X_{j,s})}{d \ln \left| TRS_{j,s,t} \right|} = \frac{d \ln(X_{j,t} / X_{j,s})}{\ln(\delta_{j,s} / \delta_{j,t}) + (\rho_j - 1) \cdot d \ln(X_{j,s} / X_{j,t})} = \frac{1}{1 - \rho_j}$$

Therefore the elasticity of substitution of this CES production function is a constant: $\boldsymbol{\sigma_j = 1/(1-\rho_j)}$.

As $\rho \to 0$, *i.e.* $\boldsymbol{\sigma \to 1}$, we can prove, with *L'Hôspital's rule*, that equation (3.6) becomes a Cobb-Douglas form. The logarithm form of equation (3.6) is:

$$\ln\left(\frac{Y_j}{A_j} \right) = \frac{\ln \left[\sum_{i=1}^{N} \delta_{j,t} X_{j,t}^{\rho_j} \right]}{\rho_j}, \text{ so that}$$

$$\lim_{\rho_j \to 0} \ln\left(\frac{Y_j}{A_j} \right) = \lim_{\rho_j \to 0} \frac{\ln \left[\sum_{i=1}^{N} \delta_{j,t} X_{j,t}^{\rho_j} \right]}{\rho_j} = \lim_{\rho_j \to 0} \frac{\sum_{i=1}^{N} \delta_{j,t} X_{j,t}^{\rho_j} \ln X_{j,t}}{\sum_{i=1}^{N} \delta_{j,t} X_{j,t}^{\rho_j}}$$

$$= \sum_{i=1}^{N} \delta_{j,t} \ln X_{j,t} = \ln \left[\prod_{i=1}^{N} X_{j,t}^{\delta_{j,t}} \right]$$

That is, when $\rho \to 0$ (*i.e.* $\sigma \to 1$), we can get a **Cobb-Douglas function**

$Y_j = A_j \prod_{i=1}^{N} X_{j,i}^{\delta_{j,i}}$, which also implies that any Cobb-Douglas function has a *unitary* elasticity of substitution. Compared to the unitary elasticity of substitution of the Cobb-Douglas functions, the elasticity (σ) of a CES function offers CGE modellers a greater flexibility because they can choose different parameter values for σ to capture a vast spectrum of production technology.

Another special case of CES is **Leontief form**. As $\rho \rightarrow -\infty$, *i.e.* $\boldsymbol{\sigma \rightarrow 0}$, Leontief form is generated, as any Leontief function has zero substitutability among its inputs:

$Y_j = \min\,(\eta_1 X_{j,1}, \eta_2 X_{j,2}, \ldots, \eta_N X_{j,N})$

Constant elasticity of transformation (CET) functions have identical functional forms as CES functions. However, while CES functions specify an output as a function of inputs, the CET functions state the input as the functions of various outputs. This functional forms is useful, for example, in disaggregating domestic output into exports and domestic sales on the assumption that the producers maximizes their profits, subject to imperfect substitution between exports and domestic sales.

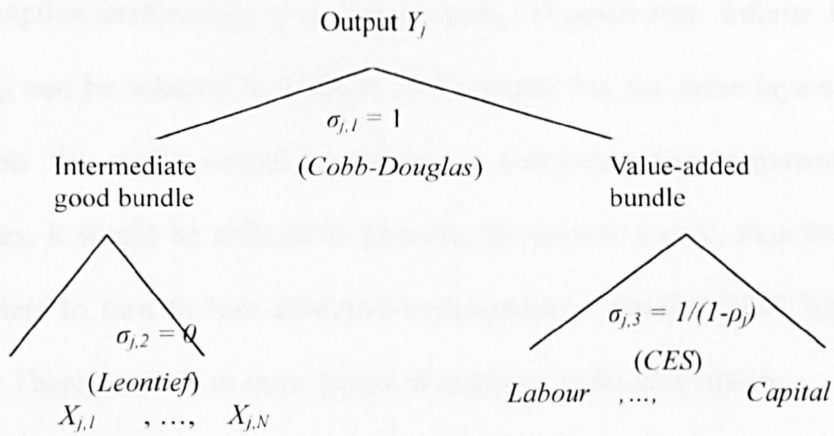
$$X_i = A_i \left[\sum_{j=1}^{N} \xi_{i,j} Y_{i,j}^{\tau_j} \right]^{1/\tau_j} \tag{3.7}$$

CES, Cobb-Douglas, Leontief and CET functions are all homogeneous of degree one.

Nested Functions

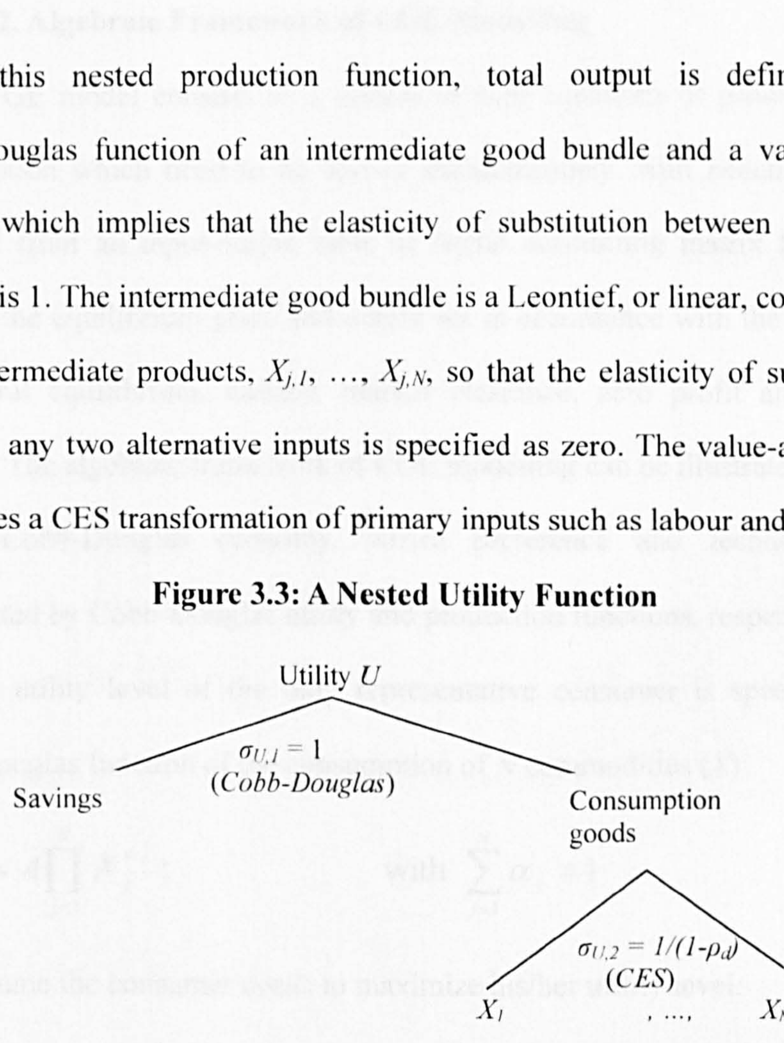
In CGE modelling, it is a common practice to combine several different functions in a nested form, with the upper level function using as its input the output of the lower level functions. Figure 3.2 provides a nested form of production.

Figure 3.2: A Nested Production Function



In this nested production function, total output is defined as a Cobb-Douglas function of an intermediate good bundle and a value-added bundle, which implies that the elasticity of substitution between these two bundles is 1. The intermediate good bundle is a Leontief, or linear, combination of N intermediate products, $X_{j,1}$, …, $X_{j,N}$, so that the elasticity of substitution between any two alternative inputs is specified as zero. The value-added nest comprises a CES transformation of primary inputs such as labour and capital.

Figure 3.3: A Nested Utility Function



In a similar way, Figure 3.3 provides a nested utility function. The utility function is a Cobb-Douglas function of savings (future consumption) and goods (current consumption), so that the elasticity of substitution is one. Current consumption of goods is a CES function of N goods.

Nesting allows for combining various production technologies and consumption preferences to a single model. Theoretically, infinite layers of nesting can be selected in a single CGE model, but the more layers the less tractable the model would be. Should a counterintuitive simulation result emerges, it would be difficult to pinpoint the precise source, thus forcing the modellers to turn to less informative explanations (Blake, 1998; Sue Wing, 2004). Therefore, two or three layers of nesting is a feasible option.

3.2.2. Algebraic Framework of CGE Modelling

A CGE model consists of a system of core equations of production and consumption which need to be solved simultaneously, with benchmark data obtained from an input-output table or social accounting matrix (SAM), to identify the equilibrium price and output set in accordance with the principles of general equilibrium, namely, market clearance, zero profit and income balance. The algebraic framework of CGE modelling can be illustrated within a closed Cobb-Douglas economy, where preference and technology are represented by Cobb-Douglas utility and production functions, respectively.

The utility level of the only representative consumer is specified as a Cobb-Douglas function of the consumption of N commodities (X):

$$U = A\prod_{j=1}^{N} X_j^{\alpha_j}; \qquad \text{with } \sum_{j=1}^{N} \alpha_j = 1$$

Assume the consumer needs to maximize his/her utility level:

$$\max\ U = A\prod_{j=1}^{N} X_j^{\alpha_j}$$

$$s.t.\ \sum_{j=1}^{N} P_j X_j \le \overline{M}$$

where the bar over a variable indicates the value of the variable is exogenously given.

The quantity of demand for the *j*th good can be derived:

$$X_j = \frac{\overline{M}}{P_j} \times \frac{\alpha_j}{\sum_{j=1}^{N} \alpha_j} = \frac{\alpha_j \overline{M}}{P_j}$$

This can be rewritten as $\alpha_j = \frac{P_j X_j}{\overline{M}}$. Therefore α_j is the share of the *j*th commodity in the total expenditure. Constant expenditure shares is also an important property of a Cobb-Douglas utility function.

The production function can be defined in a similar way. Assume the *j*th producer needs to produce the *j*th good or service using N types of intermediate inputs g and F types of primary inputs E with a Cobb-Douglas function:

$$Y_j = A_j \prod_{i=1}^{N} G_{j,i}^{\beta_{j,i}} \prod_{f=1}^{F} E_{j,f}^{\gamma_{j,f}} ; \qquad \text{with } \sum_{i=1}^{N} \beta_{j,i} + \sum_{f=1}^{F} \gamma_{j,f} = 1$$

This producer needs to minimize its total cost:

$$\min\ C_j = \sum_{i=1}^{N} P_i G_{j,i} + \sum_{f=1}^{F} R_f E_{j,f}$$

$$s.t.\ Y_j \le A_j \prod_{i=1}^{N} G_{j,i}^{\beta_{j,i}} \prod_{f=1}^{F} E_{j,f}^{\gamma_{j,f}} ; \qquad \text{with } \sum_{i=1}^{N} \beta_{j,i} + \sum_{f=1}^{F} \gamma_{j,f} = 1$$

The quantity of demand for the *i*th intermediate input and *f*th primary input are:

$$G_{j,i} = \frac{Y_j \beta_{j,i}}{A_j P_i} \prod_{i=1}^{N} \left(\frac{P_i}{\beta_{j,i}} \right)^{\beta_{j,i}} \prod_{f=1}^{F} \left(\frac{R_f}{\gamma_{j,f}} \right)^{\gamma_{j,f}}$$

$$E_{j,f} = \frac{Y_j \gamma_{j,f}}{A_j P_f} \prod_{i=1}^{N} \left(\frac{P_i}{\beta_{j,i}} \right)^{\beta_{j,i}} \prod_{f=1}^{F} \left(\frac{R_f}{\gamma_{j,f}} \right)^{\gamma_{j,f}}$$

With the solutions to consumption demand, intermediate and primary inputs in production, the four central conditions of a general equilibrium specified by equation (3.1), (3.2), (3.3) and (3.4) can be reformulated.

Commodity market clearance condition (3.1) can be transformed into an N-dimension excess demand vector which measures the gap between supply and demand in the market for the jth commodity:

$$\Delta_j^C = \sum_{i=1}^{N} G_{j,i} + X_j - Y_j$$
$$= \sum_{i=1}^{N}\left[\frac{Y_j \beta_{j,i}}{A_j P_i}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}}\right]+\frac{\alpha_j \overline{M}}{P_j}-Y_j \tag{3.8}$$

Primary input market clearance condition (3.2) can be transformed into an F-dimension excess demand vector which measures the gap between supply and demand in the market for the fth primary input:

$$\Delta_f^F = \sum_{j=1}^{N} E_{f,j} - \overline{E}_f$$
$$= \sum_{j=1}^{N}\left[\frac{Y_j \gamma_{j,f}}{A_j P_f}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}}\right]-\overline{E}_f \tag{3.9}$$

Zero profit condition in equation (3.3) can be transformed into an N-dimension vector which measures the gap between the cost incurred in production and total revenue for the jth commodity:

$$\Delta_j^\pi = P_j Y_j - \sum_{i=1}^{N} P_i G_{j,i} - \sum_{f=1}^{F} P_f E_{j,f}$$
$$= P_j Y_j - \frac{Y_j}{A_j}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}} \tag{3.10}$$

Finally, the income balance condition in equation (3.4) can be transformed into the excess income which measures the difference of total expenditure and the scalar income $\overline{M}$ of the representative consumer:

$$\Delta^m = \sum_{f=1}^{F} R_f E_f - \overline{M} \tag{3.11}$$

Vectors (3.8), (3.9), (3.10) and (3.11) formulate *2N+F+1* equations for *2N+F* unknowns: *N* industry output levels $\boldsymbol{Y} = [Y_1, Y_2, ..., Y_N]$, *N* commodity prices $\boldsymbol{P} = [P_1, P_2, ..., P_N]$ and *F* primary factor prices $\boldsymbol{R} = [R_1, R_2, ..., R_F]$.

The general equilibrium is therefore the joint solution to these *2N+F* unknowns with *2N+F+1* equations denoted by (3.8), (3.9), (3.10) and (3.11). This process can be reformulated as solving a mixture of the following *complementarity problem* (as defined in Table 3.1):

$$\begin{aligned} &\boldsymbol{V} \geq 0 \\ &s.t.\ \psi(\boldsymbol{V}) \leq \boldsymbol{0},\ \boldsymbol{V}'\psi(\boldsymbol{V}) = \boldsymbol{0} \end{aligned} \tag{3.12}$$

where $\boldsymbol{V} = [\boldsymbol{Y}, \boldsymbol{P}, \boldsymbol{R}]$' is the vector of commodity prices, primary input prices, quantities of commodity and income levels. $\psi(\boldsymbol{V}) = [\varDelta^C, \varDelta^F, \varDelta^\pi, \varDelta^m]$ is a system of equations from (3.8) to (3.11). This complementarity problem is summarized in Table 3.2.

Table 3.1: Complementarity Problem

A general equilibrium model can be formulated as a square system of weak inequalities, each with an associated non-negative variable. This is referred to as a **complementarity problem** in mathematics, and the associated variables are referred to as complementary variables.

For example, if a zero profit condition holds as a strict inequality in equilibrium, profits for that activity are negative, thus that good will not be produced. So the complementary variable to a zero-profit condition is the quantity of the activity level. Take the profit of the *j*th product as an example as shown in equation (3.11):

Inequality: $\Delta_j^\pi = P_j Y_j - \sum_{i=1}^{N} P_i G_{j,i} - \sum_{f=1}^{F} R_f E_{j,f} \leq 0$

Associated **complementary variable**: Y_j

Complementary form: $Y_j * \Delta_j^\pi = 0$

Table 3.2: A Sketch of the Complementarity Problem (3.13)

Inequality	Variable	Dimension
$\Delta_j^C = \sum_{i=1}^{N}\left[\frac{Y_j\beta_{j,i}}{A_jP_i}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}}\right]+\frac{\alpha_j m}{P_j}-Y_j$	P_j	N
$\Delta_j^F = \sum_{j=1}^{N}\left[\frac{Y_j\gamma_{j,f}}{A_jP_f}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}}\right]-E_f$	R_f	F
$\Delta_j^\pi = P_jY_j-\frac{Y_j}{A_j}\prod_{i=1}^{N}\left(\frac{P_i}{\beta_{j,i}}\right)^{\beta_{j,i}}\prod_{f=1}^{F}\left(\frac{R_f}{\gamma_{j,f}}\right)^{\gamma_{j,f}}$	Y_j	N

Therefore, problem (3.12) is an extended representation of the Walras' Law with the presence of firms and production. As the system of equations (3.8), (3.9), (3.10) and (3.11) is homogeneous of degree zero in prices, once a nominal vector (***P***, ***R***) are identified to solve the problem (3.12), then (λ***P***, λ***R***) should also be the solution to it for any constant λ. Therefore, only *relative* nominal values matter in solving a general equilibrium model. In other words, the model displays a "neutrality of money" (Robinson and Lofgren, 2005).

So when the price for a certain good or primary factor is chosen as a numéraire, *e.g.* $P_1 = 1$, all other nominal variables can be defined relative to the numéraire, *e.g.* $P_2' = P_2 / P_1$; ...; $P_N' = P_N / P_1$. In CGE modelling, if a numéraire is not specified, prices obtained from different simulations are not directly comparable as they can be the base values (***P***, ***R***) simultaneously multiplied by an arbitrary scalar (λ***P***, λ***R***). To avoid this problem, one must specify a price as numéraire and fix it at a constant value (normally 1) throughout all simulations, so that simulation results can be compared.

Theoretically any price can be taken as the numéraire, e.g. labour wage, nominal exchange rate and domestic price index. Prices obtained from a simulation may be different dependent on the choice of the numéraire, but no quantities are affected by it. Choosing the exchange rate as the numéraire does not imply a fixed exchange rate regime. Similarly, choosing domestic consumer's price as the numéraire does not imply zero inflation. To design a fixed real exchange rate we have to put one more constraint on the exchange rate, *i.e.* to fix the ratio of exchange rate to domestic price index.

3.2.3. Labour and Capital Markets

Classic CGE models usually assume full employment of primary factors of production (labour and capital) so that the economy always functions at its production possibility frontier. The product prices and factor prices adjust so that all factor markets clear, i.e. there is no excess supply or demand of factors.

The supply of various types of labour (e.g. skilled and unskilled) can be assumed to be fixed in a static model so that the total labour supply as a sum of them is also fixed. Constrained by their sector-specific skills and experience, labour can also be assumed to be imperfectly mobile across sectors in the short run, subject to certain constant elasticity of transformation functions.

Similarly, the total supply of capital can also be assumed fixed in a static model. Usually capital is treated as a homogenous factor and does not need to be further disaggregated into different types. But as capital is associated with ownership, entrepreneurship and sector-specific factors in the real economy, capital can also be assumed imperfectly mobile across sectors in the short run. Foreign direct investment can be introduced into a CGE model as an increment to the capital stock invested by a representative agent for multinational enterprises.

There are also two alternatives in terms of capital supply (Bussolo and

Round, 2003). The first is to fix the savings rate so that the change of capital stock will be proportionate to the change of GDP ("savings-driven"). The second one is to keep the savings rate endogenous, so that a target real return to capital is achieved and maintained ("investment-driven"). These two options concern the relationship between investment and savings, and will also be addressed in Section 3.2.4.

The above full-employment and imperfect-mobility assumptions are suitable in the short run only. In the long run, it is usually more appropriate to assume that both capital and labour are freely mobile across sectors and there exists slack capacity in the economy so that the wage and capital rental are maintained at stable levels (Bussolo and Round, 2003).

3.2.4. Model Closure

In CGE modelling, modellers often need to incorporate macroeconomic mechanisms (e.g. government activities, international trade and foreign exchange) into general equilibrium models by including some variables that are central to policy considerations. Closure rules refer to how endogenous *microeconomic* price and quantity variables are constrained by exogenous *macroeconomic* balances.

Sen (1963) was the first economist identifying the necessity of closure rule in applied general equilibrium modelling with macroeconomic variables. He found that it would be impossible to warrant the *ex post* identity between savings and investment if some market equilibrium conditions have to be imposed on the model simultaneously. Therefore to find a reasonable solution for a CGE model with macroeconomic variables, one of the conditions must be relaxed. Choosing a "closure rule" means deciding which of the conditions should be relaxed. In other words, a closure rule is a modified balancing constraint that does not necessarily represent a market equilibrium condition (Ginsburgh and Keyzer, 1997). The design of closure rules is crucial to CGE modelling, in that it affects the model structure, simulation results and policy conclusions (Whalley and Yeung, 1984; Dewatripont and Michel, 1987; Bussolo and Round, 2003; Robinson and Lofgren, 2005).

Generally there are three types of macroeconomic closure rules that need to be designed by CGE modellers, namely *government closure* dealing with government behaviour, *savings-investment closure* for the determination of savings and investment, and *external closure* for current account and exchange rate regime. Each of the above three types of closure rules contains a variety of alternatives, the most commonly applied of which are outlined in Table 3.3.

Table 3.3: Alternative Macroeconomic Closures

Government	Savings-investment	External
❖ Fixed government savings or spending ❖ Fixed government savings rate *w.r.t.* GDP ❖ Fixed real government consumption and subsidy ❖ Utility-maximising agent	❖ Savings-driven ❖ Investment-driven	❖ Large/small open economy ❖ Current account balance ❖ Floating or fixed exchange rate

Source: Löfgren, Harris and Robinson (2002).

(1) Government closure

Government is generally modelled in CGE models as an agent collecting taxes, allocating transfer payments, and purchasing goods and services. There are a variety of choices to deal with government revenue and expenditure as well as government savings (surplus) or borrowing (deficit).

The first option is that the ratio of fiscal expenditure to GDP is maintained at a fixed level by introducing an endogenous tax variable. This policy design would reflect the target of the government to maintain a relatively stable level of economic intervention.

The target magnitude of fiscal savings (borrowings) can also be taken into consideration in the the government closure. For example, it could also be desirable to fix the level of government savings (borrowings), by forcing government spending and revenue to move in tandem. More realistically, we can also fix the fiscal savings (borrowings) rate with respect to GDP at a target level. This closure rule is pertinent to some countries whose political stability is easily threatened by inflationary pressure. For example, all European Union member states must abide by the Stability and Growth Pact, which requires an annual budget deficit no higher than 3% of GDP. The above two "fiscal neutral" settings on fiscal savings (borrowings) will transmit any pressure of external shock impacting government expenditure directly to taxpayers.

There are also alternative government balance closure rules related to poverty-relieving policies. For example, both government consumption and subsidy can be set fixed in *real* terms to guarantee stable poverty-relieving efforts, and government revenue comes from fixed tax rates. Thus the government savings (borrowings) is determined as a residual which is equal to the difference between variable government expenditure and revenue.

Finally, we can also treat government analogous to a private representative utility-maximising agent (Shoven and Whalley, 1992). In that case the government has a utility function determining government demand and the government meets its demand subject to its fiscal constraint.

The instrument by which the government reaches its closure target is also important. With any of the above fixed savings and/or consumption targets, the government can balance its budget by a variety of measures. Using a non-distortionary lump-sum transfer is often suitable if the distortionary costs of tax changes need to be separated from the costs or benefits of the simulation being imposed. Using a tax rate (e.g. an income tax) to meet the government's budget balance is often more suitable in practice.

(2) Savings-investment closure

Savings-investment closure refers to the mechanism of how savings and investment are generated. It is either savings-driven (the value of investment adjusts endogenously) or investment-driven (the value of savings adjusts endogenously). Savings-driven closure fixes all non-government saving rates and scales investment demand so that investment spending equals savings. A standard investment-driven closure fixes real investment quantities and adjusts the savings rate of households endogenously.

(3) External closure

External closure for CGE models with export and import activities concerns three basic questions: (a) whether the country modelled is a large country; (b) how current account balance (foreign savings) is treated; and (c) whether the foreign exchange rate is flexible.

For a small open economy, its economy scale is so small that it has no monopolistic power to influence its export or import prices. Under such an assumption, we need to fix the export and import prices at which this country engages transactions with the rest of the world. But under the large-open-economy assumption, the export and import prices at world market need to change endogenously with the changes of the economy's exports and imports.

As for the current account balance, the most widely adopted solution for current account balance is to fix the balance as an exogenous parameter in the modelling. This implies that modellers need to force both exports and imports to change with the same magnitude, and in the same direction (Robinson and Lofgren, 2005).

Another equilibrium variable which is also integral for open economy modelling is foreign exchange rate, which is the *relative* price of commodities in international markets and commodities consumed in domestic market. Fixed exchange rate closure means that this price has to be fixed relative to a certain domestic price index, while the flexible exchange rate closure lets this price freely determined by the current account balance. Under a flexible exchange rate regime, an increase of current account surplus suggests a relatively higher demand for domestically manufactured commodities. This lifts up the relative prices of domestic commodities and leads to an appreciation (decrease) of real exchange rate (Robinson and Lofgren, 2005).

3.3. DATA FOR CGE MODELLING

3.3.1. Input-output Table

An input-output table contains the information on transactions within and between production sectors and non-production sectors. It represents the value of transactions in a given year. The demand for marketed goods and services is disaggregated into two blocks, namely intermediate demand by producers and final demand by households, government, and external markets. In terms of the input side, total input is divided into intermediate input and value added. The value-added items include, *inter alia*, compensation to employment, net taxes and depreciation. As Table 3.4 shows, an input-output table can be broken down into three blocks. Block $\overline{\boldsymbol{G}}$ captures the detailed intermediate input and demand presented by $N \times N$ inter-industry and intra-industry transactions. The entry $\overline{G}_{i,j}$ measures how much output of sector i is used by sector j. Block $\overline{\boldsymbol{X}}$ displays the final demand for each of the N industries, while block $\overline{\boldsymbol{E}}$ contains the value-added items for each of the N industries.

An input-output table provides an ideal dataset for CGE modelling as it represents a "balanced" economy characterized by *goods and factor market clearance*, *zero profit* and *income balance*. In Table 3.3, the row sum of any sector i in block $\overline{\boldsymbol{G}}$ and $\overline{\boldsymbol{X}}$ is equal to the total output in the corresponding sector, $\overline{Y}_j$. This stands for the *goods market clearance*, which is what the equation (3.1) conveys. The column sum of block $\overline{\boldsymbol{E}}$ is equal to the total factor endowment of the corresponding factor supplier, E_f, which implies the *factor market clearance* condition as shown in equation (3.2). The sum for any column in block $\overline{\boldsymbol{G}}$ and $\overline{\boldsymbol{E}}$ is the total value of intermediate inputs and value added from primary inputs. This is equal to the gross value of output, which is exactly the *zero profit* condition in equation (3.3). Finally, the sum of all the element of block $\overline{\boldsymbol{X}}$ and $\overline{\boldsymbol{E}}$ should be equal, which means that the total factor endowment should be exhausted. This implies *income balance*, as stated in equation (3.5).

Table 3.4: A Basic Structure of an Input-output Table

<table>
<tr><th colspan="3" rowspan="3"></th><th colspan="8">Total Demand</th><th rowspan="3">Total Output</th></tr>
<tr><th colspan="3">Intermediate Demand</th><th colspan="5">Final Demand</th></tr>
<tr><th>Industry 1</th><th>...</th><th>Industry N</th><th>Households</th><th>Government</th><th>Export</th><th>...</th><th>Change in Inventories</th></tr>
<tr><td rowspan="2">Total Inputs</td><td>Intermediate Input</td><td>Industry 1
...
Industry N</td><td colspan="3">$\bar{G}$</td><td colspan="5">$\bar{X}$</td><td>$\bar{Y}_1$
$\vdots$
$\bar{Y}_N$</td></tr>
<tr><td>Value Added</td><td>Net Taxes
Wages
...
Depreciation
Operating surplus</td><td colspan="3">$\bar{E}$</td><td colspan="5"></td><td>$\bar{E}_1$
$\vdots$
$\bar{E}_F$</td></tr>
<tr><td colspan="3">Total Inputs</td><td>$\bar{Y}_1$</td><td>...</td><td>$\bar{Y}_N$</td><td>$\bar{X}_1$</td><td></td><td>...</td><td></td><td>$\bar{X}_D$</td><td></td></tr>
</table>

Source: National Bureau of Statistics of China (2006b)

Table 3.5: A Basic Structure of a Social Accounting Matrix

			Expenditures							
					Factors		Institutions		Capital	Rest of
			Activities	Commodities	Labour	Capital	Households	Government	Account	the world
Receipts	Activities			Domestic commodity supply				Export subsidy		
	Commodities		Intermediate inputs				Private consumption	Government consumption	Investment	
	Factors	Labour	Wages							
		Capital	Rentals							
	Institutions	Households			Labour income	Capital income		Transfers		Capital flow
		Government	Indirect taxes	Tariffs			Direct taxes			
	Capital Account						Private saving	Government saving		
	Rest of the world			Imports				Reserve accumulation		
	Totals		Total costs	Total absorption	Factor income	Factor income	Household income	Government expenditure	Investment	Foreign exchange flow

Source: Dervis *et al* (1982, pp. 155-162), Yao and Liu (2000), Round (2003).

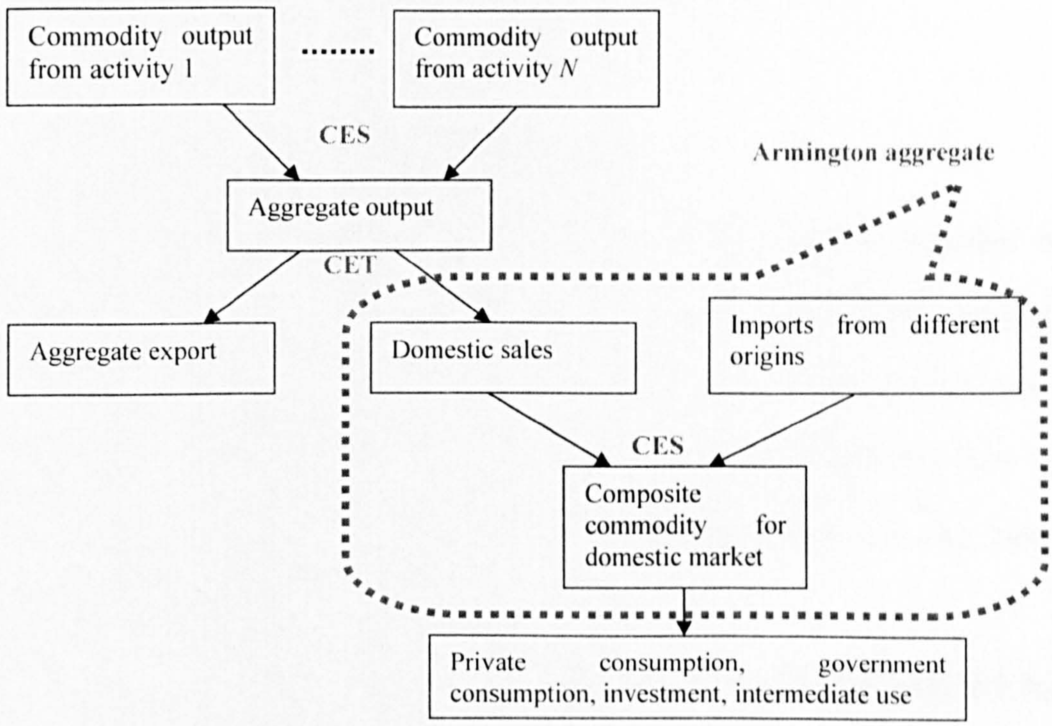
3.3.2. Social Accounting Matrix

While an input-output table only shows the relationship between production accounts and non-production accounts, an extended form of input-output table, namely social accounting matrix (SAM), includes the information of all transaction within and between all accounts. That is to say, the blank area below block $\overline{X}$ in Table 3.4 can be filled in with new information of transactions among non-production sectors in a SAM.

Table 3.5 provides an example of the standard form of a SAM. Apart from the addition of transactions among non-production sectors, a SAM has two more special features. Firstly, there is a distinction between "activities" and "commodities". While the accounts of "activities" represent the production sectors, the "commodities" accounts combine domestic supply with imports to generate a total supply to the domestic market, usually following the "Armington" assumption which specifies product differentiation by country of origin (Armington, 1969), as illustrated in Figure 3.4. Secondly, there is a separate "capital" account which can be treated as an investment bank collecting savings from households, government, and the rest of the world, and spending them on investment goods.

There is an important analogy of a balanced input-output table and SAM. For a balanced input-output table, the row sum is always equal to the column sum for each production sector, which represents the balance between production input and output. In a balanced SAM, the row sum for every "activity", "commodity", "factor", "institution" and "capital account" is equal to the associated column sum respectively, perfectly reflecting the goods and value flows at an equilibrium.

Figure 3.4: Flows of Commodities and Armington Aggregation



Source: Löfgren *et al* (2002)

The choice of CGE modellers between an input-output table and a SAM is dependent on data availability and the purpose of CGE research. For research focused on consumption, poverty, or any phenomenon directly related to household behaviour, a SAM is integral to the modelling, as a SAM has information on the transactions among non-production sectors. However, for multi-national or global economic research wherein a full set of information on transactions among non-production sectors is not available, then input-output tables can be used in place of SAMs. For example, the core datasets of the widely employed Global Trade Analysis Project database (Hertel, 1997) are mainly input-output tables instead of SAMs (Walmsley and Lakatos, 2008). Input-output tables are also suitable for other type of CGE models whose main concern is in production rather than consumption side.

3.4. CALIBRATION AND "CALIBRATED FORMS" OF A CES ECONOMY

3.4.1. Calibration of A CES Economy

Calibration is an essential step in CGE modelling to make sure that the designed model equations can replicate a balanced benchmark economy (Mansur and Whalley, 1984; Shoven and Whalley, 1984). This requires, apart from selecting existing parameters from the econometric estimates from the same time period, calculating other necessary parameters with the model equations and benchmark dataset.

In calculating the parameters, all prices should be treated as unity and thus all value flows in the input-output table or SAM can be regarded as benchmark quantities. With these parameters and those selected from the econometric estimates in literature, solving the problem of (3.12) will then make the quantities of variables equal to the corresponding values in the benchmark dataset, thus replicating the benchmark equilibrium.

For a CES function as specified by equation (3.6), or equivalently by denoting $\sigma_j=1/(1-\rho_j)$:

$$Y_j = A_j\left(\sum_{i=1}^{N}\delta_{j,i}X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)^{\sigma_j/(\sigma_j-1)} \quad \text{with} \quad \sum_{i=1}^{N}\delta_{j,i}=1 \tag{3.6a}$$

only A_j and $\delta_{j,i}$ can be calibrated. The elasticity of substitution *i.e.* σ_j should be exogenously selected by estimation or directly from literature since an economy at the benchmark equilibrium only tells the information of price and quantity levels. (Shoven and Whalley, 1984).

The marginal revenue product (MRP) of the *i*th input $X_{j,i}$ in the *j*th output Y_j is then equal to the price of the *i*th input:

$$P_j \times \frac{\partial Y_j}{\partial X_{j,i}} = P_j \times A_j \frac{\sigma_j}{\sigma_j - 1}\left(\sum_{i=1}^{N} \delta_{j,i} X_{j,i}^{(\sigma_j - 1)/\sigma_j}\right)^{1/(\sigma_j - 1)} \alpha_{j,i} \frac{\sigma_j - 1}{\sigma_j} X_{j,i}^{-1/\sigma_j}$$

$$= P_j \times Y_j^{1/\sigma_j} \alpha_{j,i} X_{j,i}^{-1/\sigma_j} A_j^{\rho_j - 1/\sigma_j} \tag{3.13}$$

$$= P_j \times A_j^{(\sigma_j - 1)/\sigma_j} \delta_{j,i}\left(\frac{Y_j}{X_{j,i}}\right)^{1/\sigma_j} = P_i$$

Similarly, the MRP of Y_j of the kth input $X_{j,k}$ is equal to the price of $X_{j,k}$

$$P_j \times A_j^{(\sigma_j - 1)/\sigma_j} \delta_{j,k}\left(\frac{Y_j}{X_{j,k}}\right)^{1/\sigma_j} = P_k \tag{3.14}$$

Divide (3.13) by (3.14) and we can get the quantity of one input in terms of the other:

$$X_{j,k} = X_{j,i}\left(\frac{\delta_{j,k} P_i}{\delta_{j,i} P_k}\right)^{\sigma_j} \tag{3.15}$$

Equation (3.15) can be transformed with benchmark values $(\overline{X}, \overline{P})$ from the input-output table (in Table 3.3):

$$\overline{X}_{j,k} = \overline{X}_{j,i}\left(\frac{\delta_{j,k} \overline{P}_i}{\delta_{j,i} \overline{P}_k}\right)^{\sigma_j}$$

$$\delta_{j,k} = \delta_{j,i} \frac{\overline{P}_k}{\overline{P}_i}\left(\frac{\overline{X}_{j,k}}{\overline{X}_{j,i}}\right)^{1/\sigma_j}$$

Since $\sum_{k=1}^{N} \delta_{j,k} = 1$,

$$\sum_{k=1}^{N} \delta_{j,i} \frac{\overline{P}_k}{\overline{P}_i}\left(\frac{\overline{X}_{j,k}}{\overline{X}_{j,i}}\right)^{1/\sigma_j} = \delta_{j,i} \frac{\sum_{k=1}^{N} \overline{P}_k \left(\overline{X}_{j,k}\right)^{1/\sigma_j}}{\overline{P}_i \overline{X}_{j,i}^{1/\sigma_j}} = 1$$

$$\delta_{j,i} = \frac{\overline{P}_i \overline{X}_{j,i}^{1/\sigma_j}}{\sum_{k=1}^{N} \overline{P}_k \left(\overline{X}_{j,k}\right)^{1/\sigma_j}} \tag{3.16}$$

With calibrated value of $\delta_{j,i}$, A_j can then be derived by rearranging equation (3.6a):

$$A_j = \frac{\overline{Y}_j}{\left(\sum_{i=1}^{N} \delta_{j,i} \overline{X}_{j,i}^{(\sigma_j - 1)/\sigma_j}\right)^{\sigma_j/(\sigma_j - 1)}} \tag{3.17}$$

With the calibrated parameter values of (A_j, $\delta_{j,i}$) and selected parameter values of (σ_j), a CGE model can solve the counterfactual results of ($X_{j,i}$, Y_j, P_j, $P_{j,i}$) when an external policy shock is introduced to the model.

3.4.2. "Calibrated Forms" of CES Functions

In CGE counterfactual simulations, an alternative algorithm, namely the "*calibrated form*" of CES functions can be employed to replace the complicated and error-prone calibration procedures with more elegant and intuitive specifications (Blake, Rayner and Reed, 1999; Rutherford, 1995).

We need to specify a certain input as a function of the total output first. With zero-profit condition:

$$P_j Y_j = \sum_{k=1}^{N} P_k X_{j,k} = \sum_{k=1}^{N} P_k X_{j,i} \left(\frac{\delta_{j,k} P_i}{\delta_{j,i} P_k}\right)^{\sigma_j} = X_{j,i} \left(\frac{P_i}{\delta_{j,i}}\right)^{\sigma_j} \sum_{k=1}^{N} P_k \left(\frac{\delta_{j,k}}{P_k}\right)^{\sigma_j}$$

$$= X_{j,i} \left(\frac{P_i}{\delta_{j,i}}\right)^{\rho_j} \sum_{k=1}^{N} \delta_{j,k}^{\sigma_j} P_k^{1-\sigma_j}$$

$$X_{j,i} = P_j Y_j \left(\frac{\delta_{j,i}}{P_i}\right)^{\sigma_j} \Bigg/ \sum_{k=1}^{N} \delta_{j,k}^{\sigma_j} P_k^{1-\sigma_j} = P_j Y_j \left(\frac{\delta_{j,i}}{P_i}\right)^{\sigma_j} \Bigg/ \sum_{i=1}^{N} \delta_{j,i}^{\sigma_j} P_i^{1-\sigma_j} \tag{3.18}$$

Since equation (3.18) only contains four variables, *i.e.* the prices and quantities of an input and total output, replace $X_{j,i}$ in equation (3.18) with that in equation (3.6a), and eliminate Y_j, then we can derive the relationship between input price and output price. With equations (3.6a) and (3.18):

$$Y_j = A_j \left(\sum_{i=1}^{N} \delta_{j,i} \left(\frac{P_j Y_j \left(\frac{\delta_{j,i}}{P_i}\right)^{\sigma_j}}{\sum_{i=1}^{N} \delta_{j,i}^{\sigma_j} P_i^{1-\sigma_j}} \right)^{(\sigma_j - 1)/\sigma_j} \right)^{\sigma_j/(\sigma_j - 1)}$$

$$= A_j\left(\left(\frac{P_jY_j}{\sum_{i=1}^{N}\delta_{j,i}^{\sigma_j}P_i^{1-\sigma_j}}\right)^{(\sigma_j-1)/\sigma_j}\times\sum_{i=1}^{N}\delta_{j,i}\left(\frac{\delta_{j,i}}{P_i}\right)^{(\sigma_j-1)}\right)^{\sigma_j/(\sigma_j-1)}$$

$$= A_j\frac{P_jY_j}{\sum_{i=1}^{N}\delta_{j,i}^{\sigma_j}P_i^{1-\sigma_j}}\left(\sum_{i=1}^{N}\delta_{j,i}^{\sigma_j}P_i^{1-\sigma_j}\right)^{\sigma_j/(\sigma_j-1)} = A_jP_jY_j\left(\sum_{i=1}^{N}\delta_{j,i}^{\sigma_j}P_i^{1-\sigma_j}\right)^{1/(\sigma_j-1)}$$

By eliminating Y_j from both sides, we get a unit cost function:

$$P_j = \frac{1}{A_j}\left(\sum_{i=1}^{N}\delta_{j,i}^{\sigma_j}P_i^{1-\sigma_j}\right)^{1/(1-\sigma_j)} \tag{3.19}$$

Calibrated form of quantity

With equation (3.17),

$$Y_j = A_j\left(\sum_{i=1}^{N}\delta_{j,i}X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)^{\sigma_j/(\sigma_j-1)} = \frac{\left(\sum_{i=1}^{N}\delta_{j,i}X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)^{\sigma_j/(\sigma_j-1)}}{\left(\sum_{i=1}^{N}\delta_{j,i}\overline{X}_{j,i}^{(\sigma_j-1)/\sigma_j}\right)^{\sigma_j/(\sigma_j-1)}}\overline{Y}_j$$

With equation (3.16), the above equation can be transformed into:

$$Y_j = \overline{Y}_j\left(\frac{\sum_{i=1}^{N}\delta_{j,i}X_{j,i}^{(\sigma_j-1)/\sigma_j}}{\sum_{i=1}^{N}\delta_{j,i}\overline{X}_{j,i}^{(\sigma_j-1)/\sigma_j}}\right)^{\sigma_j/(\sigma_j-1)} = \left(\frac{\sum_{i=1}^{N}\left(\frac{\overline{P}_i\overline{X}_{j,i}^{1/\sigma_j}}{\sum_{k=1}^{N}\overline{P}_k\left(\overline{X}_{j,k}\right)^{1/\sigma_j}}X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)}{\sum_{i=1}^{N}\left(\frac{\overline{P}_i\overline{X}_{j,i}^{1/\sigma_j}}{\sum_{k=1}^{N}\overline{P}_k\left(\overline{X}_{j,k}\right)^{1/\sigma_j}}\overline{X}_{j,i}^{(\sigma_j-1)/\sigma_j}\right)}\right)^{\sigma_j/(\sigma_j-1)}\times\overline{Y}_j$$

$$= \overline{Y}_j\left(\frac{\sum_{i=1}^{N}\left(\overline{P}_i\overline{X}_{j,i}^{1/\sigma_j}\times X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)}{\sum_{i=1}^{N}\left(\overline{P}_i\overline{X}_{j,i}^{1/\sigma_j}\times\overline{X}_{j,i}^{(\sigma_j-1)/\sigma_j}\right)}\right)^{\sigma_j/(\sigma_j-1)} = \overline{Y}_j\left(\frac{\sum_{i=1}^{N}\left(\overline{P}_i\overline{X}_{j,i}^{1/\sigma_j}\times\left(\frac{X_{j,i}}{\overline{X}_{j,i}}\right)^{1/\sigma_j}\times X_{j,i}^{(\sigma_j-1)/\sigma_j}\right)}{\sum_{i=1}^{N}\overline{P}_i\overline{X}_{j,i}}\right)^{\sigma_j/(\sigma_j-1)}$$

$$
= \overline{Y}_j \left(\frac{\sum_{i=1}^{N} \left(\overline{P}_i \left(\frac{\overline{X}_{j,i}}{X_{j,i}} \right)^{1/\sigma_j} \times X_{j,i} \right)}{\sum_{i=1}^{N} \overline{P}_i \overline{X}_{j,i}} \right)^{\sigma_j/(\sigma_j-1)} = \overline{Y}_j \left(\frac{\sum_{i=1}^{N} \left(\overline{P}_i \times \frac{\overline{X}_{j,i}}{\overline{X}_{j,i}} \times \left(\frac{\overline{X}_{j,i}}{X_{j,i}} \right)^{1/\sigma_j} \times X_{j,i} \right)}{\sum_{i=1}^{N} \overline{P}_i \overline{X}_{j,i}} \right)^{\sigma_j/(\sigma_j-1)}
$$

$$
= \overline{Y}_j \left(\frac{\sum_{i=1}^{N} \left(\overline{P}_i \overline{X}_{j,i} \times \left(\frac{X_{j,i}}{\overline{X}_{j,i}} \right)^{(\sigma_j-1)/\sigma_j} \right)}{\sum_{i=1}^{N} \overline{P}_i \overline{X}_{j,i}} \right)^{\sigma_j/(\sigma_j-1)} = \overline{Y}_j \left(\sum_{i=1}^{N} \left(\frac{\overline{P}_i \overline{X}_{j,i}}{\sum_{i=1}^{N} \overline{P}_i \overline{X}_{j,i}} \times \left(\frac{X_{j,i}}{\overline{X}_{j,i}} \right)^{(\sigma_j-1)/\sigma_j} \right) \right)^{\sigma_j/(\sigma_j-1)}
$$

$$
= \overline{Y}_j \left(\sum_{i=1}^{N} \left(\theta_{j,i} \times \left(\frac{X_{j,i}}{\overline{X}_{j,i}} \right)^{(\sigma_j-1)/\sigma_j} \right) \right)^{\sigma_j/(\sigma_j-1)}
$$

where $\theta_{j,i}$ denotes the cost **share** of the ith input in product value. Replace the upper case variables with lower case ones which represent the **ratios** to the benchmark quantities *i.e.* $y_j = \frac{Y_j}{\overline{Y}_j}$ and $x_j = \frac{X_{j,i}}{\overline{X}_{j,i}}$:

$$
y_j = \left(\sum_{i=1}^{N} \theta_{j,i} x_{j,i}^{(\sigma_j-1)/\sigma_j} \right)^{\sigma_j/(\sigma_j-1)} \tag{3.6b}
$$

With equation (3.6b), it would be faster to solve the values of y_j and $x_{j,i}$ in counterfactual scenarios. Then new values of outputs and inputs can be obtained by multiplying these **ratios** with the associated benchmark values. We can see that there is no need to calibrate the parameters here. Equation (3.6b) exhibits elegance and conciseness compared to equation (3.6a).

Calibrated form of prices

Substitute $a_{j,i}$, A_j in equation (3.19) with the specifications in equations (3.16) and (3.17) and follow similar procedures, we can get the relationship between multiples of output price and input price:

$$p_j = \left(\sum_{i=1}^{N} \theta_{j,i} p_i^{1-\sigma_j} \right)^{1/(1-\sigma_j)} \tag{3.19a}$$

This specification also applies to CET production functions specified as (3.7).

Calibrated form of input demands

With equation (3.16), we can get an equation to capture the relationship between output and input demand from equation (3.19) as well:

$$x_{j,i} = y_j \left(\frac{p_j}{p_i} \right)^{\sigma_j} \tag{3.18a}$$

For a CET production function specified by equation (3.7), the calibrated share form of *output supply* is similar to equation (3.18a):

$$y_{j,i} = x_j \left(\frac{p_j}{p_i} \right)^{1/(1-\tau_j)} \tag{3.18b}$$

Extensions with $\sigma_j \to 1$

Nonetheless, for the case of $\sigma_j = 1$, an extension to equations (3.6b) and (3.19a) with calibrated form is necessary. Otherwise they will collapse as $1/(1-\sigma_j)$ can not take $\sigma_j=1$.

We can get a logarithm form of equation (3.19a),

$$\ln p_j = \frac{\ln\left(\sum_{i=1}^{N} \theta_{j,i} p_i^{1-\sigma_j} \right)}{1-\sigma_j}$$

When σ_j approaches 1, both numerator and denominator of the equation above approach zero. *L'Hôspital's rule* applies:

$$\lim_{\sigma_j \to 1}(\ln p_j) = \lim_{\rho_j \to 0} \frac{\partial\left(\ln\left(\sum_{i=1}^{N}\theta_{j,i}p_i^{1-\sigma_j}\right)\right)\Big/\partial\sigma_j}{\partial(1-\sigma_j)/\partial\sigma_j} = \lim_{\rho_j \to 0} \frac{\sum_{i=1}^{N}\theta_{j,i}p_i^{1-\sigma_j}(\ln p_i)\times(-1)}{(-1)\times\sum_{i=1}^{N}\theta_{j,i}p_i^{1-\sigma_j}}$$

$$= \frac{\sum_{i=1}^{N}\theta_{j,i}\ln p_i}{\sum_{i=1}^{N}\theta_{j,i}} = \sum_{i=1}^{N}\ln p_i^{\theta_{j,i}} = \ln\prod_{i=1}^{N}p_i^{\theta_{j,i}}$$

Thus, when $\sigma_j \to 1$, equation (3.19a) will be transformed to be its "*Cobb-Douglas* counterpart":

$$p_j = \prod_{i=1}^{N} p_i^{\theta_{j,i}} \tag{3.19b}$$

For equation (3.6b), when $\sigma_j \to 1$, we can get its "*Cobb-Douglas* form" with *L'Hôspital's rule* as well:

$$y_j = \prod_{i=1}^{N} x_{j,i}^{\theta_{j,i}/\sigma_j} \tag{3.6c}$$

With equations **(3.6b), (3.18a), (3.19a, b)**, most of equations of a CGE model can be listed succinctly. Actually, all of the *generalized* "production" functions, *e.g.* Armington aggregate, export and import, labour and capital disaggregation can be denoted by (3.18a) and (3.19a, b) forms. These functions together with the associated variables and parameters can then be used to derive the income balance equations, demand-supply equilibrium equations and zero profit conditions, which provide a more parsimonious specification of a general equilibrium analysis. These "calibrated forms" will be heavily used in Chapter 5 where a benchmark CGE model for the Chinese economy is constructed.

3.5. A FLOWCHART OF CGE MODELLING

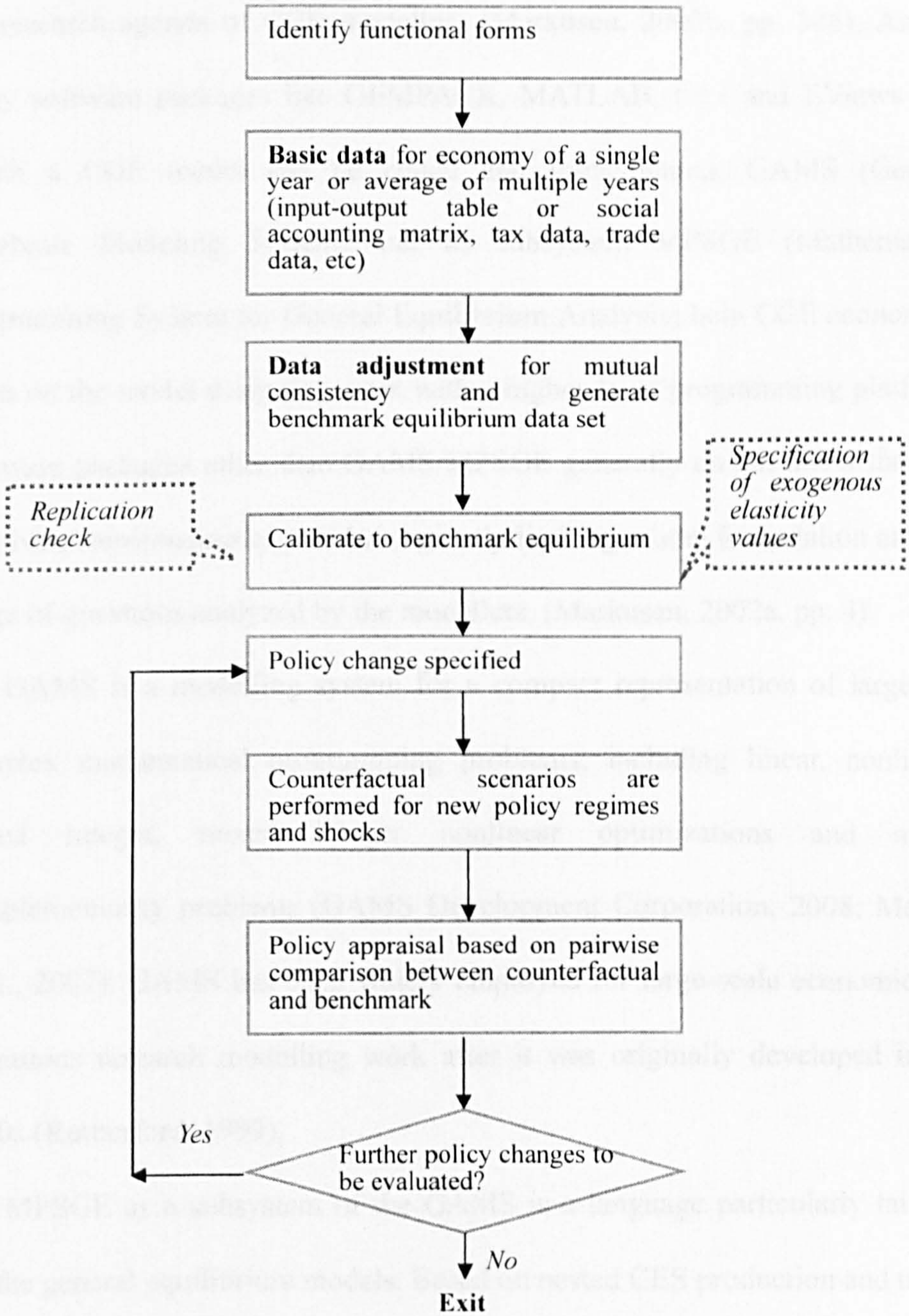
A typical CGE modelling work consists of a sequence of steps such as model design, data collection and compilation, model benchmark checking and counterfactual simulation.

First of all, a reasonable and feasible model framework should be built up. Beside the basic equations for standard production and consumption, special specifications should be designed to accommodate different features of the research project. The model should be flexibly designed so that the efforts can be focused on the major research topic. For example, a CGE model designed for examining the productivity spillover effects in *manufacturing* sectors should avoid using complex nested production functions for *services* sectors.

Then basic datasets of a benchmark year should be collected. They include an input-output table or SAM, tax data, trade data, etc. After the data have been manipulated for mutual consistency, they can be used in computer programming to calibrate the benchmark equilibrium.

Counterfactual policy shocks are simulated to estimate the impact on the whole economy, the results of which need to be compared with the benchmark scenario for policy appraisal.

Figure 3.5: A Flowchart of CGE Modelling



Source: Shoven and Whalley (1984)

3.6. SOFTWARE TO IMPLEMENT CGE MODELS

3.6.1. GAMS/MPSGE

More and more powerful computer software has helped CGE modellers to be able to solve problems and arrive at insights that they would have not been able to achieve otherwise. It has dramatically changed, extended and deepened the research agenda of CGE modellers (Markusen, 2002b, pp. 346). Among many software packages like GEMPACK, MATLAB, C++ and EViews with which a CGE model can be coded and implemented, GAMS (General Algebraic Modeling System) and its subsystem MPSGE (Mathematical Programming System for General Equilibrium Analysis) help CGE economists focus on the model designing work with a higher-level programming platform. Software packages other than GAMS/MPSGE generally do not allow the user to solve *complementarity problems*, greatly limiting model formulation and the range of questions analyzed by the modellers. (Markusen, 2002a, pp. 4)

GAMS is a modelling system for a compact representation of large and complex mathematical programming problems, including linear, nonlinear, mixed integer, mixed integer nonlinear optimizations and mixed complementarity problems (GAMS Development Corporation, 2008; McCarl et al., 2007). GAMS has been widely employed for large-scale economic and operations research modelling work after it was originally developed in the 1970s (Rutherford, 1999).

MPSGE as a subsystem of the GAMS is a language particularly tailored for the general equilibrium models. Based on nested CES production and utility functions, a MPSGE framework provides a concise modelling representation for the large-scale system of nonlinear inequalities which are the core of a CGE model.

The interface of GAMS/MPSGE hybrid combines the strength of both systems. While the GAMS language has a strong capacity for managing large datasets, the MPSGE is of particular use for solving the general equilibrium models. With MPSGE employing an extended syntax based on GAMS sets, the integrated system GAMS/MPSGE uses GAMS as the "front end" and "back end" to MPSGE, providing a compact model specification. This provides great benefits to economists who are more interested in the insights achieved by the CGE models than the time-consuming programming work (Rutherford, 1999). What a CGE modeller needs to do is to specify the production and utility nest structure, select or estimate parameters for the elasticity of substitution at each nest level and then select a representative point of the functions which contains output quantities, input quantities and prices. Once this information has been collected, the production functions and utility functions are uniquely determined.

3.6.2. An Example of Modelling CGE in GAMS/MPSGE

Tables 3.6 to 3.10 provide an example of modelling CGE in GAMS/MPSGE syntax. It provides a transformed SAM in Part 1 and initiates two parameters in Part 2. Part 3 is the core model which is written in MPSGE syntax. Part 4 implements the benchmark check and counterfactual simulations.

In Part 1, positive entries are values of commodity flows into the economy (sales or factor supplies), while negative entries are values of commodity flows out of the economy (factor demands or final demands). Zero row sum implies market clearance while zero column sum denotes zero profit for production sectors and income balance for consumers.

In Part 2, the initial ad-valorem tax rate (`TY1`) for Y_l sector's inputs is 0. The initial labour endowment level (`LENDOW`) is 1. These parameters will be changed in counterfactual simulations to examine the effects of tax reform and change of country size.

Table 3.6: A Closed Economy in GAMS/MPSGE Syntax

```
$TITLE A Closed 2x2 Economy
* Part 1: Transformed SAM
$ONTEXT
      Production Sectors     Consumers
Markets | Y1      Y2       W       CONS    |    SUM
-----------------------------------------------------
    PY1 | 100            -100               |   0
    PY2 |         100    -100               |   0
    PW  |                 200     -200      |   0
    PL  | -25     -75              100      |   0
    PK  | -75     -25              100      |   0
-----------------------------------------------------
  SUM   | 0       0        0       0
$OFFTEXT
* Part 2: Parameters
PARAMETERS
TY1 ad-valorem tax rate for Y1 sector inputs
LENDOW labour endowment multiplier for counterfactual simulations;
TY1 = 0;
LENDOW = 1;

* Part 3: Core MPSGE model
$ONTEXT
$MODEL: Markusen
$SECTORS:
    Y1!   Activity level for sector y1
    Y1!   Activity level for sector y2
    W!    Activity level for sector W (Hicksian welfare index)
$COMMODITIES:
    PY1!  Price index for commodity y1
    PY2!  Price index for commodity y2
    PL!   Price index for primary factor L
    PK!   Price index for primary factor K
    PW!   Price index for welfare (expenditure function)
$CONSUMERS:
    CONS!   Income level for consumer CONS
```

Source: Markusen (2002a)

In Part 3, the `$SECTOR` statement indicates the model involves three activities that convert commodity/welfare inputs into commodity/welfare outputs. All the activity levels are unity. For example, activity Y_1 runs at a unitary level, producing 100 units of good Y_1, as displayed in the transformed SAM. Setting unitary initial levels for the activities will make the pairwise comparison between benchmark levels and counterfactual results more straightforward.

`$COMMODITY` states that the model contains two goods, two factors, and a special product, *welfare*. `$CONSUMER` represents the individuals who supply factors and receive transfers from government. The three `$PROD` blocks describe the production for product X and Y, and welfare W.

The production of good Y_1 and Y_2 follows from a CES production function with the elasticity of substitution to be one (`s:1`), as Table 3.7 shows. This implies that the CES production technology has a special specification, *i.e.* Cobb-Douglas form, as discussed in Section 3.2.1 of this Chapter. Assume the production of Y_2 is to solve the problem below:

$$\begin{aligned} &\min \quad P_L L + P_K K \\ &s.t. \quad Y_2 \le A_2 L^{\alpha_2} K^{1-\alpha_2} \end{aligned}$$

Table 3.7: Production Blocks

```
$PROD:Y1 s:1
   O:PY1 Q:100
   I:PL Q:25 A:CONS T:ty1
   I:PK Q:75 A:CONS T:ty1
$PROD:Y2 s:1
   O:PY2 Q:100
   I:PL Q:75
   I:PK Q:25
```

The cost ratio of the two inputs can be derived:

$$\frac{P_K K}{P_L L} = \frac{1-\alpha_2}{\alpha_2} \Rightarrow \frac{1-\alpha_2}{\alpha_2} = \frac{25}{75} \Rightarrow \alpha_2 = 0.75$$

With L=75 and K=25, the value of A_2 can be obtained: $A_2 = Y_2 / L^{0.75} K^{0.25}$=1.75. Thus the underlying Cobb-Douglas production function is $Y_2 = 1.75 * L^{0.75} K^{0.25}$.

The above "standard" calibration process, however can be replaced with "calibrated forms" without calculating the values of parameters of α_2 and A_2. With equation (3.18a) and (3.19b), we can get **ratio** equations for prices and input demands (with lower case letters denoting *ratio* rather than *level* variables):

$$py_1 = p_L^{0.75} p_K^{0.25} \tag{3.18b}$$

$$l = y_2 \frac{py_2}{p_L} \tag{3.19c}$$

$$k = y_2 \frac{py_2}{p_K} \tag{3.19d}$$

The parsimony of these "calibrated forms" of the model will be fully manifested in Chapter 5 with a benchmark model for the Chinese economy.

As for production taxes on both inputs of labour and capital, the tax (`T:`) revenue is assigned (`A:`) to the agent "`CONS`".

The welfare is "produced" by consuming good Y_1 and Y_2, with a Cobb-Douglas function as well. The elasticity of substitution here is also one (`s:1`). Calibrations and "calibrated forms" of this block is similar to that in Table 3.7.

In a demand block as shown in Table 3.9, the consumer agent demands the utility good PW and receives income from his/her endowment which is denoted by "E:". LENDOW is a shift parameter to multiply the endowment amount.

Table 3.8: Welfare Block

```
$PROD:W s:1
   O:PW Q:200
   I:PY1 Q:100
   I:PY2 Q:100
```

Table 3.9: Demand Block

```
$DEMAND:CONS
   D:PW Q:200
   E:PL Q:(100*LENDOW)
   E:PK Q:100
```

After specifying the core model with parameter values and data imported, the fitness of the model is checked by seeing whether it can replicate the benchmark economy with the price of welfare as the numéraire (PW.FX = 1), which is shown in Table 3.10. If activity levels of all production sections (Y1, Y2 and W) and consumer (CONS) equal 1, and all prices (PY1, PY2, PL, PK) are equal to 1 as well, then the benchmark economy is successfully replicated. Then the shift parameters for labour endowment LENDOW and production tax TY1 can be altered to check how the production and welfare levels will be affected in these two counterfactual scenarios.

Table 3.10: Benchmark Check and Counterfactual Scenarios

```
* Part4: Benchmark checking and counterfactual scenarios
$SYSINCLUDE mpsgeset markusen
PW.FX = 1;
$INCLUDE Markusen.gen
SOLVE Markusen using MCP;
* Solve the counterfactuals
TY1 = 0.5;
```

```
LENDOW = 1;
$INCLUDE Markusen.gen
SOLVE Markusen using MCP;

TY1 = 0;
LENDOW = 2;
$INCLUDE Markusen.gen
SOLVE Markusen using MCP;
```

3.7. ADVANTAGES AND DISADVANTAGES OF MODELLING FDI SPILLOVERS WITH CGE

Generally speaking, the **advantages** of CGE modelling lie in its capability of *structurally* modelling economic general equilibrium, and thus its complementarity to econometric methodologies, especially in policy simulations. In terms of research on FDI productivity spillover, a CGE model can provide a capable research framework on this topic thanks to the conduit mechanism of FDI productivity spillovers:

Firstly, the *input-output table* used in a CGE model captures the vertical linkages which generate productivity spillovers. As discussed in Chapter 2, the importance of vertical linkages in FDI productivity spillover are theoretically modelled (e.g. Fosfuri, Motta and Ronde, 2001; Markusen and Venables, 1999) and empirically evident (Javorcik, 2004; Girma, Görg and Pisu, 2008).

Secondly, *export activities* of MNE affiliates in host countries which also provide possibilities for productivity spillover can be readily explored by a CGE model. The export pattern of foreign-invested enterprises in China merits special attention in studying FDI productivity spillover. The share of export of foreign-invested enterprises in total foreign trade in China has gradually increased from 4% in the early 1980s to over 50% after 2000. These export-oriented MNE affiliates exert a vital demonstration effect on the boom of labour-intensive exporting firms in China, especially in the coastal provinces. A CGE model for China can comprehensively incorporate MNE's export characteristics.

Thirdly, FDI productivity spillover takes place via many *other direct and indirect channels*, including labour turnover, demonstration, competition, and induced resource reallocation towards the most productive enterprises. These channels can also be captured by CGE modelling with incorporation of corresponding endogenous variables.

Finally, a CGE model can be constructed to assess FDI spillover effects by examining not only industry-level performance *e.g.* output, export and price changes, but also macroeconomic changes, *e.g.* GDP and national welfare. As a structural model, CGE can also be used to address more interesting issues which other methodologies rarely deal with, *e.g.* an assessment of the impact of FDI policy reforms on FDI productivity spillover effects.

Meanwhile we also need to understand the **weakness** of CGE in applying a CGE model to doing research on FDI productivity spillover.

Firstly, as discussed in Chapter 1 and 2, FDI productivity spillovers are subject to various macro and micro-level constraints. However, CGE models each industry as a representative agent and can only convey information on these constraints *implicitly*, in an *aggregated* way. For example, due to data limitation, the CGE model developed in this research can not disaggregate the data of foreign-invested enterprises by the origin of FDI, namely from Hong Kong, Macau, Taiwan (HMT), or from other economies. However, as suggested by the literature (Buckley, Wang and Clegg, 2007), the difference between spillover effects of the FDI from the above two types countries of origin is not trivial.

Secondly, the perceived magnitude of FDI spillover effect gauged by a CGE model, by and large, relies on the *spillover coefficients* selected from existing econometric literature or estimated from new econometric estimations. Such a reliance on parameter can pose a dilemma for researchers. The parameters in the literature are usually not estimated for the economies to be modelling in CGE. For example, Lejour et al. (2008) have to employ the value of spillover coefficient estimated for the US rather than the EU countries examined in their research. However, if researchers want to estimate spillover parameters with their own econometric models, such an ambition will require another investment into data collection and analysis.

The last drawback is related to the fact that this CGE model is based on Chinese input-output table of 2002 which is indeed the latest one, yet still a little dated. This constraint makes it unlikely to exclude the impact of long-term business cycle on the FDI inflows and the performance of domestic firms. More importantly, after China's accession into WTO in December 2001, the market barriers to foreign commodity and investment have been effectively lowered. Chinese government has also continued to use policy to channel resources into certain activities, with a view to "promoting investment in high technology, encouraging innovation, and protecting the environment" (World Trade Organization, 2008, pp. xi).

3.8. CONCLUSIONS

CGE modelling involves designing a large-scale general equilibrium model across all the industries and implementing computer-based simulations of counterfactual scenarios. CGE models are a class of models that explore the overall economic impact of policy, technology or other external "shocks". The microeconomic foundation for CGE models is Walrasian general equilibrium theory. A CGE model consists of: (a) a series of equations of production, consumption, utility and so on, which cover the whole economy including the activities of all industries, governments, and households; and (b) a detailed database consistent with the model equations.

As a *general-equilibrium* model, a CGE model is inappropriate for the analysis of small-scale, sector-specific changes, but is well tailored to the investigation of broadly based policy innovations where inter-region and inter-industry feedbacks and interdependences are important. Most of the applications of CGE fall into the categories of tax and trade policy research and more recently, resource and environment research.

The simulation work in a CGE model is based on a social accounting matrix (SAM) or input-output table in a base year. A SAM expands a cross-industry input-output table by incorporating non-production sectors, (*e.g.* households and government) in a more comprehensive way. A SAM or input-output table statistically represents flows of all economic transactions that take place within an economy.

GAMS provides a tailored and powerful higher-level coding platform for CGE modellers. MPSGE as a subsystem of GAMS is specially designed for a mix of complementarity problems that are most frequently met in general equilibrium models.

CGE modelling provides a convincing structural research framework on the topic of FDI productivity spillovers and the associated FDI policy assessmet. A CGE model can decompose FDI spillovers effects into benefit obtained through different channels, namely vertical linkages, export of MNEs and horizontal demonstration. However, due to the data constraint and the only option of a single year as the benchmark year, the reliability of CGE modelling needs to be subject to sensitivity tests.

CHAPTER 4: DATA COMPILATIONS

4.1. INTRODUCTION

This Chapter introduces how the input-output table used in the CGE modelling is constructed. Section 4.2 introduces statistical standards in China, available data sources and strategies to manipulate data. Section 4.3 discusses issues around a data consistency check. Section 4.4 presents how to aggregate the original 122 by 122 input-output table into a 39 by 39 one due to the availability of supplementary data. Section 4.5 discusses estimating data of different ownerships. Based on the data estimated in Section 4.5, Section 4.6 disaggregates the 39 by 39 input-output table into a 101 by 101 one by ownership to cater for the later research on cross-ownership productivity spillovers. Data balancing and data consistency checks are also discussed.

4.2. DATA SOURCES

4.2.1. Statistical Standards in China

Data used in the CGE modelling follow two different statistical standards, which necessitates identifying the mapping between different statistical standards. While version 1994 was the industrial classification adopted in Chinese official statistics between 1994 and 2002, version 2002 is the latest one (see Table 4.1) adopted by the National Bureau of Statistics (NBS) of China after 2002. Version 2002 is convertible to version 3.0 of the International

Standard Industrial Classification (ISIC).

Both version 1994 and version 2002 follow ISIC's practice in differentiating industries into 4 hierarchies: section, division, group, and class. The difference (Table 4.2) between version 1994 and 2002 mainly lies in the classification for services. As an interim classification standard, version 1994 has a similar structure of version 2002, but is less compatible with ISIC.

Table 4.1: Chinese Industrial Classification (Version 2002)

Section		Division	Group	Class
A:	Agriculture, forestry, animal husbandry and fishing	5	18	38
B:	**Mining**	**6**	**5**	**33**
C:	**Manufacturing**	**30**	**169**	**482**
D:	**Utilities (production of electricity, gas and water)**	**3**	**7**	**10**
E:	Construction	4	7	11
F:	Traffic, transport, storage and post	9	24	37
G:	Information transfer, computer services and software	3	10	14
H:	Wholesale and retail trade	2	18	93
I:	Accommodation and restaurants	2	7	7
J:	Finance	4	16	16
K:	Real estate	1	4	4
L:	Tenancy and business services	2	11	27
M:	Scientific research, technical service and geologic perambulation	4	19	23
N:	Management of water conservancy, environment and public establishment	3	8	18
O:	Resident services and other services	2	12	16
P:	Education	1	5	13
Q:	Sanitation, social security and social welfare	3	11	17
R:	Culture, sports and entertainment	5	22	29
S:	Public management and social organization	5	12	24
T:	International organizations	1	1	1
Total: 20		**95**	**396**	**913**

Source: Zhao (2004)

Table 4.2: A Comparison between Version 1994 and Version 2002

	2002	1994	Difference
Section	20	16	4
Division	95	92	3
Group	396	368	28
Class	913	846	67

Source: Zhao (2004)

4.2.2. Data Sources

As Table 4.3 shows, the FDI inflow to sectors of mining, manufacturing, and utilities (hereafter "MMU") in the benchmark year of 2002 accounted for 73.5% of the total FDI inflow to China. The FDI inflow to sector "manufacturing" alone accounted for 69.8% of total FDI. According to *China Statistical Yearbook 2003* (hereafter "*CSY*"), MMU contributed 44.4% of GDP of China in 2002. Given the importance of these three sectors and the data availability on FIEs and SOEs in these sectors, special attention is paid to MMU in the following data disaggregation and CGE modelling.

One point merits special attention. The statistics of FDI in China has been greatly contaminated by "*round-tripping*" FDI, *i.e.* fake FDI. Round-tripping FDI refers to cross-border investment motivated by the more favourable treatment of foreign as opposed to domestic capital in a host country. In China a large number of domestic investors transferred their capital out of, and then invested back into, the Chinese market with a new label of "foreign capital". Those enterprises invested by round-tripping investment are entered as "foreign invested enterprises" instead of "domestic enterprises" in the Chinese economic census. By 2003, about a quarter of FDI to China was round-tripping FDI (United Nations Conference on Trade and Development, 2003, pp. 45).

Those round-tripping investments are unlikely to generate the same productivity spillovers as the "authentic" foreign investments originated from successful western entrepreneurs or institutions with advanced technology and mature management skills. Due to data availability, this research can not differentiate round-tripping FDI from authentic FDI. It is also extremely difficult to find out the exact countries of origin of these round-tripping FDI, and the industry distribution of those fake foreign-invested enterprises in China. This problem might make the later analyses underestimate the real magnitude of productivity spillovers of the "authentic" FDI, especially in some sectors with a relatively concentrated presence of round-tripping FDI. However, aggregating both types of FDIs and then examining the *actual* spillover effects of such "blended" FDIs rather than "purified" FDI in China, can at least serve the purpose of reflecting the *reality* in the Chinese economy context.

The benchmark year of this CGE modelling work is 2002. The main data sources for that year include *CSY*, *China Industry Economy Statistical Yearbook 2003* (hereafter "*CIESY*"), and *China Input-Output Table 2002* (in the format of Table 3.4, hereafter "*I/O*"), all of which were complied and released by the National Bureau of Statistics of China (NBS). *CSY* and *CIESY* were published in 2003 and that is why they were titled with "Yearbook 2003" instead of "Yearbook 2002". *I/O* was released in 2006.

Table 4.3: Foreign Direct Investment by Sector in 2002

Sector	Amount ($mn)	Share (%)
Farming, forestry, animal husbandry and fishery	1,028	1.9
Mining and quarrying	581	1.1
Manufacturing	**36,800**	**69.8**
Electric power, gas and water production and supply	1,375	2.6
Construction	709	1.3
Geological perambulation and water conservancy	7	0.0
Transport, storage, post and telecommunication services	913	1.7
Wholesale & retail trade and catering services	933	1.8
Banking and insurance	107	0.2
Real estate	5,663	10.7
Social services	2,943	5.6
Health care, sports and social welfare	128	0.2
Education, culture and arts, radio, film and television	38	0.1
Scientific research and polytechnic services	198	0.4
Other sectors	1,321	2.5
Total	**52,743**	**100**

Source: National Bureau of Statistics of China (2003b). "Amount" denotes *utilised* amount rather than *contracted* amount.

4.4). Two supplementary data sources are (1) *China Economic Census Yearbook 2004* (*CECY*) published by NBS in 2006; and (2) the data available in the paper of Girma and Gong (2008a) which employs Chinese firm-level industrial survey data to evaluate FDI spillovers.

Table 4.4: Available Data

CSY	*CIESY*	*I/O*
1. For FIEs, SOEs, Private enterprises in MMU: 1) Total output 2) Value added 3) Annual average employees 2. Amount of utilised foreign direct investment by Section 3. GDP 4. Total export & import	1. For FIEs, SOEs, Private enterprises in mining, manufacturing, and utilities: 1) Total output 2) Value added 3) Annual average employees 4) Export	1. Total intermediate inputs 2. Total value added 1) Compensation of employees 2) Net taxes on production 3) Depreciation of fixed capital 4) Operating surplus 3. Total input 4. Total intermediate use 5. Total final use 1) Rural household consumption 2) Urban household consumption 3) Government consumption 4) Gross fixed capital formation 5) Change in inventories 6) Exports 6. Imports 7. Gross output

In *CSY*, disaggregated data of total output and value added at ownership level are available for foreign invested enterprises (hereafter "FIEs")[3] and state-run and state-holding enterprises (hereafter "SOEs")[4] in MMU are provided. Section-level data of FDI inflows are provided in *CSY* as well (Table

[3] "*FIEs*" represents foreign-invested enterprises. As introduced in Chapter 1, it consists of enterprises funded by investment from Hong Kong, Macau, Taiwan, and from any country other than the People's Republic of China.

[4] "*SOEs*" denotes state-run and state-holding enterprises. They consist of state-owned enterprises, state joint ownership enterprises, sole sate-invested enterprises, and state-holding enterprises. State-holding enterprises refer to enterprises where the percentage of state assets is larger than any other single share holder of the same enterprise.

4.4). Disaggregated data of FDI to MMU at Division level are also available at the website of "Investment in China" project, Ministry of Commerce of China (hereafter "MOFCOM", *http://www.fdi.gov.cn*).

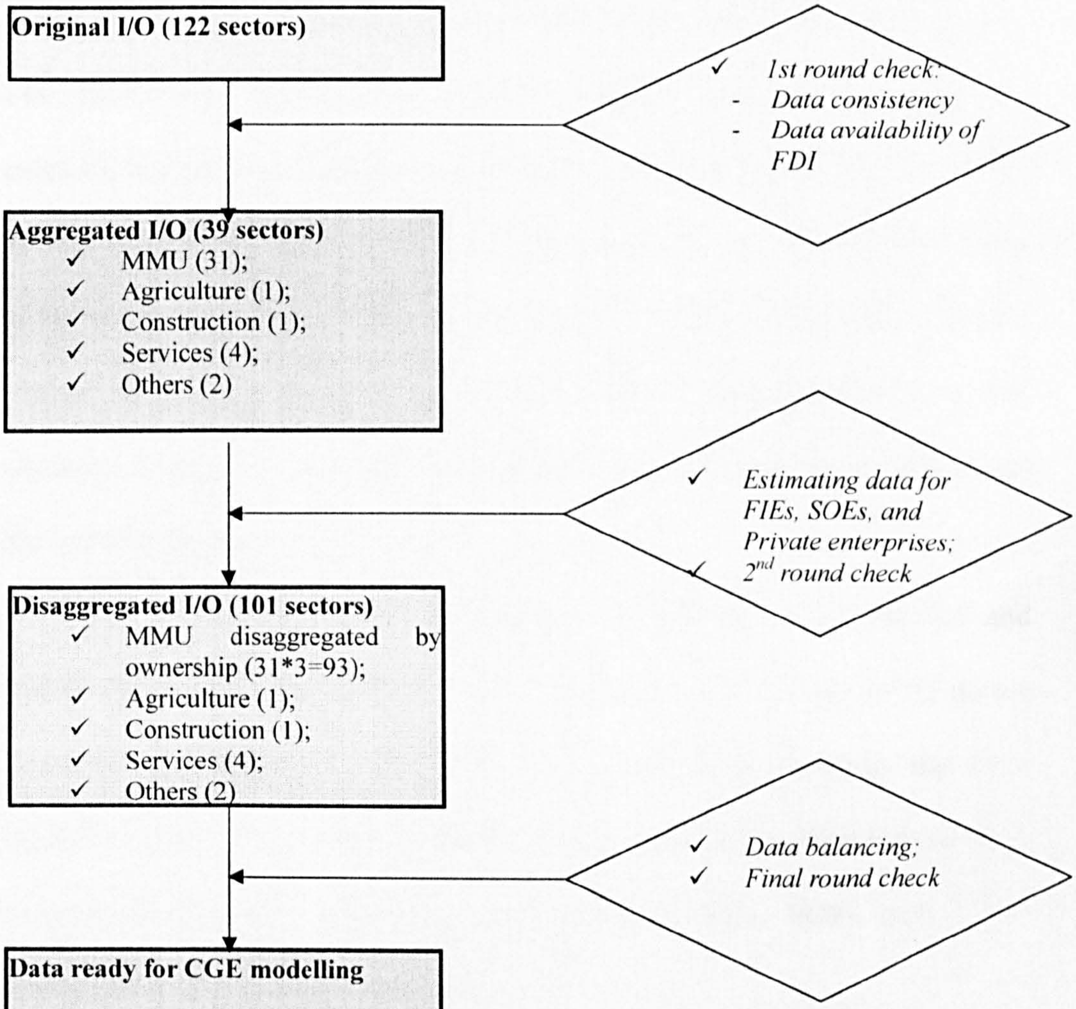
The data of FIEs and SOEs in MMU are originally collected by statistical officials with Annual Report of Industrial Enterprise Statistics from (1) *all state-controlled* industrial enterprises that account for 36.3% and 48.3% of gross output and value added of all enterprises surveyed, respectively; and (2) *non-state-owned* industrial enterprises with annual sales above RMB 5 million (equivalent to approximately US$600,000, with an exchange rate of 8.27 RMB per Dollar in 2002). The enterprises surveyed account for 68% of *total* industrial output and 69% of *total* value added in MMU in 2002.

Similar to any input-output table, the Chinese *I/O* exhibits an interdependence of an economy's various productive sectors, as it contains the information of transactions within and between production sectors and non-production sectors. The *I/O* also provides data of value added, private consumption, export, import, and investment.

4.2.3. Data Compilation Strategy

There are many steps to go in transforming the original I/O into a tailored one for this CGE modelling work (see Figure 4.1). The first step is to check data consistency caused by different statistical standards. While the compilation of the *CSY* and *CIESY* follows the old Chinese industry classification standard (version 1994), the *I/O* follows the new one (version 2002). As will be discussed in Section 4.3, a data consistency check shows that the data of two sectors in the *I/O* are inconsistent with those from *CSY* and *CIESY*. That problem can be sorted by aggregating the data of sectors in question with those of other similar sectors.

Figure 4.1: Transformations of the Input-output Table



The second step is to reconcile the data availability of FDI inflows. MOFCOM only releases data on FDI at "Section (see Table 4.1)" level. The only exception is manufacturing. As FDI to manufacturing accounts for about 70% of total FDI in recent years, MOFCOM also releases disaggregated data of FDI to manufacturing at "Division (see Table 4.1)" level, although data of some of these 30 Divisions are missing. Thus an FDI shock introduced to the CGE model (see Section 6.2) can only take the values at a relatively aggregated level. This problem requires relevant data aggregation of some sectors in the *I/O*, which will be discussed in detail in Section 4.4.

The third step involves estimating data of FIEs, SOEs, and other domestically-invested enterprises (hereafter "Private"), as will be discussed in Section 4.5. As the main function of this CGE model is to analyze the effects of FDI productivity spillovers on Chinese domestic enterprises, it would be essential to expand the dimensions of *I/O* by disaggregating each of 31 MMU sectors into three ownership-sectors. To take sector "textile" for example, it can to be disaggregated into three individual sectors, namely, "FIEs textile sector", "SOEs textile sector", and "Private textile sector". This procedure can help *explicitly* model FDI productivity spillovers from FIEs sectors to SOEs and Private enterprises.

This can be done with the supplementary information from the *CSY* and *CIESY*. But the problem is that the data provided by the *CSY* and *CIESY* do not cover *all* enterprises, as introduced in Section 4.2.2; however the CGE modelling needs input-output information at *national* level. Therefore we need to *estimate* the total output and value added of FIEs, SOEs and Private enterprises with certain techniques.

The fourth step is then to disaggregate the input-output table with the additional information on ownerships, which will be discussed in Section 4.6. The last step involves data balancing and final-round data consistency check.

4.3. DATA CONSISTENCY CHECK

4.3.1. Data of FDI in Real Estate

FDI to the sector of "real estate" in China in 2002 and recent years are extraordinarily high, and accounts for about 10% of total FDI. Although this ratio is higher than most of other countries, it is not unusual in the context of

China due to following four factors:

(1) *Urbanization.* Since the implementation of "Reform and Opening-up" policy in 1978, the level of urbanization in China has increased from 17.9% to 39.1% in 2002. Cities and towns hosted a population of 502 million by the end of 2002, which generated a great demand on real estate development and management (Ministry of Housing and Rural-urban Development of China).

(2) *Policy incentives.* Real estate is among the industries where non-resident investment is always encouraged by China's FDI policies, as is explicitly stated in the *Guiding Directory on Industries Open to Foreign Investment*, although 136 out of 184 IMF member countries have various controls on the non-resident investment on real estate (International Monetary Fund, 2004, pp. 12, 225).

(3) *Macroeconomic prospects.* As one of the most rapidly growing economies in the world, China has attracted a very high amount of FDI in real estate.

(4) *Speculative investment.* As a high-profit industry, real estate in China is very attractive to foreign institution investors (Jiang, Chen and Isaac, 1998). Combined with the expectation of Reminbi revaluation, FDI in real estate soared dramatically after 2004.

4.3.2. "Tobacco Processing" Sector

The total output data (RMB 172 billion) and value added data (131 billion) for "tobacco processing" sector in the *I/O* are smaller than the figures in *CSY* for 2002 (RMB 204 billion and 136 billion) respectively. As introduced in 4.2.2, the total output of each sector in *CSY* only covers (1) all SOEs, and (2) enterprises of other ownerships with annual sales above RMB 5 million. So

CSY data should have been smaller than the counterpart *I/O* data.

The causes of this problem could be the fact that the industry classification adopted in *I/O* and *CSY* are different. Some sub-sectors might be classified as "tobacco processing" in *CSY* but not in *I/O*.

To solve this problem, we can aggregate tobacco processing with related sectors, namely food processing, food manufacturing and beverage manufacturing.

4.3.3. "Production of Electric Power, Steam and Hot Water" Sector

According to *CSY*, total output of all SOEs and other above-scale enterprises in this sector is RMB 5,889 billion. The figure for SOEs is 4,930 billion, and the figure for other above-scale enterprises is 1,080 billion. That means the national output level is even *smaller* than the sum of the ownership-disaggregated enterprises, 6,010 billion.

The cause for this problem is double counting of some enterprises with multiple ownership. There is a possibility that some enterprises fall into *both* categories of "FIE" and "SOE". If a firm's foreign share accounts for more than 25%, the threshold to register as an "FIE", then it is an "FIE". However, if its largest portion of share (e.g. 40%) is owned by the state agencies, then it is also an "SOE".

Therefore to avoid double counting, we need to purify the "SOEs" by excluding FIEs from them. The paper of Girma and Gong (2008a) provides a useful reference. They provide the shares of total output of FIEs and SOEs in total output of each sector in 2002. Their dataset and *CSY* dataset come from precisely the same source, *i.e.* Annual Report of Industrial Enterprise Statistics of (1) all SOEs; and (2) all above-scale (with annual sales of RMB 5 million

Yuan) enterprises of other ownership.

Table 4.5: Different Definitions of "SOEs"

Girma & Gong's SOEs	CSY SOEs	Enterprise Types
		Domestic-invested Enterprises
▲	●	State-owned enterprises
		Collective-owned enterprises
		Cooperative enterprises
		Joint ownership enterprises
▲	●	State joint ownership enterprises
		Collective joint ownership enterprises
▲		Joint state-collective ownership enterprises (with state-owned fund dominated)
		Joint state-collective ownership enterprises (without state-owned fund dominated)
		Limited liability corporations
▲	●	Sole sate-funded enterprises
		Share-holding enterprises
		Private enterprises
		Other enterprises
		Enterprises with funds from Hong Kong, Macao and Taiwan
		Foreign-invested enterprises

Source: Girma and Gong (2008a); National Bureau of Statistics of China (2003b).

Girma and Gong's definition of FIEs is exactly the same as that adopted by the *CSY*. However their definition of "SOEs" is slightly different from that in the *CSY*, as shown in Table 4.5. In the paper of Girma and Gong, "SOEs" includes state-owned enterprises, state joint ownership enterprises, joint state-collective ownership enterprises (with state-owned funded dominated), and sole state-funded enterprises. However, in CSY, "SOEs" only consists of state-owned enterprises, state joint ownership enterprises, and sole state-funded enterprises. Joint state-collective ownership enterprises (with state-owned funded dominated) are categorized into state-holding enterprises in the *CSY*. In brief, Girma and Gong's definition of SOEs will be adopted here.

4.4. DATA AGGREGATION

Prior to the CGE modelling work, the original China *I/O* is aggregated from 122 sectors to 39 sectors, as shown in Table 4.6 and 4.7. This aggregation reconciles the difference between industry classifications used in *I/O* and FDI data so that one and only one FDI inflow figure corresponds to each "model section". The list of sectors after aggregation is given by Table 4.8.

Table 4.6: I/O prior to Aggregation

	Sector 1	Sector i (i=2,…,121)	Sector 122	Final use	Import	Error	Total Output
Sector 1							
Sector i (i=2,…,121)		Intermediate input-output matrix					
Sector 122							
Value Added							
Total Input							

Note: Total input$_i$ = Total output$_i$, i=1, …, 122.

Table 4.7: I/O after Aggregation

	Sector 1	Sector i (i=2, … ,38)	Sector 39	Final use	Import	Error	Total Output
Sector 1							
Sector i (i=2,…,38)		Intermediate input-output matrix					
Sector 39							
Value Added							
Total Input							

Note: Total input$_i$ = Total output$_i$, i=1, …, 39.

Table 4.8: I/O Aggregation

Category	Model sector	NBS Version 2002	Name of model sectors
Mining*	1	06, 07	Resource manufacturing (coal, petroleum, and gas)
	2	08	Ferrous metals mining and dressing
	3	09	Nonferrous metals mining and dressing
	4	10, 11	Mining of non-metal, other minerals, and other ores
Manufacturing*	5	13-16	Food, beverage, and tobacco manufacturing
	6	17	Textile industry
	7	18	Garments and other fibre products
	8	19	Leather, furs, down and related products
	9	20	Timber processing, bamboo, cane, palm fibre etc.
	10	21	Furniture manufacturing
	11	22	Papermaking and paper products
	12	23	Printing and record medium reproduction
	13	24	Cultural, educational and sports goods
	14	25	Petroleum processing and coking
	15	26	Raw chemical materials and chemical products
	16	27	Medical and pharmaceutical products
	17	28	Chemical fibre
	18	29	Rubber products
	19	30	Plastic products
	20	31	Non-metal mineral products
	21	32	Smelting and pressing of ferrous metals
	22	33	Smelting and pressing of nonferrous metals
	23	34	Metal products
	24	35	Ordinary machinery
	25	36	Special purpose equipment
	26	37	Transport equipment
	27	39, 40	Electronic and electric products
	28	41	Instruments, meters, cultural and office machinery
Utilities*	29	44	Production of electric power, steam and hot water
	30	45	Production of gas
	31	46	Production of tap water
Agriculture	32	01-05	Farming, forestry, animal husbandry & fishing
Other Manufacturing	33	42	Manufacture of artwork and other manufacturing
	34	43	Recycling and disposal of waste
Construction	35	47-50	Construction
Banking and Insurance	36	68-71	Banking and insurance
Real Estate	37	72	Real estate
Other services	38	51-63; 65-67; 73-92	Geological perambulation & water conservancy; transport, storage, post & telecommunication services; wholesale & retail trade & catering; Social services; healthcare, sports & social welfare; Education, culture and arts, radio, films & television; Scientific and technical services
	39	93-98	Public administration & other services

Note: (a) Categories marked with "*" (*i.e.* MMU or Industry) will be further disaggregated by ownership, namely FIEs, SOEs, and Private in Section 4.6. (b) In the NBS statistical standard version 2002, there are 98 two-digit sectors in total. Some of them are disaggregated into three-digit sectors in the *I/O* 2002, so that the *I/O* contains 122 sectors.

4.5. ESTIMATING DATA OF FIES, SOES AND PRIVATE ENTERPRISES

4.5.1. Total output

With Girma and Gong's data on share of SOEs by sector, and *CSY*'s data on total output for each sector, we can estimate the data of total output of SOEs in manufacturing sectors by "reverse engineering":

$$Q^i_{SOEs} = Ratio^i_{SOEs} \times Q^i_{(CSY)All},\ i \in Manufacturing$$

where $Ratio^i_{SOEs}$ is the share of total output of each manufacturing sector (with "SOEs" ownership) obtained from Girma and Gong (2008a). Thus, we can get total output value for "*pure*" SOEs.

The next step is to estimate the output level for SOEs in MMU based on the data of the output level of "pure" SOEs in MMU and manufacturing alone.

Assuming $\frac{Q^{MMU}_{SOEs}}{Q^{Manufacturing}_{SOEs}} = \frac{Q^{MMU}_{(CSY)SOEs}}{Q^{Manufacturing}_{(CSY)SOEs}}$; we get $Q^{MMU}_{SOEs} = Q^{Manufactuing}_{SOEs} \times \frac{Q^{MMU}_{(CSY)SOEs}}{Q^{Manufactuing}_{(CSY)SOEs}}$.

Then the output level for each sector in *mining* and *utilities* can be estimated by allocating the difference between Q^{MMU}_{SOEs} and $Q^{Manufacturing}_{SOEs}$ with sector shares of corresponding SOEs and state-holding enterprises (SHEs) in CSY in each sector as a proxy for the share of sole SOEs.

$$Q^i_{SOEs} = (Q^{MMU}_{SOEs} - Q^{Manufacturing}_{SOEs}) \times Share^i_{SOEs+SHEs},\quad i \in Mining, Utilities$$

Now we can augment (with a multiplier $Ratio^Q_{FIEs}$) the output value of *above-scale* FIEs in CSY to estimate an output value for *all* the FIEs.

$$Ratio^{Q}_{FIEs} = \frac{Q^{I/O}_{Total} - Q^{I/O}_{SOEs}}{Q^{CSY}_{Total} - Q^{CSY}_{SOEs}} = 1.59$$

As there are only three categories of ownerships in the CGE modelling, namely, FIEs, SOEs, and Private, the total output value of all Private enterprises can be obtained by subtracting total output values of FIEs and SOEs from the total output values of corresponding sectors.

4.5.2. Value Added

The value added of SOE sectors in MMU are estimated based on the total output value for each sector with an *average* ratio of value added to total output of SOEs in manufacturing, 29.22%.

Then, with a similar estimation, we can augment (with a multiplier $Ratio^{VA}_{FIEs}$) the value added of *above-scale* FIEs in CSY to get actual value added for *all* the FIEs.

$$Ratio^{VA}_{FIEs} = \frac{VA^{IO}_{Total} - VA^{IO}_{SOEs}}{VA^{CSY}_{Total} - VA^{CSY}_{SOEs}} = 1.52$$

As there are only three categories of ownership in the present CGE modelling, namely, FIEs, SOEs, and all Private, the total value added of all Private enterprises is obtained by subtracting total value added of FIEs and SOEs from the total value added of corresponding sectors.

Table 4.9: Shares of Output and Value Added of SOEs, FIEs and Private Enterprises in MMU (%)

Division Name	SOEs		FIEs		Private	
	Output share	Value added share	Output share	Value added share	Output share	Value added share
Resource manufacturing (coal, petroleum, and gas)	29.5	13.6	5.2	3.9	65.3	82.5
Ferrous metals mining and dressing	6.0	3.8	0.5	0.3	93.5	95.9
Nonferrous metals mining and dressing	13.3	9.8	1.3	0.9	85.4	89.3
Mining of non-metal, other minerals, and other ores	4.7	2.9	1.7	1.0	93.7	96.0
Food, beverage, and tobacco manufacturing	21.0	19.7	34.8	31.8	44.2	48.4
Textile industry	8.2	9.7	24.8	24.2	67.0	66.1
Garments and other fibre products	1.4	1.5	51.2	47.5	47.4	51.0
Leather, furs, down and related products	0.9	1.3	60.1	72.5	39.0	26.1
Timber processing, bamboo, cane, palm fibre etc.	2.1	2.2	12.7	11.0	85.2	86.8
Furniture manufacturing	0.7	0.8	29.2	29.2	70.1	70.1
Papermaking and paper products	5.7	5.6	30.5	28.8	63.9	65.6
Printing and record medium reproduction	8.4	5.8	20.0	15.1	71.7	79.1
Cultural, educational and sports goods	1.2	1.2	53.0	44.0	45.7	54.8
Petroleum processing and coking	27.3	46.4	12.7	15.9	60.0	37.8
Raw chemical materials and chemical products	15.1	17.5	24.0	25.5	60.9	57.0
Medical and pharmaceutical products	15.9	12.0	29.7	28.4	54.4	59.7
Chemical fibre	11.8	16.0	38.2	39.6	50.0	44.4
Rubber products	11.1	11.8	39.0	39.8	49.8	48.5
Plastic products	1.5	1.8	30.5	32.1	68.0	66.1
Non-metal mineral products	10.0	8.9	23.4	20.8	66.5	70.3
Smelting and pressing of ferrous metals	24.6	27.6	6.8	5.9	68.5	66.5
Smelting and pressing of nonferrous metals	15.9	23.5	13.1	13.0	71.0	63.5
Metal products	3.0	3.7	31.3	31.9	65.7	64.5
Ordinary machinery	9.9	10.2	19.8	19.1	70.3	70.7
Special purpose equipment	14.1	14.9	17.4	17.7	68.4	67.4
Transport equipment	25.8	28.8	43.7	45.2	30.4	26.0
Electronic and electric products	6.4	8.5	81.5	78.7	12.1	12.8
Instruments, meters, cultural and office machinery	5.5	6.3	63.3	51.4	31.1	42.3
Production of electric power, steam and hot water	32.2	18.8	21.7	22.9	46.1	58.3
Production of gas	22.5	32.2	27.7	14.0	49.9	53.8
Production of tap water	29.5	17.2	3.9	3.0	66.7	79.8

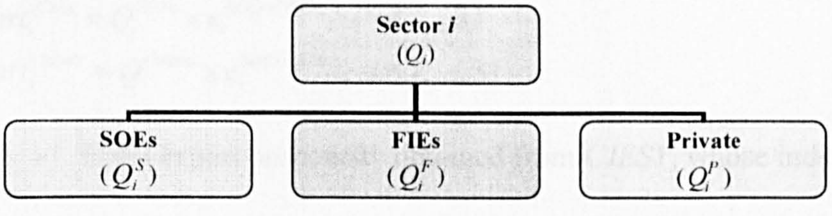
Note: the sum of output shares across SOEs, FIEs, and Private in each division is equal to 100%. The same rule applies to the value added shares.

Source: National Bureau of Statistics of China (2006b); National Bureau of Statistics of China (2003b); Girma and Gong (2008a).

4.6. DISAGGREGATION OF INPUT-OUTPUT TABLE BY OWNERSHIP

The CGE model constructed in this research is used to estimate the productivity spillover effects of FIEs on SOEs and other enterprises. It is necessary, therefore, to differentiate the ownership of enterprises and disaggregate the input-output table (Gillespie et al., 2001, 2002). As ownership-disaggregated data of total output and value added for sector 1 to 31 in MMU are available only, we disaggregate each of those 31 sectors into three separate sectors by ownership, while the other 8 sectors remain intact.

Figure 4.2: Disaggregate Output and Value Added by Ownership



Note: $Q_i = Q_i^S + Q_i^F + Q_i^P$, $i = 1, ..., 31$; and Q represents total output or value added.

To take the "textile" sector for example, it can be disaggregated into three individual sectors, namely, "FIEs textile sector", "SOEs textile sector", and "Private textile sector". Therefore, we can get 31×3=93 ownership-disaggregated sectors plus 8 other un-disaggregated sectors. In other words, there will be altogether (31×3)+8 = 101 sectors: 31 foreign Industry sectors, 31 SOE Industry sectors, 31 Private Industry sectors, and 8 non-Industry sectors.

4.6.1. Disaggregation of Output by Ownership

With the estimated ratios of output and value added by ownership (FIEs, SOEs, and Private) to total output and value added by industry as shown in

Table 4.9, we can, at the first step, divide total output of each sector (see Table 4.10) into output by ownership (see Table 4.11). For example, sector "nonferrous metals" purchases 11,819 unit output of sector "coal, petroleum, and gas". As shown in Table 4.10, we can find that FIEs, SOEs and Private provide output level of 611, 3490, and 7,718, respectively. The export propensity, *i.e.* the portion of export in total output, of FIEs, SOEs, and Private are distinct from each other according to the *CIESY*. As export of multinational enterprises is one of the channels of productivity spillover effects by FIEs, we need to incorporate this distinction and make minor adjustments on the "Export" values:

$$
\begin{aligned}
Export_i^{FIEs} &= Q_i^{FIEs} \times e_i^{FIEs}, \quad i = 1, \ldots, 31 \\
Export_i^{SOEs} &= Q_i^{SOEs} \times e_i^{SOEs+SHEs}, \quad i = 1, \ldots, 31 \\
Export_i^{Others} &= Q_i^{Others} \times e_i^{SOEs+SHEs}, \quad i = 1, \ldots, 31
\end{aligned}
$$

where e_i^j is the export propensity obtained from *CIESY*, whose industrial statistical data comes from the same source as *CSY*. Due to the data availability of *CIESY*, the export values for SOEs and Private can only be estimated by multiplying corresponding output level with the export propensity values of SOEs *plus SHEs*.

But the sum of the estimated export values is larger than the sum of original export values of these 31 industry sectors. To make the adjusted I/O as approximate to the original one as possible, it is necessary to make a further adjustment. We can get a ratio of total original export value in the sum of estimated total export value of these 31 sectors.

$$
Ratio = \frac{\sum_{i=1}^{31} \sum_{j} Export_{ij}^{Original}}{\sum_{i=1}^{31} \sum_{j} Export_{ij}^{Estimated}} = 0.79; \; j = FIEs, SOEs, Others
$$

Table 4.10: I/O prior to Disaggregation by Ownership (to be cont'd)

		1: Coal, petroleum, gas			Section i, (i=2,…,30)			31: Nonferrous metals		
		All	-	-	All	-	-	All	-	-
1: Coal, petroleum, gas	All	1,530,390	-	-	…	-	-	**11,819**	-	-
	-	-	-	-	…	-	-	-	-	-
	-	-	-	-	…	-	-	-	-	-
Section i, (i=2,…,30)	All	0	-	-	…	-	-	0	-	-
	-	-	-	-	…	-	-	-	-	-
	-	-	-	-	…	-	-	-	-	-
31: Nonferrous metals	All	86,257	-	-	…	-	-	234,702	-	-
	-	-	-	-	…	-	-	-	-	-
	-	-	-	-	…	-	-	-	-	-
32	All	305,261	-	-	…	-	-	15	-	-
Sector j (j=33,…,38)	All	…	-	-	…	-	-	…	-	-
39	All	0	-	-	…	-	-	0	-	-
TII	All	26,729,892	-	-	…	-	-	2,829,596	-	-

Note: "all" means that the aggregate value is the sum of *all* three ownerships (SOEs, FIEs, Private).

Table 4.10: I/O prior to Disaggregation by Ownership (cont'd)

		Non-industry sectors			Final use			Other		
		32: Agriculture	…	39: Private	Rural consumption	…	Export	Import	Error	Total Output
1: Coal, Petroleum, Gas	All	896,766	…	275,332	725,778	…	2,785,896	11,244,793	4,222,156	72,742,143
	-	-	…	-	-	…	-	-	-	-
	-	-	…	-	-	…	-	-	-	-
Section *i*, (*i*=2,…,30)	All	…	…	…	…	…	…	…	…	…
	-	…	…	…	…	…	…	…	…	…
	-	…	…	…	…	…	…	…	…	…
31: Nonferrous Metals	All	87,588	…	105,509	217,195	…	10,558	1,367,136	-36,903	5,664,668
	-	-	…	-	-	…	-	-	-	-
	-	-	…	-	-	…	-	-	-	-
32	All	46,368,196	…	0	49,328,792	…	4,741,965	6,811,579	7141,077	285,787,423
Sector *j* (*j*=33,…,38)	All	…	…	…	…	…	…	…	…	…
39	All	0	…	0	0	…	304,817	371,087	-7,147,553	95,754,579
TII	All	119,482,762	…	47,076,127						

Note: TII = Total Intermediate Input = $\sum_{i=1}^{39} input_i$

Table 4.11: The First Step of Disaggregation by Ownership (to be cont'd)

		1: Coal, Petroleum, Gas			**Section *i*, (*i*=2,…,30)**			**31: Nonferrous Metals**		
		All	-	-	All	-	-	All	-	-
1: Coal, Petroleum, Gas	FIEs	79,144	-	-	…	-	-	**611**	-	-
	SOEs	451,888	-	-	…	-	-	**3,490**	-	-
	Private	999,358	-	-	…	-	-	**7,718**	-	-
Section *i*, (*i*=2,…,30)	FIEs	…	-	-	…	-	-	…	-	-
	SOEs	…	-	-	…	-	-	…	-	-
	Private	…	-	-	…	-	-	…	-	-
31: Nonferrous Metals	FIEs	3,359	-	-	…	-	-	9,139	-	-
	SOEs	2,540	-	-	…	-	-	69,134	-	-
	Private	57,490	-	-	…	-	-	156,429	-	-
32	All	305,261	-	-	…	-	-	15	-	-
Sector *j* (*j*=33,…,38)	All	…	-	-	…	-	-	…	-	-
39	All	0	-	-	…	-	-	0	-	-
TII	All	26,729,892	-	-	…	-	-	2,829,596	-	-

Table 4.11: The First Step of Disaggregation by Ownership (cont'd)

		Non-industry sectors			Final use			Other		
		32: Agriculture	…	39: Private	Rural consumption	…	Export	Import	Error	Total Output
1: Coal, petroleum, gas	FIEs	46,376	…	14,239	37,534	…	1,158,936	581,524	-796515	3,761,858
	SOEs	264,794	…	81,299	214,305	…	1,018,944	3,320,323	1050369	21,479,046
	Private	585,596	…	179,794	473,939	…	608,016	7,342,945	3968302	47,501,240
Section *i*, (*i*=2,…,30)	FIEs	…	…	…	…	…	…	…	…	…
	SOEs	…	…	…	…	…	…	…	…	…
	Private	…	…	…	…	…	…	…	…	…
31: Nonferrous metals	FIEs	3,411	…	4,108	8,457	…	0	53,234	-1026	220,575
	SOEs	25,800	…	31,079	63,977	…	259	402,704	-8019	1,668,587
	Private	58,377	…	70,322	144,761	…	585	911,198	-18144	3,775,507
32	All	46,368,196	…	0	49,328,792	…	4,741,965	6,811,579	7141077	285,787,423
Sector *j* (*j*=33,…,38)	All	…	…	…	…	…	…	…	…	…
39	All	0	…	0	0	…	304,817	371,087	-7147553	95,754,579
TII	All	119,482,762	…	47,076,127						

Note: TII = Total Intermediate Input = $\sum_{i=1}^{39} input_i$

This ratio can be multiplied to the estimated export values to make them "shrink" to new values, whose sum is equal to the sum of the original total export for these 31 sectors.

4.6.2. Disaggregation of Value Added by Ownership

We also need to disaggregate the value added for sector 1 to 31 by ownership.

The original value added matrix for industrial sector 1 to 31 is shown in Table 4.12. With the portions of value added for each type of ownerships (see Table 4.9), we can disaggregate each item in the upper panel into three items in Table 4.13. For example, total value added for Sector 1 is 46,012,251. After disaggregation, the corresponding total value added for FIEs, SOEs, and Private are 1,773,282, 6,276,175 and 37,962,794, respectively.

Table 4.12: Value Added Matrix prior to Disaggregation by Ownership

	1: Coal, petroleum, gas			Section *i*, (*i*=2,…,30)			31: Nonferrous metals		
	All	-	-	All	-	-	All	-	-
CP	18,695,996	-	-	…	-	-	1,272,821	-	-
NT	4,344,716	-	-	…	-	-	387,779	-	-
DP	5,285,208	-	-	…	-	-	1,200,874	-	-
OP	17,686,331	-	-	…	-	-	-26,402	-	-
TVA	46,012,251	-	-	…	-	-	2,835,072	-	-

Note: CP = Compensation to employees; NT = Net taxes on production; DP = Depreciation of fixed capital; OP = Operating surplus; TVA = Total value added.

Table 4.13: Value Added Matrix after Disaggregation by Ownership

	1: Coal, petroleum, gas			Section *i*, (*i*=2,…,30)			31: Nonferrous metals		
	FIEs	SOEs	Private	FIEs	SOEs	Private	FIEs	SOEs	Private
CP	720531	2550176	15425288	…	…	…	37953	218892	1015975
NT	167443	592629	3584645	…	…	…	11563	66688	309528
DP	203688	720914	4360605	…	…	…	35808	206519	958547
OP	681620	2412456	14592256	…	…	…	-787	-4540	-21074
TVA	1773282	6276175	37962794	…	…	…	84537	487559	2262976

Note: same as Table 4.12.

4.6.3. Further Disaggregation of Intermediate Inputs by Ownership

We can further disaggregate the make-use matrix in the upper left panel in Table 4.11 under a simplistic hypothesis, *i.e.* the more a sector produces, the more it purchases from other sectors. But the disaggregation is not as straightforward as that used in constructing Table 4.11. At the first step, as total input is equal to total output for each ownership-disaggregated sector, if we transpose the column "Total Output" in the lower panel of Table 4.11, we get a row of "Total Input". In the second step, we can estimate the *ratio* of input in total intermediate input (*TII*) for each category of ownership by:

$$Ratio_{ij} = \frac{Total\ Output_{ij} - TVA_{ij}}{TII_i} \qquad i = 1, \ldots, 39\,;\, j = FIEs,\ SOEs,\ Private.$$

For example, the ratio for partitioning the input value for "All" categories of ownerships to get the input value for FIEs in Sector 1 can be obtained by:

$$Ratio_{1j} = \frac{Total\ Output_{1j} - TVA_{1j}}{TII_1} = \frac{3{,}761{,}858 - 1{,}773{,}282}{26{,}729{,}892} = 0.074$$

where j = *FIEs*, *SOEs*, *Private*. The three numbers in the above calculation, i.e. 3,761,858, 1,773,282 and 26,729,892, come from Table 4.11, 4.13 and 4.11, respectively.

With 0.074 as the share of input value for FIEs in Sector 1, we can get all the 101 input values for FIEs in Sector 1, as shown in the third column of Table 4.15. With the value of each ownership in every sector, we can sum up all the inputs by columns and get all the values for "TII", as shown in the third last row in Table 4.15.

Table 4.14: Intermediate Input-output Matrix by Ownership (prior to Further Disaggregation)

		1: Coal, petroleum, gas			Section *i*, (*i*=2,…,30)			31: Nonferrous metals		
		All	-	-	All	-	-	All	-	-
1: Coal, petroleum, gas	FIEs	79,144	-	-	…	-	-	611	-	-
	SOEs	451,888	-	-	…	-	-	3,490	-	-
	Private	999,358	-	-	…	-	-	7,718	-	-
Section *i*, (*i*=2,…,30)	FIEs	…	-	-	…	-	-	…	-	-
	SOEs	…	-	-	…	-	-	…	-	-
	Private	…	-	-	…	-	-	…	-	-
31: Nonferrous metals	FIEs	3,359	-	-	…	-	-	9,139	-	-
	SOEs	25,408	-	-	…	-	-	69,134	-	-
	Private	57,490	-	-	…	-	-	156,429	-	-
32	All	305,261	-	-	…	-	-	15	-	-
Sector *j* (*j*=33,…,38)	All	…	-	-	…	-	-	…	-	-
39	All	0	-	-	…	-	-	0	-	-
TII	All	26,729,892	-	-	…	-	-	2,829,596	-	-
TVA	All	1,773,282	6,276,175	37,962,794	…	…	…	84,537	487,559	2,262,976
Total Input	All	3,761,858	21,479,046	47,501,240	…	…	…	220,575	1,668,587	3,775,507

Table 4.15: Intermediate Input-output Matrix by Ownership (after Further Disaggregation)

		1: Coal, petroleum, gas			Section *i*, (*i*=2,…,30)			31: Nonferrous metals		
		FIEs	SOEs	Private	FIEs	SOEs	Private	FIEs	SOEs	Private
1: Coal, petroleum, Gas	FIEs	5,888	45,014	28,242	…	…	…	29	255	327
	SOEs	33,618	257,016	161,254	…	…	…	168	1,457	1,865
	Private	74,347	568,394	356,616	…	…	…	371	3,221	4,125
Section *i*, (*i*=2,…,30)	FIEs	…	…	…	…	…	…	…	…	…
	SOEs	…	…	…	…	…	…	…	…	…
	Private	…	…	…	…	…	…	…	…	…
31: Nonferrous metals	FIEs	250	1,910	1,199	…	…	…	439	3,814	4,885
	SOEs	1,890	14,451	9,067	…	…	…	3,324	28,855	36,955
	Private	4,277	32,698	20,515	…	…	…	7,521	65,291	83,617
32	All	22,710	173,620	108,931	…	…	…	1	6	8
Sector *j* (*j*=33,…,38)	All	…	-	-	…	…	…	…	-	-
39	All	0	0	0	…	…	…	0	0	0
TII	All	1,988,576	15,202,871	9,538,446	…	…	…	136,038	1,181,028	1,512,530
TVA	All	1,773,282	6,276,175	37,962,794	…	…	…	84,537	487,559	2,262,976
Total Input	All	3,761,858	21,479,046	47,501,240	…	…	…	220,575	1668,587	3,775,507

4.6.4. Negative Data and Data Balancing

The "Operating Surplus" in sector "production of tap water" is negative (see Table 4.16). This negativity is not acceptable in coding the CGE model. To solve this problem, we need to "smooth" the values for the whole "Utilities" by ownership whilst keeping row "Net Taxes on Production (*NT*)" unchanged.

Table 4.16: Old Dataset for "Utilities" Sectors

	Production of electric power, steam and hot water			Production of gas			Production of tap water		
	FIEs	SOEs	Private	FIEs	SOEs	Private	FIEs	SOEs	Private
CP	1,953,597	1,607,695	4,986,182	42,187	96,651	161,472	37,953	218,892	1,015,975
NT	*1,814,021*	*1,492,832*	*4,629,940*	*19,388*	*44,417*	*74,206*	*11,563*	*66,688*	*309,528*
DP	2,481,278	2,041,945	6,332,986	42,570	97,528	162,937	35,808	206,519	958,547
OP	2,807,624	2,310,509	7,165,923	22	50	83	**-787**	**-4540**	**-21,074**

Note: same as Table 4.12.

Table 4.17: Sum of Value Added (NT Excluded) of Three "Utilities" Sectors

Sum of Three "Utility" Sectors			
	FIEs	SOEs	Private
CP	2,033,738	1,923,238	6,163,630
NT	-	-	-
DP	2,559,656	2,345,992	7,454,469
OP	2,806,859	2,306,019	7,144,932
Sum	7,400,253	6,575,249	20,763,031
Shares			
	FIEs	SOEs	Private
CP	27.5%	29.2%	29.7%
NT	-	-	-
DP	34.6%	35.7%	35.9%
OP	37.9%	35.1%	34.4%
Sum	100%	100%	100%

Note: same as Table 4.12.

The first step is to sum up *CP*, *DP*, and *OP* of the three "Utilities" sectors by ownership, as shown in Table 4.17. *NT* ("Net Tax of Production") is excluded here to keep its values unchanged, as this variable is important for tax reform analysis in Chapter 7. The second step is to calculate the percentage of

CP, *DP*, and *OP* in their sums (see lower panel in Table 4.17). With these weighted shares, we can then "redistribute" *CP*, *DP*, and *OP* within each ownership. The results are shown in Table 4.18. A comparison of Table 4.16 and 4.18 shows that (1) the values of NT do not change; (2) values of *OP* in "production and supply of tap water" sectors are now positive.

Table 4.18: New Dataset for "Utilities" Sectors

	Production of electric power, steam and hot water			Production of gas			Production of tap water		
	FIEs	SOEs	Private	FIEs	SOEs	Private	FIEs	SOEs	Private
CP	1990384	1743324	5487410	23299	56811	96327	20055	123103	579893
NT	*1814021*	*1492832*	*4629940*	*19388*	*44417*	*74206*	*11563*	*66688*	*309528*
DP	2505091	2126530	6636629	29324	69299	116501	25241	150163	701339
OP	2747024	2090296	6361052	32156	68118	111664	**27678**	**147605**	**672217**

Note: same as Table 4.12.

The "Error" column in the I/O table needs to be removed and the remaining I/O matrix needs to be balanced with certain data manipulation skills. Usually this job can be done by nonlinear programming (NLP). However, this balancing technique generated big discrepancies between the old unbalanced data set and the new balanced data set. An explanation for this is that many observations in column "Change in Inventories" are negative. When forcing all the data in the new estimated SAM to be positive in NLP, the overall quality of the data will be impaired.

To avoid the problem caused by NLP, we have to do the data balancing in Excel manually. We can augment each entry in the "Final Demand" columns with a multiplier so that the new "Final Demand" data plus the "Intermediate Demand" for each sector is equal to the "Gross Output". The multiplier is obtained by:

$$\alpha_i = \frac{FD_i + ER_i}{FD_i}, \quad i = 1,2,\ldots,101$$

where FD_i and ER_i represent "Final Demand" and "Error" of the ith industry respectively.

4.6.5. Final-round Data Consistency Check

Before importing the new ownership-disaggregated input-output table into CGE modelling, it is very important to take a final round data validity checking to make sure that the table is *balanced* in an accounting sense.

The first step is to check whether the sum of ownership-disaggregated intermediate inputs is equal to the corresponding disaggregated "Total Intermediate Inputs" (TII). For example, for FIEs in sector 1, we need to check whether

$$\sum_{i=1}^{31} input_{1i}^{FIEs} + \sum_{i=32}^{39} input_{1i}^{FIEs} = TII_1^{FIEs} = 1{,}988{,}576.$$

The second step is to check whether the sum of disaggregated value added is equal to the corresponding disaggregated "Total Value Added" (TVA). For example, for FIEs in sector 1, we need to check whether

$$CP_1^{FIEs} + NT_1^{FIEs} + DP_1^{FIEs} + OP_1^{FIEs} = TVA_1^{FIEs} = 1{,}773{,}282.$$

The third step is to check whether the sum of disaggregated intermediate use is equal to the corresponding disaggregated "Total Intermediate Use" (TIU). For example, for FIEs in sector 1, we need to check whether

$$\sum_{i=1}^{31} use_{1i}^{FIEs} + \sum_{i=32}^{39} use_{1i}^{FIEs} = TIU_1^{FIEs} = 1{,}988{,}576.$$

The final step is to check whether the sum of disaggregated final use (FU), export (EX), error (ERR) with import excluded is equal to the corresponding disaggregated "Gross Output" (GO). For example, for FIEs in sector 1, we need to check whether

$$FU101_1^{FIEs} + FU102_1^{FIEs} + FU103_1^{FIEs} + FU201_1^{FIEs} + FU202_1^{FIEs} + EX_1^{FIEs} - IM_1^{FIEs}$$
$$= GO_1^{FIEs} = 3{,}761{,}858$$

4.7. CONCLUSIONS

The transformation of the original input-output table involves complex data manipulation process, which mainly involves three types of work: (1) aggregating the original 122 by 122 input-output table into a 39 by 39 one; (2) disaggregating the 39 by 39 one into a 101 by 101 one with information on different ownership, which enables the CGE model constructed on this input-output table to address issues regarding ownership (*i.e.* spillovers from foreign-invested enterprises to domestic enterprises); (3) data balancing and consistency check.

Data employed are mainly from *China Statistical Yearbook 2003*, *China Industry Economy Statistical Yearbook 2003* and *China Input-Output Table 2002*. Data of several sectors are aggregated to reconcile different statistical standards. Data of agriculture, construction, and services are also aggregated to a great extent to cater for the data availability on FDI inflows. By doing so, we obtain a 39 by 39 input-output table. With data estimated for FIEs, SOEs, and Private enterprises, 31 out of the 39 sectors can be further disaggregated into 31×3=93 ownership-sectors. Data balancing techniques are used to make the transformed input-output table balance. In the process of data manipulations, three rounds of data consistency checks are conducted.

CHAPTER 5: A BENCHMARK CGE MODEL FOR THE CHINESE ECONOMY AND ITS EXTENSIONS

5.1. INTRODUCTION

This research on the productivity spillover effects of FDI in China is conducted in a static single-country CGE model with 101 sectors. The basic framework of the benchmark model will be discussed first. Three extensions to the benchmark model are also presented. In the first extension, endogenous variables are constructed to capture the FDI productivity spillovers. Parameters of FDI productivity spillovers are estimated with econometric analysis. The second extension incorporates monopolistic competition into the CGE model with FDI spillovers. Then the model is further extended to examine the effects of FDI spillovers under monopolistic competition among firms with heterogeneous productivities.

5.2. CGE MODEL STRUCTURE

The CGE model structurally encapsulates the productivity spillover effects of FDI on domestic firms by endogenising four spillover channels, namely backward linkages, forward linkages, export of MNEs, and horizontal impact (demonstration, competition and resource reallocation). The model is focused on the manufacturing sectors in that almost 70% of FDI flows are into manufacturing in China. The research is done in the context of the Chinese economy considering the fact that China has been the largest FDI host among the developing countries since 1993. In China, as a country in transition from a centrally planned economy to a market economy, the potential impact of FDI productivity spillovers on state-owned enterprises and the emerging private sectors is of special interest.

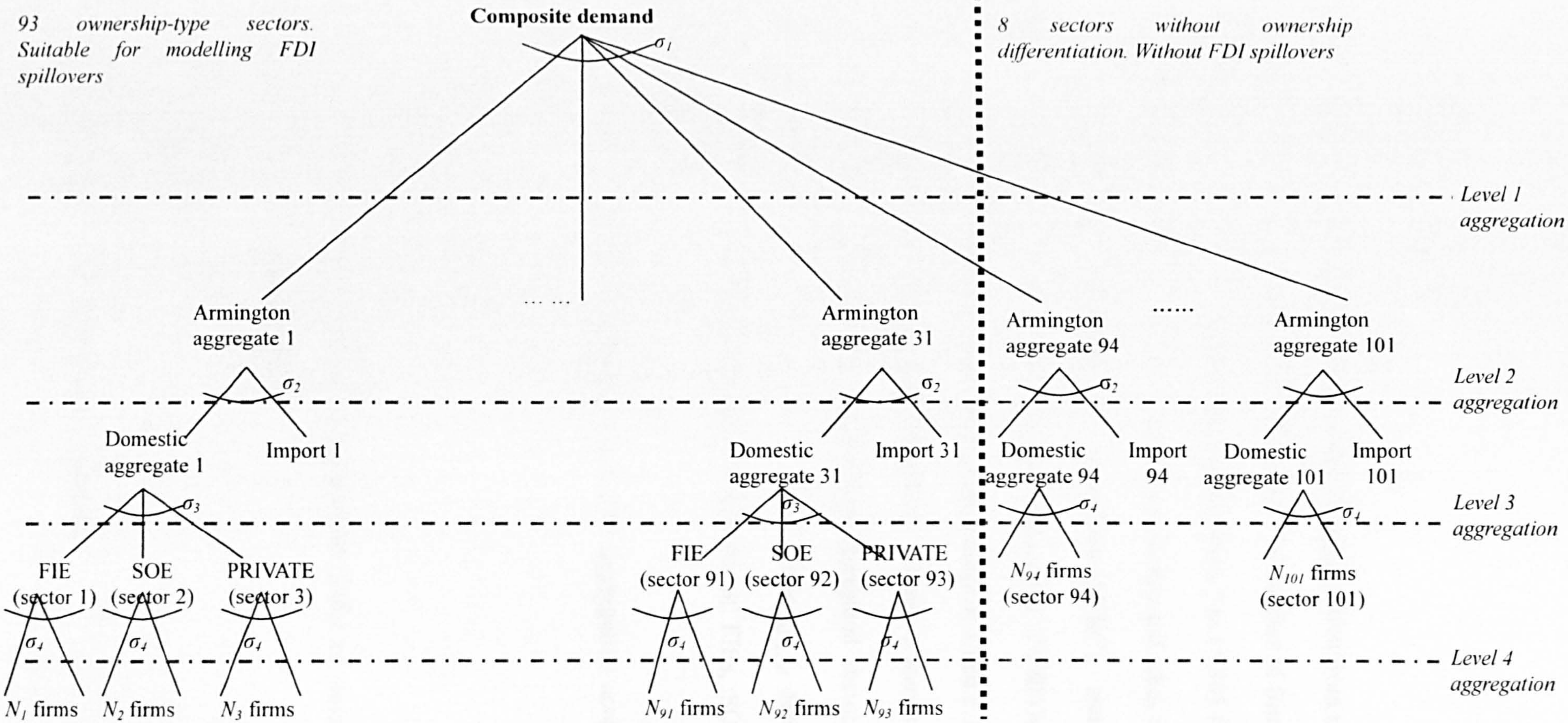
The circular flows of the Chinese economy are depicted by Figure 3.1 in Chapter 3. Commodity aggregation and disaggregation are sketched by Figure 3.4.

31 out of 39 industries (*i.e.* manufacturing and utilities industries) are disaggregated into $31\times3=93$ sectors by ownership, namely foreign-invested sectors, state-owned sectors, and domestic private sectors, as discussed in Chapter 4. The data of the other 8 agricultural and services industries remain unchanged. Thus a 101×101 dimension input-output table is constructed as the basis of this CGE model on FDI productivity spillovers.

In this model, the national composite demand for products and services is satisfied through a nested aggregation structure, each nesting level of which can be represented by a CES function, as shown by Figure 5.1 and equation (5.1) to (5.4).

The lowest level (level 4) aggregates the commodity across firms in the same industry with the same ownership, *e.g.* the products of stated-owned enterprises in the textile industry:

Figure 5.1: Consumption Aggregation (101 Sectors)



$$Y_{i,j,k} = \left[\sum_{f=1}^{N_f} \varphi_{i,j,k,f} Q_{i,j,k,f}^{\frac{\sigma_4 - 1}{\sigma_4}} \right]^{\frac{\sigma_4}{\sigma_4 - 1}} \tag{5.1}$$

where i, j, k, f index the hierarchy of this composite aggregation from the top to the bottom respectively. f indexes individual firms. The number of firms ($N_{i,j,kf}$) in each ownership sector is rather different, ranging from 2 to 15,305 (National Bureau of Statistics of China, 2003a). k indexes ownership and takes values of 1, 2, 3, representing foreign-invested enterprises ("FIE"), state-owned enterprises ("SOE"), and domestic private enterprises ("PRIVATE"). j represents sources of commodities and takes binary values of 1 and 2, denoting domestically produced and imported commodities. Finally i stands for the sectors. There are 101 sectors: 93 ownership-disaggregated sectors and 8 ownership-mixed sectors. Thus i =1, 2, …, 101. While $Q_{i,j,k,f}$ denotes the firm-level output, $Y_{i,j,k}$, denotes aggregate production of FIEs, SOEs, and private enterprises.

The second last level of aggregation is a CES aggregation across three ownerships:

$$DI_{i,j} = \left[\sum_{k=1}^{3} \gamma_k Y_{i,j,k}^{\frac{\sigma_3 - 1}{\sigma_3}} \right]^{\frac{\sigma_3}{\sigma_3 - 1}} \tag{5.2}$$

At the second level is Armington aggregation (AR_i) of domestically manufactured goods and imported goods:

$$AR_i = \left[\sum_{j=1}^{2} \beta_j DI_{i,j}^{\frac{\sigma_2 - 1}{\sigma_2}} \right]^{\frac{\sigma_2}{\sigma_2 - 1}} \tag{5.3}$$

At the top level, a further aggregation is applied:

$$AG = \left[\sum_{i=1}^{101} \alpha_i AR_i^{\frac{\sigma_1 - 1}{\sigma_1}} \right]^{\frac{\sigma_1}{\sigma_1 - 1}} \tag{5.4}$$

The sum over the shares parameters at each aggregation level is assumed to be equal to one:

$$\sum_{i=1}^{101} \alpha_i = \sum_{j=1}^{2} \beta_{i,j} = \sum_{k=1}^{3} \gamma_{i,j,k} = \sum_{f=1}^{N_f} \varphi_{i,j,k,f} = 1$$

5.3. A BENCHMARK CGE MODEL

In this section, we will discuss the framework, closure rules and numéraire of the benchmark model. Table A5.1 to A5.13 in the Appendix to this Chapter list the MPSGE declaration, equations, variables and parameters of the benchmark model.

5.3.1. Model Characteristics

(1) Sectors, commodities and representative agents

In the model, there exist many production activities (`SECTOR`) that convert inputs (including primary inputs and intermediary inputs) into outputs (`COMMODITY`). The complementary variable associated with a sector is the activity level, while the complementary variable associated with a commodity is its price.

Consumers are represented by a domestic representative agent (`RA`). He or she receives the returns to the labour and capital and the balance of current account, and then purchases investment and private consumption. The government is also designated to be a representative agent (`GOV`). In an imperfect competitive market where markups or profits exist, a representative enterprise can also be denoted as a representative agent (`ENTRE`) to collect markup and pay its fixed cost. Finally, a foreign representative agent (FDI) is designed to allocate foreign investments into different sectors and collects earnings to foreign capital in each sector.

(2) Production of value-added composite

The production of value-added composite is the starting point of the core model. Value added is produced with a Cobb-Douglas (C-D) technology from two primary inputs, labour (WL) and capital (RK). The elasticity of substitution is thus equal to 1 (S:1). The choice of C-D functions, rather than CES or Leontief forms, is consistent with Chow and Lin (2002) who employ C-D to estimate the TFP in China, and Fan, Liao, and Wei (2007) who find non-zero substitution between labour and capital in the Chinese economy. This choice is also echoed by Balistreri, McDaniel and Wong (2003) who fail to reject the C–D specification in 20 of the 28 industries in the U.S.

The FDI productivity spillovers are modelled as an economic externality taking place during the production of value added, which will be discussed in detail in Section 5.4 of this Chapter. The productivity spillovers take the form of "increment" to the value added, with an incremental rate of NTFP. This extra increase of value added exists due to the presence of foreign enterprises, but it does not "borrow" resources from any one of the agents in the economy. In coding productivity spillover in the CGE modelling, the incremental part (i.e. the spillover part) of the value added is "transferred" by the government (GOV). But this does not change the government budget balance at all – in the event of productivity spillover, there is always an exact match of extra government expenditure for spillover and extra government revenue (i.e. extra "endowment") to offset the "spillover expenditure".

(3) Production sectors

The value-added composite and intermediate products are employed for production of commodities with a Leontief production function (`S:0`). *Ad valorem* tax is levied on the output at a rate of `NTP(A)` and is redistributed to the government (`GOV`). The change of production tax rate (`TDIFF1(A)`) can be added to the existing tax rates to perform simulations on FDI tax reforms which will be analysed in Chapter 7.

The production block will also be used to capture the effect of monopolistic competition and firm heterogeneity, theoretical models of which will be constructed in Section 5.4 and 5.5 respectively.

(4) CET transformation of production

Outputs of each sector are disaggregated into two portions with a CET technology, one for export and the other for domestic use. The elasticity of transformation takes values from the Global Trade Analysis Project database version 6.

(5) Labour and capital disaggregation

The total supplies of labour and domestic capital are both fixed and the economy is assumed to in full employment. Extra capital can be introduced to the stock of foreign capital in the form of an FDI shock, which will be discussed in detail in the next Chapter. The purpose of imposing the assumption of fixed domestic capital supply is to simplify the model so that we could focus on the pure effects of an FDI shock with spillovers.

The assumption of fixed total labour supply is consistent with the economic environment in China in the last three years or so. It was argued in the literature that China was in the process of fast urbanisation and industrialisation, and it had a huge amount of hidden unemployment in both urban and rural areas, which provided a large pool of extra labour supply to the economy (Fu and Balasubramanyam, 2005). However, this "excess labour supply" story is no longer true. Since the early 2006 China's export-concentrated provinces began to face a mounting pressure of labour shortage, partly because massive rural tax cuts have helped keep people working on farms, and also because the "one-child policy" has started to affect the supply of young Chinese workers[5].

Both capital and labour are first disaggregated across 39 industries at an upper nesting level first, subject to constant elasticity of transformation (CET) technologies. For each of the 31 MMU industries (mining, manufacturing and utilities), both primary inputs will be further allocated to the three ownership-disaggregated sectors, namely FIEs, SOEs, and Private sectors, also subject to CET technologies.

Both labour and capital can move imperfectly across industries and ownerships within each of the 31 MMU industries. The elasticity of transformation for the upper nesting CET function is set to be 1, while the elasticity for the lower nesting CET function takes the form of a parameter (`TAU_L` for labour and `TAU_K` for capital), the value of which will be subject to sensitivity tests in the next Chapter.

(6) Armington aggregation

There are two nesting levels here in the generation of Armington aggregate goods. At the lower nesting level, domestically produced goods are

[5] David Barboza, "Labor Shortage in China May Lead to Trade Shift", *New York Times*, April 3, 2006.

aggregated across ownerships in each industry. Then at the higher nesting level, domestically produced goods in each industry are aggregated with imported goods. The elasticity of substitution between domestic and imported goods takes values from the Global Trade Analysis Project database version 6.

(7) Export and import

In the export block, exported goods generate a special output, foreign currency (PFX), while in the import block foreign currency is exchanged for imported goods.

(8) Representative domestic agent

The representative domestic agent (RA) is endowed with primary factors, *i.e.* labour and capital. Using the returns to the labour and capital and the balance of the current account, the agent purchases investment goods, which include fixed asset formation and change of inventory. The remaining part is expended over private consumption.

(9) Representative agent for multinational enterprises

An agent representing multinational firms (FDI) is added here to capture the capital flow of FDI. This agent manipulates its capital and re-directs the earnings worldwide. Its investment stock in China is approximately RMB 2×10^5 million in 2002, which is denoted as an endowment of foreign exchange. An increment of total capital in the form of worldwide earnings will take the form of new FDI. This FDI flows to each foreign-invested sector and will thus boost the production of these sectors. This agent also earns returns to capital since the agent has its presence in every industry. With these endowments and earnings, the agent FDI spends 2×10^5 foreign currency in investment plus the returns to its presence.

5.3.2. Closure Rules and Numéraire

(1) Government closure

Tax revenue is less than government consumption demand, suggesting a fiscal deficit. The deficit is financed by borrowing money from the private households in the form of "direct taxes". In this model, the direct taxes are measured by a *fixed* quantity of consumed commodities multiplied by the endogenous commodity prices. In other words, this model assumes a fiscal-*neutral* deficit, which is *fixed* in terms of the quantity of consumed commodities.

The government consumes a variable quantity of commodities and their prices may also vary endogenously. The fiscal revenue comes from the collection of indirect taxes (i.e. "net taxes on production" which will be introduced in section 7.4 in Chapter 7) at *fixed* tax rates.

In counterfactual simulations the fiscal revenue collected from indirect taxes will vary with the change of tax bases (production). Thus the government has to adjust its consumption demand given its variable indirect tax revenue and fixed amount of deficit in terms of commodity quantity. This fiscal-neutral closure therefore "insulates" the external shock from the amount of commodities to be consumed by private households, as the government can only borrow a fixed amount of commodities from the households. So this closure provides a reasonable environment for the analysis of welfare changes caused purely by the shock of FDI productivity spillover in the next Chapters.

(2) Savings-investment closure

This is a static model and there is no intertemporal savings-investment transformation. The model is based on input-output table data, so data on savings and investment are determined by gross domestic fixed capital formation. The investment demand of the representative agent is fixed and includes fixed asset formation and changes of inventories. The representative agent receives income from labour and capital and makes (fixed) purchases of foreign exchange (net transfers and foreign savings) and investment. The remainder of his or her income is spent on private consumption.

(3) External closure

The nominal exchange rate is selected as the numéraire[6] and a *flexible* real exchange rate regime is adopted. Alternatively we could set a fixed real exchange rate by fixing the ratio of exchange rate to domestic price index and allowing the government to sell and buy foreign exchange to maintain this price ratio. However the Chinese government has switched to a managed *floating* exchange rate regime since July 2005 and let the exchange rate of Renminbi appreciate 17.4% gradually over the last four years. Therefore it is preferable not to fix the real exchange rate in the model.

The model adopts a small open economy assumption, which suggests that changes of export and import volumes in each sector in counterfactual simulations are not large enough to affect the export and import prices in international markets. The quantity of exports and imports change endogenously, but the current account balance is set to be *fixed*.

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[6] As discussed in Chapter 3, the purpose of the numéraire is to normalise all other nominal variables and make simulation results comparable. Theoretically we can choose any nominal variable as the numéraire, which does not affect the quantities in the simulation results at all. Choosing the exchange rate as the numéraire does not imply a fixed exchange rate regime.

5.4. EXTENSION 1: FDI PRODUCTIVITY SPILLOVERS

5.4.1. Productivity Decomposition

The benchmark CGE model can be extended to endogenously incorporate four possible productivity spillover channels, namely *backward linkages, forward linkages*, *exports of FIEs*, and *horizontal effects* (including demonstration, competition, and resource reallocation). The spillover channel of *labour turnover* between FIEs and domestic enterprises is dropped in the model because such industry-level data are not available.

Suppose $VA_{i,t}=TFP_{i,t}\times K_{i,t}^{\alpha_K} L_{i,t}^{\alpha_L}$, where $K_{i,t}$ and $L_{i,t}$ denote capital and labour respectively. As discussed in Section 5.3.1, $G(K_{i,t}, L_{i,t})$ takes Cobb-Douglas rather than CES functional forms here, which is consistent with the literature.

Then *TFP* can be *decomposed* into:

$$TFP = TFP_{indigenous} + TFP_{spillover} \tag{5.5}$$

where $TFP_{indigenous}$ captures all indigenous factors that contribute the TFP of a firm (*e.g.* R&D, employee education level, employee training hours, and management skills), while $TFP_{spillover}$ measures the FDI productivity spillover effects.

The TFP and spillover effects can be estimated in a 2-stage approach:

$$\ln(VA_{i,t}) = \alpha_0 + \alpha_K \ln K_{i,t} + \alpha_L \ln L_{i,t} + \varepsilon_{i,t} \tag{5.6a}$$

$$TFP_{i,t} = \exp(\alpha_0 + \varepsilon_{i,t}) = \alpha_I + \boldsymbol{\beta}\times \boldsymbol{SPL} + \zeta_{i,t} \tag{5.6b}$$

where the vector ***SPL*** collectively denotes three FDI spillover channels. It contains four variables: horizontal demonstration, $HZDS_{i,t}$, backward linkages $BL_{i,t}$, forward linkages $FL_{i,t}$, and export concentration of multinational enterprises $EXCO_{i,t}$,.

$HZDS_{i,t}$, is the share of FIEs in the gross output in sector j at time t. $BL_{i,t}$ and $FL_{i,t}$ are horizontal demonstrations weighted by input-output coefficients. They are designed to capture local firm interactions with FIEs as purchasers and suppliers, respectively. The specifications of *BL* and *FL* follow the practice adopted in the literature (Javorcik, 2004; Kneller and Pisu, 2007; Girma, Görg and Pisu, 2008; Girma and Gong, 2008a).

$$BL_{i,t} = \sum_{j} (\delta_{i,j,t} * HZDS_{j,t}) \tag{5.7a}$$

$$FL_{j,t} = \sum_{i} (\delta_{i,j,t} * HZDS_{i,t}) \tag{5.7b}$$

where $\delta_{i,j}$ are input-output coefficients. They measure the percentage of output of industry i provided to industry j in the total output of industry i: $\delta_{i,j} = Y_{i,j}/Y_i$

For example, assume the foreign presences at industry 1, 2, 3 are 10%, 20%, and 30%, respectively. Industry 1 provides its products to itself, industry 2 and 3 with proportion of 40%, 35% and 25%. Then coefficient of backward linkage is $BL = 40\% \times 10\% + 20\% \times 35\% + 30\% \times 25\% = 0.185$.

The selection of the above two input-output linkage variable as a measure of FDI spillovers has three merits. Firstly, they have been widely applied in many country contexts (China, Lithuania and the UK) in the econometric studies in the literature mentioned above, to examine the correlation between the productivity of domestic enterprises and the FIEs in downstream and upstream sectors. Secondly as *BL* and *FL* are both weighted measures of *HZDS* across a large number of sectors, the independence of *BL*, *FL* and *HZDS* is always observed in the literature. Thirdly, in the subsequent CGE modelling, both *BL* and *FL* can be modelled as endogenous variables and whole values can change endogenously in counterfactual simulations. This will be discussed in detail shortly.

Finally, $EXCO_i$ is the ratio of the export of foreign-invested firms sector i to the total export in sector i, which measures "export concentration" as another spillover channel.

Equation (5.6a) and (5.6b) are estimated with an industry-level *panel dataset*. As discussed by Görg and Strobl (2001), panel data analyses are superior to cross-sectional studies in their capability of capturing time-invariant sector-specific factors which may impact on the relationship between foreign presence and the performance of domestic enterprises. Ignorance of such time-invariant factors usually leads to an overestimation of FDI productivity spillovers.

There are three issues regarding the above econometric model that merit discussion. The first one is the measurement of the labour input. It would be ideal to measure L with employment weighted by schooling years. But unfortunately the data of schooling years by ownership-sector are not available.

The second issue is whether or not to include industry dummies to control for potential fixed industry effects. If industry dummy variables are included, equation (5.6b) can be transformed into

$$TFP_{i,t} = \exp(\alpha_0 + \varepsilon_{i,t}) = \alpha_1 + \boldsymbol{\beta} \times \boldsymbol{SPL} + \alpha_i \times DUMMY_i + \zeta_{i,t} \qquad (5.6c)$$

then the decomposition of TFP as specified by (5.5) and (5.6b) will not be confined to be uniform across all industries. In other words, the indigenous part of productivity could vary across industries ($TFP_{indigenous} = \alpha_1 + \alpha_i \times DUMMY_i + \zeta_i$), while the spillover part of productivity takes a uniform specification across industries ($TFP_{spillover} = \boldsymbol{\beta} \times \boldsymbol{SPL}$). Unfortunately this option was not available for two reasons. (a) As we will discuss shortly, while for SOEs we have 31 (industries) × 5 (years) = 155 observations, for Private enterprises we only have 31 (industries) × 2(years) = 62 observations. The latter rules out including 30 industry dummies. (b) While our spillover variables (*HZDS*, *EXCO*, *BL* and *FL*, collectively denoted by the vector ***SPL***) for the CGE modeling can change endogenously in counterfactual simulations (to be discussed shortly), we cannot allow for endogenous changes in industry fixed effects.

The third issue is whether or not to include year dummy variables to control for the effect of CGE benchmark year (2002). Again the limited data on Private enterprises (for two years only, 2005 and 2006) preclude this.

Thus we can employ econometric regression to obtain the share of TFP caused by spillovers in total TFP.

$$\frac{TFP_{spillover}}{TFP_{total}} = \frac{\hat{\boldsymbol{\beta}} \times \boldsymbol{SPL}}{\hat{\alpha}_1 + \hat{\boldsymbol{\beta}} \times \boldsymbol{SPL}} \tag{5.8}$$

where $\hat{\boldsymbol{\beta}} \times \boldsymbol{SPL} \equiv \hat{\beta}_1 BL_{i,t} + \hat{\beta}_2 FL_{i,t} + \hat{\beta}_3 HZDS_{i,t} + \hat{\beta}_4 EXCO_{i,t}$.

In the CGE modelling, the share of FIEs in sectoral output ($HZDS_i$) and the share of FIEs in sectoral export ($EXCO_i$) will be both *endogenously* determined in counterfactual experiments. Backward linkages (BL_i) and forward linkages (FL_i) are also endogenously determined by equation (5.7a) and (5.7b), respectively. Therefore, the share of productivity spillovers is also *endogenous*, as specified by equation (5.8). Thus we can transform equation of value-added production into

$$VA_{i,t} = \Theta_i \times TFP_{i,t} \times K_{i,t}^{\alpha_K} L_{i,t}^{\alpha_L} \tag{5.9}$$

where $\Theta_i = \dfrac{TFP_i}{\overline{TFP0_i}}$, $\overline{TFP0_i}$ denotes the benchmark TFP ($\hat{\alpha}_i + \hat{\boldsymbol{\beta}} \times \overline{\boldsymbol{SPL}}$)

and TFP_i denotes endogenous TFP value ($\hat{\alpha}_i + \hat{\boldsymbol{\beta}} \times \boldsymbol{SPL}$). In this way we can model the FDI productivity spillovers *endogenously*. In the benchmark scenario, Θ_i=1, so that the above equation simplifies to $VA_{i,t} = TFP_{i,t} \times K_{i,t}^{\alpha_K} L_{i,t}^{\alpha_L}$.

5.4.2. Econometric Estimations of Spillover Parameters

The CGE model is built on the *Input-output Table of China in 2002*, so the FDI spillover parameters $\boldsymbol{\beta}$ have to be estimated for the years around 2002.

Table 5.1: Available Data for Industry-level Panel Data Analysis

Variables	Symbols	Source	Years
Value added	VA	*CIESY*	2001-2003, 2005-2006
Net fixed assets	K	*CIESY*	2001-2003, 2005-2006
Total employment	L	*CIESY*	2001-2003, 2005-2006
Input-output coefficients	$\delta_{i,j}$	*I/O*	2002
Backward linkages	$BL_{i,t} = \sum_j (\delta_{i,j,t} * HZDS_{j,t})$	*CIESY, I/O*	2002
Forward linkages	$FL_{j,t} = \sum_i (\delta_{i,j,t} * HZDS_{i,t})$	*CIESY, I/O*	2002
Horizontal demonstrations	$HZDS$	*CIESY*	2001-2003, 2005-2006
Export concentration	$EXCO$	*CIESY*	2001-2003, 2005-2006

Note: *CIESY* is the acronym of *China Industrial Economy Statistical Yearbook* (2001-2003 and 2005-2006); *I/O* denotes the input-output table of China in 2002. Value added VA and intermediate input M will be deflated with an "ex-factory or wholesale price index". Net fixed assets K will be deflated with a "fixed asset investment price index". Both indexes are obtained from *China Statistical Yearbook* (National Bureau of Statistics of China, 2007).

The main data sources for estimation are *China Industrial Economy Statistical Yearbook* (hereafter *CIESY*) and the *I/O Table*, both released by the National Bureau of Statistics of China (hereafter "NBS"). The available *CIESY*s around the year of 2002 are for the years of 2001-2003 and 2005-2006. NBS releases I/O tables every five years and the latest one is for the year of 2002. So the I/O table of 2002 only will be employed to calculate all the input-output coefficients $\delta_{i,j,t}$ (thus t can be suppressed) for the years of 2001-2003 and 2005-2006.

The available data sources are summarised in Table 5.1. There are

31(industries)×5(years) = 155 observations (panel data) for estimations of SOEs. But the data for private enterprises are only available in 2005 and 2006, so total observations for the private sectors are only 62.

Table 5.2: Estimation of Value Added

Firm types	constant	*K*	*L*	Obs.	R^2
SOEs	0.13 (0.04)***	**0.91** **(0.02)*** **	**0.09** **(0.03)*** **	155	0.99
Private	1.01 (0.19)***	**0.39** **(0.06)*** **	**0.70** **(0.04)*** **	62	0.97

Note: (1) Estimation of equation (5.6a). (2) Standard errors in parentheses. *, **, *** denote statistically significant at 10%, 5%, and 1% level, respectively. (3) "SOEs" and "Private" denote state-owned enterprises and domestic private enterprises respectively.

Table 5.3: Estimation of Productivity Spillovers

Firm types	constant	*BL*	*FL*	*HZDS*	*EXCO*	Obs.	R^2
SOEs	0.91 (0.05)***	0.40 (0.42)	**0.29** **(0.15)***	**0.33** **(0.17)***	0.04 (0.07)	155	0.31
Private	2.21 (0.32)***	0.15 (2.73)	**2.58** **(0.97)*** **	**2.88** **(1.11)*** **	**-1.74** **(0.47)*** **	62	0.30

Note: (1) Estimation of equation (5.6b). (2) Standard errors in parentheses. *, **, *** denote statistically significant at 10%, 5%, and 1% level, respectively. (3) "SOEs" and "Private" denote state-owned enterprises and domestic private enterprises respectively. (4) Similar to the results in the literature, the correlation coefficients of *BL*, *FL* and *HZDS* are reasonably low (both below 0.30), so that their independence is justified.

The TFP estimated ($TFP_{i,t} = \exp(\alpha_0 + \varepsilon_{i,t})$) from equation (5.6a) are further regressed against spillover variables as specified by equation (5.6b).

As shown by Table 5.3, there is a significant relationship between the productivity of domestic enterprises and FDI presence. Both SOEs and Private domestic firms benefit from spillovers from foreign-invested firms in upstream and horizontal sectors, and the coefficients for private enterprises are larger and more statistically significant. This difference could be caused by the relatively weak absorptive capacity of SOEs that undertake less R&D activity and employee training, as suggested by Girma and Gong (2008a). Neither SOEs nor Private enterprises benefit from the contacts with the FIEs in downstream sectors (coefficients for *BL* are not significant). The reason for this could be that the potential benefit of backward linkages is counterbalanced by the increased competition among domestic enterprises in the upstream sectors triggered by the FIEs in the downstream sectors.

Finally, it seems that the export of MNE affiliates has no effects on improving the productivity of SOEs. Private enterprises are even negatively affected by the MNE exports. The latter makes little sense as an "export spillover" and may reflect industry characteristics – i.e. FIEs have a higher share of exports in industries where domestic firms have relatively lower TFP.[7] Because this effect can vary endogenously in our simulations, we retain it but note that it may not be picking up a spillover as such.

Based on the above econometric estimation, we calculate that the average contribution of FDI productivity spillovers to the overall TFP (estimated from equation (5.6a)) of SOEs and private enterprises (calculated with equation (5.8)) are 22% and 20%, respectively. The estimated significant and insignificant, and positive and negative spillover coefficients (denoted by the vector $\boldsymbol{\beta}$) will be carried forward into the CGE modelling as specified by equation (5.8).

5.5. EXTENSION 2: FDI SPILLOVERS UNDER MONOPOLISTIC COMPETITION

5.5.1. Incorporating Monopolistic Competition into the CGE Model

The CGE model constructed in previous sections assumes that the Chinese

[7] It has been suggested that export-oriented FIEs may "cherry pick" the best skilled workers from domestic firms leading to lower productivity in the latter. (Girma and Gong, 2008a).

economy is a perfectly competitive market. However perfect competition is only one among various possible market structures and it is important to further examine the effects of FDI productivity spillovers in an alternative scenario *i.e.* "**monopolistic competition**" (Dixit and Stiglitz, 1977). Monopolistic competition refers to a market structure where a relatively large group of firms produce different varieties of a particular product. The product of one firm within the group is highly, but not perfectly, substitutable for the product of another firm. Therefore each firm has a limited monopoly power and faces a downward rather than horizontal demand curve. Entry barriers are low so that entry occurs in a monopolistically competitive group when a new firm introduces a new product. In the long run, every surviving firm makes zero profit due to the assumption of free entry and exit.

The scenario of monopolistic competition has been applied widely in the analysis of trade liberalization (e.g. Blake, Rayner and Reed, 1999; Francois and Roland-Holst, 1997; Harrison, Rutherford and Tarr, 1994, 1995, 1997). Their analyses conclude that the benefits of trade liberalization under monopolistic competition include consumption of a greater product variety, lower product price and higher production efficiency due to increased competition.

However, FDI productivity spillovers in this scenario have not yet been studied so far. This Section is aimed at filling this gap. The *key* to modelling monopolistic competition in the CGE model on FDI productivity spillovers is to find the *markup rate* (to be defined by equation (5.11)).

For a firm with certain market power, its total revenue is $TR = P(Q) * Q$, where price of product (P) is a function of total output (Q).

Marginal revenue (MR) is

$$MR = \frac{\partial TR}{\partial Q} = P + \frac{\partial P}{\partial Q} Q = P(1 - \frac{1}{|\varepsilon|}) \tag{5.10}$$

where $|\varepsilon|$ denotes the price elasticity of demand $\left(\frac{P}{Q} \frac{\partial Q}{\partial P} \right)$.

$$MR = MC \Rightarrow \frac{1}{|\varepsilon|} = \frac{P - MC}{P} \equiv markup(\%) \tag{5.11}$$

As discussed, in the long run, every surviving firm makes zero profit due to the assumption of free entry and exit, so that $TR=P\times Q=TC$. Therefore the markup rate is also equal to the proportion of fixed cost in total cost:

$$markup(\%) = \frac{P - MC}{P} = \frac{(P - MC) \times Q}{P \times Q} = \frac{TC - VC}{P \times Q} = \frac{FC}{P \times Q} = \frac{FC}{TC}$$

where TC, VC, and FC denote total cost, variable cost, and fixed cost, respectively.

This indicates that in a monopolistic competitive market, each firm has to collect a markup to pay the fixed cost. This transformed *zero profit* condition, together with market clearance and income balance conditions, is an important property of a *general equilibrium* (see Section 3.1.3), and the *markup rate* is crucial to modelling monopolistic competition in a CGE model.

In the FDI spillover model, the representative agent has a nested consumption structure, each of which can be represented by a CES function, as shown by equation (5.1) to (5.4). With FDI productivity spillovers specified by equation (5.5.2) and (5.6.1), we know that $Y_{i,j,k}$, as ownership-type products is a function of FDI productivity spillovers, *i.e.*

$Y_{i,j,k}(\Theta_{i,j,k})$, where $\Theta_{i,j,k} = \dfrac{NTFP_{i,j,k}}{NTFP0_{i,j,k}}$.

Since such spillovers are assumed to take place between FIEs and domestic firms, so that $NTFP_{i,j,k} = NTFP0_{i,j,k}$ and $\Theta_{i,j,k} = 1$ for $k=1$ (FIEs).

The associated demand functions of CES equation (5.1), (5.2), (5.3) and (5.4) can be derived:

Top level aggregation: $$AR_i = \left(\frac{P_{AG}}{P_{AR(i)}}\right)^{\sigma_1} \times AG \quad (5.4a)$$

2^{nd} level aggregation: $$DI_{i,j} = \left(\frac{P_{AR(i)}}{P_{DI(i,j)}}\right)^{\sigma_2} \times AR_i \quad (5.3a)$$

3^{rd} level aggregation: $$Y_{i,j,k} = \left(\frac{P_{DI(i,j)}}{P_{Y(i,j,k)}}\right)^{\sigma_3} \times DI_{i,j} \quad (5.2a)$$

Bottom level aggregation: $$Q_{i,j,k,f} = \left(\frac{P_{Y(i,j,k)}}{P_{Q(i,j,k,f)}}\right)^{\sigma_4} \times Y_{i,j,k} \quad (5.1a)$$

Starting from the bottom level aggregation, we transform (5.1a) to be:

$$P_{Q(i,j,k,f)} = \left(\frac{Y_{i,j,k}}{Q_{i,j,k,f}}\right)^{1/\sigma_4} \times P_{Y(i,j,k)} = \left(Q^{-1}_{i,j,k,f}\right)^{1/\sigma_4} \times \left(Y_{i,j,k}\right)^{1/\sigma_4} \times \left(P_{Y(i,j,k)}\right) \quad (5.1b)$$

All the three terms in brackets on the right hand side of equation (5.1b) are functions of $Q_{i,j,k,f}$. So we can differentiate equation (5.1b) *w.r.t.* $Q_{i,j,k,f}$ following the *product rule*:

$$\begin{aligned}\frac{\partial P_{Q(i,j,k,f)}}{\partial Q_{i,j,k,f}} &= -\frac{1}{\sigma_4}\frac{P_{Q(i,j,k,f)}}{Q_{i,j,k,f}} + \frac{1}{\sigma_4}\frac{P_{Q(i,j,k,f)}}{Y_{i,j,k}}\frac{\partial Y_{i,j,k}}{\partial Q_{i,j,k,f}} \\ &+ \frac{P_{Q(i,j,k,f)}}{P_{Y(i,j,k)}}\frac{\partial P_{Y(i,j,k)}}{\partial Q_{i,j,k,f}}\end{aligned} \quad (5.12)$$

Unitary "*conjectural variation*" (Kamien and Schwartz, 1983) is assumed here, *i.e.* each firm assumes that an increase of one unit of its own product value will bring exactly the same increase of total value of the product aggregate of its group. In other words, no other firm changes its output:

$P_{Y(i,j,k)} \times \Delta Y_{i,j,k} = P_{Q(i,j,k,f)} \times \Delta Q_{i,j,k,f}$, so that

$$\frac{\Delta Y_{i,j,k}}{\Delta Q_{i,j,k,f}} = \frac{P_{Q(i,j,k,f)}}{P_{Y(i,j,k)}} \tag{5.13}$$

The term $\frac{\partial P_{Y(i,j,k)}}{\partial Q_{i,j,k,f}}$ in (5.12) can thus be transformed with equation (5.13):

$$\frac{\partial P_{Y(i,j,k)}}{\partial Q_{i,j,k,f}} = \frac{\partial P_{Y(i,j,k)}}{\partial Y_{i,j,k}} \frac{\partial Y_{i,j,k}}{\partial Q_{i,j,k,f}} = \frac{\partial P_{Y(i,j,k)}}{\partial Y_{i,j,k}} \frac{P_{Q(i,j,k,f)}}{P_{Y(i,j,k)}} \tag{5.14}$$

Substitute (5.13) and (5.14) back into (5.12), and multiply both sides of (5.12) with $\frac{Q_{i,j,k,f}}{P_{Q(i,j,k)}}$, we can get:

$$\begin{aligned}
\frac{1}{\varepsilon_{Q(i,j,k,f)}} &= \frac{\partial P_{Q(i,j,k,f)}}{\partial Q_{i,j,k,f}} \frac{Q_{i,j,k,f}}{P_{Q(i,j,k)}} = -\frac{1}{\sigma_4} + \frac{1}{\sigma_4} \frac{P_{Q(i,j,k,f)}}{P_{Y(i,j,k)}} \frac{Q_{i,j,k,f}}{Y_{i,j,k}} \\
&\quad + \left(\frac{P_{Q(i,j,k,f)}}{P_{Y(i,j,k)}} \frac{Q_{i,j,k,f}}{Y_{i,j,k}} \right) \times \left(\frac{\partial P_{Y(i,j,k)}}{\partial Y_{i,j,k}} \frac{Q_{i,j,k,f}}{P_{Y(i,j,k)}} \right) \\
&= -\frac{1}{\sigma_4} + \frac{1}{\sigma_4} \varphi_{i,j,k,f} + \varphi_{i,j,k,f} \times \frac{1}{\varepsilon_{Y(i,j,k)}}
\end{aligned} \tag{5.15}$$

where $\varphi_{i,j,k,f}$ denotes the market share of the *f*th firm in the *k*th sector.

From equation (5.15), we can find that the inverse of elasticity of demand of the *f*th firm's products is a function of the inverse elasticity of demand of the *k*th sector, which can be derived following a similar procedure:

$$\frac{1}{\varepsilon_{Y(i,j,k)}} = -\frac{1}{\sigma_3} + \frac{1}{\sigma_3} \gamma_{i,j,k} + \gamma_{i,j,k} \times \frac{1}{\varepsilon_{DI(i,j)}} \tag{5.16}$$

$$\frac{1}{\varepsilon_{DI(i,j)}} = -\frac{1}{\sigma_2} + \frac{1}{\sigma_2} \beta_{i,j} + \beta_{i,j} \times \frac{1}{\varepsilon_{AR(i)}} \tag{5.17}$$

$$\frac{1}{\varepsilon_{AR(i)}} = -\frac{1}{\sigma_1} + \frac{1}{\sigma_1} \alpha_i + \alpha_i \times \frac{1}{\varepsilon_{AG}} \tag{5.18}$$

where α_i, $\beta_{i,j}$ and $\gamma_{i,j,k}$ are market share parameters of AR_i, $DI_{i,j}$, and $Y_{i,j,k}$ respectively:

$$\alpha_i = \frac{AR_i \times P_{AR(i)}}{AG \times P_{AG}}; \quad \beta_{i,j} = \frac{DI_{i,j} \times P_{DI(i,j)}}{AR_i \times P_{AR(i)}}; \quad \gamma_{i,j,k} = \frac{Y_{i,j,k} \times P_{Y(i,j,k)}}{DI_{i,j} \times P_{DI(i,j)}}$$

As $Y_{i,j,k}$ is a function of the endogenous FDI productivity spillover terms $\Theta_{i,j,k} = \frac{NTFP_{i,j,k}}{NTFP0_{i,j,k}}$, its market share $\gamma_{i,j,k}$ is also a function of $\Theta_{i,j,k}$.

For the aggregate product AG, assume $P_{AG} \cdot AG = E$, where E denotes the consumer's fixed expenditure. Then $AG = \frac{E}{P_{AG}}$. Thus we can get the elasticity of demand for this aggregate product:

$$\varepsilon_{AG} = \frac{\partial AG}{\partial P_{AG}} \frac{P_{AG}}{AG} = \left(-\frac{E}{P_{AG}^2}\right)\left(\frac{P_{AG}}{E/P_{AG}}\right) = -1 \tag{5.19}$$

Substitute (5.19) back to (5.18), and then substitute (5.18) to (5.17), and so on until we get the final expression of the firm level inverse elasticity of demand, which is also the firm-level markup rate:

$$\begin{aligned} mk_{i,j,k,f}(\%) &= \left|\frac{1}{\varepsilon_{Q(i,j,k,f)}}\right| \\ &= \frac{1}{\sigma_4} + \varphi_{i,j,k,f}\left(\frac{1}{\sigma_3} - \frac{1}{\sigma_4}\right) + \varphi_{i,j,k,f}\gamma_{i,j,k}\left(\frac{1}{\sigma_2} - \frac{1}{\sigma_3}\right) \\ &\quad + \beta_{i,j}\gamma_{i,j,k}\varphi_{i,j,k,f}\left(\frac{1}{\sigma_1} - \frac{1}{\sigma_2}\right) + \alpha_i\beta_{i,j}\gamma_{i,j,k}\varphi_{i,j,k,f}\left(\frac{1}{\sigma_1} - 1\right) \end{aligned} \tag{5.20}$$

In Section 5.6 which examines the FDI productivity spillovers in a new market structure, *i.e.* monopolistic competition among firms with heterogeneous productivities (in short "firm heterogeneity"), a firm's market share $\varphi_{i,j,k,f}$ will be determined by its *productivity* within each group (Melitz, 2003). We will then replace equation (5.20) with alternative specifications to contain richer information of the new scenario.

But in the current "representative producer" CGE model, only the ownership-level aggregate markup rate matters. Suppose each "ownership group" (indexed by k) is populated by N_f firms with identical size although they produce differentiated products. Thus their market share $\varphi_{i,j,k,f}$ is simply equal to $1/N_f$. This size symmetry also implies that the markup rate of each *group* is equal to that of its representative *firm*:

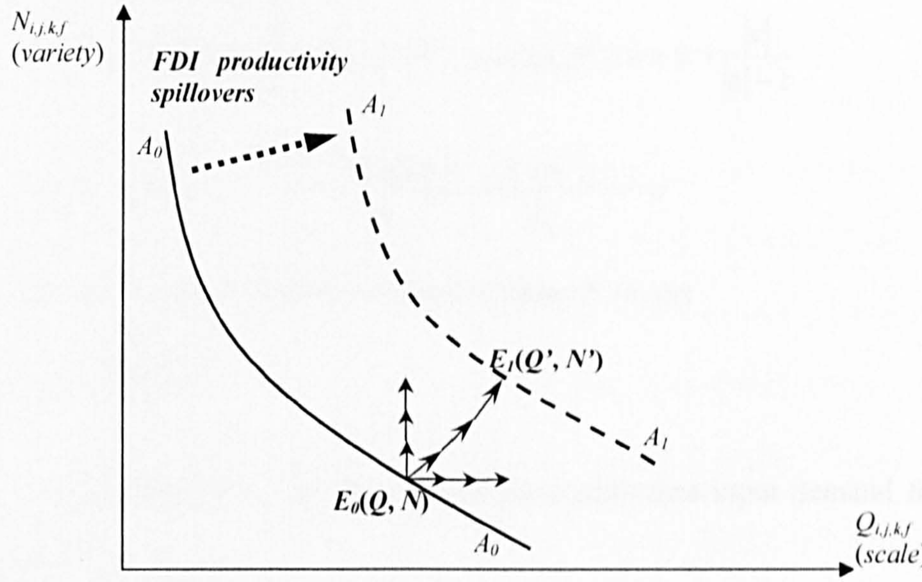
$$\begin{aligned} mk_{i,j,k}(\%) = mk_{i,j,k,f}(\%) &= \left| \frac{1}{\varepsilon_{Q(i,j,k,f)}} \right| \\ &= \frac{1}{\sigma_4} + \frac{1}{N_{i,j,k,f}}\left(\frac{1}{\sigma_3} - \frac{1}{\sigma_4}\right) + \frac{\gamma_{i,j,k}}{N_{i,j,k,f}}\left(\frac{1}{\sigma_2} - \frac{1}{\sigma_3}\right) \\ &\quad + \frac{\beta_{i,j}\gamma_{i,j,k}}{N_{i,j,k,f}}\left(\frac{1}{\sigma_1} - \frac{1}{\sigma_2}\right) + \frac{\alpha_i \beta_{i,j}\gamma_{i,j,k}}{N_{i,j,k,f}}\left(\frac{1}{\sigma_1} - 1\right) \end{aligned} \tag{5.20a}$$

In equation (5.20a), the market share parameters (α_i, $\beta_{i,j}$, $\gamma_{i,j,k}$) are *endogenously* determined while the elasticities of substitution (σ_i, $i=1, 2, 3, 4$) are exogenously chosen. $\gamma_{i,j,k}$ is of particular importance as it is a function of the term $\Theta_{i,j,k}$ and conveys information of FDI spillover.

5.5.2. FDI Productivity Spillovers under Monopolistic Competition

The impact of FDI productivity spillovers in a scenario of monopolistic competition can be illustrated by a variety-scale diagram (originally proposed by Francois and Roland-Holst (1997, pp. 349) in a trade model) for a certain *domestic* sector whose aggregate output is denoted by $Y_{i,j,k}$. As shown in Figure 5.2, $N_{i,j,k,f}$ (variety, in short "N") and $Q_{i,j,k,f}$ (scale, in short "Q") are the vertical and horizontal axis, respectively. A down-sloping curve A_0A_0 depicts the trade-off between variety and scale due to the resource constraint facing the producers in this sector. A_0A_0 can also be understood as a "variety-scale possibility frontier".

Figure 5.2: FDI Productivity Spillovers under Monopolistic Competition



Now consider a case wherein the production capacity of this *domestic* sector expands from A_0A_0 to A_1A_1 due to FDI productivity spillovers, which helps the domestic producers in this sector produce more efficiently with the given resources.

Suppose an initial production point is $E_0(Q, N)$, then a production capacity enlargement can result in two dimensions of expansion, one along Q (scale) and the other along N (variety), as shown in Figure 5.2.

This can be illustrated algebraically in a simple model (Krugman, 1980). Suppose the composite input for each firm is denoted by l, and total factor supply is L. All firms take the same input function $l=f+vQ$, where f and v denote fixed cost and variable cost measured in units of input, respectively. Then the profit of any firm is $\pi = p(Q)Q - w(f + vQ)$, where p and w denotes prices of output and input, respectively.

At long-run equilibrium with entry and exit, two conditions should be both satisfied. The first one is profit maximisation *i.e.* $MR=MC$, and the second one is zero profits in long-run equilibrium, *i.e.* $P=AC$.

With equation (5.10), MR=MC means

$$MR = P \times \left(1 - \frac{1}{|\varepsilon|}\right) = v \times w = MC \quad \text{so that} \quad P = v \times w \times \frac{|\varepsilon|}{|\varepsilon| - 1}$$

P=AC leads to $P = \dfrac{(f + vQ) \times w}{Q} = \dfrac{f \times w}{Q} + v \times w$

Substituting for equilibrium product price P we get

$$Q = \frac{f(|\varepsilon| - 1)}{b}$$

Substituting Q to l=f+vQ, we can get equilibrium input demand for any variety:

$$l = f + vQ = f + v\frac{f(|\varepsilon| - 1)}{v} = f|\varepsilon|$$

Thus the number of varieties which can possibly produced given the limited total supply of factor L is determined by the full employment condition L=N×l, which implies that:

$$N = L/l = \frac{L}{f \times |\varepsilon|}$$

Given the equilibrium solution of scale and variety (Q, N) = $\left(\dfrac{f(|\varepsilon| - 1)}{v}, \dfrac{L}{f \times |\varepsilon|}\right)$, we can now examine how FDI productivity spillovers affect the parameter values of f and v, which in turn affect the solutions of (Q, N).

In this context, both f and v are functions of FDI spillovers, *i.e.* $f(\Theta)$ and $v(\Theta)$. As FDI spillovers push both fixed cost and variable cost lower, *i.e.* $\partial f(\Theta)/\partial\Theta < 0$, and $\partial v(\Theta)/\partial\Theta < 0$, then the number of varieties $\left(N = \dfrac{L}{f \times |\varepsilon|}\right)$ produced in the economy will increase. When variable cost decreases faster than fixed cost does, *i.e.* $|\partial v(\Theta)/\partial\Theta| > |\partial f(\Theta)/\partial\Theta|$, then the production scale $Q = \dfrac{f(|\varepsilon|-1)}{v}$ will also increase with FDI spillovers.

The above two expansion possibilities (*i.e.* both Q and N increase with FDI productivity spillovers) jointly result in a new equilibrium point $E_1(Q', N')$ in Figure 5.2. An up-sloping curve connecting E_0 and E_1 depicts the positive correlation between N and Q, and can be understood as a "sectoral variety-scale expansion path". Therefore under the assumption of *monopolistic* competition, if domestic firms receive productivity spillovers from foreign-invested firms, the new equilibrium $E_1(N', Q')$ will bring consumers *welfare improvement* thanks to more varieties and cheaper prices ($P = v \times w \times \dfrac{|\varepsilon|}{|\varepsilon|-1}$). However, only the price benefits may be available if goods are homogeneous and markets are *perfectly* competitive.

5.6. EXTENSION 3: FDI SPILLOVERS UNDER FIRM HETEROGENEITY

5.6.1. Firm Heterogeneity and CGE Modelling

The CGE model under monopolistic competition assumes a representative firm of each type in each sector. However, this assumption is at odds with the reality. Recent empirical research has shown that firms differ a lot in productivity. For example, Girma *et al* (2005) find that a productivity hierarchy exists and determines the behaviour of British firms, *i.e.* only the most productive firms can engage in FDI, and less productive firms export, while the least productive firms can only serve the domestic market.

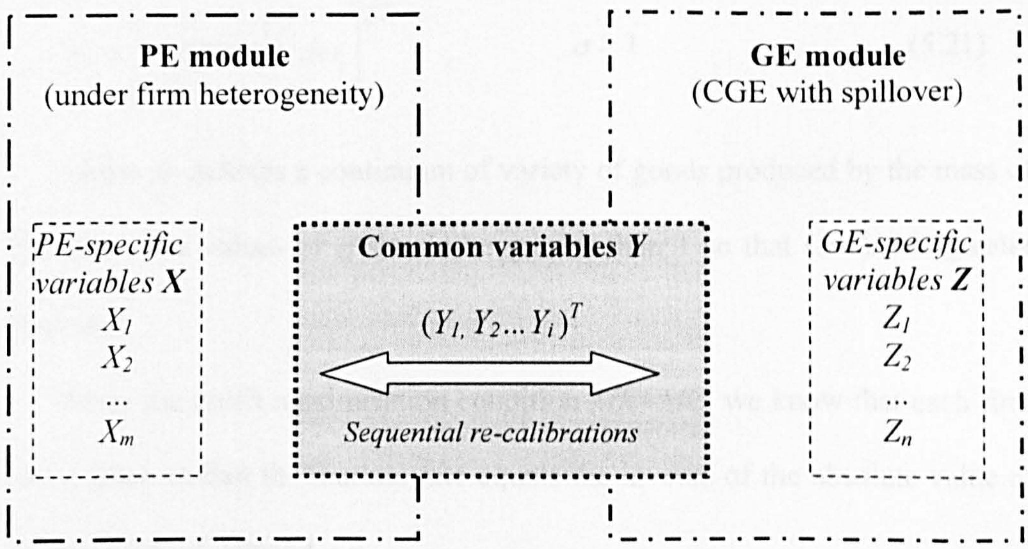
Moreover, such pervasive productivity heterogeneity leads to firm size difference within each sector, *i.e.* the productivity of a firm is positively related to the size of this firm, as shown by Melitz (2003). In his model explicitly considering the productivity heterogeneity among firms, Melitz theoretically analyses the impact of trade on intra-industry resource reallocations and aggregate industry productivity. The model shows that only the most productive firms can afford the sunk cost of exporting. Trade liberalization can induce these firms to produce more and engage in export, leading to stronger competition for a common pool of labour. This can push up labour cost and drive the least productive firms to exit. So firms with higher productivity survive the trade liberalisation and grow larger by absorbing the resources released by the exiting firms. Thus aggregate industry productivity increases due to the resource reallocation effect of trade under firm heterogeneity. These conclusions are supported by Feenstra and Kee (2008), who find that export variety of firms accounts for the time-series variation in productivity. In brief, firm heterogeneity is an important theoretical assumption for explaining productivity growth caused by the endogenous self-selection of exporters.

In this research on FDI productivity spillovers, the assumption that firms have heterogeneous productivity is also important in accounting the effects of potential FDI spillovers *i.e.* productivity improvement effect and resource reallocation effect. This will be discussed in detail in Section 5.6.3.

In each sector, firms are heterogeneous in that they produce differentiated goods and are different in productivity. Every firm incurs fixed cost and variable cost in production.

An option for incorporating heterogeneous firms into a standard "representative firm" CGE model is to decompose the whole CGE model into a partial equilibrium (PE) module and general equilibrium (GE) module (Balistreri, Hillberry and Rutherford, 2007). This option has been adopted here. Firm behaviour is determined in the PE module, while the aggregate economy is calibrated in the GE module. Key variables are selected to transmit *information* recursively between PE and GE modules. PE and GE modules recursively recalibrate to the new *information*. This sequential re-calibration (SR) process will continue until all variables common to the PE and GE are consistent, *i.e.* the discrepancy between the variable values obtained from the (t-1)th and tth iterations is at a trivial level. This SR has proven effective in achieving model convergence (Rausch and Rutherford, 2007; Rutherford and Tarr, 2008). The decomposition is sketched in Figure 5.3.

Figure 5.3: A Decomposition of CGE Model under Firm Heterogeneity



5.6.2. Model Construction for Firm Heterogeneity (PE Module)

The PE module is constructed to model the heterogeneity of firms in their productivity. Suppose there is a mass of M_i heterogeneous firms in the ith sector. These M_i firms produce highly, but not perfectly, substitutable products in that sector and have limited monopoly power, so that they can set their prices higher than their marginal costs, charge markups to compensate fixed costs and earn possible profits. On entry each firm is assumed to take a *free* draw (*i.e.* no entry cost) of productivity φ_i from a Pareto distribution $g(\varphi_i) = \frac{a}{\varphi_i}\left(\frac{b}{\varphi_i}\right)^a$, and sets a price $P_{i,f}(\varphi_i)$, produces output $Q_{i,f}(\varphi_i)$. The values of parameters a and b can be taken from the literature (Bernard et al., 2003; Zhai, 2008).

(1) Market structure

Suppose every firm in the ith sector needs to pay the same fixed cost F_i, which is assumed not to change to any external shock, *e.g.* productivity spillovers. Suppose firms in the ith sector face a market with a Dixit-Sliglitz style of preference (Dixit and Stiglitz, 1977):

$$U_i = \left[\int_{\omega_i \in \Omega_i} Q(\omega_i)^{\frac{\sigma-1}{\sigma}} d\omega_i \right]^{\frac{\sigma}{\sigma-1}} \qquad \sigma > 1 \qquad (5.21)$$

where ω_i indexes a continuum of variety of goods produced by the mass of M_i firms. The values of σ should be greater than 1 so that $(\sigma\text{-}1)/\sigma$ is greater than zero.

From the profit maximisation condition MR=MC, we know that each firm sets a price so that the markup rate equals the inverse of the absolute value of the elasticity of demand, *i.e.*

$$mk_{i,f}(\%) = \frac{1}{|\varepsilon_i|} = \frac{1}{\sigma} \qquad (5.11a)$$

From markup rule (5.11a), one can derive the optimal pricing rule for a firm with productivity $\varphi_{i,f}$:

$$mk_{i,f}(\%) = \frac{P_{i,f} - C_i/\varphi_{i,f}}{P_{i,f}} = \frac{1}{\sigma}, \text{ so that}$$

$$P_{i,f} = \frac{\sigma}{\sigma - 1}\frac{C_i}{\varphi_{i,f}} \tag{5.22}$$

where C_i denotes the price of unit input cost in the ith sector, which is a weighted average of the intermediate input prices ($P_{i,j}$) and primary input prices ($P_{i,k}$):

$$C_i = \frac{\sum_z \left(PA_{i,z} \times \overline{IOD_{i,z}}\right) + PVA_i \times \overline{VA_i}}{\sum_z \overline{IOD_{i,z}} + \overline{VA_i}}$$

In the above equation $\overline{IOD_{i,z}}$ denotes the zth intermediate input while $\overline{VA_i}$ denotes the primary input composite used for the production in the ith sector. The denotations for the prices of the two types of inputs ($PA_{i,z}$ and PVA_i) are identical to those in Table 5.3. The amount of these inputs also corresponds to the parameters in Table 5.3, *i.e.* $\overline{IOD_{i,z}} = \overline{IOD(i,z)}$, and $\overline{VA_i} = \overline{CP(i)} + \overline{DP(i)} + \overline{OP(i)}$.

The duality of CES preference (5.21) implies that the aggregate price is:

$$\begin{aligned}
\hat{P}_i &= \left[\int_{\omega_i \in \Omega} P_{i,f}(\omega_i)^{1-\sigma} d\omega_i\right]^{\frac{1}{1-\sigma}} \\
&= \left[\int_0^{+\infty} P_{i,f}(\varphi_i)^{1-\sigma} \cdot M_i \cdot g(\varphi_i) d\varphi_i\right]^{\frac{1}{1-\sigma}} = \left[\int_0^{+\infty} \left(\frac{\sigma \cdot C_i}{(\sigma - 1)\varphi_i}\right)^{1-\sigma} \cdot M_i \cdot g(\varphi_i) d\varphi_i\right]^{\frac{1}{1-\sigma}} \\
&= \frac{\sigma \cdot C_i}{\sigma - 1} M_i^{\frac{1}{1-\sigma}} \left[\int_0^{+\infty} \varphi_i^{\sigma-1} g(\varphi_i) d\varphi_i\right]^{\frac{1}{1-\sigma}} = \frac{\frac{\sigma \cdot C_i}{\sigma - 1} M_i^{\frac{1}{1-\sigma}}}{\left[\int_0^{+\infty} \varphi_i^{\sigma-1} g(\varphi_i) d\varphi_i\right]^{\frac{1}{\sigma-1}}} \qquad (5.23) \\
&= \left[\frac{\sigma \cdot C_i}{(\sigma - 1)\widetilde{\varphi}_i}\right] M_i^{\frac{1}{1-\sigma}} = P_i(\widetilde{\varphi}_i) \cdot M_i^{\frac{1}{1-\sigma}}
\end{aligned}$$

where $\tilde{\varphi}_i \equiv \left[\int_0^{+\infty} \varphi_i^{\sigma-1} g(\varphi_i) d\varphi_i \right]^{\frac{1}{\sigma-1}}$ (5.24)

$\tilde{\varphi}_i$ denotes a weighted average of the firms' productivity levels φ.

For the feasibility of computation, one needs information on the *productivity distribution* of corresponding sectors. In the literature, the Pareto distribution has been found "compelling" in approximating the real distribution of firm productivity (Helpman, 2006, pp. 597). For a Pareto distribution with probability density function of $g(\varphi_i) = \frac{a}{\varphi_i}\left(\frac{b}{\varphi_i}\right)^a$, the corresponding cumulative distribution is:

$$
\begin{aligned}
G(\varphi_i) &= \int_0^{\varphi_i} g(x)dx = \int_0^{\varphi_i} \frac{a}{x}\left(\frac{b}{x}\right)^a dx = \int_0^{\varphi_i} ab^a x^{-a-1} dx \\
&= \frac{ab^a x^{-a}\Big|_0^{\varphi_i}}{-a} = -\left(\frac{b}{x}\right)^a\Bigg|_0^{\varphi_i} = 1 - \left[-\left(\frac{b}{x}\right)^a\Bigg|_{\varphi_i}^{+\infty} \right] \\
&= 1 + \left[0 - \left(\frac{b}{\varphi_i}\right)^a \right] = 1 - \left(\frac{b}{\varphi_i}\right)^a
\end{aligned}
\tag{5.25}
$$

Now we can have a definition of the "marginal firm". For any firm, the demand for its products from consumers is determined by the preference equation (5.21). Assuming the total expenditure of the products in the *i*th sector are E_i, then

$$Q_{i,f} = \frac{E_i}{\hat{P}_i}\left(\frac{\hat{P}_i}{P_{i,f}(\varphi_{i,f})}\right)^\sigma \tag{5.26}$$

The profit function of a firm can be derived from (5.26) and (5.23):

$$
\begin{aligned}
\pi_{i,f}(\varphi_{i,f}) &= P_{i,f}(\varphi_{i,f}) \times Q_{i,f}(\varphi_{i,f}) - C_i F_i = E_i \times \hat{P}_i^{\sigma-1} \times \left[P_{i,f}(\varphi_{i,f})\right]^{1-\sigma} - C_i F_i \\
&= E_i \times \hat{P}_i^{\sigma-1} \times \left[\frac{C_i \cdot \sigma}{(\sigma-1)\varphi_{i,f}}\right]^{1-\sigma} - C_i F_i = E_i \times \left[\frac{C_i \cdot \sigma}{\hat{P}_i(\sigma-1)}\right]^{1-\sigma} \times \varphi_{i,f}^{\sigma-1} - C_i F_i
\end{aligned}
$$

(5.27)

As can be seen from (5.27), since σ>1, profit ($\pi_{i,f}$) is a monotonically increasing function of productivity ($\varphi_{i,f}$). Suppose there exists a productivity level φ_i^* which satisfies $\pi_i^*(\varphi_i^*)=0$, *i.e.* "*zero cutoff profit*". Then for a firm whose $\varphi_{i,f} > \varphi_i^*$, $\pi_{i,f} > 0$ so that it can survive; while for other firms whose $\varphi_{i,f} < \varphi_i^*$, $\pi_{i,f} < 0$ so that they have to exit. A firm taking a productivity draw of φ_i^* can be called a "*marginal firm*". Therefore the probability of *successful* entry (those firms with productivity higher than the marginal one φ_i^*):

$$1-G(\varphi_i^*)=\left(\frac{b}{\varphi_i^*}\right)^a \tag{5.28}$$

For the "marginal firm", its markup equals the fixed cost, *i.e.*

$$C_i \cdot F_i = P_i(\varphi_i^*)\cdot Q_i(\varphi_i^*)\cdot\frac{1}{\sigma} \tag{5.29}$$

(2) Aggregate productivity

The conditional distribution of $g(\varphi_i)$ on $[\varphi_i^*, +\infty)$ can be obtained with the information of the probability of *successful* entry (equation 5.40):

$$\mu(\varphi_i)=\begin{cases}\dfrac{g(\varphi_i)}{1-G(\varphi_i^*)} & \textit{if } \varphi_i \geq \varphi_i^*, \\ 0 & \textit{otherwise.}\end{cases}$$

Suppose $\tilde{\varphi}_i$ (denoted by equation (5.24)) as the productivity of a firm pricing at $\tilde{P}_i$, then weighted average of the firm productivity $\tilde{\varphi}_i$ can be "inflated" (with equation (5.28)) conditional on the successful entry:

$$\tilde{\varphi}_i(\varphi_i^*) \equiv \left[\int_{\varphi_i^*}^{+\infty} \varphi_i^{\sigma-1} \frac{g(\varphi_i)}{1-G(\varphi_i^*)} d\varphi_i \right]^{\frac{1}{\sigma-1}} = \left[\frac{1}{1-G(\varphi_i^*)} \int_{\varphi_i^*}^{+\infty} \varphi_i^{\sigma-1} g(\varphi_i) d\varphi_i \right]^{\frac{1}{\sigma-1}}$$

$$= \left[\left(\frac{\varphi_i^*}{b}\right)^a \int_{\varphi_i^*}^{+\infty} \varphi_i^{\sigma-1} g(\varphi_i) d\varphi_i \right]^{\frac{1}{\sigma-1}} = \left[\left(\frac{\varphi_i^*}{b}\right)^a \int_{\varphi_i^*}^{+\infty} \varphi_i^{\sigma-1} \frac{a}{\varphi_i}\left(\frac{b}{\varphi_i}\right)^a d\varphi_i \right]^{\frac{1}{\sigma-1}}$$

$$= \left[a\left(\varphi_i^*\right)^a \int_{\varphi_i^*}^{+\infty} \varphi_i^{\sigma-a-2} d\varphi_i \right]^{\frac{1}{\sigma-1}} = \left[\frac{a\left(\varphi_i^*\right)^a}{\sigma-a-1} \varphi_i^{\sigma-a-1} \Big|_{\varphi_i^*}^{+\infty} \right]^{\frac{1}{\sigma-1}}$$

If σ-a-1>0, $\tilde{\varphi}_i$ approaches to infinity. When σ-a-1<0 (consistent with the results of Bernard *et al.*(2003)), a solution can be obtained:

$$\tilde{\varphi}_i(\varphi_i^*) = \left(\frac{a}{a+1-\sigma} \right)^{\frac{1}{\sigma-1}} \varphi_i^* \tag{5.30}$$

Thus the weighted aggregate productivity in sector i ($\tilde{\varphi}_i$) is denoted as a function of the cutoff productivity (φ_i^*). The purpose of this denotation is to facilitate the interaction of GE module and PE module in the CGE model. In the PE module, the values of cutoff productivity (φ_i^*) are simulated, then the values of aggregate productivity ($\tilde{\varphi}_i$) can be obtained with equation (5.30), summarising the productivity distribution of the firms in sector i. A virtual "quasi-representative" firm with a productivity level of $\tilde{\varphi}_i$ can be assumed here to represent the whole mass of firms in that sector. Such a "quasi-representative" firm takes the place of the conventional "representative" firm in each sector in the GE module, enabling the CGE model to capture how firm behaviour (*e.g.* productivity spillovers) affects the macroeconomic performance.

(3) Zero cutoff profit condition

From the model of Melitz (2003, pp. 1700), one knows that the ratio of any two firms' revenues depends on the ratio of their productivity levels, so that using equation (5.30):

$$\frac{P_i(\tilde{\varphi}_i)Q_i(\tilde{\varphi}_i)}{P_i(\varphi_i^*)Q_i(\varphi_i^*)} = \left(\frac{\tilde{\varphi}_i}{\varphi_i^*}\right)^{\sigma-1} = \left[\left(\frac{a}{a+1-\sigma}\right)^{\frac{1}{\sigma-1}}\right]^{\sigma-1} = \frac{a}{a+1-\sigma}$$

$$\text{and } P_i(\varphi_i^*)Q_i(\varphi_i^*) = \tilde{P}_i(\tilde{\varphi}_i)\tilde{Q}_i(\tilde{\varphi}_i)\left(\frac{a+1-\sigma}{a}\right) \quad (5.31)$$

Substitute equation (5.31) into equation (5.29), we can get a new condition dependent on the weighted average productivity $\tilde{\varphi}_i$:

$$C_i \cdot F_i = P_i(\tilde{\varphi}_i)Q_i(\tilde{\varphi}_i)\left(\frac{a+1-\sigma}{a\sigma}\right) \quad (5.32)$$

(4) Firm-level demand

The duality of CES preference also implies that the demand for the output of the "quasi-representative firm" is determined by:

$$\tilde{Q}_i = \frac{E_i}{\hat{P}_i}\left(\frac{\hat{P}_i}{\tilde{P}_i(\tilde{\varphi}_i)}\right)^{\sigma} = \frac{E_i}{\hat{P}_i}\left(\frac{\hat{P}_i}{\tilde{P}_i(\varphi_i^*)}\right)^{\sigma} \quad (5.33)$$

where $\hat{P}_i$ and E_i are the composite output price and expenditure level for the corresponding ith sector.

(5) Input partial equilibrium

Finally, one more equation is needed to link the partial equilibrium module to the general equilibrium module. This equation concerns the cost of total input for each sector:

$$M_i \cdot C_i \cdot \left(F_i + \frac{\tilde{Q}_i(\tilde{\varphi}_i)}{\tilde{\varphi}_i}\right) = \sum_z \left(PA_{i,z} \times \overline{IOD}_{i,z}\right) + PVA_i \times \overline{VA}_i \quad (5.34)$$

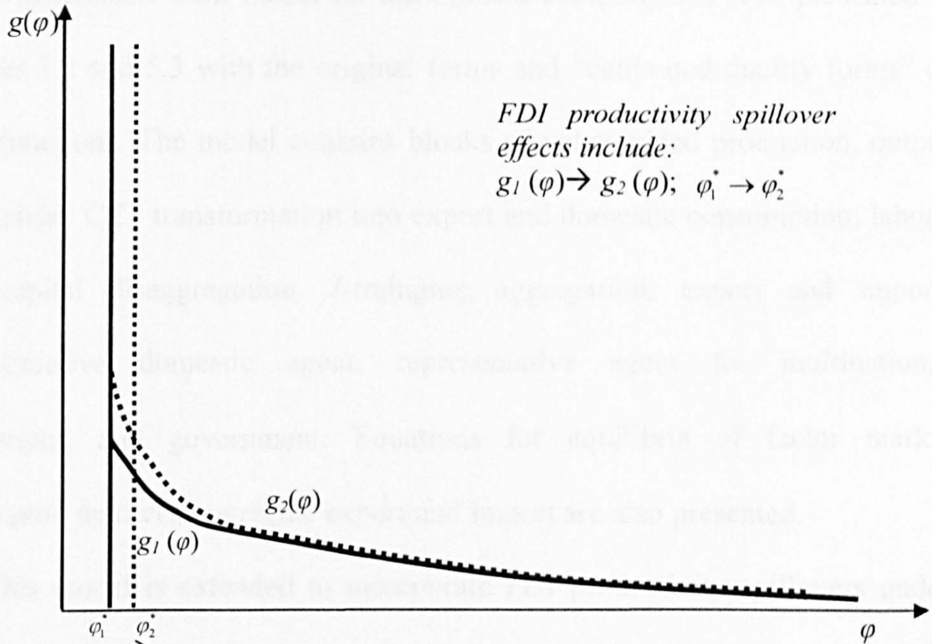
where, again, $\overline{IOD}_{i,z}$ denotes the zth intermediate input while $\overline{VA}_i$ denotes the primary input composite used for the production in the ith sector.

With the information of *key price variables* from the GE module (output price vector, **P**, and input price vector **C**), the above system of five shaded equations **(5.22), (5.30), (5.32), (5.33), and (5.34)** can be solved to obtain the values of five endogenous variables, ($M_t, \widetilde{Q}_t, \widetilde{P}_t, \widetilde{\varphi}_t, \varphi_t^*$). Then the information of computed productivity level $\widetilde{\varphi}_t$ is passed back to the GE module, and GE module will recalibrate to this new information. This sequential recalibration process will continue until the values of the above *three key variable vectors* $(\boldsymbol{P}, \boldsymbol{C}, \widetilde{\varphi})$ obtained from the re-calibrations in PE and GE module are mutually consistent, *i.e.* the discrepancy between the variable values obtained from the (*t-1*)th and *t*th iterations is at a trivial level. With the PE module constructed above, we can thus extend the CGE model from a representative-firm model to one capable of analysing firm-level changes caused by productivity shocks.

5.6.3. FDI Productivity Spillovers under Firm Heterogeneity

If the FDI productivity spillovers occur, then *two* effects arise. The first one is *productivity improvement effect*, *i.e.* SOEs and private domestic enterprises can improve their productivity accordingly. As shown in Figure 5.4, the probability density function $g_1(\varphi)$ of the productivity distribution will be shifted rightwards from $g_1(\varphi)$ to $g_2(\varphi)$. Another effect is *resource reallocation effect*. The domestic firms are now generally more productive than before, and the market becomes more competitive. As a higher productivity enables a firm to reduce its price and to sell more, this will increase the demand for limited resources and thus lift input costs. Those least productive enterprises can no longer afford the higher costs and will be forced to exit. Thus the *cutoff* productivity level φ^* will be lifted from the original level φ_1^* (without spillovers) to a new level φ_2^* (with spillovers). With the above two effects combined, the productivity of existing firms improves as does the distribution from which new entrants draw productivity.

Figure 5.4: FDI Spillovers under Firm Heterogeneity



Therefore the cutoff productivity level φ^* is a function of the variable measuring FDI productivity spillovers, *i.e.* $\varphi^*(\Theta)$ (defined in Section 5.5.2). If we assume that the $g(\varphi)$ will be shifted in the same magnitude as φ^* does, then a Pareto distribution function of domestic firms' productivity can be transformed into:

$$g(\varphi - \Delta\varphi^*) = \frac{ab^a}{(\varphi - \Delta\varphi^*(\Theta))^{a+1}} = \frac{ab^a}{(\varphi - (\varphi_2^*(\Theta) - \varphi_1^*(\Theta)))^{a+1}}$$

In computer programming, we can calibrate the benchmark value of $\varphi_1^*(\Theta)$ first. Then in counterfactual scenarios with FDI productivity spillovers, new cutoff productivity value $\varphi_2^*(\Theta)$ is endogenously determined.

We will discuss the results obtained in computer simulations in the next Chapter.

5.7. CONCLUSIONS

A benchmark CGE model for the Chinese economy has been presented in Section 5.2 and 5.3 with the original forms and "calibrated duality forms" of CES functions. The model contains blocks of value-added production, output production, CET transformation into export and domestic consumption, labour and capital disaggregation, Armington aggregation, export and import, representative domestic agent, representative agent for multinational enterprises, and government. Equations for equilibria of factor marks, Armington markets, aggregate export and import are also presented.

This model is extended to incorporate FDI productivity spillovers under perfect competition in Section 5.4. Chinese industry-level data during 2001 and 2006 are employed to estimate the coefficients of four spillover channels. Forward linkages and horizontal demonstration are found to be the most significant channels via which spillovers take place.

Section 5.5 models the FDI productivity spillovers in an alternative market structure, namely monopolistic competition with homogeneous firms. In this scenario, the markup rate of a representative firm of each sector is derived, which is essential to extending a CGE model to incorporate monopolistic competition. A CGE model to study FDI spillovers under monopolistic competition can also reflect the changes of product varieties and quantities caused by the spillovers.

Section 5.6 models the FDI productivity spillovers in another alternative market structure, *i.e.* monopolistic competition with heterogeneous firms. This market structure is a newly explored one in the literature, and is potentially important in explaining the productivity change of domestic firms. A CGE model under firm heterogeneity is composed of a general equilibrium module and a partial equilibrium module. The former is a model with FDI spillovers under perfect competition. The latter deals with firm heterogeneity, assuming a virtual "quasi-representative" firm and "summarising" the distribution of firm productivity in each sector. The CGE model in this scenario can provide alternative perspective to the effects of spillovers by examining productivity improvement under FDI productivity spillovers in a more direct way.

In the next Chapter, the effects of an FDI shock to the economy under three market structures (*i.e.* perfect competition assumption, monopolistic competition with homogeneous firms and heterogeneous firms) will be evaluated and compared. The effects of 2008 corporate income tax reform in the above three market structures will then be analysed and compared in Chapter 7.

APPENDIX: THE GAMS CODE AND MATHEMATICAL SPECIFICATION OF THE BENCHMARK CGE MODEL

The following tables will present the benchmark model in GAMS/MPSGE syntax block by block. In interpreting the benchmark CGE model coded in GAMS/MPSGE syntax, the price ratio equation (3.19a) and input demand ratio equations (3.18a) and (3.18b) discussed in Chapter 3 need to be employed frequently. Equations are categorized into four groups:

[1] Original CES functions.

[2] Ratio equations: prices. These equations are applications of (3.19a). The equation (3.19b) is also applied when the elasticity of substitution (transformation) is equal to one which implies a Cobb-Douglas form.

[3] Ratio equations: input demand or **output supply.** These ratio equations are applications of (3.18a), or (3.18b) if the production has a CET form.

[4] Level equations. These equations define the level quantities that correspond to output and input demand in the corresponding sector. A level value is a ratio variable multiplied by the base quantity denoted with a *bar* ($\bar{}$) over a variable. The level variables for input demand and output supply will be used in the market clearing equations to be listed in the end of the Appendix.

Table A5.1: Sectors, Commodities and Representative Agents

```
$SECTORS:
        Y(A)            !SECTORAL PRODUCTION
        YN(A)           !SECTORAL PRODUCTION
        DX(A)           !CET TRANSFORMATION FROM Y(A)
        VA(A)           !VALUE ADDED
        AR1(Z)          !ARMINGTON SUPPLY AT OWNERSHIP LEVEL
        AR(Z)           !ARMINGTON SUPPLY AT INDUSTRY LEVEL
        X(A)            !EXPORT
        M(A)            !IMPORT AT SECTOR LEVEL
        MZ(Z)           !IMPORT AT INDUSTRY LEVEL
```

```
        CS              !PRIVATE CONSUMPTION
        G               !PUBLIC CONSUMPTION
        INV             !INVESTMENT
        LZ(Z)           !LABOUR SUPPLY AT INDUSTRY LEVEL
        LTOTAL          !TOTAL LABOUR SUPPLY
        KZ(Z)           !CAPITAL SUPPLY AT INDUSTRY LEVEL
        KTOTAL          !TOTAL CAPITAL SUPPLY

$COMMODITIES:
        PY(A)           !TOTAL OUTPUT
        PYY(A)          !TOTAL OUTPUT
        PAA(Z)          !ARMINGTON PRICE FOR EACH OWNERSHIP
        PA(Z)           !ARMINGTON PRICE FOR INDUSTRY
        PD(A)           !DOMESTIC MARKET PRICE
        PM(Z)           !IMPORT PRICE AT INDUSTRY LEVEL
        PMA(A)          !IMPORT PRICE AT SECTOR-LEVEL
        PX(A)           !EXPORT PRICE
        PC              !CONSUMPTION PRICE
        PINV            !INVESTMENT PRICE
        PFX             !FOREIGN EXCHANGE
        PG              !LUMP-SUM TAX REVENUE
        PVA(A)          !PRICE OF AGGREGATE VALUE ADDED
        WL(A)           !WAGE RATE
        TWL             !NATIONAL-LEVEL WAGE
        ZWL(Z)          !INDUSTRY-LEVEL WAGE
        RK(A)           !RETURN TO CAPITAL
        TRK             !NATIONAL AVERAGE RETURN TO CAPITAL
        ZRK(Z)          !INDUSTRY AVERAGE RETURN TO SCALE
        PF(A)           !FIXED COST

$CONSUMER:
        RA              !REPRESENTATIVE AGENT
        FDI             !MULTINATIONAL(FOREIGN) FIRMS
        ENTRE(A)        !AGENTS TO COLLECT MARKUPS AND PAY FIXED COST
        GOV             !GOVERNMENT
```

Table A5.2: Production of Value-added Composites

MPSGE Declaration

```
$PROD: VA(FNN)          S: 1
     O: PVA(FNN)          Q: (CP(FNN)+DP(FNN)+OP(FNN))
     I: WL(FNN)           Q: CP(FNN)
     I: RK(FNN)           Q: (DP(FNN)+OP(FNN))

$PROD: VA(SNO)          S: 1
     O: PVA(SNO)        Q: ((CP(SNO)+DP(SNO)+OP(SNO))/(1+NTFP0(SNO)$NTFPFLAG))
+             A:GOV     N: NTFP(SNO)$NTFPFLAG        M:(-1)$NTFPFLAG
     I: WL(SNO)          Q: CP(SNO)
     I: RK(SNO)          Q: (DP(SNO)+OP(SNO))
```

Equations

[1] original CES functions

$$DY\_VA(FNN) = \alpha_{DY\_FNN} \times DY\_L(FNN)^{\bar{\theta}_{FNN\_wl(FNN)}} \times DY\_K(FNN)^{\bar{\theta}_{FNN\_rk(FNN)}} \quad (A5.2.1)$$

$$DY\_VA(SNO)\frac{1+NTFP(SNO)}{1+NTFP0(SNO)} = \alpha_{NY\_SNO} \times DY\_L(SNO)^{\bar{\theta}_{SNO\_wl(SNO)}} \times DY\_K(SNO)^{\bar{\theta}_{SNO\_rk(SNO)}} \quad (A5.2.2)$$

[2] ratio equations: prices

$$pva(FNN) = wl(FNN)^{\bar{\theta}_{FNN\_wl(FNN)}} \times rk(FNN)^{\bar{\theta}_{FNN\_rk(FNN)}} \quad (A5.2.3)$$

$$pva(SNO)\frac{1+NTFP(SNO)}{1+\overline{NTFP0}(SNO)} = wl(SNO)^{\bar{\theta}_{SNO\_wl}(SNO)} \times rk(SNO)^{\bar{\theta}_{SNO\_rk}(SNO)} \quad \text{(A5.2.4)}$$

[3] ratio equations: input demand

$$dy\_l(FNN) = d\_va(FNN)\left(\frac{pva(FNN)}{wl(FNN)}\right) \quad \text{(A5.2.5)}$$

$$dy\_k(FNN) = d\_va(FNN)\left(\frac{pva(FNN)}{rk(FNN)}\right) \quad \text{(A5.2.6)}$$

$$dy\_l(SNO) = d\_va(SNO)\left(\frac{pva(SNO)\frac{1+NTFP(SNO)}{1+\overline{NTFP0}(SNO)}}{wl(SNO)}\right) \quad \text{(A5.2.7)}$$

$$dy\_k(SNO) = d\_va(SNO)\left(\frac{pva(SNO)\frac{1+NTFP(SNO)}{1+\overline{NTFP0}(SNO)}}{rk(SNO)}\right) \quad \text{(A5.2.8)}$$

[4] level equations

$$DY\_VA(a) = dy\_va(a)\left(\overline{CP}(a) + \overline{DP}(a) + \overline{OP}(a)\right) \quad \text{(A5.2.9)}$$

$$DY\_L(a) = dy\_l(a)\overline{CP}(a) \quad \text{(A5.2.10)}$$

$$DY\_K(a) = dy\_k(a)\left(\overline{DP}(a) + \overline{OP}(a)\right) \quad \text{(A5.2.11)}$$

Variables

pva(a)	Ratio market price for aggregate value-added of sector *a*
wl(a)	Ratio wage level of sector *a*
rk(a)	Ratio returns to capital input of sector *a*
dy_va(a)	Ratio output of aggregate value-added of sector *a*
dy_wl(a)	Ratio input demand for labour of sector *a*
dy_rk(a)	Ratio input demand for capital of sector *a*
DY_VA(a)	Output of aggregate value-added of sector *a*
DY_L(a)	Input demand for labour of sector *a*
DY_K(a)	Input demand for capital of sector *a*
NTFP (a)	Endogenous total factor productivity spillovers of sector *a*

Parameters

α_{DY_FNN}	Shift parameter of production of value added (*FNN* sectors)
α_{NY_SNO}	Shift parameter of production of value added (*SNO* sectors)
$\bar{\theta}_{A\_VA}(a)$	Share of aggregate value-added in the total input of sector *a*
$\bar{\theta}_{A\_wl}(a)$	Share of labour cost in aggregate value-added input of sector *a*
$\bar{\theta}_{A\_rk}(a)$	Share of capital cost in aggregate value-added input of sector *a*
$\overline{NTFP0}\,(a)$	Base total factor productivity spillovers minus 1 in sector *a*
$\overline{CP}(a)$	Labour input in sector *a*
$\overline{DP}(a) + \overline{OP}(a)$	Capital input in sector *a*

Table A5.3: Production

MPSGE Declaration

```
$PROD:Y(A)
        O:PY(A)  Q:TOUTPUT(A)  A:GOV    T:(NTP0(A)+TAXREF(A))
+                P:(1/(1-NTP0(A)))
        I:PA(Z)  Q:IOD1(Z,A)
```

```
        I:PVA(A)  Q:(CP(A)+DP(A)+OP(A))

* THIS BLOCK IS FOR THE SCENARIO OF MONOPOLISTIC COMPETITION

$PROD:YN(A)
        O:PYY(A)  Q:(TOUTPUT(A)*PHI_R(A))
        I:PY(A)   Q:(TOUTPUT(A)*[1/(1+MK0(A)$NMKFLAG)])
+                 A:ENTRE(A)$NMKFLAG  N:NMK(A)$NMKFLAG
```

Equations

[1] original CES functions

$$Y(a)\times\frac{1-\overline{NTFP0}(a)-\overline{TAXREF}(a)}{1-\overline{NTFP0}(a)} = \sum_z DY\_AR(z,a)+DY\_VA(a) \tag{A5.3.1}$$

$$YY(a)\times PHI\_R(a)=Y(a)\times\frac{1+NMK(a)}{1+\overline{MK0}(a)} \tag{A5.3.2}$$

[2] ratio equations: prices

$$py(a)\times\frac{1-\overline{NTFP0}(a)-\overline{TAXREF}(a)}{1-\overline{NTFP0}(a)} = \overline{\theta}_{Y\_AR}(a)\times\sum_z pa(z,a)+\overline{\theta}_{Y\_VA}(a)\times pva(a) \tag{A5.3.3}$$

$$pyy(a)\times PHI\_R(a)=py(a)\times\frac{1+NMK(a)}{1+\overline{MK0}(a)} \tag{A5.3.4}$$

[3] ratio equations: input demand

$$dy\_ar(a)=y(a) \tag{A5.3.5}$$

$$dy\_va(a)=y(a) \tag{A5.3.6}$$

[4] level equations

$$Y(a)=y(a)\overline{TOUTPUT}(a) \tag{A5.3.7}$$

$$DY\_AR(a)=dy\_ar(a)\sum_z\overline{IODZ}(z,a) \tag{A5.3.8}$$

Variables

$py(a)$	Ratio market price for gross output of sector *a*
$pyy(a)$	Ratio *transformed* market price for gross output of sector *a*
$pa(a)$	Ratio market price for Armington aggregate goods of sector *a*
$dy\_ar(a)$	Ratio input demand for Armington aggregate goods of sector *a*
$Y(a)$	Gross output of sector *a*
$YY(a)$	Transformed output of sector *a*
$DY\_AR(a)$	Demand for Armington aggregates
$NMK(a)$	Endogenous markup rate (for monopolistic competition scenario)
$PHI\_R(a)$	Productivity ratio (for firm heterogeneity scenario)

Parameters

$\overline{\theta}_{Y\_AR}(a)$	Share of export value in total output value of sector *a*
$\overline{\theta}_{Y\_VA}(a)$	Share of domestically used value in total output value of sector *a*
$\overline{NTP0}(a)$	Base value of gross output tax on the production of sector *a*
$\overline{TOUTPUT}(a)$	Total output of sector *a*
$\overline{IODZ}(z,a)$	Intermediate inputs for sector *a*
$\overline{TAXREF}(a)$	Tax differentials (for FDI tax reform simulations in Chapter 7)
$\overline{MK0}(a)$	Initial markup rate (for monopolistic competition scenario)

Table A5.4: CET Transformation of Production

MPSGE Declaration

```
$PROD:DX(A)      T:ESUBAR(A,"EAR")
        O:PX(A)  Q:EX(A)
        O:PD(A)  Q:(TOUTPUT(A)-EX(A))
        I:PYY(A) Q:TOUTPUT(A)
```

Equations

[1] original CET function

$$Y(a) = \overline{\alpha}_Y \begin{pmatrix} \overline{\beta}_{Y\_X}(a) \times DY\_X(a)^{(\overline{ESUBAR}-1)/\overline{ESUBAR}} \\ +(1-\overline{\beta}_{Y\_D}(a)) \times DY\_D(a)^{(\overline{ESUBAR}-1)/\overline{ESUBAR}} \end{pmatrix}^{\overline{ESUBAR}/(\overline{ESUBAR}-1)} \quad (A5.4.1)$$

[2] ratio equations: prices

$$pyy(a) = \begin{pmatrix} \overline{\theta}_{Y\_X}(a) px(a)^{1-\overline{ESUBAR}} \\ +\overline{\theta}_{Y\_D}(a) pd(a)^{1-\overline{ESUBAR}} \end{pmatrix}^{1/(1-\overline{ESUBAR})} \quad (A5.4.2)$$

[3] ratio equations: *output* supply (not "*input* demand")

$$dy\_x(a) = yy(a)\left(\frac{py(a)}{px(a)}\right)^{\overline{ESUBAR}} \quad (A5.4.3)$$

$$dy\_d(a) = y(a)\left(\frac{py(a)}{pd(a)}\right)^{\overline{ESUBAR}} \quad (A5.4.4)$$

[4] level equations

$$DY\_X(a) = dy\_x(a) * \overline{EX}(A) \quad (A5.4.5)$$

$$DY\_D(a) = dy\_d(a) * \left(\overline{TOUTPUT}(A) - \overline{EX}(A)\right) \quad (A5.4.6)$$

Variables

px(a)	Ratio market price of export of sector *a*
pd(a)	Ratio market price of domestically used goods of sector *a*
dy_x(a)	Ratio export demand for *Y* (with CET specification) of sector *a*
dy_d(a)	Ratio domestic demand for *Y* (with CET specification) of sector *a*
DY_X(a)	Export demand for *Y* of sector *a*
DY_D(a)	Domestic demand for *Y* of sector *a*

Parameters

$\overline{\theta}_{Y\_X}(a)$	Share of Armington aggregate in the total input of sector *a*
$\overline{\theta}_{Y\_D}(a)$	Share of aggregate value-added in the total input of sector *a*
$\overline{\alpha}_Y$	Shift parameter of CET transformation function
$\overline{\beta}_{Y\_X}(a)$	CET function parameter
$\overline{ESUBAR}$	Elasticity of transformation in CET function of sector *a*
$\overline{EX}(a)$	Export in sector *a*
$\overline{TOUTPUT}(a)-\overline{EX}(a)$	Output in sector *a* for domestic use

Table A5.5: Labour Disaggregation

MPSGE Declaration

```
$PROD:LTOTAL     T:1
        O:ZWL(Z) Q:(SUM(A$MAP(Z,A),CP(A)))
        I:TWL    Q:(SUM(A, CP(A)))
```

```
$PROD:LZ(Z)$(SUM(A$MAP(Z,A),CP(A)))        T:TAU_L
        O:WL(A)$MAP(Z,A)            Q:CP(A)
        I:ZWL(Z)                    Q:(SUM(A$MAP(Z,A),CP(A)))
```

Equations

[1] original CES functions

$$LTOTAL = \overline{\alpha}_{LTOTAL} \prod_z LZ(z)^{\theta_{zwl}(z)} \tag{A5.5.1}$$

$$LZ(z) = \overline{\alpha}_{LZ} \left(\sum_z \overline{\beta}_{LS}(a) LS(a)^{(TAU\_L-1)/TAU\_L} \right)^{TAU\_L/(TAU\_L-1)} \tag{A5.5.2}$$

[2] ratio equations: prices

$$twl = \prod_z zwl(z)^{\theta_{zwl}(z)} \tag{A5.5.3}$$

$$zwl(z) = \left(\sum_z \overline{\theta}_{wl}(a) wl(a)^{(1-TAU\_L)} \right)^{1/(1-TAU\_L)} \tag{A5.5.4}$$

[3] ratio equations: labour supply

$$lz(z) = ltotal \left(\frac{twl}{zwl(z)} \right)^{1} \tag{A5.5.5}$$

$$ls(a) = lz(z) \left(\frac{zwl(z)}{wl(a)} \right)^{TAU\_L} \tag{A5.5.6}$$

[4] level equations

$$TWL = twl \times \sum_a \overline{CP}(a) \tag{A5.5.7}$$

$$ZWL(z) = zwl(z) \times \sum_{\forall map(z,a)} \overline{CP}(a) \tag{A5.5.8}$$

$$WL(a) = wl(a) \times \overline{CP}(a) \tag{A5.5.9}$$

$$LTOTAL = ltotal \times \sum_a \overline{CP}(a) \tag{A5.5.10}$$

$$LZ(z) = lz(z) \times \sum_{\forall map(z,a)} \overline{CP}(a) \tag{A5.5.11}$$

$$LS(a) = ls(a) \times \overline{CP}(a) \tag{A5.5.12}$$

Variables

twl	Ratio total wage level
zwl(z)	Ratio aggregate wage level for industry *z*
wl(a)	Ratio wage level for *sub-industry* sector *a*
lzs(z)	Ratio aggregate labour supply to industry *z*
ltotal	Ratio total supply of labour input
ls(a)	Ratio supply of labour for sector *a*
LTOTAL	Total supply of labour input
LZ(z)	Aggregate labour supply to industry *z*
LS(a)	Supply of labour for sector *a*

Parameters

$\overline{\theta}_{wl}(z)$	Share of labour cost in total labour cost of industry *z*
$\overline{\theta}_{wl}(a)$	Share of labour cost in total labour cost of sector *a*
$\overline{\alpha}_{LTOTAL}$	Shift parameter of CET function of total labour
$\overline{\alpha}_{LZ}$	Shift parameter of CET function of labour by industry
TAU_L	Elasticity of labour transformation between ownerships

Table A5.6: Capital Disaggregation

MPSGE Declaration

```
$PROD:KTOTAL      T:1
        O:ZRK(Z)  Q:(SUM(A$MAP(Z,A),(DP(A)+OP(A))))
        I:TRK     Q:(SUM(A, DP(A)+OP(A)))

$PROD:KZ(Z)$(SUM(A$MAP(Z,A),(DP(A)+OP(A))))        T:TAU_K
        O:RK(A)$MAP(Z,A)    Q:(DP(A)+OP(A))
        I:ZRK(Z)             Q:(SUM(A$MAP(Z,A),(DP(A)+OP(A))))
```

Equations

[1] original CET functions

$$KTOTAL = \overline{\alpha}_{KTOTAL} \prod_{z} KZ(z)^{\theta_{zrk}(z)} \qquad \text{(A5.6.1)}$$

$$KZ(z) = \overline{\alpha}_{KZS}\left(\sum_{\forall map(z,a)} \overline{\beta}_{KS}(a) KS(a)^{(TAU\_K-1)/TAU\_K} \right)^{TAU\_K/(TAU\_K-1)} \qquad \text{(A5.6.2)}$$

[2] ratio equations: prices

$$trk = \prod_{z} zrk(z)^{\theta_{zrk}(z)} \qquad \text{(A5.6.3)}$$

$$zrk(z) = \left(\sum_{\forall map(z,a)} \overline{\theta}_{rk}(a) rk(a)^{(1-TAU\_K)} \right)^{1/(1-TAU\_K)} \qquad \text{(A5.6.4)}$$

[3] ratio equations: capital supply

$$kz(z) = ktotal\left(\frac{trk}{zrk(z)} \right)^{1} \qquad \text{(A5.6.5)}$$

$$ks(a) = kz(z)\left(\frac{zrk(z)}{rk(a)} \right)^{TAU\_K} \qquad \text{(A5.6.6)}$$

[4] level equations

$$TRK = trk \times \sum_{a} \left(\overline{DP}(a) + \overline{OP}(a) \right) \qquad \text{(A5.6.7)}$$

$$ZRK(z) = zrk(z) \times \sum_{\forall map(z,a)} \left(\overline{DP}(a) + \overline{OP}(a) \right) \qquad \text{(A5.6.8)}$$

$$RK(a) = rk(a) \times \left(\overline{DP}(a) + \overline{OP}(a) \right) \qquad \text{(A5.6.9)}$$

$$KTOTAL = ktotal \times \sum_{a} \left(\overline{DP}(a) + \overline{OP}(a) \right) \qquad \text{(A5.6.10)}$$

$$KZ(z) = kz(z) \times \sum_{\forall map(z,a)} (\overline{DP}(a) + \overline{OP}(a)) \qquad \text{(A5.6.11)}$$

$$KS(a) = ks(a) \times (\overline{DP}(a) + \overline{OP}(a)) \qquad \text{(A5.6.12)}$$

Variables

trk	Ratio total return to capital
zrk(z)	Ratio aggregate return to capital for industry *z*
rk(a)	Ratio return to capital at sector *a*
kzs(z)	Ratio aggregate capital supply to industry *z*
ktotal	Ratio total capital supply
ks(a)	Ratio capital supply to for sector *a*
KTOTAL	Total capital supply
KZ(z)	Aggregate capital supply to industry *z*
KS(a)	Capital supply to for sector *a*

Parameters

$\overline{\theta}_{rk}(z)$	Share of capital cost in total labour cost of industry *z*

$\overline{\theta}_{rk}(a)$	Share of capital cost in total labour cost of sector a
$\overline{\alpha}_{KTOTAL}$	Shift parameter of CET function of total capital
$\overline{\alpha}_{KZ}$	Shift parameter of CET function of capital by industry
$\overline{\beta}_{KS}(a)$	CET parameter
TAU_K	Elasticity of capital transformation between ownerships

Table A5.7: Armington Aggregate

MPSGE Declaration

```
$PROD:AR1(Z)  S:10
        O:PAA(Z)             Q:(SUM(A$MAP(Z,A),(ARAG(A)-IM(A))))
        I:PD(A)$MAP(Z,A)   Q:(ARAG(A)-IM(A))$MAP(Z,A)
$PROD:AR(Z)$ARAGZ(Z)  S:ESUBAR(Z,"EAR")
        O:PA(Z)              Q:ARAGZ(Z)
        I:PAA(Z)             Q:(SUM(A$MAP(Z,A),(ARAG(A)-IM(A))))
        I:PM(Z)              Q:(SUM(A$MAP(Z,A), IM(A)))
```

Equations

[1] original CES functions

$$AR1(z)=\overline{\alpha}_{AR1}\left(\sum\overline{\beta}_{AR\_D}(a)AR\_D(a)^{(10-1)/10}\right)^{10/(10-1)} \quad \text{(A5.7.1)}$$

$$AR(z)=\overline{\alpha}_{AR}\begin{pmatrix}\overline{\beta}_{AR\_A}(z)AR1(z)^{(\overline{ESUBAR}-1)/\overline{ESUBAR}}\\ +\overline{\beta}_{AR\_M}(z)MZ(z)^{(\overline{ESUBAR}-1)/\overline{ESUBAR}}\end{pmatrix}^{\overline{ESUBAR}/(\overline{ESUBAR}-1)} \quad \text{(A5.7.2)}$$

[2] ratio equations: prices

$$paa(z)=\left(\sum\theta_{AR\_D}(a)pd(a)^{(1-10)}\right)^{1/(1-10)} \quad \text{(A5.7.3)}$$

$$pa(z)=\begin{pmatrix}\overline{\theta}_{AR\_A}(z)paa(z)^{1-\overline{ESUBAR}}\\ +\overline{\theta}_{AR\_M}(z)pm(z)^{1-\overline{ESUBAR}}\end{pmatrix}^{1/(1-\overline{ESUBAR})} \quad \text{(A5.7.4)}$$

[3] ratio equations: input demand

$$ar\_d(a)=ar1(z)\times\left(\frac{paa(z)}{pd(a)}\right)^{\overline{ESUBAR}} \quad \text{(A5.7.5)}$$

$$mz(z)=ar(z)\times\left(\frac{paa(z)}{pm(z)}\right)^{\overline{ESUBAR}} \quad \text{(A5.7.6)}$$

$$ar1(a)=ar(z)\times\left(\frac{pa(z)}{paa(z)}\right)^{10} \quad \text{(A5.7.7)}$$

[4] level equations

$$AR1(a)=ar1(a)\times\overline{ARAG}(a) \quad \text{(A5.7.8)}$$

$$AR(z)=ar(z)\times\overline{ARAG}(z) \quad \text{(A5.7.9)}$$

$$AR\_D(a)=ar\_d(a)\times(\overline{ARAG}(a)-\overline{IM}(a)) \quad \text{(A5.7.11)}$$

$$MZ(z)=mz(z)\times\overline{IM}(z) \quad \text{(A5.7.12)}$$

$AR1(z) = ar1(z) \times \overline{ARAG(z)}$	(A5.7.13)
Variables	
paa(a)	Ratio price level of Armington aggregate of sector *a*
pm(a)	Ratio price level of imported goods of sector *a*
pa(z)	Ratio price level of Armington aggregate of industry *z*
ar_d(a)	Ratio input demand for domestically produced goods of sector *a*
mz(a)	Ratio input demand for imported goods of sector *a*
ar_a(a)	Ratio input demand for Armington aggregate of industry *z*
ar1(a)	Ratio Armington output of sector *a*
ar(z)	Ratio Armington output of industry *z*
AR_D(a)	Input demand for domestically produced goods of sector *a*
MZ(a)	Input demand for imported goods of sector *a*
AR_A(a)	Input demand for Armington aggregate of industry *z*
AR1(z)	Armington output of sector *a*
AR(z)	Armington output of industry *z*
Parameters	
$\overline{\theta}_{AR\_D}(a)$	Share of domestically produced products in Armington aggregate in sector *a*
$\overline{\theta}_{MZ}(a)$	Share of imported products in Armington aggregate in sector *a*
$\overline{\theta}_{AR\_Z}(a)$	Share of the *a*th Armington goods in upper level Armington aggregate in industry *z*
$\overline{\alpha}_{AR}$	Shift parameter of aggregation over ownerships
$\overline{\alpha}_{AR1}$	Shift parameter of Armington aggregation
$\overline{\beta}_{AR\_D}(a)$	CES parameter of domestic products in Armington aggregation
$\overline{\beta}_{AR\_M}(a)$	CES parameter of import in Armington aggregation
$\overline{\beta}_{AR\_A}(a)$	CES parameter in ownership aggregation
$\overline{ARAG(a)}$	Armington aggregate in sector *a*
$\overline{IM(a)}$	Import in sector *a*

Table A5.8: Export and Import

MPSGE Declaration

```
$PROD: X(A) $EX(A)
          O:PFX    Q:EX(A)
          I:PX(A)  Q:EX(A)

$PROD: M(A) $IM(A)
          O:PMA(A)  Q:IM(A)
          I:PFX     Q:IM(A)

$PROD: MZ(Z) $SUM(A$MAP(Z,A), IM(A))       S:2
          O:PM(Z)                 Q:(SUM(A$MAP(Z,A), IM(A)))
          I:PMA(A)$MAP(Z,A)       Q:IM(A)$MAP(Z,A)
```

Equations

[1] original Leontief functions

$$FX = \sum_{a} \overline{\theta}_{EX\_A}(a)X(a) \qquad \text{(A5.8.1)}$$

$$FX = \sum_{z} \overline{\theta}_{IM\_Z}(z)MZ(z) \qquad \text{(A5.8.2)}$$

$$MZ(z) = \overline{\alpha}_{MZ} \left(\sum_{\forall map(z,a)} \overline{\beta}_{MZ}(a) MA(a)^{(2-1)/2} \right)^{2/(2-1)}$$	(A5.8.3)
[2] ratio equations: prices	
$$pfx = \sum_{a} \overline{\theta}_{EX\_A}(a) px(a)$$	(A5.8.4)
$$\sum_{a} \overline{\theta}_{IM\_A}(a) pma(a) = pfx$$	(A5.8.5)
$$pm(z) = \left(\sum_{a} \overline{\theta}_{IM\_A} pma(a)^{1-2} \right)^{1/(1-2)}$$	(A5.8.6)
[3] ratio equations: input demand	
$$exd(a) = x(a)$$	(A5.8.7)
$$fx = m(a)$$	(A5.8.8)
$$ma(a) = mz(z) \times \left(\frac{pm(z)}{pma(a)} \right)^{2}$$	(A5.8.9)
[4] level equations	
$$X(a) = x(a) \times \overline{EX}(a)$$	(A5.8.10)
$$MZ(a) = m(a) \times \overline{IM}(a)$$	(A5.8.11)
$$EXD(a) = exd(a) \times \overline{EX}(a)$$	(A5.8.12)
$$FX(a) = fx(a) \times \overline{IM}(a)$$	(A5.8.13)
$$M(a) = m(a) \times \overline{IM}(a)$$	(A5.8.14)
Variables	
pfx	Ratio foreign exchange rate
px(a)	Ratio price of exported goods in sector *a*
pm(z)	Ratio price of imported goods in industry *z*
pma(a)	Ratio price of imported goods in sector *a*
exd(a)	Ratio demand for export from sector *a*
x(a)	Ratio export activity in sector *a*
m(a)	Ratio import activity in sector *a*
fx	Ratio demand for foreign currency to import
mz(z)	Ratio import activity in industry *z*
Parameters	
$\overline{\theta}_{EX\_A}(a)$	Share of export of sector *a* in the total export value
$\overline{\theta}_{IM\_Z}(Z)$	Share of import of industry *z* in the total import value
$\overline{\alpha}_{MZ}$	Shift parameter of CES function (A5.8.3)
$\overline{EX}(a)$	Benchmark export value of sector *a*
$\overline{IM}(a)$	Benchmark import value of sector *a*
M(z)	Import activity in industry z

Table A5.9: Public and Private Consumption Demand

MPSGE Declaration

```
$PROD:G          S:1
        O:PG     Q:GO
        I:PA(Z)  Q:GC1(Z)
```

```
$PROD:CS         S:1
         O:PC     Q:TC
         I:PA(Z)  Q:CON(Z)
```

Equations

[1] original CD functions

$$G = \bar{\alpha}_G \prod_z G\_A(z)^{\bar{\theta}_G(z)} \quad \text{(A5.9.1)}$$

$$CS = \bar{\alpha}_{CS} \prod_z G\_A(z)^{\bar{\theta}_P(z)} \quad \text{(A5.9.2)}$$

[2] ratio equations: prices

$$pg = \prod_z pa(z)^{\bar{\theta}_G(z)} \quad \text{(A5.9.3)}$$

$$pc = \prod_z pa(z)^{\bar{\theta}_P(z)} \quad \text{(A5.9.4)}$$

[3] ratio equations: input demand

$$g\_a(z) = g \times \frac{pg}{pa(z)} \quad \text{(A5.9.5)}$$

$$p\_a(z) = cs \times \frac{pc}{pa(z)} \quad \text{(A5.9.6)}$$

[4] level equations

$$G = g \times \overline{GO} \quad \text{(A5.9.7)}$$

$$CS = cs \times \overline{TC} \quad \text{(A5.9.8)}$$

$$G\_A(z) = g\_a(z) \times \overline{GC1}(z) \quad \text{(A5.9.9)}$$

$$P\_A(z) = p\_a(z) \times \overline{CON}(z) \quad \text{(A5.9.10)}$$

Variables

pg	Ratio government expenditure price index
$pa(z)$	Ratio price level for Armington aggregate of industry z
pc	Ratio private consumption price index
$g\_a(z)$	Ratio government demand for the products from industry z
$p\_a(z)$	Ratio private demand for the products from industry z
g	Ratio government consumption
cs	Ratio private consumption

Parameters

$\bar{\theta}_G(z)$	Share of the consumption of goods from industry z in total government expenditure
$\bar{\theta}_P(z)$	Share of the consumption of goods from industry z in total private expenditure
$\bar{\alpha}_G$	Shift parameter of government expenditure function
$\bar{\alpha}_{CS}$	Shift parameter of private expenditure function
$\overline{GO}$	Benchmark total government consumption
$\overline{TC}$	Benchmark total private consumption
$\overline{GC1}(z)$	Government expenditure on industry z
$\overline{CON}(z)$	Private expenditure on industry z

Table A5.10: Investment Demand

MPSGE Declaration

```
$PROD:INV S:1
          O:PINV  Q:TI
          I:PA(Z) Q:ID1(Z)
```

Equations

[1] original CES functions

$$INV = \overline{\alpha}_{INV} \prod_{z} INV\_A(z)^{\overline{\theta}_{INV}(z)} \quad \text{(A5.10.1)}$$

[2] ratio equations: prices

$$pinv = \prod_{z} pa(z)^{\overline{\theta}_{INV}(z)} \quad \text{(A5.10.2)}$$

[3] ratio equations: input demand

$$inv\_a(z) = inv \times \frac{pinv}{pa(z)} \quad \text{(A5.10.3)}$$

[4] level equations

$$INV = inv \times \overline{TI} \quad \text{(A5.10.4)}$$

$$INV\_A(z) = inv\_a(z) \times \overline{ID1}(z) \quad \text{(A5.10.5)}$$

Variables

pinv	Ratio price index for investment
inv_a(z)	Ratio demand for the input from industry *z*
inv	Ratio investment level

Parameters

$\overline{\theta}_{INV}(z)$	Share of the investment from industry *z* in total investment
$\overline{\alpha}_{INV}$	Shift parameter of investment demand function
$\overline{TI}$	Total investment value in benchmark economy
$\overline{ID1}(z)$	Investment demand in industry *z*

Table A5.11: Representative Domestic Agent

MPSGE Declaration

```
$DEMAND:RA
          D:PC    Q:TC
          E:TWL   Q:(SUM(A,CP(A)))
          E:TRK   Q:(SUM(A,((DP(A)+OP(A))*(1-FOREIGN (A)))))
          E:PFX   Q:(TB)
          E:PINV  Q:(-TI)
```

Equations

[1] Agent's activity level

$$ra = twl \times \sum_{a} \overline{CP}(a) + trk \times \sum_{a} (\overline{DP}(a) + \overline{OP}(a))(1 - \overline{FOREIGN}(a)) + pfx \times \overline{TB} + pinv \times (-\overline{TI}) \quad \text{(A5.11.1)}$$

[2] consumption and welfare demand

$$dtc = ra / pc = \overline{TC} \quad \text{(A5.11.2)}$$

$$dwelra = ra / \overline{TC} \quad \text{(A5.11.3)}$$

Variables

ra	Representative agent
dtc	Demand for total consumption

dwelra	Demand for welfare of representative agent
pc	Price index of final consumption
Parameters	
$\overline{TB}$	Trade balance
$\overline{FOREIGN(a)}$	Foreign presence in sector *a*

Table A5.12: Government

MPSGE Declaration

```
$DEMAND:GOV
        D:PG     Q:GO
        E:PC     Q:(SUM[Z,(GC1(Z)-NT(Z))])

* THIS LINE PROVIDES THE SOURCE OF FDI PRODUCTIVITY SPILLOVERS
        E:PVA(SNO)$NTFPFLAG
+         Q:((CP(SNO)+DP(SNO)+OP(SNO))/(1+NTFP0(SNO)))$NTFPFLAG
+                                          R: QNTFP(SNO)$NTFPFLAG
```

Equations

[1] Agent's activity level

$$gov = pc \times \sum_z \left(\overline{GC1}(Z) - \overline{NT}(Z)\right) + \sum_a py(a) \times \overline{TOUTPUT}(a) \times \overline{NTFP0}(a) + \sum_{SNO} pva(SNO) \times \left[\overline{CP}(SNO) + \overline{DP}(SNO) + \overline{OP}(SNO)\right] \times \frac{QNTFP(SNO)}{1 + \overline{NTFP0}(SNO)} \quad \text{(A5.12.1)}$$

[2] consumption/ demand

$$tgo = gov / pg = \overline{GO} \quad \text{(A5.12.2)}$$

Variables

gov	Government activity level
tgo	Level of government demand and redistribution

Parameters

No new ones

Table A5.13: Representative Multinational Firm Agent

MPSGE Declaration

```
$DEMAND:FDI
     E:TRK        Q:(SUM(A,((DP(A)+OP(A))*FOREIGN (A))))
     E:RK(A)       Q:DELTAFDI(A)
     E:PFX        Q:2E+5
     D:PFX        Q:2E+5
     D:PC         Q:(SUM(A,((DP(A)+OP(A))*FOREIGN (A))))
```

Equations

[1] Agent's activity level

$$fdi = trk \times \sum_a \left[\left(\overline{DP}(a) + \overline{OP}(a)\right) \times \overline{FOREIGN}(a)\right] + \sum_a \left[rk(a) \times \overline{DELTAFDI}(a)\right] + pfx \times 2 \times 10^5 \quad \text{(A5.13.1)}$$

[2] consumption demand	
$$dfdi\_c = \left(pc \times \sum_a \left(\overline{DP}(a) + \overline{OP}(a)\right) \times \overline{FOREIGN}(a) \right) \Big/ fdi$$ (A5.13.2)	
Variables	
fdi	Activity level of multinational firms
dfdi_c	Demand level of multinational firms
Parameters	
$\overline{DELTAFDI(a)}$	FDI increment in sector *a*, for subsequent introduction of an FDI shock

Three groups of market equilibrium equations for factors, Armington goods and traded goods respectively are *implicitly* contained but "hidden" in the GAMS/MPSGE syntax. In the following discussions, these equations are listed with demands on the left hand sides and supplies on the right hand sides.

(1) Equilibrium of factor markets

The demands and supply of labour in sector a are given by equation (A5.2.10) and (A5.5.13), respectively. Thus the equilibrium condition for the labour market is:

$$DY\_L(a) = LS(a)$$

The demands and supply of capital in sector a are given by equation (A5.2.11) and (A5.6.14), respectively. Thus the equilibrium condition for capital market is:

$$DY\_K(a) = KS(a)$$

(2) Equilibrium of Armington markets

The demands for Armington aggregate goods originate from three blocks, namely production (Table A5.3), public and private consumption (Table A5.9), and investment demand (Table A5.10). So the total demand for Armington aggregate goods is the sum of over these four demands which are represented by equation (A5.3.9), (A5.9.9), (A5.9.10), and (A5.10.4) respectively.

$$DY\_AR = \sum_a DY\_AR(a) + \sum_z G\_A(z) + \sum_z P\_A(z) + \sum_z INV\_A(z)$$

The total supply of Armington aggregate goods can be obtained by summing equation (A5.7.9) over z:

$$TS\_AR = \sum_{z} AR(Z)$$

Therefore the demand-supply equilibrium equation is:

$$\sum_{a} DY\_AR(a) + \sum_{z} G\_A(z) + \sum_{z} P\_A(z) + \sum_{z} INV\_A(z) = \sum_{z} AR(z)$$

(3) Equilibrium of aggregate export and import

The demand and supply of aggregate export are represented by equation (A5.8.7) and (A5.4.5), respectively. Therefore the equilibrium condition is:

$$DY\_X(a) = X(a)$$

The demand and supply of aggregate import are represented by equation (A5.7.12) and (A5.8.8), respectively. Therefore the equilibrium condition is:

$$AR\_M(a) = M(a)$$

CHAPTER 6: FDI PRODUCTIVITY SPILLOVERS UNDER THREE MARKET STRUCTURES

6.1. INTRODUCTION

This Chapter presents the main research findings of computer simulations based on the theoretical models constructed in Chapter 5. Section 6.2 discusses the effects of an FDI shock *without* productivity spillovers to the economy under perfect competition assumption. Section 6.3, 6.4 and 6.5 examine the effects of an FDI shock *with* productivity spillovers under three market structures respectively, *i.e.* perfect competition, monopolistic competition and firm heterogeneity. The *net* FDI spillover effects will be calculated by deducting the effects of the FDI shock *without* spillovers from the effects of the FDI shock *with* spillovers under three market structures, respectively. The net FDI spillover effects will also be compared across three market structures. Section 6.6 concludes.

6.2. AN FDI SHOCK TO THE BENCHMARK ECONOMY (WITHOUT SPILLOVERS)

An FDI shock without spillovers is introduced into the economy by increasing the capital stock in each foreign-invested sector. The investment data actually take the amount of FDI inflows in 2003, the year subsequent to the benchmark year 2002. As shown in Table 6.1, FDI into the manufacturing sectors account for almost 70% of total FDI. Among manufacturing sectors, the top five sectors in attracting FDI are electronical products (11.9% of total FDI), textile (5.1% of total FDI), raw chemical materials and chemical products (4.9% of total FDI), garments and other fibre products (4.4% of total FDI), and transport equipment (4.4% of total FDI).

When the above FDI shock is introduced into the CGE model by changing the values of $\overline{DELTAFDI(A)}$ in equation (A5.13.1), the changes in sectors of different ownerships are different, as shown in Table 6.2.

Table 6.1: FDI to China by Sectors in 2003 ($ million)

Groups	Sectors	FDI	%
Mining	Coal, petroleum and gas	2,779	0.6
	Ferrous metals mining and dressing	0	0.0
	Nonferrous metals mining and dressing	0	0.0
	Mining of non-metal, other minerals, and other ores	0	0.0
Manufacturing	Food, beverage, and tobacco manufacturing	11,206	2.5
	Textile industry	22,591	**5.1**
	Garments and other fibre products	19,653	**4.4**
	Leather, furs, down and related products	14,344	3.2
	Timber processing, bamboo, cane, palm fibre etc.	3,252	0.7
	Furniture manufacturing	4,438	1.0
	Papermaking and paper products	9,807	2.2
	Printing and record medium reproduction	4,268	1.0
	Cultural, educational and sports goods	7,083	1.6
	Petroleum processing and coking	2,354	0.5
	Raw chemical materials and chemical products	21,518	**4.9**
	Medical and pharmaceutical products	7,864	1.8
	Chemical fibre	3,595	0.8
	Rubber products	5,966	1.3
	Plastic products	16,201	3.7
	Non-metal mineral products	13,615	3.1
	Smelting and pressing of ferrous metals	10,809	2.4
	Smelting and pressing of nonferrous metals	5,836	1.3
	Metal products	16,635	3.8
	Ordinary machinery	12,906	2.9
	Special purpose equipment	10,128	2.3
	Transport equipment	19,622	**4.4**
	Electronic and electric products	52,490	**11.9**
	Instruments, meters, cultural and office machinery	13,671	3.1
Utilities	Production of electric power, steam and hot water	4,549	1.0
	Production of gas	3,919	0.9

	Production of tap water	2,244	0.5
Agriculture	Farming, forestry, animal husbandry & fishing	8,278	1.9
Construction	Construction	5,061	1.1
Banking and Insurance	Banking and insurance	1,919	0.4
Real Estate	Real estate	43,302	9.8
Other services	Geological perambulation & water conservancy; transport, storage, post & telecommunication services; wholesale & retail trade & catering; social services; healthcare, sports & social welfare; education, culture, radio, films & television; scientific and technical services	60,578	13.7
	Public administration & other services	0	0.0
Subtotal	**All manufacturing**	309,852	**69.9**
Total	**All sectors**	**442,481**	**100**

Source: Ministry of Commerce of China; *China Industrial Economy Statistical Yearbook 2004* (National Bureau of Statistics of China, 2004). Compilations by the author.

Table 6.2: Effects of an FDI Shock to the Benchmark Economy (without Spillovers)

Variables	Change (%)
National output	5.9
GDP	5.7
Output of foreign-invested enterprises in MMU	20.8
Output of domestic enterprises (SOEs + private) in MMU	-1.9
-- SOEs	-0.6
-- private enterprises	-2.3
Output of non-MMU sectors (both foreign and domestic)	6.3
Welfare (equivalent variation)	2.5

Note: (a) MMU is composed of mining, manufacturing, and utilities. (b) Welfare level (or equivalent variation) denotes the scale of total consumption by the representative consumer. (c) Elasticity of transformation of capital and labour (τ_K, τ_L) = (2.0, 0.5)

Table 6.2 shows that an FDI shock to the benchmark economy can help the output of foreign-invested enterprises in the MMU sectors (*i.e.* manufacturing, mining and utilities) surge by 20.8%, while the domestic enterprises (both SOEs and private) are negatively affected. This negative impact is caused by the expansion of foreign-invested firms which attract labour away from the domestic enterprises in the same industries. Nonetheless, the overall impact of FDI to total output, GDP and welfare is positive.

Table 6.3 shows how FDI affects the performance of enterprises of different ownership in the top five FDI recipient industries. The changing patterns of output, value added, and export are consistent with those exhibited by Table 6.2, *i.e.* the outputs of foreign-invested enterprises increase dramatically, while the outputs of domestic enterprises contract.

Table 6.3: Impacts of FDI on Enterprises with Different Ownerships in the top 5 Recipient Sectors in Manufacturing (%) (without Spillovers)

		Export	Output	P_L	P_K
	FIEs	46.1	39.9	7.7	-39.3
Textile	SOEs	-7.9	-4.0	-4.6	-1.3
	Private	-8.8	-4.7	-5.4	-2.4
	FIEs	43.4	31.9	5.2	-34.4
Garments	SOEs	-5.9	-9.1	-9.0	-4.6
	Private	-5.9	-9.1	-9.0	-4.6
	FIEs	41.6	32.7	6.5	-29.2
Chemicals	SOEs	-5.5	-3.2	-2.6	-0.5
	Private	-6.0	-3.6	-3.0	-1.2
	FIEs	31.0	16.1	-2.2	-24.6
Transport	SOEs	0.5	-4.6	-7.5	-2.3
	Private	-0.9	-5.5	-8.5	-3.7
	FIEs	15.7	12.0	4.7	-12.5
Electronicals	SOEs	-5.2	-4.6	-0.8	0.0
	Private	-5.3	-4.7	-0.9	-0.1

Source: Same as Table 6.2.

Prices of capital are generally pulled down by the influx of foreign capital. Due to the imperfect transformability (with a benchmark elasticity of 2) of capital between foreign-invested and domestic enterprises, prices of capital in domestic sectors do not decrease with a magnitude as large as those in foreign-invested sectors.

Prices of labour in foreign-invested sectors are generally higher as more foreign capital is pursuing the limited amount of labour. Due to the very low transformability (with an benchmark elasticity of 0.5) of labour between foreign-invested and domestic enterprises, a contraction of domestic sectors will lead to less demand for labour and pulls down the price of labour.

The elasticity of transformation of labour between ownerships is lower than that of capital because inter-ownership labour mobility is still very low in China. According to a recent firm-level survey conducted by the Asia Market Intelligence (see Table 6.4), in the 1,500 firms surveyed, only about **0.2%** of the employees had work experience in foreign-invested enterprises in 2000. The labour mobility in the other direction, *i.e.* from domestic firms to foreign-invested firms should be higher given the higher salary (Zhao, 2002) and more vibrant work environment in the latter. In brief, the labour mobility between ownerships is a rather unidirectional one, if any. Knight and Yueh (2004) also argue that the inter-firm labour mobility in urban areas in China is still very low in 1999. Therefore it is reasonable to set a relatively low benchmark parameter value for the elasticity of transformation of labour.

Table 6.4: Employees with Employment History in Foreign Firms, 2000

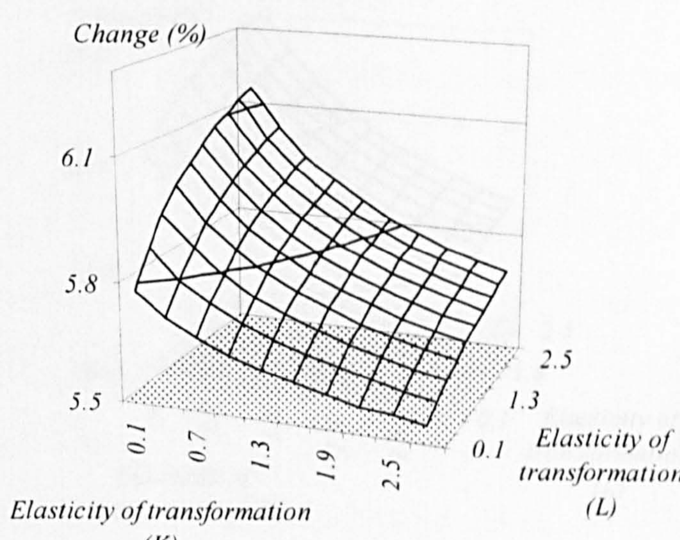
Industries	Number of surveyed firms	Percentage
Accounting and related services	104	0.5%
Advertising and marketing	89	0.4%
Apparel and leather goods	222	0.1%
Business logistics services	110	0.0%
Communication services	71	0.0%
Consumer products	165	0.1%
Electronic components	203	0.2%
Electronic equipment	192	0.6%
Information technology services	128	0.6%
Vehicles and vehicle parts	216	0.1%
Total	**1,500**	**0.2%**

Source: Asia Market Intelligence.

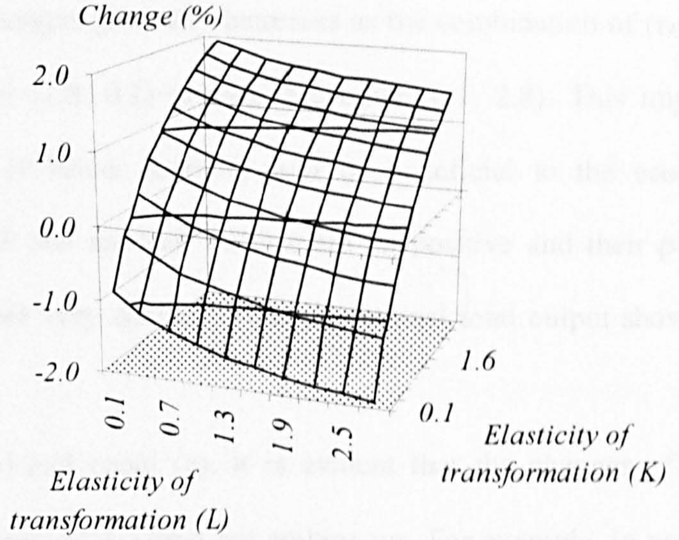
However, as a robustness check, we can also try different parameter values for the elasticities of capital (τ_K) and labour (τ_L) transformation and see how the results will change accordingly. In the experiments, τ_K takes 10 alternative values (τ_K =0.1, 0.4, 0.7, …, 2.8) consecutively, and τ_L also takes these 10 values consecutively as well. While some studies take 3 or 4 as the elasticity of capital transformation in the literature (e.g. Lejour, Rojas-Romagosa and Verweij, 2008; Springer, 1998), 3 is taken here as the upper limit given the idiosyncratic characteristics of foreign capital, state capital and private capital in the Chinese economy in transition. 3 is also set as the upper limit for the elasticity of labour transformability due to the reasons discussed earlier. Therefore there are in total 10×10=100 sets of combinations of (τ_K, τ_L). The CGE model is run for each of these 100 sets of parameters and thus can generate 100 simulation results, as shown in the 3-dimension diagrams in Figure 6.1. The X and Y axes are parameter values, while the vertical axis represents the values in regard. A "value net" has 100 "knots" with each of them corresponding to a combination of (τ_K, τ_L).

Figure 6.1: Impact of FDI Shock on Output under Perfect Competition (without Spillovers)

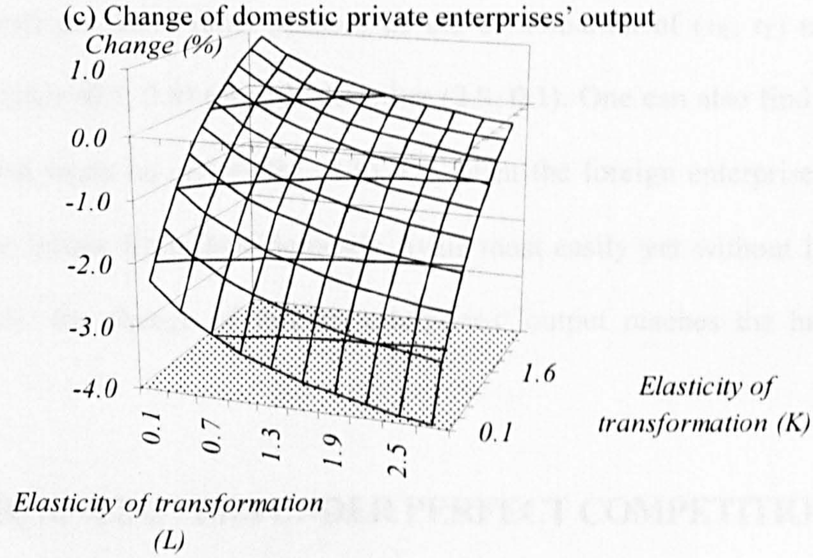
(a) Total output change



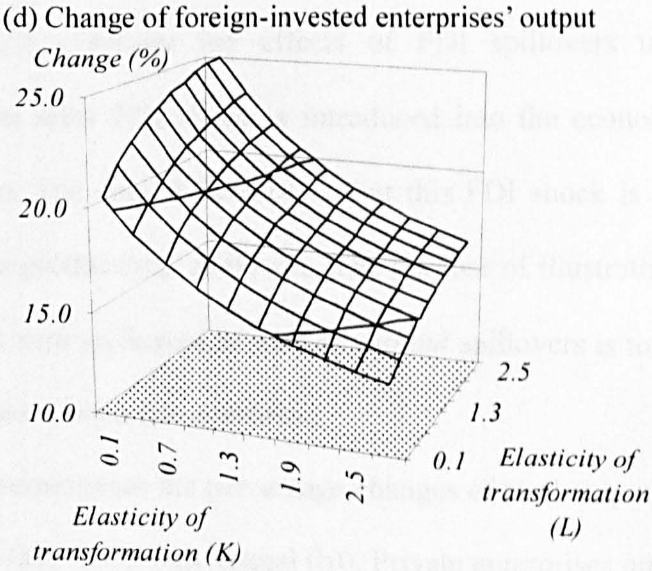
(b) Change of domestic SOEs' output



(c) Change of domestic private enterprises' output



(d) Change of foreign-invested enterprises' output



From panel (a), one can see that total output always increases. The magnitude of changes gradually increases as the combination of (τ_K, τ_L) moves from one corner (2.8, 0.1) towards the other (0.1, 2.8). This implies that a higher degree of labour mobility will be beneficial to the economy. The changes of GDP and national welfare are all positive and their patterns (not reported here) are very similar to that of national total output shown in Panel (a).

In panel (b) and panel (c), it is evident that the changes of SOEs and Private enterprises' total output are ambiguous. For example, in panel (b), the output change gradually turns positive as the combination of (τ_K, τ_L) moves from one corner (0.1, 2.8) towards the other (2.8, 0.1). One can also find from panel (d) that when (τ_K, τ_L) = (0.1, 2.8), *i.e.* when the foreign enterprises can attract away labour from their domestic rivals most easily yet without losing much capital, the change of foreign enterprises' output reaches the highest level.

6.3. FDI SPILLOVERS UNDER PERFECT COMPETITION

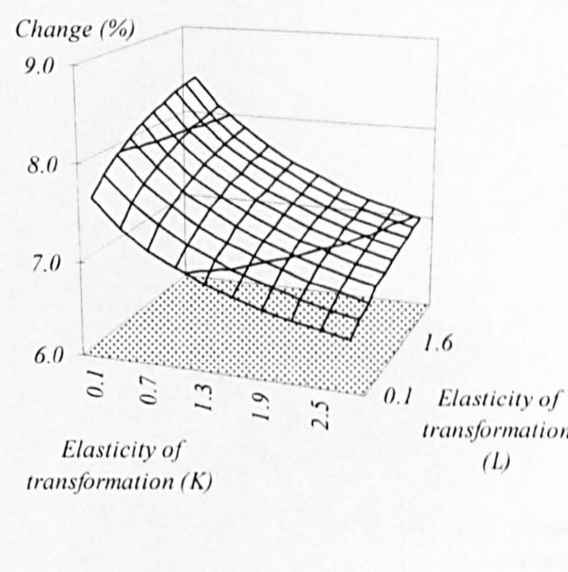
This Section examines the effects of FDI spillovers under perfect competition. The same FDI shock is introduced into the economy as in the previous Section. The only difference is that this FDI shock is accompanied with endogenous productivity spillovers. The purpose of illustrating the effects of an FDI shock *with* spillovers as well as *without* spillovers is to facilitate the comparison between three two scenarios.

Figure 6.2 summarises the percentage changes of total output of the whole economy (panel (a)), SOEs only (panel (b)), Private enterprises only (panel (c)), and FIEs only (panel (d)). A comparison of the corresponding panels of Figure 6.1 and 6.2 exhibits highly similar effects of FDI shock with or without FDI productivity spillovers. When (τ_K, τ_L) moves from the corner of (low, high) to the corner of (high, low), SOEs and Private enterprises benefit more from the FDI shock. However the FIEs will lose more as (τ_K, τ_L) moves towards the (high, low) corner, because capital is more easily attracted away to SOEs and Private enterprises, while labour is more difficult to be attracted by the FIEs. Collectively, **national** total output benefits more as (τ_K, τ_L) is moving from the corner of (high, low) to the corner of (low, high).

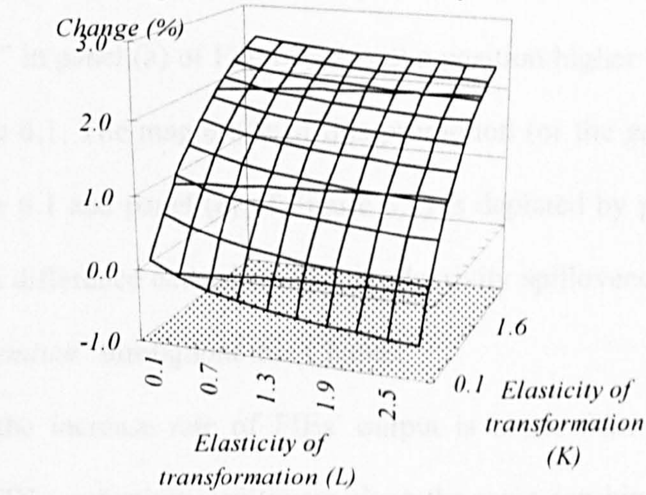
The changes of GDP and national welfare are all positive and their patterns are very similar to that of total output shown in panel (a) of Figure 6.2. So their diagrams are skipped here.

Figure 6.2: Impact of FDI Shock on Output under Perfect Competition (with Spillovers)

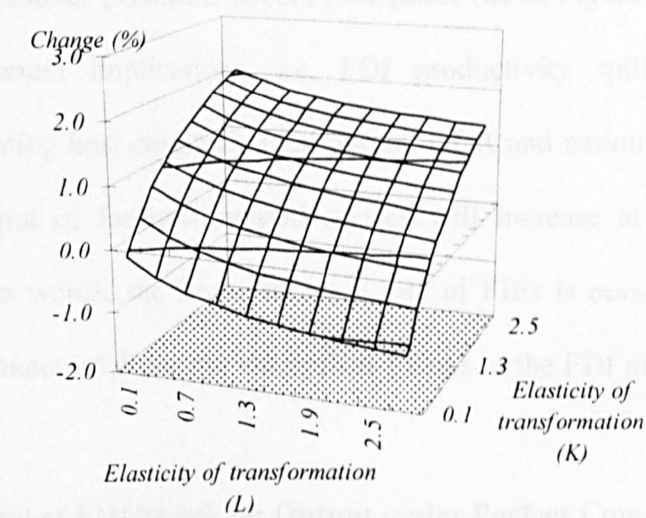
(a) Total output change



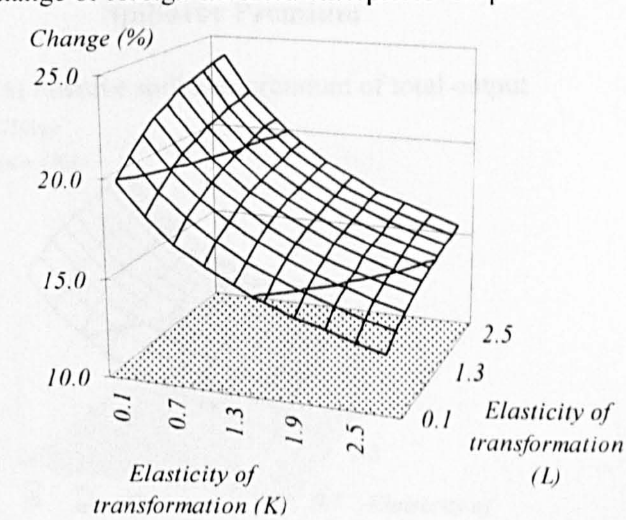
(b) Change of domestic SOEs' output



(c) Change of domestic private enterprises' output



(d) Change of foreign-invested enterprises' output

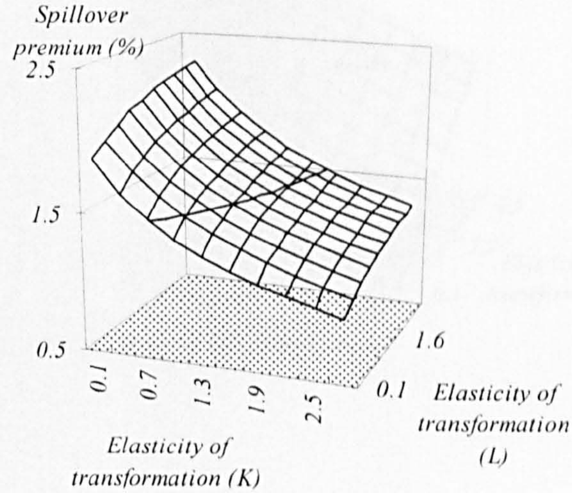


Although Figure 6.1 and 6.2 look very similar, there exist differences between them. For example, the increase rates of national total output are higher than those in the scenario without FDI productivity spillovers. That is to say, the "value net" in panel (a) of Figure 6.2 is at a position higher than that in panel (a) of Figure 6.1. The magnitude of this promotion (or the *gap* between panel (a) of Figure 6.1 and panel (a) of Figure 6.2) is depicted by panel (a) of Figure 6.3. Such a difference caused by FDI productivity spillovers is referred to as "*spillover premium*" throughout this Chapter.

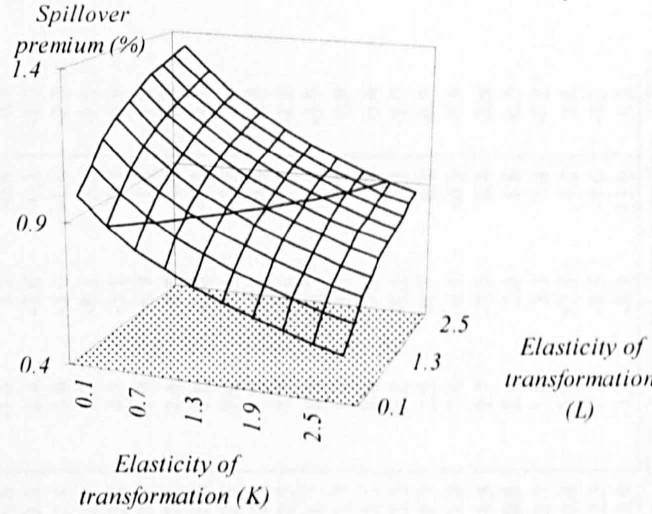
Nonetheless, the increase rate of FIEs' output is lower than that in the scenario without FDI productivity spillovers given the same combination of (τ_K, τ_L), *i.e.* negative spillover premium occurs (see panel (d) in Figure 6.3). This contrast has important implications, *i.e.* FDI productivity spillovers are beneficial to promoting host country's total output, GDP, and national welfare, although total output of foreign-invested sectors will increase at a smaller magnitude. In other words, the lower increase rate of FIEs is *outweighed* by even better performance of domestic enterprises thanks to the FDI productivity spillovers.

Figure 6.3: Impact of FDI Shock on Output under Perfect Competition: Spillover Premium

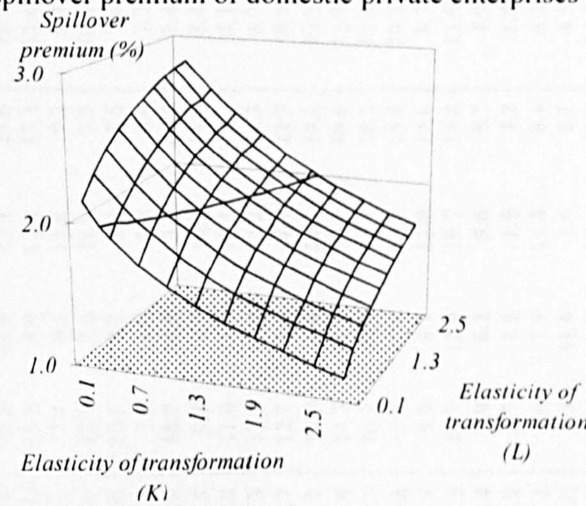
(a) Positive spillover premium of total output



(b) Positive spillover premium of domestic SOEs' output



(c) Positive spillover premium of domestic private enterprises' output



(d) Negative spillover premium of foreign-invested enterprises' output

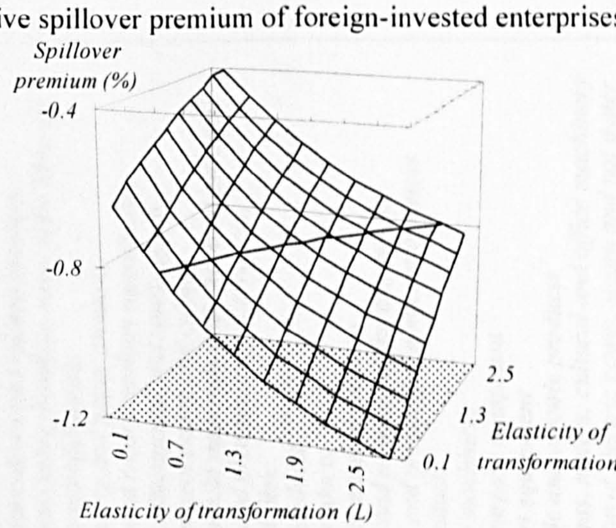


Table 6.5: Changes (%) of SOEs with an FDI Shock under Perfect Competition

	*FDI**	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*
Coal, petroleum and gas	0.6	7.8	7.6	6.8	9.6	6.7	0.8	-4.5	8.8	1.3	2.0
Ferrous metals mining and dressing	0.0	7.2	18.0	-2.6	N.A.	11.2	1.2	-3.9	9.1	1.8	1.9
Nonferrous metals mining and dressing	0.0	8.8	19.7	-2.0	-2.9	12.3	1.3	-6.4	15.4	3.5	3.4
Mining of non-metal, other minerals, and other ores	0.0	9.6	13.9	-1.9	-2.5	9.6	0.8	-4.2	7.7	0.6	1.6
Food, beverage, and tobacco manufacturing	2.5	4.7	3.0	0.8	1.4	1.4	0.2	-16.2	22.2	0.0	6.1
Textile industry	**5.1**	**14.0**	**12.6**	**16.6**	**21.0**	**11.8**	**2.6**	**0.6**	**7.8**	**2.0**	**0.4**
Garments and other fibre products	**4.4**	**14.8**	**9.6**	**9.9**	**9.2**	**8.7**	**2.4**	**6.6**	**-7.5**	**0.3**	**-1.6**
Leather, furs, down and related products	3.2	9.5	10.4	10.2	10.5	7.1	2.8	5.7	4.0	4.2	-0.4
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.3	13.9	17.4	23.6	13.3	1.6	-1.6	3.1	-0.6	0.3
Furniture manufacturing	1.0	13.5	8.9	17.4	17.3	13.6	2.3	6.4	-7.6	-0.3	-1.7
Papermaking and paper products	2.2	12.4	9.3	13.8	9.2	9.4	2.4	5.0	-3.0	-1.6	-2.2
Printing and record medium reproduction	1.0	12.9	7.6	11.9	9.3	10.0	1.7	5.7	-8.3	-3.6	-3.1
Cultural, educational and sports goods	1.6	10.5	8.7	9.8	8.5	7.6	2.3	4.3	-5.1	0.7	-0.9
Petroleum processing and coking	0.5	7.2	11.0	6.6	8.6	7.2	0.7	-1.9	6.9	1.8	1.8
Raw chemical materials and chemical products	**4.9**	**10.7**	**10.9**	**13.3**	**16.5**	**9.4**	**2.2**	**2.6**	**3.5**	**1.7**	**-0.3**
Medical and pharmaceutical products	1.8	9.8	9.9	10.2	14.3	8.4	1.6	-1.6	-3.6	-5.2	-1.1
Chemical fibre	0.8	11.0	11.8	10.1	12.8	8.1	2.5	9.4	-1.1	2.5	-2.0
Rubber products	1.3	12.2	7.8	12.4	14.3	8.7	2.3	1.5	0.3	-0.8	-0.7
Plastic products	3.7	12.7	7.0	14.1	12.3	8.5	2.5	7.7	-1.6	1.5	-1.8
Non-metal mineral products	3.1	10.9	6.8	14.7	14.2	10.2	1.7	8.0	-10.7	-3.9	-3.9
Smelting and pressing of ferrous metals	2.4	14.7	11.9	31.0	46.0	15.0	1.7	1.1	3.3	1.0	0.0
Smelting and pressing of nonferrous metals	1.3	16.1	6.8	24.4	38.3	10.4	2.1	0.4	7.5	2.8	0.6
Metal products	3.8	15.8	7.8	13.7	15.4	10.2	2.2	9.2	-5.2	1.5	-1.9
Ordinary machinery	2.9	9.9	8.2	12.9	13.6	8.7	1.7	3.9	-0.7	0.8	-0.7
Special purpose equipment	2.3	10.7	12.9	19.7	14.8	13.0	1.8	7.9	-6.1	-0.3	-1.9
Transport equipment	**4.4**	**7.9**	**6.1**	**5.6**	**5.7**	**4.9**	**1.5**	**9.7**	**-7.1**	**0.4**	**-2.0**
Electronic and electric products	**11.9**	**3.7**	**2.5**	**1.5**	**1.2**	**1.5**	**0.8**	**2.9**	**2.4**	**1.5**	**-0.3**
Instruments, meters, cultural and office machinery	3.1	5.6	7.9	11.4	8.4	6.2	2.7	1.4	3.1	0.8	-0.2
Production of electric power, steam and hot water	1.0	6.2	11.4	1.4	0.1	4.5	0.8	-3.7	12.5	4.2	2.8
Production of gas	0.9	9.3	10.2	20.8	51.1	14.2	2.3	7.7	-8.5	-1.6	-3.2
Production of tap water	0.5	9.0	10.9	160.2	N.A.	26.3	2.9	-4.3	-8.2	-13.0	-3.3

Note: (1) *FDI*: percentage of total FDI in corresponding sectors; (2) *BL*: backward linkages; *FL*: forward linkages; *HZDS*: horizontal demonstration; *EXCO*: export concentration of FIEs; *NTFP*: share of TFP spillovers in total TFP, measured by equation (5.8); *TFP*: industry-level productivity, measured by the denominator of fraction (5.8); *Export*: export of SOEs; *Output*: total output of SOEs; *PL*: average wage level of SOEs; *PK*: average wage level of SOEs; *Variety*: number of firms; *Scale*: production scale of each variety. (3) $(\tau_K, \tau_L) = (2.0, 0.5)$; (4) Data not available are marked "N.A.", as the initial values are zero and it is not possible to calculate the percentage changes.

Table 6.6: Changes (%) of Private Enterprises with an FDI Shock under Perfect Competition

	FDI	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*
Coal, petroleum and gas	0.6	7.8	7.6	6.8	9.6	6.0	1.5	-3.5	8.8	2.1	1.9
Ferrous metals mining and dressing	0.0	7.2	18.0	-2.6	N.A.	13.7	2.9	-1.9	9.1	3.5	1.8
Nonferrous metals mining and dressing	0.0	8.8	19.7	-2.0	-2.9	14.1	3.2	-5.5	15.4	4.3	3.3
Mining of non-metal, other minerals, and other ores	0.0	9.6	13.9	-1.9	-2.5	10.1	1.5	-2.9	7.7	1.6	1.5
Food, beverage, and tobacco manufacturing	2.5	4.7	3.0	0.8	1.4	1.2	0.6	-14.6	22.2	1.4	6.0
Textile industry	**5.1**	**14.0**	**12.6**	**16.6**	**21.0**	**9.3**	**5.0**	**0.2**	**7.8**	**1.7**	**0.4**
Garments and other fibre products	**4.4**	**14.8**	**9.6**	**9.9**	**9.2**	**5.1**	**2.9**	**6.3**	**-7.5**	**0.1**	**-1.6**
Leather, furs, down and related products	3.2	9.5	10.4	10.2	10.5	5.6	4.9	-6.1	4.0	-5.5	0.2
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.3	13.9	17.4	23.6	11.7	3.6	-0.1	3.1	0.6	0.2
Furniture manufacturing	1.0	13.5	8.9	17.4	17.3	10.9	3.9	6.1	-7.6	-0.6	-1.7
Papermaking and paper products	2.2	12.4	9.3	13.8	9.2	6.6	4.9	6.8	-3.0	-0.3	-2.3
Printing and record medium reproduction	1.0	12.9	7.6	11.9	9.3	7.8	2.7	11.6	-8.3	0.5	-3.5
Cultural, educational and sports goods	1.6	10.5	8.7	9.8	8.5	5.6	2.9	5.3	-5.1	1.5	-1.0
Petroleum processing and coking	0.5	7.2	11.0	6.6	8.6	6.5	1.8	-2.2	6.9	1.6	1.8
Raw chemical materials and chemical products	**4.9**	**10.7**	**10.9**	**13.3**	**16.5**	**7.1**	**4.5**	**2.3**	**3.5**	**1.5**	**-0.2**
Medical and pharmaceutical products	1.8	9.8	9.9	10.2	14.3	6.6	3.0	5.7	-3.6	0.2	-1.6
Chemical fibre	0.8	11.0	11.8	10.1	12.8	5.5	5.0	5.1	-1.1	-0.6	-1.7
Rubber products	1.3	12.2	7.8	12.4	14.3	5.9	4.2	0.4	0.3	-1.7	-0.6
Plastic products	3.7	12.7	7.0	14.1	12.3	5.7	4.5	6.9	-1.6	0.9	-1.7
Non-metal mineral products	3.1	10.9	6.8	14.7	14.2	7.9	3.5	13.2	-10.7	-0.2	-4.3
Smelting and pressing of ferrous metals	2.4	14.7	11.9	31.0	46.0	12.9	4.0	2.6	3.3	2.1	-0.1
Smelting and pressing of nonferrous metals	1.3	16.1	6.8	24.4	38.3	7.0	4.3	-1.5	7.5	1.4	0.7
Metal products	3.8	15.8	7.8	13.7	15.4	6.6	4.0	7.2	-5.2	0.0	-1.8
Ordinary machinery	2.9	9.9	8.2	12.9	13.6	7.1	3.2	5.0	-0.7	1.6	-0.8
Special purpose equipment	2.3	10.7	12.9	19.7	14.8	13.4	3.9	9.5	-6.1	0.8	-2.0
Transport equipment	**4.4**	**7.9**	**6.1**	**5.6**	**5.7**	**3.1**	**2.3**	**7.5**	**-7.1**	**-1.0**	**-1.9**
Electronic and electric products	**11.9**	**3.7**	**2.5**	**1.5**	**1.2**	**0.7**	**1.0**	**2.2**	**2.4**	**1.0**	**-0.3**
Instruments, meters, cultural and office machinery	3.1	5.6	7.9	11.4	8.4	7.2	5.0	3.3	3.1	2.5	-0.2
Production of electric power, steam and hot water	1.0	6.2	11.4	1.4	0.1	3.4	1.5	-5.0	12.5	3.0	2.9
Production of gas	0.9	9.3	10.2	20.8	51.1	12.0	5.8	0.9	-8.5	-6.8	-2.8
Production of tap water	0.5	9.0	10.9	160.2	N.A.	40.7	8.1	21.3	-8.2	4.8	-5.1

Note: same as Table 6.5

Table 6.5 and 6.6 provide detailed illustrations of how the FDI shock has affected the performance of SOEs and private firms. The column of "FDI" measures the percentage of FDI of each sector in total FDI. The columns of *BL*, *FL*, *HZDS*, and *EXCO* show the percentage changes of the four spillover variables, namely backward linkages, forward linkages, horizontal demonstrations, and export concentration of foreign-invested enterprises, respectively. As shown in Table 6.5 and 6.6, almost all four spillover variables have increased due to the FDI shock.

As introduced in Section 5.4, the changes of the values of the above spillover variables will affect the productivity spilt over from foreign firms to domestic firms. The contribution of FDI productivity spillovers to the total productivity measured by equation (5.8) in Chapter 5 will also change endogenously. This change is shown in the column "*NTFP*". For both SOEs and private firms in almost all industries, the contribution of FDI spillovers to their productivity has increased. For SOEs, the "production of tap water" gains the most from the FDI spillovers. This is probably because the FDI volume in this industry was relatively low. For the private enterprises, the industry "instruments, meters, cultural and office machinery" benefit most for a similar reason.

While the column "*NTFP*" measures the contribution rate of FDI spillovers to total productivity, "*TFP*" simply measures the total productivity as measured by $\hat{\alpha}_1 + \hat{\boldsymbol{\beta}} \times \boldsymbol{SPL}$ in equation (5.8). The FDI productivity spillovers also make the total TFP of each industry improve. Almost all SOEs and private enterprises in all industries have a positive TFP change with the FDI shock. However, the top five FDI recipient industries are not necessarily among the top recipient industries of such FDI spillovers. The reason for this "inconsistency" is that FDI shock affects the productivity of domestic enterprises via four spillover channels, and the importance of these channels varies, as shown in Table 5.3 in Chapter 5.

Regarding the total output in the "*output*" column and product price in the "*price*" column, the results are mixed. The reasons are twofold. On the one hand, the FDI shock can generally improve the productivity of domestic enterprises (SOEs and private firms), which can potentially raise their total output. On the other hand, the FDI shock can attract away resources from domestic firms and pose threat to the latter. The above two forces make the collective results ambiguous.

6.4. FDI SPILLOVERS UNDER MONOPOLISTIC COMPETITION

6.4.1. Impact of Spillovers on Output

Similar to the scenario of perfect competition, the FDI productivity spillovers in the scenario of monopolistic competition can also exert positive impacts on national total output, GDP, welfare, and total output of domestic enterprises. Total products of foreign invested enterprises will increase at a lower rate due to the fact that limited resources are attracted by domestic enterprises which become more productive with FDI productivity spillovers.

The initial number of firms, and also the number of varieties, is set to be 8 in each ownership type in each industry in the benchmark economy. Figure 6.3 provides a summary of the findings. Panel (a) shows that the national total output with spillover increases, with a highest increase rate at (τ_K, τ_L) = (0.1, top recipient industries of such FDI spillovers. The reason for this "inconsistency" is that FDI shock affects the productivity of domestic enterprises via four spillover channels, and the importance of these channels varies, as shown in Table 5.3 in Chapter 5.

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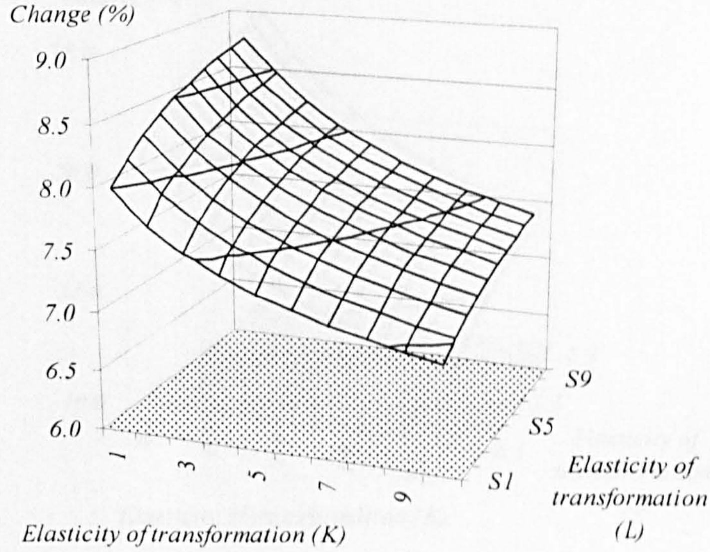
2.8). The changes of GDP and national welfare (not shown in diagrams) also show the similar pattern of positive changes, *i.e.* when (τ_K, τ_L) approaches (0.1, 2.8), the increase rates of GDP and welfare are the highest.

Both SOEs (see panel (b)) and Private enterprises (see panel (c)) benefit the most from FDI spillovers if labour can not easily be attracted away by foreign enterprises and they can easily absorb capital from the latter, *i.e.* when (τ_K, τ_L) approaches (2.8, 0.1). In contrast, the total output of FIEs (see panel (d)) increases by the least when (τ_K, τ_L) = (2.8, 0.1). However, panel (a) shows that the national total output increases most when (τ_K, τ_L) = (0.1, 2.8) because the increase in the foreign enterprises outweighs the loss incurred in the domestic enterprises.

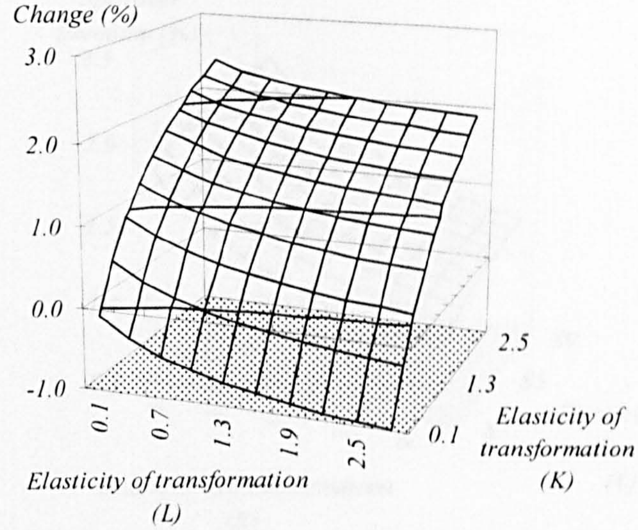
Panel (e), (f), (g) and (h) depict the productivity "spillover premium" under monopolistic competition that exists between the effects of FDI shock *with* and *without* spillovers. Domestic enterprises get a positive premium while foreign enterprises' premium is negative. But the overall premium is collectively positive, *i.e.* a conclusion similar to Section 6.3.

Figure 6.4: FDI Spillover Effects under Monopolistic Competition

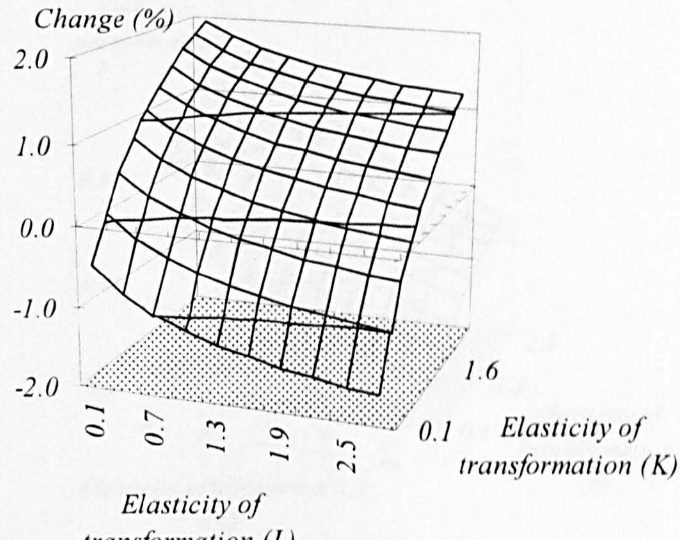
(a) *Total* output change with spillovers



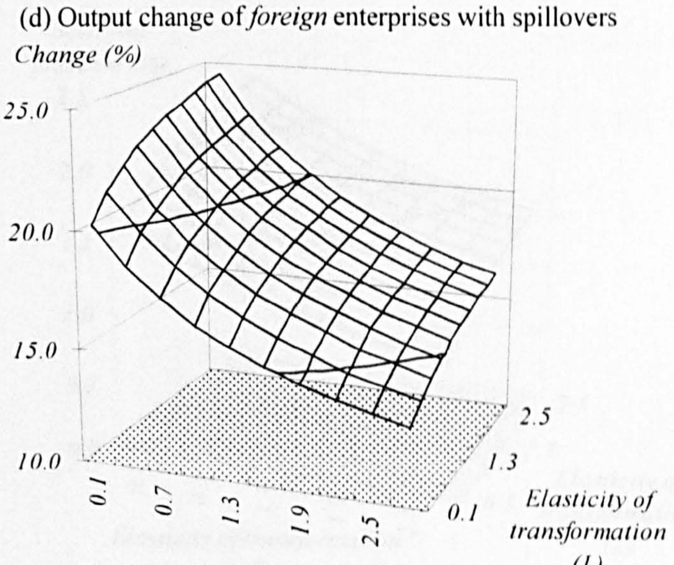
(b) Output change of *SOEs* with spillovers



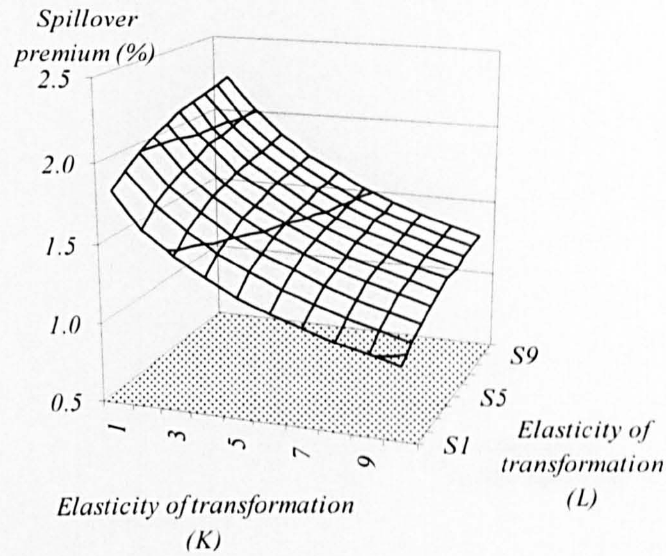
(c) Output change of *private* enterprises with spillovers



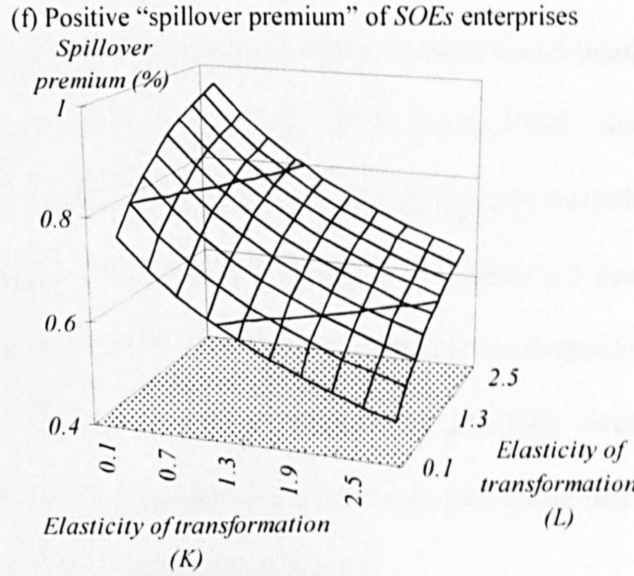
(d) Output change of *foreign* enterprises with spillovers



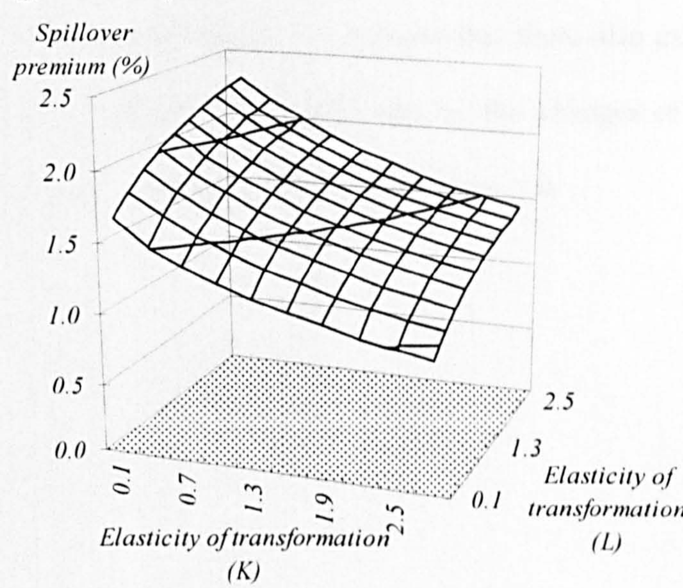
(e) Positive "spillover premium" of *total* output



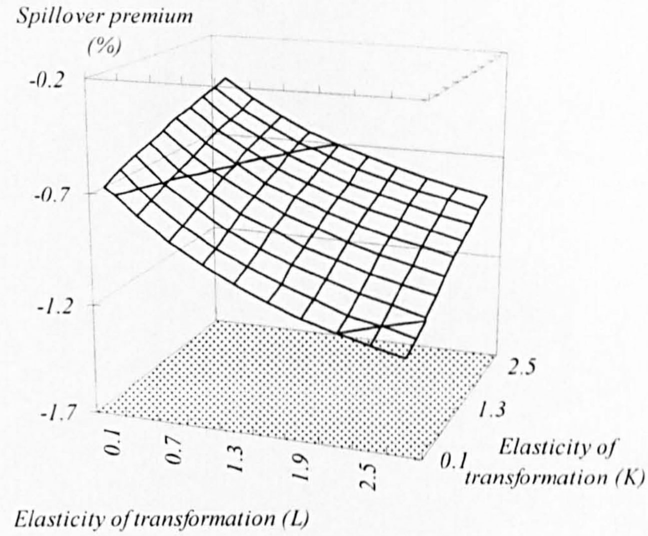
(f) Positive "spillover premium" of *SOEs* enterprises



(g) Positive "spillover premium" of *Private* enterprises



(h) Negative "spillover premium" of *foreign* enterprises



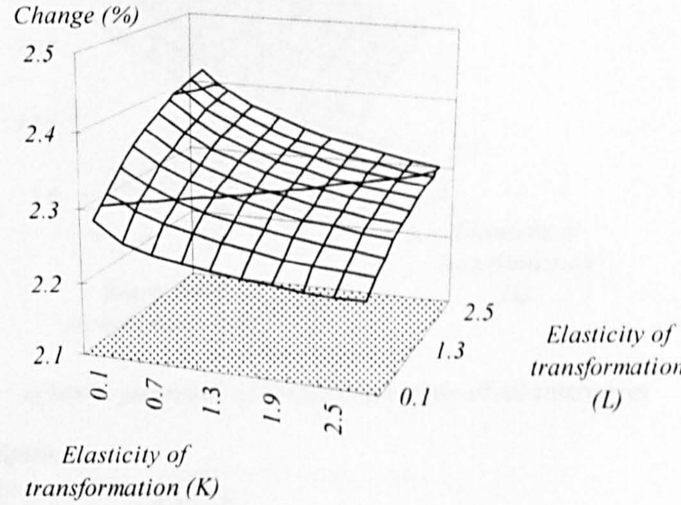
6.4.2. Impact of Spillovers on Product Varieties and Scale

Another important impact of FDI productivity spillovers under monopolistic competition is reflected by the changes of varieties and scale of domestic enterprises. From panel (b) and (c) of Figure 6.5 one can find that, with FDI productivity spillovers under monopolistic competition, the number of varieties produced by *domestic* enterprises generally decreases. But the number of total varieties in each sector increases (see panel (a)) thanks to more varieties created by foreign-invested sectors.

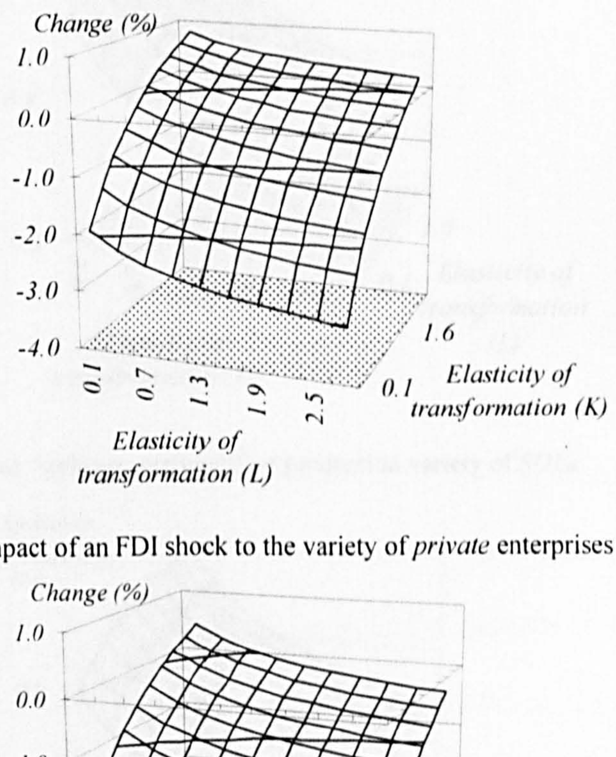
Panel (e), (f) and (g) of Figure 6.5 indicate that there also exists positive "spillover premium" effects of FDI spillovers on the changes of variety, *i.e.* $\Delta N/N_0$ (with spillovers) $-\Delta N'/N'_0$ (without spillovers) > 0.

Figure 6.5: Variety Changes with FDI Productivity Spillovers under Monopolistic Competition

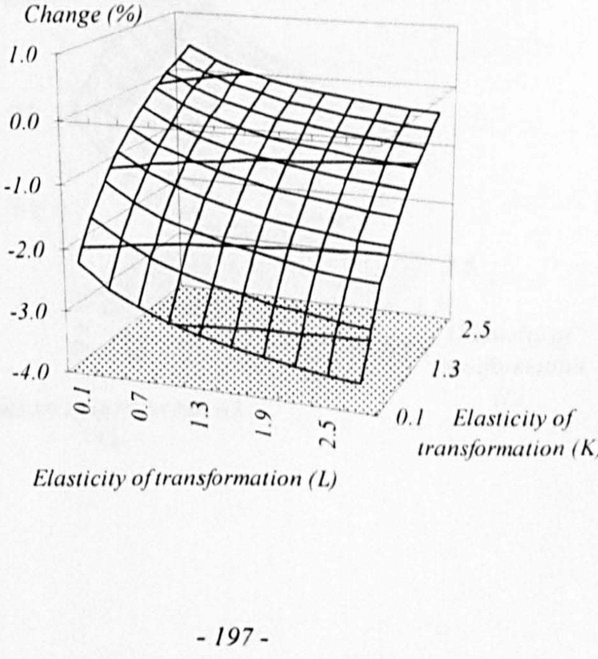
(a) Positive impact of an FDI shock to the variety of *all* enterprises



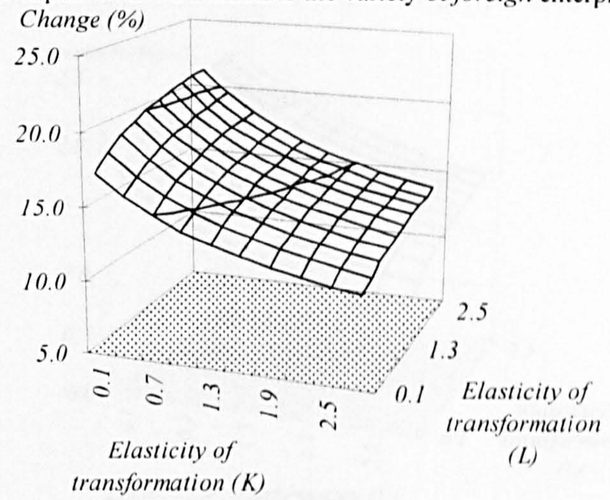
(b) Mixed impact of an FDI shock to the variety of *SOEs*



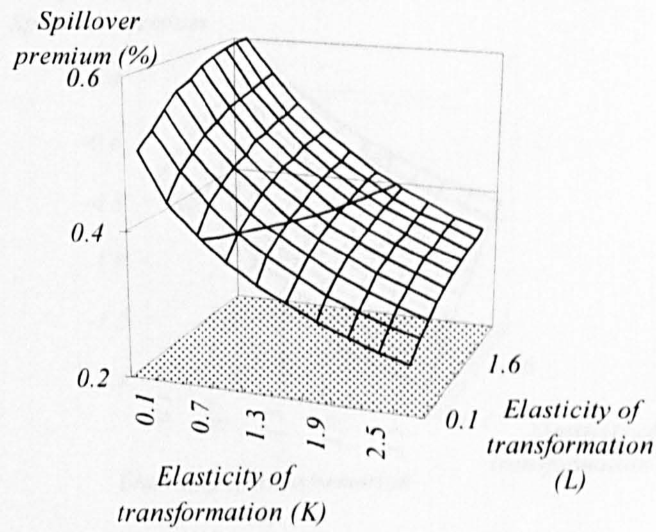
(c) Mixed impact of an FDI shock to the variety of *private* enterprises



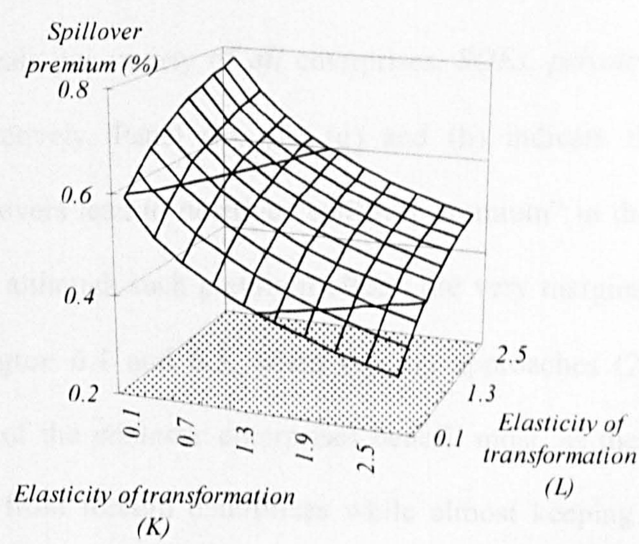
(d) Positive impact of an FDI shock to the variety of *foreign* enterprises



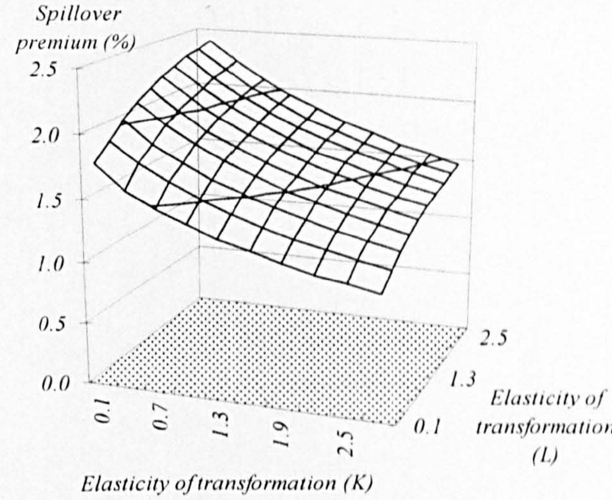
(e) Positive "spillover premium" of production variety of *all* enterprises



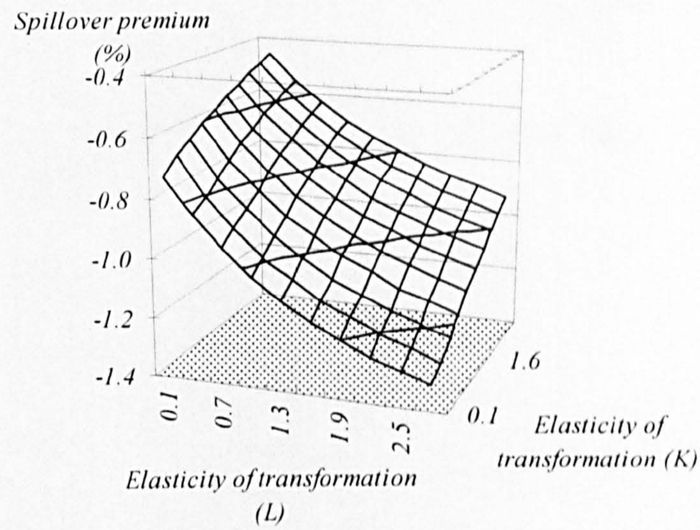
(f) Positive "spillover premium" of production variety of *SOEs*



(g) Positive "spillover premium" of production variety of *private* enterprises



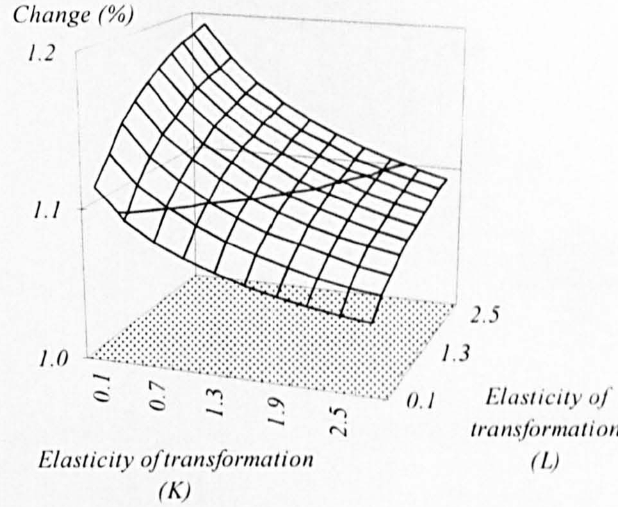
(h) Negative "spillover premium" of production variety of *foreign* enterprises



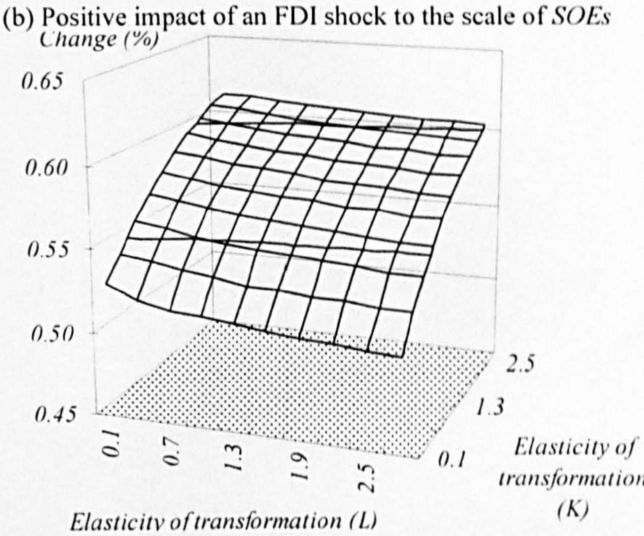
Panel (a), (b), (c) and (d) of Figure 6.6 show how the FDI shock increases the production scale per variety of *all* enterprises, *SOEs*, *private* and *foreign* enterprises respectively. Panel (e), (f), (g) and (h) indicate that the FDI productivity spillovers lead to positive "spillover premium" in the changes of production scale, although such premium effects are very marginal. Similar to the results of Figure 6.4 and 6.5, when (τ_K, τ_L) approaches (2.8, 0.1), the production scale of the *domestic* enterprises benefit most, as they can attract the most capital from foreign enterprises while almost keeping their labour input unchanged.

Figure 6.6: Scale per Variety Changes with FDI Productivity Spillovers under Monopolistic Competition

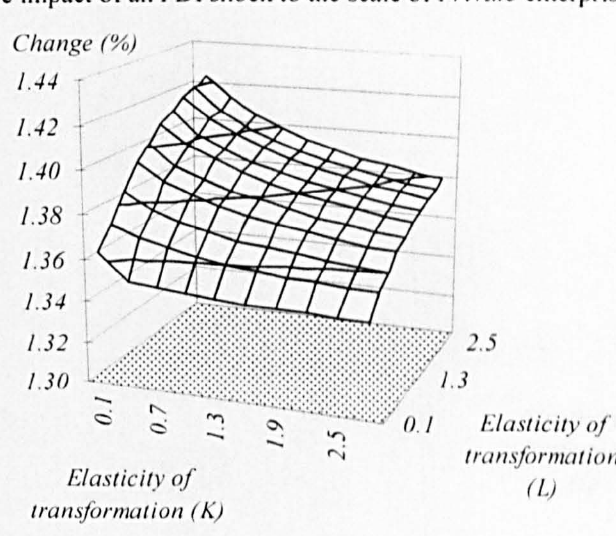
(a) Positive impact of an FDI shock to the scale of *all* enterprises



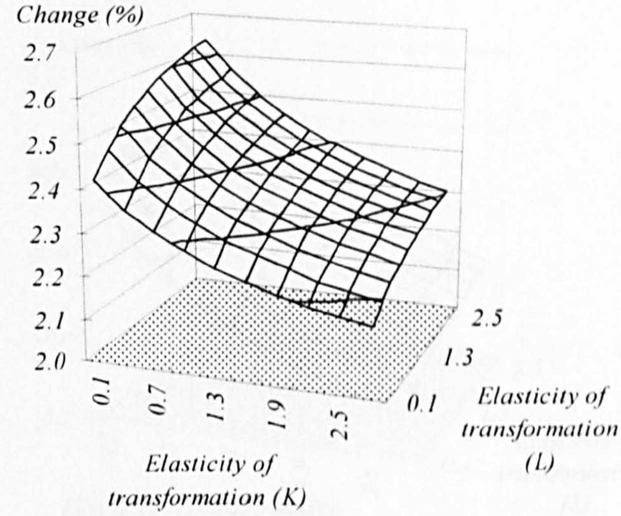
(b) Positive impact of an FDI shock to the scale of *SOEs*



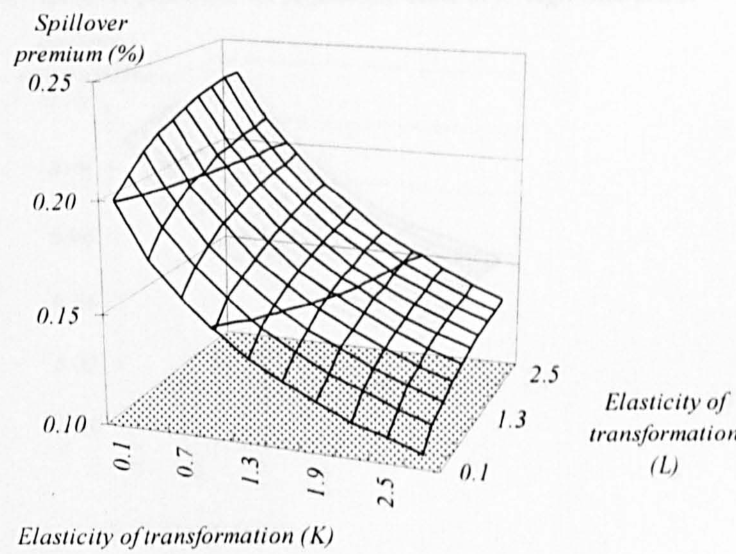
(c) Positive impact of an FDI shock to the scale of *Private* enterprises



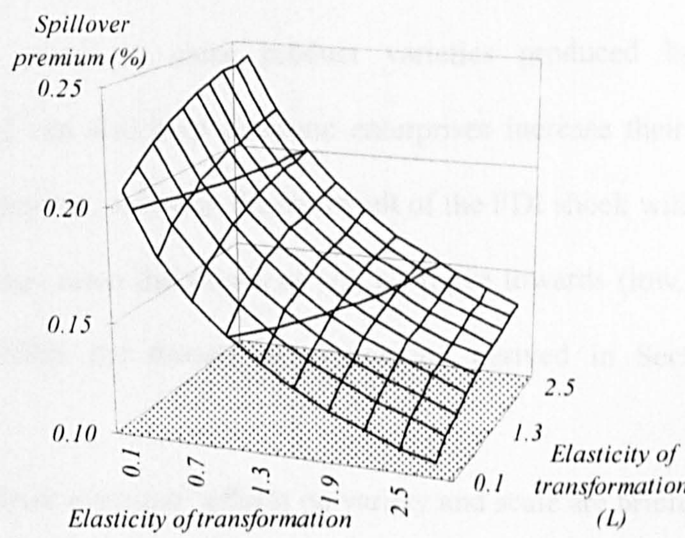
(d) Positive impact of an FDI shock to the scale of *Foreign* enterprises



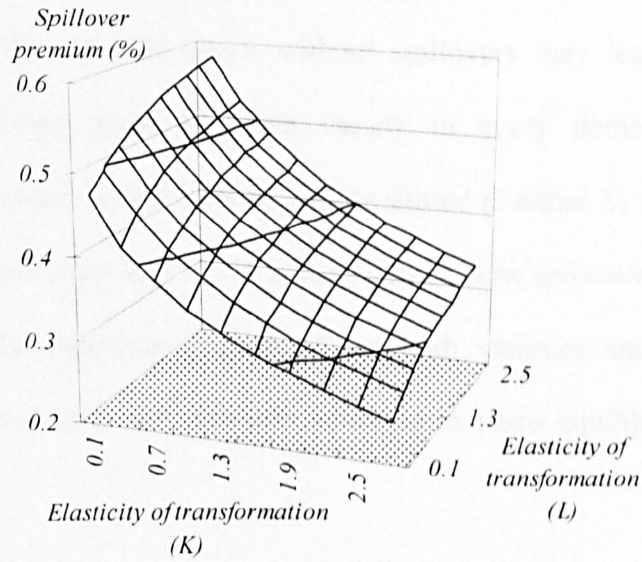
(e) Positive "spillover premium" of production scale of *all* enterprises



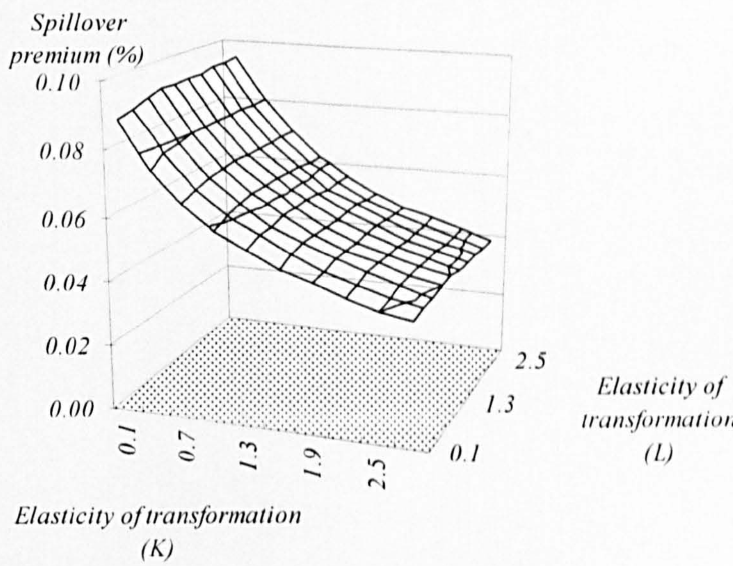
(f) Positive "spillover premium" of production scale of *SOEs*



(g) Positive "spillover premium" of production scale of *private* enterprises



(h) Positive "spillover premium" of production scale of *foreign* enterprises

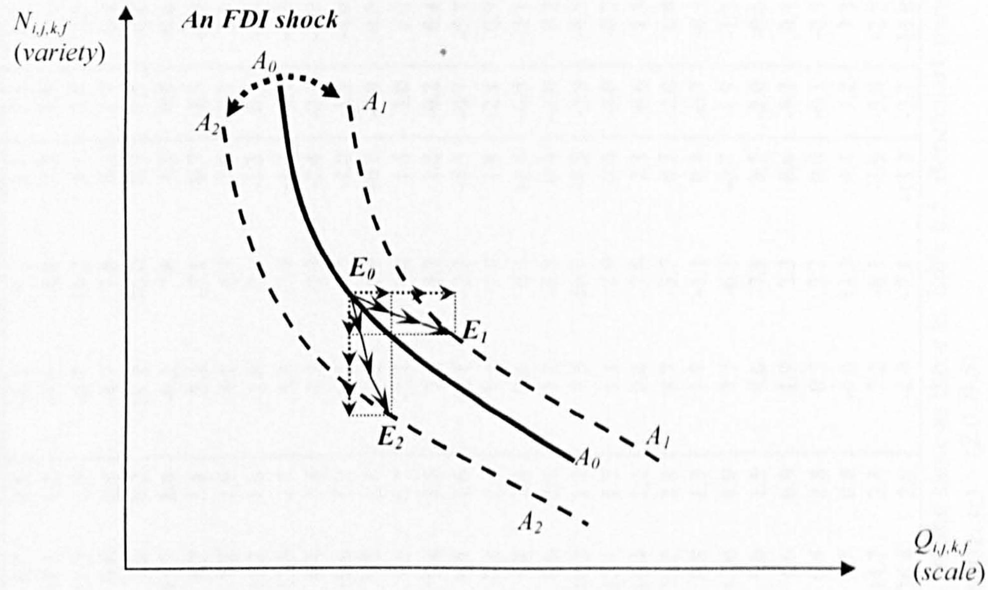


Thus a conclusion can be drawn from Figure 6.5 and Figure 6.6 that FDI spillovers can result in more product varieties produced by domestic enterprises, and can also help domestic enterprises increase their production scale for each product, although the net result of the FDI shock will be reduced domestic varieties when the values of (τ_K, τ_L) move towards (low, high). This conclusion justifies the theoretical proposition derived in Section 5.5 of Chapter 5.

The "spillover premium" effects on variety and scale are briefly illustrated in Figure 5.2 in Chapter 5. Figure 6.7 is drawn here to compare how an FDI shock *with* and *without* productivity spillovers affects the domestic sectors. Panel (a) shows that an FDI shock without spillovers may lead to fewer varieties and a larger scale for each variety in every domestic sector. Collectively, benchmark equilibrium E_0 will be shifted to either E_1 or E_2. Panel (b) (same as Figure 5.2 in Chapter 5 in nature) depicts how spillovers can affect these changes. The "spillover premiums" on both varieties and scale are positive, pushing A_1A_1 and A_2A_2 upwards, resulting in a new equilibrium at E'_1 or E'_2.

Figure 6.7: Variety and Scale of Domestic Enterprises with an FDI Shock

(a) *Without* spilllovers



(b) *With* spillovers

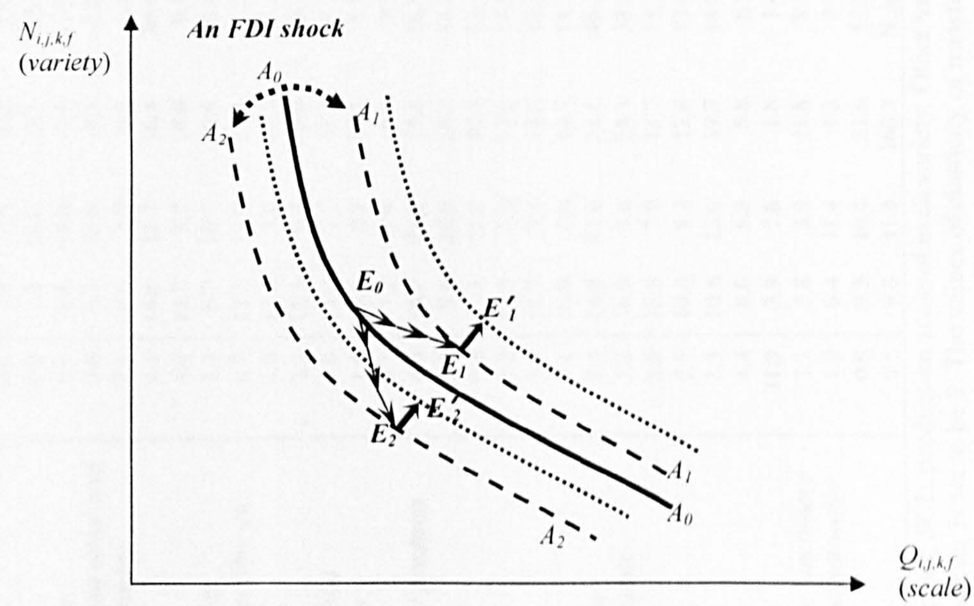


Table 6.7: Changes (%) of SOEs with an FDI Shock under Monopolistic Competition

	*FDI**	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*	*VRT*	*SCL*
Coal, petroleum and gas	0.6	7.9	7.6	6.8	9.6	6.7	0.8	-5.1	9.3	1.1	2.1	0.7	0.4
Ferrous metals mining and dressing	0.0	7.2	18.0	-3.1	N.A.	11.2	1.2	-4.5	8.8	1.2	1.9	1.0	0.2
Nonferrous metals mining and dressing	0.0	8.8	19.6	-2.5	-3.5	12.3	1.3	-6.7	15.2	3.1	3.4	2.5	0.6
Mining of non-metal, other minerals, and other ores	0.0	9.7	14.0	-2.1	-2.8	9.6	0.8	-4.7	7.8	0.3	1.7	0.2	0.1
Food, beverage, and tobacco manufacturing	2.5	4.6	2.9	0.6	1.4	1.3	0.2	-18.2	26.0	0.2	7.1	-0.1	0.2
Textile industry	**5.1**	**14.0**	**12.7**	**16.4**	**20.9**	**11.7**	**2.6**	**-0.2**	**7.8**	**1.3**	**0.5**	**0.6**	**0.6**
Garments and other fibre products	**4.4**	**14.7**	**9.7**	**10.0**	**9.3**	**8.7**	**2.4**	**5.2**	**-7.1**	**-0.7**	**-1.5**	**-0.9**	**0.2**
Leather, furs, down and related products	3.2	9.7	10.7	10.6	10.8	7.2	2.9	4.1	4.3	3.0	-0.3	2.7	0.3
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.3	13.9	17.3	23.5	13.2	1.6	-2.8	3.4	-1.3	0.5	-1.3	0.0
Furniture manufacturing	1.0	13.6	9.0	17.3	17.1	13.5	2.3	5.1	-7.4	-1.3	-1.7	-1.3	0.0
Papermaking and paper products	2.2	12.5	9.4	13.9	9.3	9.4	2.4	4.3	-3.3	-2.4	-2.2	-2.7	0.3
Printing and record medium reproduction	1.0	13.0	7.7	11.9	9.3	10.0	1.7	5.3	-8.3	-4.0	-3.1	-4.0	0.1
Cultural, educational and sports goods	1.6	10.6	8.9	10.1	8.7	7.7	2.4	3.2	-4.9	-0.3	-0.9	-0.5	0.2
Petroleum processing and coking	0.5	7.2	11.0	6.5	8.5	7.2	0.7	-2.4	7.0	1.5	2.0	1.0	0.5
Raw chemical materials and chemical products	**4.9**	**10.7**	**11.0**	**13.3**	**16.5**	**9.4**	**2.2**	**2.2**	**3.3**	**1.2**	**-0.2**	**0.4**	**0.8**
Medical and pharmaceutical products	1.8	9.9	10.0	10.3	14.4	8.4	1.6	-3.1	-2.3	-5.5	-0.7	-5.7	0.2
Chemical fibre	0.8	11.1	11.8	10.3	13.1	8.2	2.6	9.4	-1.9	1.8	-2.1	0.9	0.8
Rubber products	1.3	12.3	7.9	12.6	14.5	8.8	2.3	0.6	0.5	-1.4	-0.5	-2.1	0.7
Plastic products	3.7	12.7	7.1	14.0	12.2	8.6	2.5	7.2	-2.5	0.4	-2.0	0.2	0.2
Non-metal mineral products	3.1	10.9	7.0	14.7	14.2	10.2	1.7	7.5	-10.7	-4.3	-3.9	-4.5	0.2
Smelting and pressing of ferrous metals	2.4	14.8	12.0	31.1	46.2	15.1	1.7	1.1	2.9	0.6	0.0	-0.2	0.8
Smelting and pressing of nonferrous metals	1.3	16.0	7.0	24.3	38.1	10.4	2.1	0.4	7.0	2.3	0.6	1.5	0.8
Metal products	3.8	15.8	7.9	13.7	15.3	10.2	2.3	8.7	-5.7	0.7	-2.0	0.4	0.3
Ordinary machinery	2.9	10.0	8.3	12.8	13.4	8.8	1.7	3.7	-1.1	0.4	-0.7	-0.1	0.5
Special purpose equipment	2.3	10.8	13.0	19.7	14.8	13.0	1.9	7.7	-6.3	-0.7	-1.9	-1.3	0.6
Transport equipment	**4.4**	**8.0**	**6.3**	**5.8**	**5.9**	**5.0**	**1.5**	**9.6**	**-7.1**	**0.2**	**-2.0**	**-0.6**	**0.9**
Electronic and electric products	**11.9**	**3.9**	**2.8**	**1.8**	**1.4**	**1.6**	**0.9**	**1.9**	**2.3**	**0.6**	**-0.3**	**0.1**	**0.5**
Instruments, meters, cultural and office machinery	3.1	5.8	8.0	11.8	8.7	6.4	2.8	0.5	3.2	0.0	-0.1	-0.5	0.5
Production of electric power, steam and hot water	1.0	6.4	11.4	1.3	0.1	4.5	0.8	-4.0	13.3	4.4	3.2	3.3	1.0
Production of gas	0.9	9.5	10.4	21.6	53.3	14.7	2.4	7.2	-8.1	-1.9	-3.0	-2.5	0.6
Production of tap water	0.5	9.0	11.0	160.7	N.A.	26.4	2.9	-4.9	-7.8	-13.2	-3.1	-13.8	0.6

Note: *VRT*: number of firms in the sector; *SCL*: production scale of each variety. Other variables are the same as those in Table 6.5. Benchmark number of firms (under monopolistic competition) in each sector is set to be 8. The values of elasticity of transformation (τ_K, τ_L) = (2.0, 0.5).

Table 6.8: Changes (%) of Private Enterprises with an FDI Shock under Monopolistic Competition

	*FDI**	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*	*VRT*	*SCL*
Coal, petroleum and gas	0.6	7.9	7.6	6.8	9.6	5.9	1.5	-4.1	9.3	1.9	2.1	1.3	0.6
Ferrous metals mining and dressing	0.0	7.2	18.0	-3.1	N.A.	13.7	2.9	-1.8	8.8	3.3	1.9	2.3	0.9
Nonferrous metals mining and dressing	0.0	8.8	19.6	-2.5	-3.5	14.1	3.1	-5.2	15.2	4.2	3.4	2.9	1.2
Mining of non-metal, other minerals, and other ores	0.0	9.7	14.0	-2.1	-2.8	10.1	1.5	-3.1	7.8	1.5	1.6	1.1	0.4
Food, beverage, and tobacco manufacturing	2.5	4.6	2.9	0.6	1.4	1.1	0.6	-16.7	26.0	1.6	7.0	1.3	0.4
Textile industry	**5.1**	14.0	12.7	16.4	20.9	9.2	5.0	0.6	7.8	1.7	0.6	-0.4	2.1
Garments and other fibre products	**4.4**	14.7	9.7	10.0	9.3	5.1	2.9	6.9	-7.1	0.3	-1.3	-2.7	3.1
Leather, furs, down and related products	3.2	9.7	10.7	10.6	10.8	5.8	5.1	-6.5	4.3	-6.0	0.5	-8.2	2.4
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.3	13.9	17.3	23.5	11.6	3.6	-0.5	3.4	0.4	0.5	-0.6	0.9
Furniture manufacturing	1.0	13.6	9.0	17.3	17.1	10.8	3.8	6.5	-7.4	-0.5	-1.4	-2.6	2.1
Papermaking and paper products	2.2	12.5	9.4	13.9	9.3	6.7	4.9	7.4	-3.3	-0.4	-2.2	-2.1	1.7
Printing and record medium reproduction	1.0	13.0	7.7	11.9	9.3	7.8	2.7	11.7	-8.3	0.4	-3.4	-0.5	1.0
Cultural, educational and sports goods	1.6	10.6	8.9	10.1	8.7	5.8	2.9	5.9	-4.9	1.5	-0.6	-2.0	3.6
Petroleum processing and coking	0.5	7.2	11.0	6.5	8.5	6.5	1.8	-2.3	7.0	1.6	2.0	0.8	0.7
Raw chemical materials and chemical products	**4.9**	10.7	11.0	13.3	16.5	7.2	4.5	2.7	3.3	1.5	-0.1	-0.2	1.6
Medical and pharmaceutical products	1.8	9.9	10.0	10.3	14.4	6.7	3.0	4.7	-2.3	0.2	-1.2	-0.8	1.0
Chemical fibre	0.8	11.1	11.8	10.3	13.1	5.6	5.0	5.7	-1.9	-0.9	-1.7	-2.5	1.7
Rubber products	1.3	12.3	7.9	12.6	14.5	6.0	4.3	0.3	0.5	-1.9	-0.4	-3.6	1.8
Plastic products	3.7	12.7	7.1	14.0	12.2	5.7	4.5	8.3	-2.5	0.9	-1.7	-1.3	2.2
Non-metal mineral products	3.1	10.9	7.0	14.7	14.2	7.9	3.5	13.5	-10.7	-0.2	-4.1	-1.4	1.2
Smelting and pressing of ferrous metals	2.4	14.8	12.0	31.1	46.2	12.9	4.0	3.1	2.9	2.1	-0.1	0.8	1.2
Smelting and pressing of nonferrous metals	1.3	16.0	7.0	24.3	38.1	7.0	4.4	-0.6	7.0	1.5	0.8	-0.1	1.6
Metal products	3.8	15.8	7.9	13.7	15.3	6.6	4.0	8.3	-5.7	0.1	-1.7	-1.9	2.0
Ordinary machinery	2.9	10.0	8.3	12.8	13.4	7.1	3.2	5.7	-1.1	1.6	-0.7	0.2	1.5
Special purpose equipment	2.3	10.8	13.0	19.7	14.8	13.4	3.9	10.1	-6.3	0.8	-1.9	-0.7	1.5
Transport equipment	**4.4**	8.0	6.3	5.8	5.9	3.2	2.4	7.6	-7.1	-1.1	-1.8	-1.9	0.9
Electronic and electric products	**11.9**	3.9	2.8	1.8	1.4	0.9	1.2	1.5	2.3	0.2	-0.2	-0.6	0.8
Instruments, meters, cultural and office machinery	3.1	5.8	8.0	11.8	8.7	7.5	5.1	3.1	3.2	2.2	0.0	-0.4	2.6
Production of electric power, steam and hot water	1.0	6.4	11.4	1.3	0.1	3.4	1.5	-5.7	13.3	2.9	3.3	1.8	1.0
Production of gas	0.9	9.5	10.4	21.6	53.3	12.4	6.0	0.6	-8.1	-6.9	-2.6	-7.6	0.7
Production of tap water	0.5	9.0	11.0	160.7	N.A.	40.8	8.1	21.4	-7.8	4.8	-4.7	2.6	2.2

Note: same as Table 6.7.

Table 6.7 and 6.8 illustrate the changes of key variables at industry-level. Similar to Table 6.5 and 6.6, the contribution rate of productivity spillovers to total spillovers of domestic enterprises (*NTFP*) increases, resulting in moderate productivity (*TFP*) improvement. Table 6.7 and 6.8 also report the changes of varieties and scale of production in each industry. The results are consistent with those shown in Figure 6.5 and 6.6, *i.e.* varieties of both SOEs and Private enterprises decrease while scale per variety increase.

6.4.3. A Comparison of an FDI Shock under Perfect and Monopolistic Competitions

The impacts of FDI productivity spillovers on macroeconomic variables with different initial degrees of monopolistic power are also shown in Table 6.9. Two alternative values of the initial number of firms (N), and also the number of varieties, are chosen in each ownership type in each industry in the benchmark economy. N is an endogenous variable, the value of which may change in the counterfactual simulations. For example, when N=10, the percentage change of total output under an FDI shock *without* spillovers is 6.0%, while this figure under the same FDI shock *with* spillover turns out to be 7.2%, suggesting a net 1.2% FDI productivity spillover premium.

We also include the outcomes for perfect competition for comparison. As we can see, the reduction in the number of competitors increases the impact of an FDI shock, with or without FDI spillovers. For example, the increase rate of GDP under perfect competition with spillovers is 7.1%, but this figure becomes 7.8% and 8.3% when N=10 and N=5, respectively. Moreover, the FDI spillover premia are higher when the benchmark number of firms (varieties) is smaller. For example, the spillover premia of total output increase rate are 1.1%, 1.2%

and 1.3%, when the economy is competitive, N=10 and N=5, respectively. To conclude, the lower the degree of competition in the benchmark, the higher returns to the FDI shock from competition.

The only exception is the total output of SOEs, whose spillover premium exhibits a relatively stable pattern, reflecting the balance of the benefits from the FDI shock (productivity spillovers and cheaper capital), and the negative impact of increased competition from foreign firms.

Table 6.9: An FDI Shock under Perfect & Monopolistic Competitions

	% change of	***Perfect competition***	***N=10***	***N=5***
With spillovers	*Total output*	6.8	7.2	7.5
	GDP	7.1	7.8	8.3
	Total output of SOEs	1.9	1.8	1.8
	Total output of private enterprises	1.2	1.3	1.4
	Total output of FIEs	14.9	15.3	15.6
	National welfare	3.6	4.4	5.0
Without spillovers	*Total output*	5.6	6.0	6.2
	GDP	5.6	6.2	6.6
	Total output of SOEs	*1.3*	*1.3*	*1.3*
	Total output of private enterprises	0.0	0.1	0.1
	Total output of FIEs	15.5	15.9	16.3
	National welfare	2.5	3.1	3.6
Spillover premium	*Total output*	1.1	1.2	1.3
	GDP	1.5	1.6	1.7
	Total output of SOEs	0.5	0.5	0.5
	Total output of private enterprises	1.2	1.2	1.3
	Total output of FIEs	-0.6	-0.6	-0.6
	National welfare	1.2	1.3	1.4

Note: Elasticity of transformation of capital and labour (τ_K, τ_L) = (2.0, 0.5).

6.5. FDI SPILLOVERS UNDER FIRM HETEROGENEITY

6.5.1. Impact of Spillovers on Output

In the scenario of firm heterogeneity, firms are different in their productivities so that the least productive enterprises will be driven out of the market when input prices are higher. Similar to the scenarios of perfect competition and monopolistic competition, the FDI productivity spillovers in the scenario of heterogeneous competition can also exert positive impacts on national total output, GDP, welfare, and total output of domestic enterprises. Total products of foreign invested enterprises will increase at a lower rate due to the fact that resources are attracted by domestic enterprises which become more productive with FDI productivity spillovers.

Table 6.10 shows how FDI shock affects the national total output with and without productivity spillovers. As we can see, the existence of FDI productivity spillovers helps the total output increase with a greater magnitude. This difference is reflected in the bottom panel titled with "*spillover premium*".

Figure 6.8 presents the findings in diagrams. Panel (a) shows that total output of all industries with spillovers increases, with a highest increase rate at $(\tau_K, \tau_L) = (0.4, 2.8)$, where only labour is relatively mobile. SOEs (see panel (b)) benefit the most from the FDI shock with spillovers when $(\tau_K, \tau_L) = (2.8, 2.8)$. However Private domestic enterprises (see panel (c)) benefit the most from FDI spillovers if labour can not easily be attracted away by foreign enterprises while they can easily absorb capital from the latter, *i.e.* $(\tau_K, \tau_L) = (2.8, 0.4)$. In contrast, the total output of FIEs increases by the least at $(\tau_K, \tau_L) = (2.8, 0.4)$.

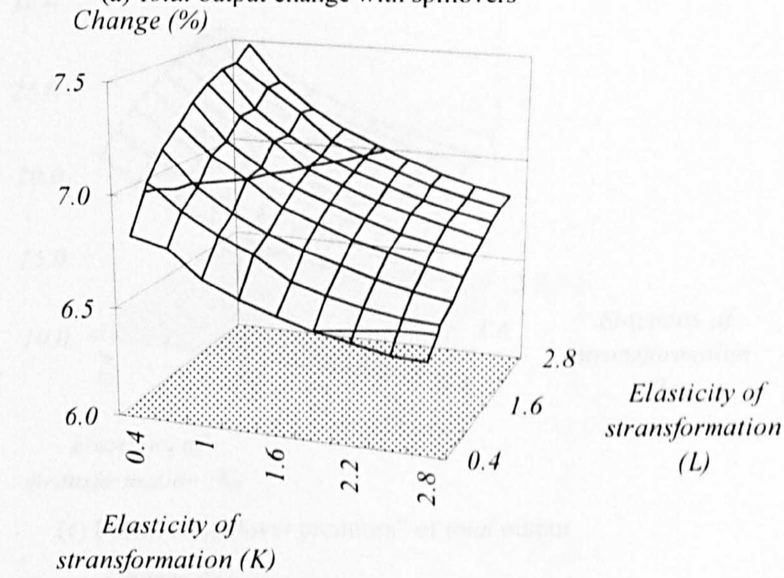
Similar to the conclusions drawn under perfect competition and monopolistic competition, domestic enterprises get positive productivity "spillover premium" (see panel (f) and (g)) while foreign enterprises' premium is negative (see panel (h)). But the overall premium is collectively positive (see panel (e)).

Table 6.10: Total Output Changes (%) with and without Spillovers under Firm Heterogeneity

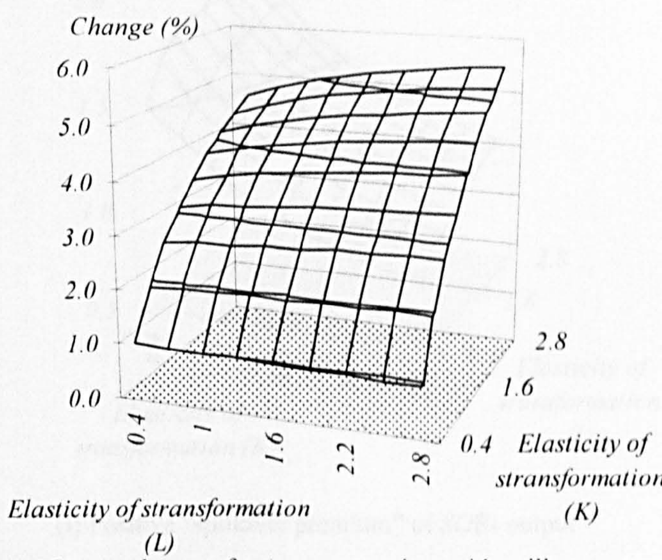
Total output change (%)			Elasticity of labour transformation (τ_L)								
			0.4	*0.7*	*1*	*1.3*	*1.6*	*1.9*	*2.2*	*2.5*	*2.8*
Elasticity of capital transformation (τ_K)	*Under firm heterogeneity (without spillovers)*	*0.4*	5.3	5.3	5.4	5.4	5.5	5.4	5.5	5.5	5.5
		0.7	5.4	5.4	5.4	5.5	5.5	5.5	5.5	5.5	5.5
		1	5.4	5.5	5.5	5.5	5.5	5.5	5.6	5.6	5.6
		1.3	5.5	5.5	5.5	5.5	5.6	5.6	5.6	5.6	5.6
		1.6	5.5	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6
		1.9	5.5	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.6
		2.2	5.6	5.6	5.6	5.6	5.6	5.6	5.6	5.7	5.7
		2.5	5.6	5.6	5.6	5.6	5.6	5.7	5.7	5.7	5.7
		2.8	5.6	5.6	5.6	5.6	5.7	5.7	5.7	5.7	5.7
	Under firm heterogeneity (with spillovers)	*0.4*	6.8	7.0	7.1	7.2	7.3	7.4	7.4	7.4	7.5
		0.7	6.8	6.9	7.0	7.1	7.1	7.2	7.2	7.3	7.3
		1	6.7	6.8	6.9	7.0	7.0	7.1	7.1	7.2	7.2
		1.3	6.6	6.7	6.8	6.9	6.9	7.0	7.0	7.1	7.1
		1.6	6.5	6.7	6.7	6.8	6.9	6.9	7.0	7.0	7.0
		1.9	6.5	6.6	6.7	6.8	6.8	6.9	6.9	6.9	7.0
		2.2	6.5	6.6	6.6	6.7	6.8	6.8	6.8	6.9	6.9
		2.5	6.4	6.5	6.6	6.7	6.7	6.8	6.8	6.8	6.9
		2.8	6.4	6.5	6.6	6.6	6.7	6.7	6.8	6.8	6.8
	Spillover premium	*0.4*	**1.5**	**1.7**	**1.8**	**1.8**	**1.9**	**1.9**	**1.9**	**1.9**	**2.0**
		0.7	**1.4**	**1.5**	**1.5**	**1.6**	**1.7**	**1.7**	**1.7**	**1.8**	**1.8**
		1	**1.3**	**1.4**	**1.4**	**1.5**	**1.5**	**1.6**	**1.6**	**1.6**	**1.6**
		1.3	**1.1**	**1.2**	**1.3**	**1.3**	**1.4**	**1.4**	**1.4**	**1.5**	**1.5**
		1.6	**1.0**	**1.1**	**1.2**	**1.2**	**1.3**	**1.3**	**1.4**	**1.4**	**1.4**
		1.9	**1.0**	**1.0**	**1.1**	**1.2**	**1.2**	**1.2**	**1.3**	**1.3**	**1.3**
		2.2	**0.9**	**1.0**	**1.0**	**1.1**	**1.1**	**1.2**	**1.2**	**1.2**	**1.2**
		2.5	**0.9**	**1.0**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**1.2**	**1.2**
		2.8	**0.8**	**0.9**	**0.9**	**1.0**	**1.0**	**1.1**	**1.1**	**1.1**	**1.1**

Figure 6.8: FDI Spillover Effects under Firm Heterogeneity

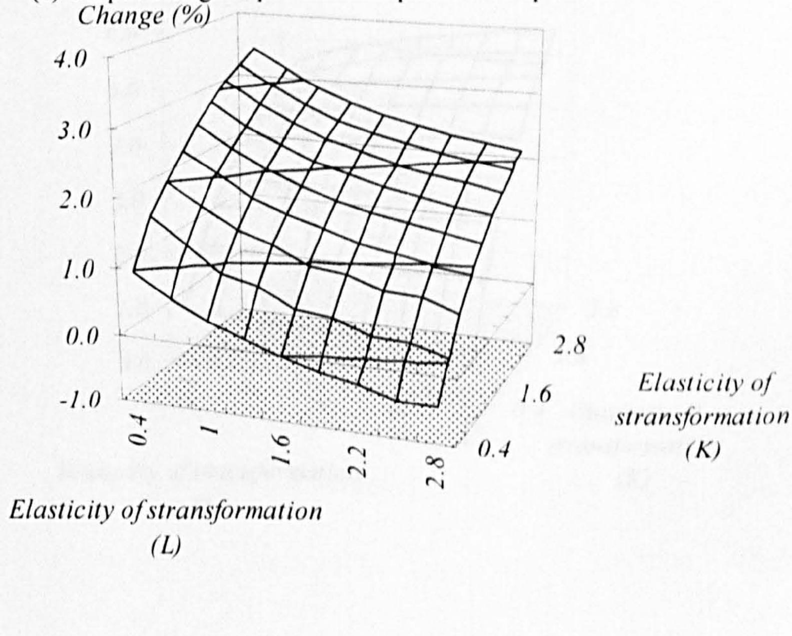
(a) *Total* output change with spillovers



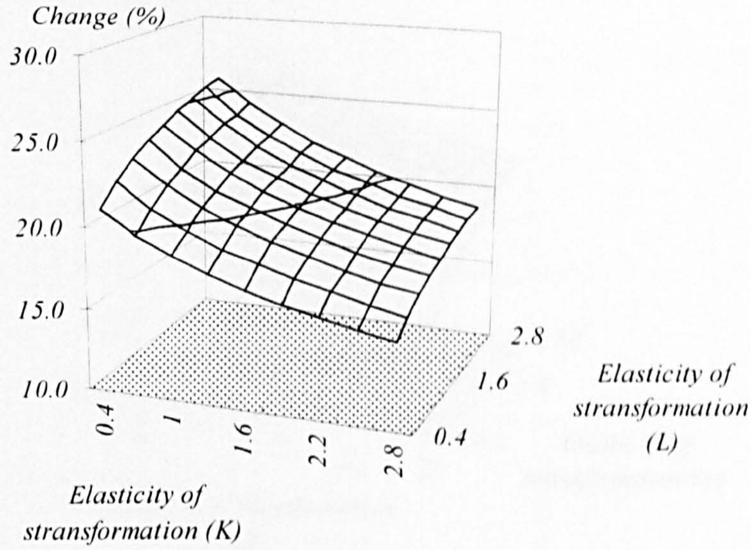
(b) Output change of *SOEs* with spillovers



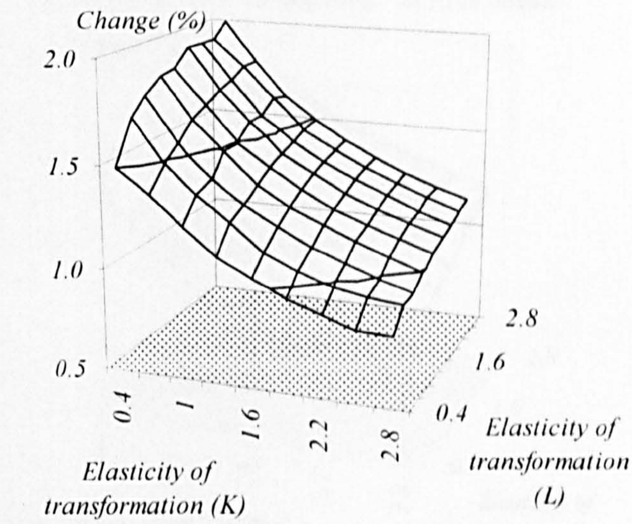
(c) Output change of *private* enterprises with spillovers



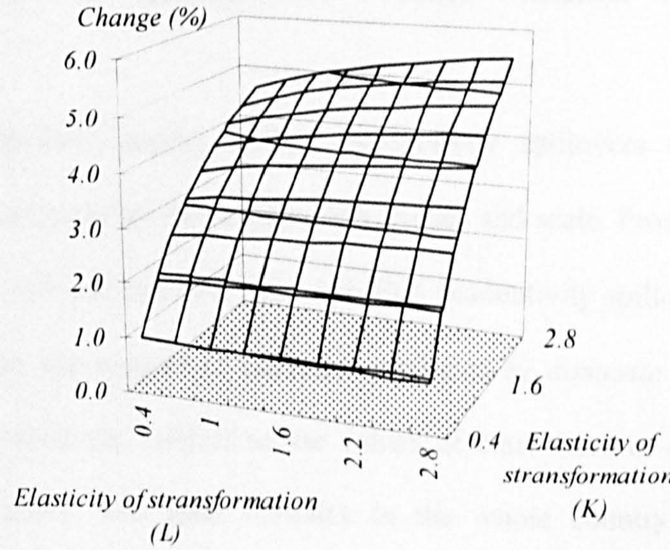
(d) Output change of *FIEs* with spillovers



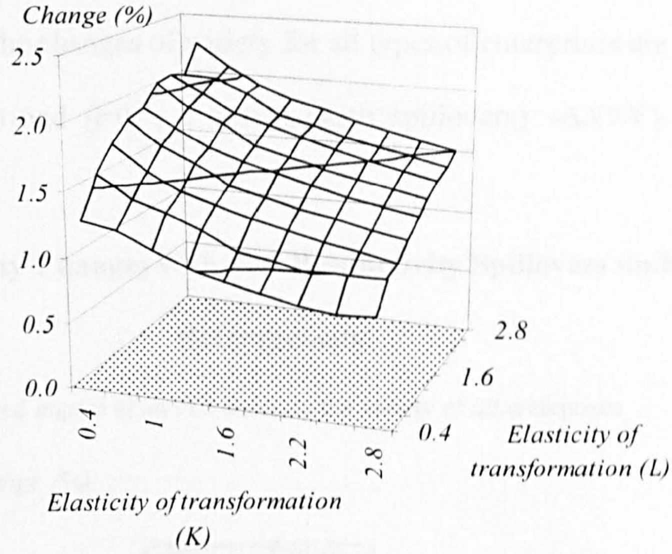
(e) Positive "spillover premium" of *total* output



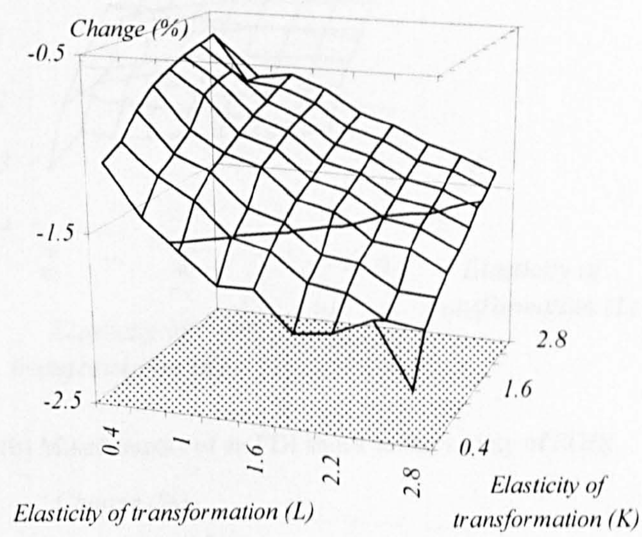
(f) Positive "spillover premium" of *SOEs* output



(g) Positive "spillover premium" of *Private* enterprises' output



(h) Negative "spillover premium" of *FIEs* output

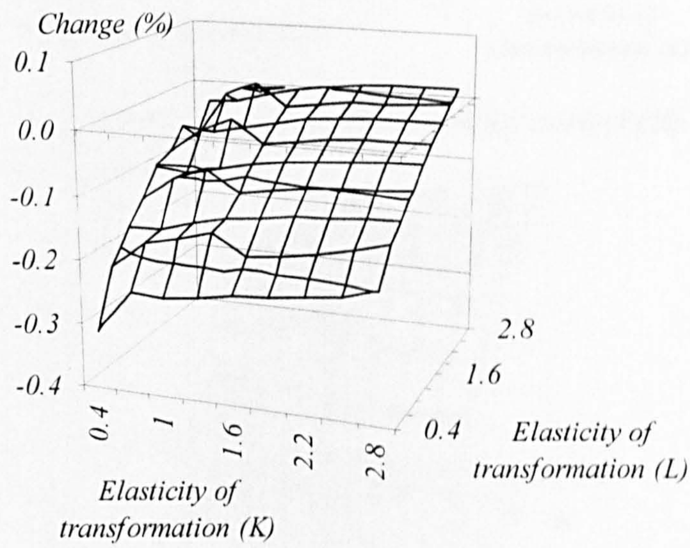


6.5.2. Impact of Spillovers on Product Varieties, Scale and Productivity

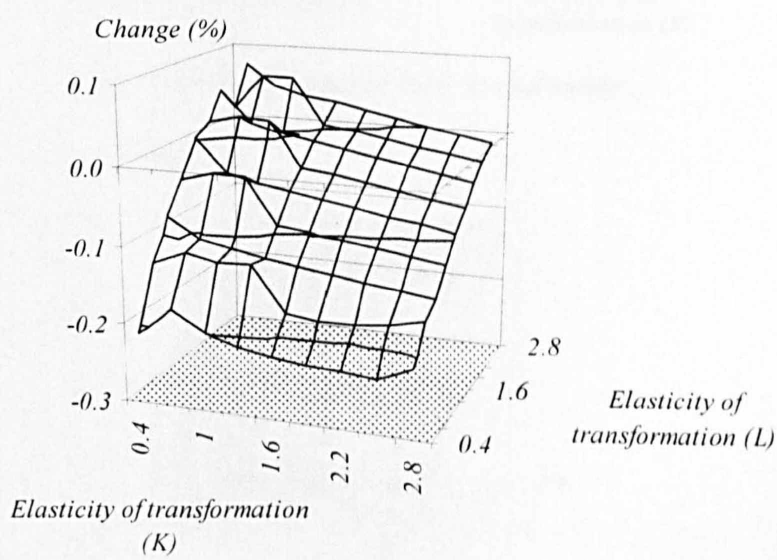
Another important impact of FDI productivity spillovers under firm heterogeneity is reflected by the changes of varieties and scale. From panel (b) and (c) of Figure 6.9 one can find that, with FDI productivity spillovers under firm heterogeneity, the number of **varieties** produced by *domestic* enterprises may increase or decrease, subject to the values of elasticities of capital and labour transformation. The total varieties in the whole country may also increase and decrease (see panel (a)). The impact on the variety of foreign-invested enterprises is negative. The "spillover premium" effects of FDI spillovers on the changes of variety for all types of enterprises are negative (see panel (f), (g) and (h)), *i.e.* $\Delta N/N_0$ (with spillovers) $-\Delta N'/N'_0$ (without spillovers) < 0.

Figure 6.9: Variety Changes with FDI Productivity Spillovers under Firm Heterogeneity

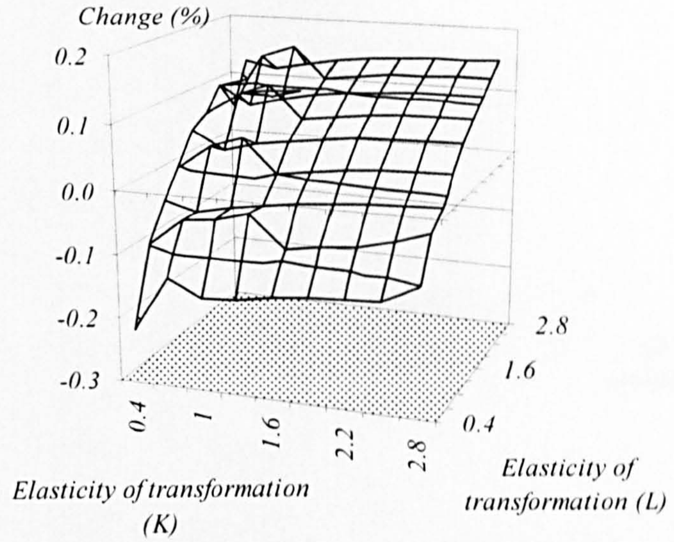
(a) Mixed impact of an FDI shock to the variety of *all* enterprises



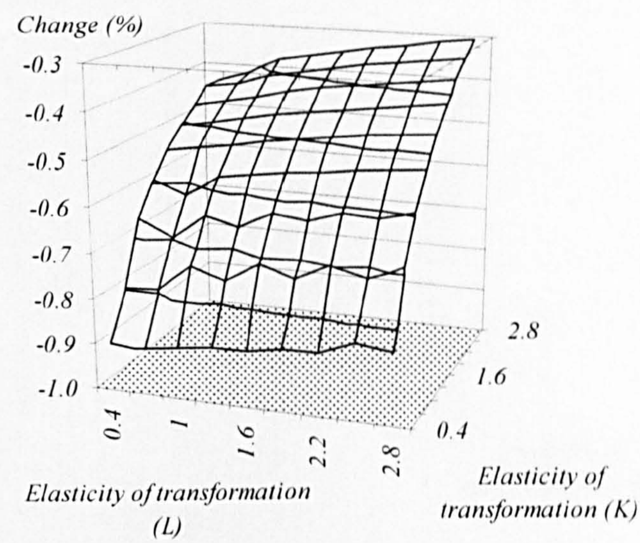
(b) Mixed impact of an FDI shock to the variety of *SOEs*



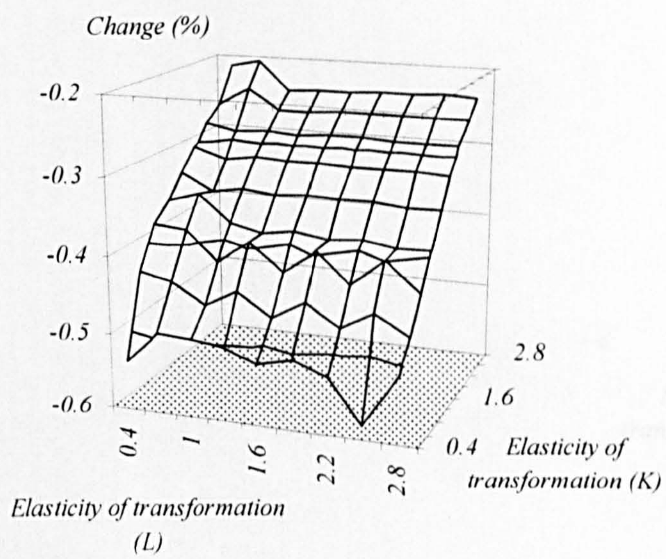
(c) Mixed impact of an FDI shock to the variety of *Private* enterprises



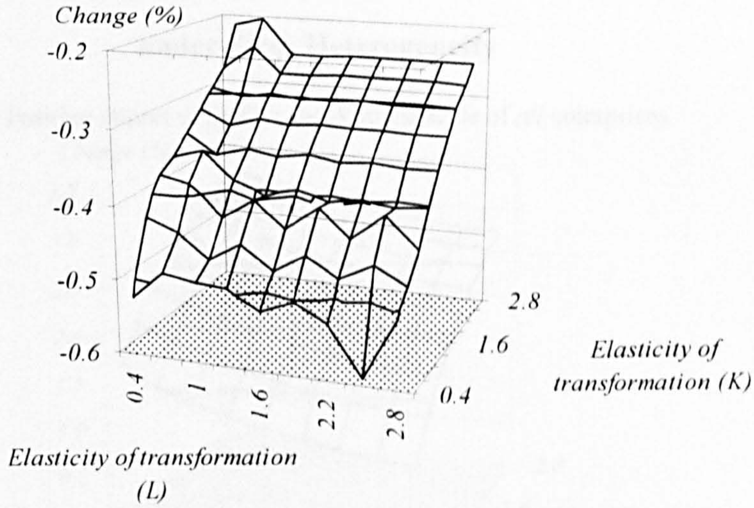
(d) Negative impact of an FDI shock to the variety of *FIEs*



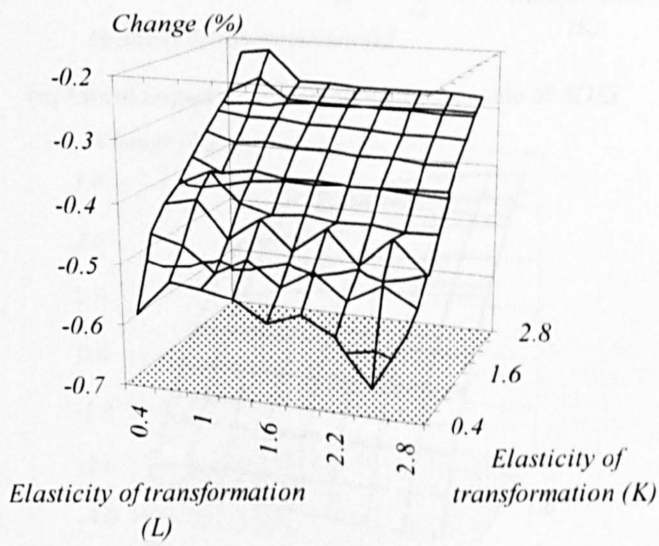
(e) Negative "spillover premium" of *total* variety



(f) Negative "spillover premium" of *SOEs* variety



(g) Negative "spillover premium" of *Private enterprises'* variety



(h) Negative "spillover premium" of *FIEs* variety

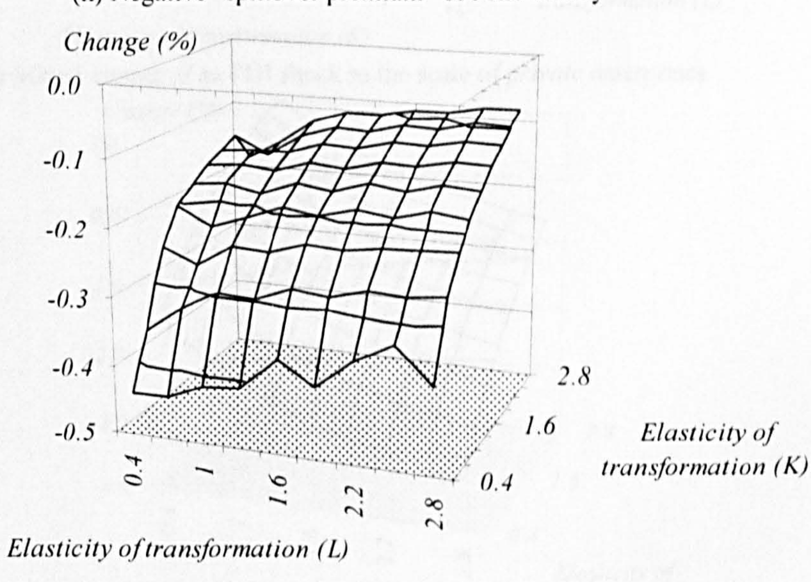
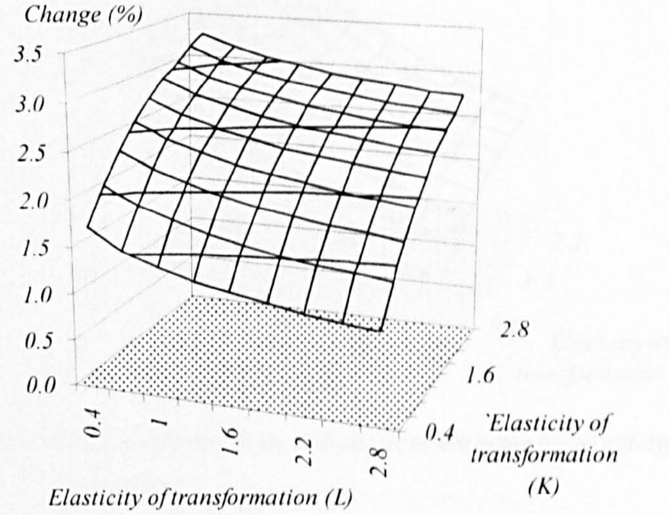
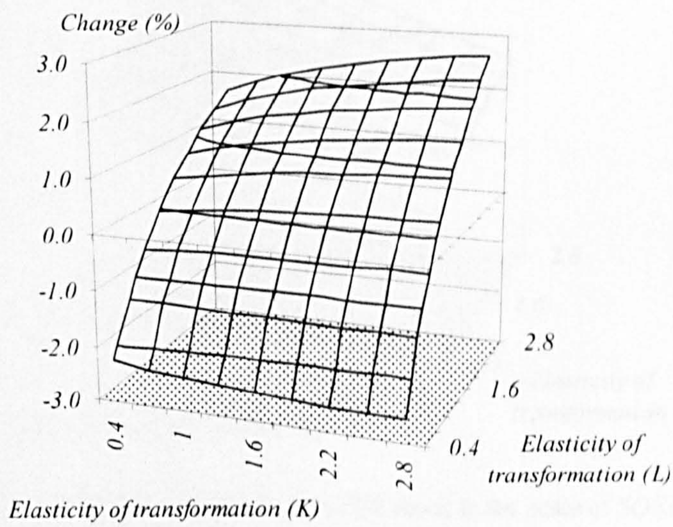


Figure 6.10: Scale per Variety Changes with FDI Productivity Spillovers under Firm Heterogeneity

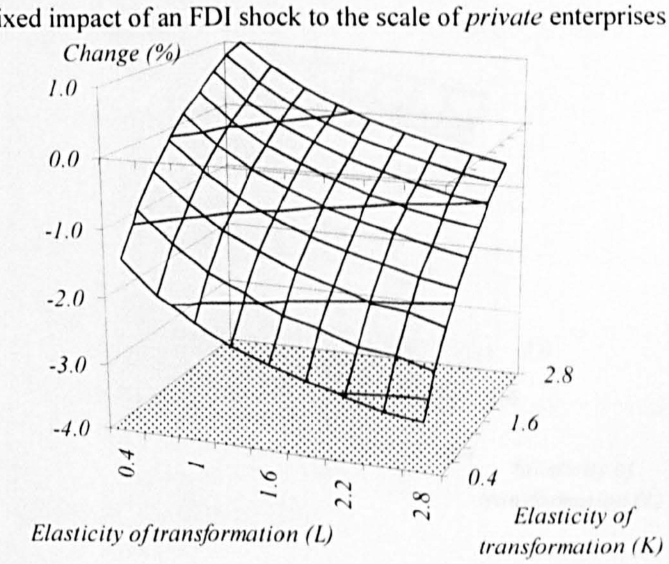
(a) Positive impact of an FDI shock to the scale of *all* enterprises



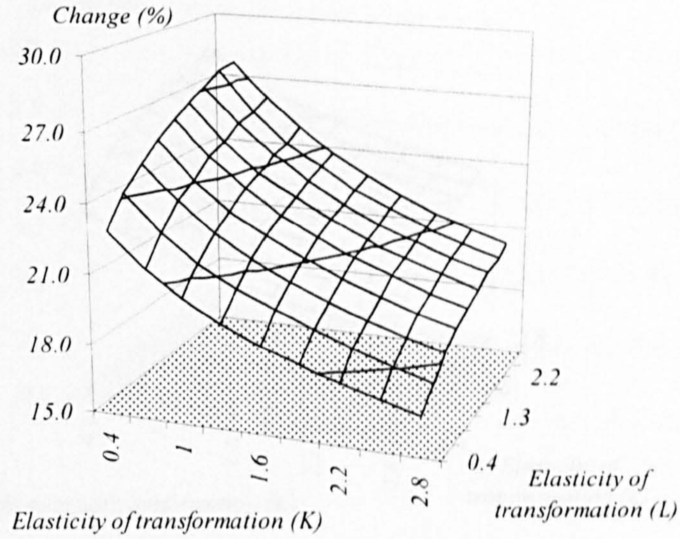
(b) Mixed impact of an FDI shock to the scale of *SOEs*



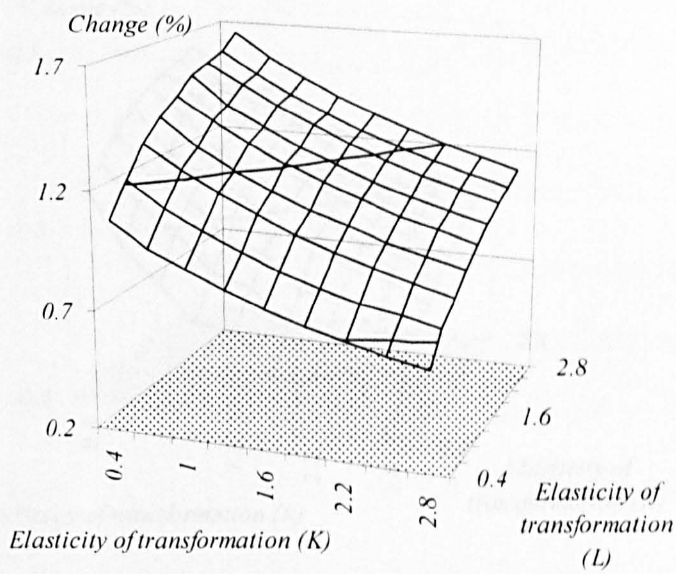
(c) Mixed impact of an FDI shock to the scale of *private* enterprises



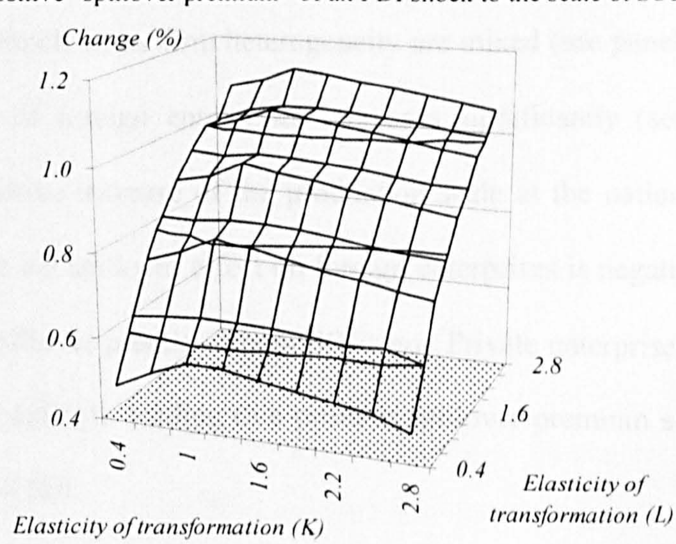
(d) Positive impact of an FDI shock to the scale of *foreign* enterprises



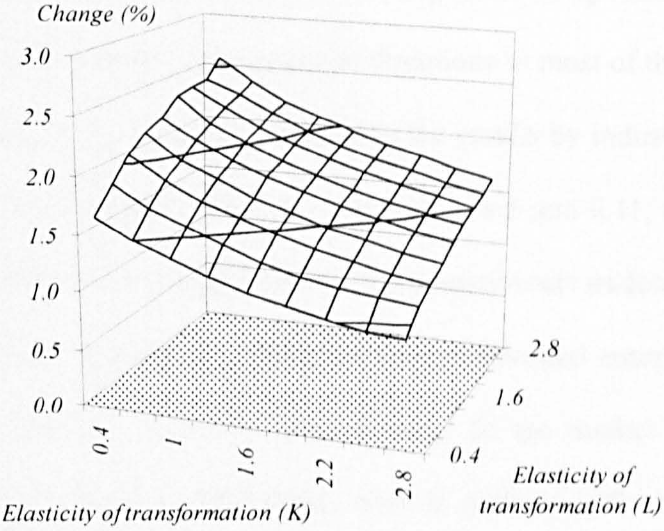
(e) Positive "spillover premium" of an FDI shock to the scale of *all* enterprises



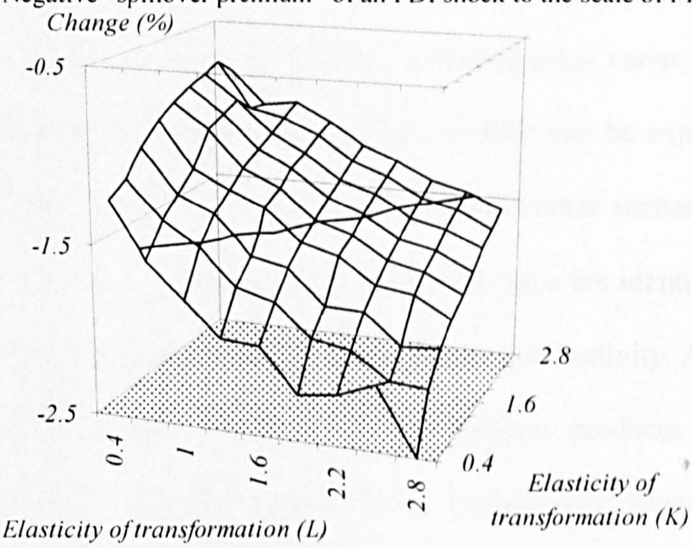
(f) Positive "spillover premium" of an FDI shock to the scale of *SOEs*



(g) Positive "spillover premium" of an FDI shock to the scale of *Private* enterprises



(h) Negative "spillover premium" of an FDI shock to the scale of *FIEs*



The changes of production scale of both SOEs and Private enterprises with the FDI shock under firm heterogeneity are mixed (see panel (b) and (c)), but the scale of foreign enterprises increases significantly (see panel (d)), leading to positive increase of the production scale at the national level (see panel (a)). The net spillover effect on foreign enterprises is negative (see panel (h)), but the spillover premia of both SOEs and Private enterprises are positive (see panel (f) and (g)), leading to a positive spillover premium at the national level (see panel (e)).

The changes of variety and scale of domestic enterprises under firm heterogeneity are similar with those under monopolistic competition in that the variety and the scale change in the opposite directions in most of the occasions. The detail for this can be found by comparing the results by industry shown in the *VRT* and *SCL* columns in Table 6.7 and 6.10, 6.8 and 6.11, respectively. This similarity reflects the binding effect of the variety-scale tradeoff.

There exists an interesting contrast in foreign-invested enterprises under monopolistic competition and firm heterogeneity. In the market structure of monopolistic competition, an FDI shock *with* or *without* spillovers can help create more varieties produced by foreign-invested sectors; however in the scenario of firm heterogeneity, an FDI shock decreases the variety produced by foreign-invested sectors in equilibrium. This contrast can be explained by the different assumptions of these two scenarios. The former scenario assumes a representative firm, i.e. all firms of any ownership type are identical; however, in the latter one, firms are distinct in terms of their productivity. An FDI shock may cause higher prices of labour and intermediate products available for foreign enterprises. In the monopolistic competition scenario, foreign enterprises "collectively" expand their production presence (in both variety and scale) with a significant increase in capital supply, regardless of the higher input costs. Under firm heterogeneity, higher input costs cause the least productive foreign firms to exit and reduce the number of varieties produced (i.e. the number of firms), but boost the production scale of surving foreign firms.[8]

[8] In this model FDI is treated as follow-up investment to the existing foreign-invested enterprises. However, if FDI is treated as greenfield investment which involves starting up new ventures, then the simulation result of "variety" might be different.

Table 6.11: Changes (%) of SOEs under Firm Heterogeneity

	*FDI**	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*	*VRT*	*SCL*
Coal, petroleum and gas	0.6	7.1	7.8	6.2	12.3	6.3	0.8	-31.0	36.8	-0.1	5.3	5.3	-5.2
Ferrous metals mining and dressing	0.0	6.6	16.0	-7.3	N.A.	10.0	1.0	-15.9	9.9	-4.0	1.9	1.9	-5.7
Nonferrous metals mining and dressing	0.0	8.6	19.7	-11.8	-15.9	11.9	1.3	12.7	-29.2	-17.4	-4.3	-4.3	-13.7
Mining of non-metal, other minerals, and other ores	0.0	10.2	13.2	-2.9	-3.3	9.5	0.8	-7.4	9.0	0.2	1.1	1.1	-0.9
Food, beverage, and tobacco manufacturing	2.5	7.3	5.6	4.9	0.8	4.8	0.9	42.0	-30.1	-5.8	-5.8	-5.8	0.1
Textile industry	**5.1**	**14.6**	**13.2**	**16.7**	**20.8**	**12.2**	**2.7**	**19.2**	**5.4**	**11.8**	**-0.8**	**-0.8**	**12.7**
Garments and other fibre products	**4.4**	**14.9**	**9.4**	**11.3**	**8.0**	**10.2**	**2.8**	**46.7**	**-32.4**	**12.5**	**-3.2**	**-3.2**	**16.1**
Leather, furs, down and related products	3.2	7.6	7.4	6.4	5.2	5.2	2.1	38.0	-6.4	19.3	-1.6	-1.6	21.3
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.9	14.3	19.5	24.2	14.5	1.8	40.4	-24.3	0.5	-4.2	-4.2	4.9
Furniture manufacturing	1.0	13.3	8.8	18.5	14.4	14.8	2.5	40.8	-28.9	5.9	-3.3	-3.3	9.6
Papermaking and paper products	2.2	9.8	7.7	9.1	7.8	6.8	1.7	-47.4	61.1	-2.8	9.3	9.3	-11.1
Printing and record medium reproduction	1.0	10.3	7.6	7.8	5.6	7.5	1.2	1.5	-16.2	-14.9	-2.5	-2.5	-12.6
Cultural, educational and sports goods	1.6	10.4	8.8	10.0	7.1	8.1	2.5	28.3	-21.1	11.9	-1.6	-1.6	13.7
Petroleum processing and coking	0.5	6.8	10.7	7.6	10.6	7.4	0.7	-29.9	40.7	5.6	8.2	8.2	-2.4
Raw chemical materials and chemical products	**4.9**	**11.7**	**12.3**	**14.4**	**17.5**	**10.5**	**2.4**	**22.7**	**-5.1**	**6.2**	**-1.9**	**-1.9**	**8.2**
Medical and pharmaceutical products	1.8	11.1	12.2	12.4	15.4	11.1	2.1	150.4	-61.8	-6.4	-12.2	-12.2	6.6
Chemical fibre	0.8	12.8	12.9	13.2	15.6	9.9	3.1	485.2	-70.7	16.9	-19.1	-19.1	44.5
Rubber products	1.3	12.2	7.4	12.2	12.3	9.0	2.4	35.3	-21.3	5.5	-3.3	-3.3	9.1
Plastic products	3.7	15.3	8.2	20.4	10.7	11.7	3.5	122.1	-46.4	5.3	-9.4	-9.4	16.2
Non-metal mineral products	3.1	9.8	6.2	12.1	12.5	8.7	1.5	-2.5	-4.1	-6.6	-0.7	-0.7	-6.0
Smelting and pressing of ferrous metals	2.4	13.7	10.1	29.6	45.3	13.6	1.5	-73.9	189.0	3.3	22.0	22.0	-15.3
Smelting and pressing of nonferrous metals	1.3	15.9	6.2	24.8	40.1	9.9	2.0	-59.1	129.3	9.5	11.0	11.0	-1.4
Metal products	3.8	14.1	6.6	9.5	15.3	7.3	1.6	-41.9	73.0	4.4	7.1	7.1	-2.5
Ordinary machinery	2.9	9.0	7.2	9.3	14.1	6.9	1.4	-29.4	25.2	-5.8	3.2	3.2	-8.8
Special purpose equipment	2.3	9.4	11.8	16.2	16.3	10.9	1.5	-26.4	17.9	-5.7	2.7	2.7	-8.2
Transport equipment	**4.4**	**7.9**	**6.5**	**6.2**	**6.6**	**5.2**	**1.5**	**7.2**	**-4.2**	**0.9**	**-0.6**	**-0.6**	**1.6**
Electronic and electric products	**11.9**	**3.6**	**2.2**	**1.3**	**0.9**	**1.4**	**0.8**	**17.5**	**-0.4**	**9.0**	**-0.8**	**-0.8**	**9.9**
Instruments, meters, cultural and office machinery	3.1	5.2	7.1	9.0	5.9	5.3	2.3	20.5	1.6	15.5	-0.6	-0.6	16.2
Production of electric power, steam and hot water	1.0	5.5	11.1	1.9	0.2	4.4	0.8	-12.5	14.9	-0.9	4.6		
Production of gas	0.9	6.5	7.3	3.2	8.3	3.9	0.6	17.8	-4.9	9.9	-2.5		
Production of tap water	0.5	8.2	10.5	146.0	N.A.	24.2	2.6	-3.5	-17.9	-19.8	-6.4	-30.9	-29.6

Note: parameters of Pareto distribution for domestic firms a=3.4, b=0.2, σ=3.8; parameters of Pareto distribution for foreign-invested firms a=3.4, b=0.3, σ=3.8. Elasticity of transformation of capital and labour (τ_K, τ_L)=(2.0, 0.5).

Table 6.12: Changes (%) of Private Enterprises under Firm Heterogeneity

	*FDI**	*BL*	*FL*	*HZDS*	*EXCO*	*NTFP*	*TFP*	*Export*	*Import*	*Output*	*P*	*VRT*	*SCL*
Coal, petroleum and gas	0.6	7.1	7.8	6.2	12.3	6.3	1.6	-27.3	36.8	3.7	5.1	5.1	-1.3
Ferrous metals mining and dressing	0.0	6.6	16.0	-7.3	N.A.	12.1	2.5	-8.7	9.9	1.9	1.5	1.5	0.4
Nonferrous metals mining and dressing	0.0	8.6	19.7	-11.8	-15.9	13.5	3.0	34.7	-29.2	-5.8	-4.9	-4.9	-0.9
Mining of non-metal, other minerals, and other ores	0.0	10.2	13.2	-2.9	-3.3	9.5	1.4	-5.5	9.0	1.8	1.0	1.0	0.7
Food, beverage, and tobacco manufacturing	2.5	7.3	5.6	4.9	0.8	1.8	1.0	49.0	-30.1	-2.3	-6.0	-6.0	3.9
Textile industry	**5.1**	**14.6**	**13.2**	**16.7**	**20.8**	**8.5**	**4.6**	**22.6**	**5.4**	**14.3**	**-0.9**	**-0.9**	**15.3**
Garments and other fibre products	**4.4**	**14.9**	**9.4**	**11.3**	**8.0**	**0.0**	**0.0**	**40.6**	**-32.4**	**8.6**	**-3.1**	**-3.1**	**12.0**
Leather, furs, down and related products	3.2	7.6	7.4	6.4	5.2	1.0	0.8	45.2	-6.4	24.4	-1.7	-1.7	26.6
Timber processing, bamboo, cane, palm fibre etc.	0.7	13.9	14.3	19.5	24.2	11.0	3.4	42.3	-24.3	1.4	-4.3	-4.3	6.0
Furniture manufacturing	1.0	13.3	8.8	18.5	14.4	6.5	2.2	36.9	-28.9	3.6	-3.3	-3.3	7.1
Papermaking and paper products	2.2	9.8	7.7	9.1	7.8	5.2	3.8	-45.4	61.1	-0.1	9.2	9.2	-8.5
Printing and record medium reproduction	1.0	10.3	7.6	7.8	5.6	5.2	1.8	25.2	-16.2	-0.6	-3.3	-3.3	2.8
Cultural, educational and sports goods	1.6	10.4	8.8	10.0	7.1	1.7	0.8	26.2	-21.1	10.3	-1.6	-1.6	12.1
Petroleum processing and coking	0.5	6.8	10.7	7.6	10.6	7.5	2.1	-29.8	40.7	5.7	8.2	8.2	-2.3
Raw chemical materials and chemical products	**4.9**	**11.7**	**12.3**	**14.4**	**17.5**	**7.5**	**4.7**	**19.7**	**-5.1**	**4.2**	**-1.8**	**-1.8**	**6.2**
Medical and pharmaceutical products	1.8	11.1	12.2	12.4	15.4	1.0	0.5	173.9	-61.8	0.3	-12.4	-12.4	14.5
Chemical fibre	0.8	12.8	12.9	13.2	15.6	6.1	5.5	233.7	-70.7	-22.1	-17.4	-17.4	-5.6
Rubber products	1.3	12.2	7.4	12.2	12.3	3.6	2.6	31.7	-21.3	3.3	-3.2	-3.2	6.7
Plastic products	3.7	15.3	8.2	20.4	10.7	5.2	4.1	110.1	-46.4	1.0	-9.2	-9.2	11.3
Non-metal mineral products	3.1	9.8	6.2	12.1	12.5	6.8	3.0	4.3	-4.1	-1.7	-0.9	-0.9	-0.8
Smelting and pressing of ferrous metals	2.4	13.7	10.1	29.6	45.3	12.3	3.8	-74.9	189.0	0.3	22.2	22.2	-17.9
Smelting and pressing of nonferrous metals	1.3	15.9	6.2	24.8	40.1	7.6	4.7	-74.5	129.3	-20.6	12.9	12.9	-29.7
Metal products	3.8	14.1	6.6	9.5	15.3	7.5	4.6	-52.0	73.0	-8.9	7.8	7.8	-15.5
Ordinary machinery	2.9	9.0	7.2	9.3	14.1	6.8	3.1	-29.1	25.2	-5.6	3.2	3.2	-8.5
Special purpose equipment	2.3	9.4	11.8	16.2	16.3	12.7	3.6	-28.0	17.9	-7.1	2.8	2.8	-9.6
Transport equipment	**4.4**	**7.9**	**6.5**	**6.2**	**6.6**	**3.5**	**2.6**	**-5.5**	**-4.2**	**-7.4**	**-0.2**	**-0.2**	**-7.2**
Electronic and electric products	**11.9**	**3.6**	**2.2**	**1.3**	**0.9**	**0.3**	**0.4**	**11.8**	**-0.4**	**5.1**	**-0.7**	**-0.7**	**5.8**
Instruments, meters, cultural and office machinery	3.1	5.2	7.1	9.0	5.9	4.5	3.0	23.4	1.6	18.0	-0.6	-0.6	18.8
Production of electric power, steam and hot water	1.0	5.5	11.1	1.9	0.2	3.5	1.6	-7.7	14.9	3.4	4.1		
Production of gas	0.9	6.5	7.3	3.2	8.3	2.7	1.2	0.4	-4.9	-3.6	-1.4		
Production of tap water	0.5	8.2	10.5	146.0	N.A.	37.6	7.4	42.6	-17.9	8.9	-9.2	-5.3	-17.6

Note: same as Table 6.11.

Finally, the net productivity spillover effects on variety and scale are different in these two market structures. Under monopolistic competition, the spillover premia of variety and scale are both positive, which supports the theoretical hypothesis proposed in Section 5.5.2. However under firm heterogeneity, FDI spillovers will enhance the efficiency of domestic enterprises and intensify the competition for limited resources, leading to even higher input costs and further decrease of variety produced by foreign-invested enterprises. Therefore productivity spillovers lead to higher input costs and force the least productive firms to exit, as proposed in Section 5.6.3. This causes negative spillover premium on the variety and positive spillover premium on the production scale.

Table 6.13 summarises the changes of variety, scale, cutoff and average productivity under firm heterogeneity. The spillover premia of cutoff and average productivity are positive for domestic enterprises, which is consistent with the hypothesis of productivity changes proposed in Section 5.6.3.

Table 6.13: The Impact of an FDI Shock on Variety, Scale, Cutoff (φ*) and Average ($\overline{\varphi}$) Productivity under Firm Heterogeneity

	Variety			Scale			φ^*			$\overline{\varphi}$		
	A	*F*	*D*	*A*	*F*	*D*	*A*	*F*	*D*	*A*	*F*	*D*
Without spillovers	+/-	-	+	+/-	+	+/-	+	+	+/-	+	+	+/-
With spillovers	+/-	-	+/-	+	+	+/-	+	+	+/-	+	+	+/-
Spillover premium	-	-	-	+	-	+	+	-	+	+	-	+

Note: (1) "*A*" refers to *All* enterprises' output; "*F*" refers to *Foreign*-invested enterprises in manufacturing sectors only; "*D*" refers to *Domestic*-invested enterprises (including SOEs and private enterprises). (2) "+" and "-" denote positive and negative changes. (3) Some results can be positive or negative, depending on the values of elasticities of capital and labour elasticities.

6.6. A COMPARISON ACROSS THE THREE MARKET STRUCTURES

We have examined the FDI productivity spillover effects in three different market structures, namely perfect competition, monopolistic competition, and firm heterogeneity. The spillover effects and spillover premia are compared in Table 6.14. Panel (a) presents the numerical results with the elasticity of transformation of capital and labour (τ_K, τ_L) = (2.0, 0.5). Panel (b) summarises the results of sensitivity tests against the changes of (τ_K, τ_L). The range of τ_K (τ_L) is 0.1, 0.4, ... 2.8, the same range adopted in the sensitivity experiments performed in previous Sections. The results show that the spillover effects and premia are similar across the three market structures:

(a) Total output

With FDI productivity spillovers, domestic enterprises can acquire higher productivity and attract extra labour, capital and intermediate products from foreign-invested enterprises. Therefore total output of the latter will be negatively affected by FDI spillovers. However, the benefit obtained by domestic enterprises outweighs the cost incurred by foreign firms, collectively resulting in a positive net spillover premium for the economy's total output.

(b) Productivity level

An FDI shock brings favourable changes to the *endogenous* spillover variables (not shown in Table 6.14, but shown in Table 6.5-6.8, and Table 6.11-6.12), *i.e.* backward linkages, forward linkages, export of foreign firms, and horizontal effects. These changes collectively lead to a productivity improvement for domestic enterprises under all three market structures.

(c) Importance of spillovers in TFP

For domestic enterprises, with an FDI shock, the amount of productivity "spilt over" from FDI changes *endogenously* and accounts for a larger portion in the total TFP under all three market structures.

(d) Spillover effects across three market structures

The three "spillover premium" columns in both panels illustrate the distinct net effects brought by the *endogenous* FDI productivity spillovers. The simulation results obtained from monopolistic competition scenario are numerically comparable with those obtained from perfect competition scenario with all parameter values controlled, because the former scenario is simply an extreme example of the latter when the number of firms in a sector approaches infinity. As we have discussed on Table 6.9, the net spillover effects under monopolistic competition is larger than that under perfect competition for domestic enterprises and for GDP, welfare and total output.

However the net spillover effects obtained under firm heterogeneity are less comparable with those obtained under the other two alternative market structures, because the simulation results obtained under firm heterogeneity depend on the parameter values of the Pareto distribution of firm productivity taken from estimates for US firms (Bernard et al., 2003).

Panel (a) shows that the spillover premia of output, GDP and welfare given the Pareto parameters under firm heterogeneity are very close to those obtained under monopolistic competition.

Panel (b) shows that the spillover premia exhibit a highly similar pattern across the three market structures, except for the variety changes. The reason for the exception is the different theoretical assumptions for monopolistic competition and firm heterogeneity, as explained in Section 6.5.2.

Table 6.14: The Effects of an FDI Shock (% change)

(a) *Elasticity of transformation of capital and labour* $(\tau_K, \tau_L) = (2.0, 0.5)$

		Perfect competition		Monopolistic competition		Firm heterogeneity	
		With spillovers	Spillover premium	With spillovers	Spillover premium	With spillovers	Spillover premium
Output	*All*	6.8	1.1	7.2	1.2	6.6	1.0
	FIEs	14.9	-0.6	15.3	-0.6	17.0	-0.8
	SOEs	1.9	0.5	1.8	0.5	4.2	0.5
	Private	1.2	1.2	1.3	1.2	2.8	1.1
Variety	*All*	*Not applicable*		2.4	0.3	-0.2	-0.3
	FIEs			13.3	-0.7	-0.5	-0.2
	SOEs			0.3	0.4	-0.2	-0.3
	Private			-0.2	1.3	-0.1	-0.3
Scale	*All*			1.0	0.1	2.9	0.8
	FIEs			2.0	0.0	18.4	-0.9
	SOEs			0.5	0.1	1.2	0.6
	Private			1.3	0.3	0.4	1.2
Productivity	*SOEs*	1.8	1.8	1.9	1.9	5.3	5.3
	Private	3.5	3.5	3.6	3.6	5.4	5.4
Spillovers	*SOEs*	8.7	8.7	8.7	8.7	10.3	10.3
	Private	7.3	7.3	7.4	7.4	8.3	8.3
Welfare		3.6	1.2	4.4	1.3	4.0	1.0
GDP		7.1	1.5	7.8	1.6	2.6	1.4

(b) *Sensitivity test of the elasticity of transformation of capital and labour*

		Perfect competition		Monopolistic competition		Firm heterogeneity	
		With spillovers	Spillover premium	With spillovers	Spillover premium	With spillovers	Spillover premium
Output	*All*	+	+	+	+	+	+
	FIEs	+	-	+	-	+	-
	SOEs	+/-	+	+/-	+	+	+
	Private	+/-	+	+/-	+	+/-	+
Variety	*All*	*Not applicable*		+	+	+/-	-
	FIEs			+	-	-	-
	SOEs			+/-	+	+/-	-
	Private			+/-	+	+/-	-
Scale	*All*			+	+	+	+
	FIEs			+	-	+	-
	SOEs			+	+	+/-	+
	Private			+	+	+/-	+
Productivity	*SOEs*	+	+	+	+	+	+
	Private	+	+	+	+	+	+
Spillovers	*SOEs*	+	+	+	+	+	+
	Private	+	+	+	+	+	+
Welfare		+	+	+	+	+	+
GDP		+	+	+	+	+	+

Note: (1) The range of (τ_K, τ_L) is 0.1, 0.4, … 2.8, the same range adopted in the sensitivity experiments performed in previous Sections. (2) "productivity" is denoted by equation (5.6b); (3) "spillovers" measures how the importance of productivity spillovers in domestic enterprises' TFP changes, as denoted by equation (5.8). (4) The initial number of firms in each ownership-sector is set to be 10.

6.7. CONCLUSIONS

This Chapter discusses how an FDI shock to the benchmark economy together with productivity spillovers affects economic performance. Simulations are conducted under three different market structures, namely, perfect competition, monopolistic competition, and firm heterogeneity.

Results show that (1) in terms of national aggregate indicators, an FDI shock is beneficial to the economy, and FDI productivity spillovers are followed by positive spillover premiums under the three market structure assumptions; (2) for domestic enterprises (including SOEs and Private enterprises), FDI productivity spillovers promote their performance and always outweigh the negative impact of an FDI shock; (3) for foreign-invested enterprises, FDI productivity spillovers cause resources to be attracted away by their rivals that are more productive thanks to the FDI spillovers, thus making the increase in foreign-invested enterprises' total output *lower* than otherwise; This finding also applies to all the three market structures; (4) product variety and production scale per variety can both be improved by an FDI shock, and FDI productivity spillovers can exert positive "spillover premiums" under certain conditions; and (5) the experiments under the monopolistic competition assumption show that FDI productivity spillovers are more prominent in an industry with a lower initial degree of competition.

The simulation results obtained under three market structures are generally consistent with the theoretical hypotheses derived in the previous Chapter. Under any market structure, productivity spillovers enable domestic enterprises to attract more labour, capital and intermediate products from foreign enterprises. In this way FDI generates positive spillover premia for domestic enterprises and negative spillover premia for foreign enterprises.

Under monopolistic competition, Section 5.5.2 derives a theoretical hypothesis that both variety and production scale of domestic enterprises can increase due to the possibly lower input costs brought by the FDI productivity spillovers. This hypothesis is justified by the simulation results presented in Figure 6.5.

Under firm heterogeneity, Section 5.6.3 derives two theoretical hypotheses, namely *productivity improvement effect* caused by the FDI spillovers from foreign to domestic enterprises, and *resource reallocation effect* which transfers resources from the least productive firms (exiting the market due to the increased competition) to the remaining firms. Both effects boost average productivity of the remaining firms. This proposition is also justified by the simulation results presented in Table 6.13 and 6.14.

But there is one result seemingly counter to the theoretical hypotheses set out earlier in the thesis. Under firm heterogeneity, the spillover premium of domestic enterprises' ouput is not significantly larger than that obtained under the other two alternative market structures. However as the average productivity levels of both foreign and domestic enterprises can become higher with an FDI shock (às hypothesized in Section 5.6.3 and justified with the simulation results presented in the "with spillovers" row in Table 6.13), it was anticipated that the spillover premium in terms of the change of domestic enterprises' output would be much more significant. This may reflect the parameters of the Pareto distribution of firm productivity, which were taken from values estimated for US rather than Chinese enterprises, as we discussed in Section 6.6.

In brief, the simulated effects of the FDI productivity spillovers obtained under the three market structures generally support the theoretical hypotheses derived earlier in the thesis. The trivial deviation between expected and actual results arises mainly due to the selection of parameter values and model design.

CHAPTER 7: 2008 CORPORATE INCOME TAX REFORM AND FDI PRODUCTIVITY SPILLOVERS

7.1. INTRODUCTION

In 2008, the Chinese government abolished the preferential tax treatment granted to foreign-invested enterprises almost three decades ago. This Chapter discusses the impact of the 2008 tax reform on the FDI productivity spillover effects in China. Section 7.2 introduces the tax incentives used to attract FDI. Section 7.3 discusses the cost and benefit of such a preferential FDI treatment. Section 7.4 simulates the economic effects of the 2008 corporate income tax harmonisation. The responsiveness of FDI inflow to the tax rate is taken from the literature. Section 7.5 concludes.

7.2. CHINA'S FDI POLICIES

China's FDI policies are mainly stated in two types of official documents, namely the *Guiding Directory on Industries Open to Foreign Direct Investment* (hereafter *FDI Directory*) and various laws and regulations (see Table 7.1), which were originally issued at the early stage of "Reform and Opening-up" policy implementation, *i.e.* the late 1970s and early 1980s. Although these official documents have been amended various times in the past three decades, one of the priority targets has never been changed, *i.e.* FDI policies should provide foreign firms with preferential incentives (Prasad and Rajan, 2006) aimed at swapping domestic market access for advanced foreign technology and productivity (Long, 2005).

Table 7.1: China's Main FDI Policies

Category	Name	Last updated
Directory	• *Guiding Directory on Industries Open to Foreign Investment*	2007
Laws	• *Corporate Income Tax Law*	2007
	• *Law on Wholly Foreign-owned Enterprises*	2001
	• *Law on Chinese-Foreign Joint Ventures*	2000
	• *Law on Chinese-Foreign Cooperative Enterprises*	1988
	• *Law on Protection of Investment by Compatriots from Taiwan*	1994
Regulations	• *Regulations for Encouraging Investment from Overseas Chinese and Compatriots from Hong Kong and Macao*	1990
	• *Regulations for Encouraging Investment from Compatriots from Taiwan*	1988

7.2.1. FDI Directory

The *FDI Directory* lists three categories of industries, to which FDI are "*encouraged*", "*restricted*" and "*prohibited*", respectively. It has been amended five times since its first release in 1995. As shown in Table 7.2, the proportion of "encouraged" industries gradually increased from 53.9% in 1995 to 73.4% in 2007, while the proportion of "restricted" industries decreased by half during that period.

Table 7.2: Three Categories of Industries Listed in the FDI Directory

Version	Encouraged		Restricted		Prohibited	
	Number	%	Number	%	Number	%
1995	172	**53.9**	116	36.4	31	9.7
1997	186	**57.1**	112	34.4	28	8.6
2002	262	**71.0**	75	20.3	32	8.7
2004	257	**70.2**	76	20.8	33	9.0
2007	351	**73.4**	87	18.2	40	8.4

Source: Same as Figure 1.1. By author's compilation.

7.2.2. Laws and Regulations Related to Tax Incentives

Various preferential treatments used to be granted to the foreign invested enterprises (FIEs)[9] in manufacturing sectors and such treatments were enforced by laws and regulations. The most controversial treatment was the differential corporate income tax rates. According to the *Income Tax Law for Enterprises with Foreign Investment and Foreign Enterprises* passed in 1991 (abolished in 2008), foreign-invested firms should pay an income tax at the rate of 30%. However, any enterprise with foreign investment of a manufacturing nature scheduled to operate for a period of not shorter than 10 years shall, from the year in which it begins to make profits, be exempted of income tax in the first and second years and be qualified to claim a 50% reduction in the third to fifth years. That is to say, most FIEs only needed to pay income tax at an average rate of roughly **15% in the first seven years** of operation. In contrast, the corporate income tax rate of domestic firms was as high as **33%**.

The dual differential corporate income tax system was abolished by China's Parliament and the new tax rate for both domestic firms and FIEs have been set to be **25%** since January 2008. Nonetheless, FIEs established before 16 March 2007 can still enjoy the tax exemption during a five-year interim period, *i.e.* from 1 January 2008 until 31 December 2012.

Regardless of the above *de facto* dual tax system during the five-year interim period, both domestic enterprises and FIEs can also equally enjoy various nationwide tax incentives, such as:

[9] FIEs include all types of enterprises listed in Table 1.1, namely solely foreign owned enterprises, joint ventures, and co-operative enterprises, and other types of foreign-invested enterprises.

(a) A reduced rate of 20% may be applied to small or low-profit enterprises. The withholding tax[10] rate is 10% on interest, royalties, capital gains and dividends;

(b) Reduced tax rate of 15% to advanced technology enterprises;

(c) Tax exemption or reduction for enterprises that engage in infrastructure projects, agriculture, forestry, fishery, energy and water preservation, environmental protection business and transfer of qualified technology;

(d) Reduced taxable income in proportion to the investment of venture capital;

(e) Tax reduction for R&D expenses for developing new technology, new products and new processes.

7.2.3. Objectives of China's FDI Policies

(a) *Export promotion*

Before China's accession into the World Trade Organization (WTO) in 2001, export promotion and technology transfer were among the most important targets of China's FDI policies.

In the late 1970s when China started transforming from almost an autarky economy into an export-oriented one, the foreign exchange reserves it held were as little as US$0.2 billion, which was a trivial figure compared to the reserves it had by December 2008, US$1946.0 billion (State Administration of Foreign Exchange of China, *http://www.safe.gov.cn/*). In desperate need of foreign exchange reserves to fund the import of intermediate products and advanced technology, China adopted a series of mercantilist measures to

[10] Withholding tax is income tax withheld from employees' wages and paid directly to the government by the employer.

promote exports. The FDI policies regarding exports required that FIEs should keep a balance of exchange, or make sure the proportion of their domestically made products in the total number of products maintains at a reasonable level, or a certain percentage of their products should be exported. Besides, any FIE with 70% of its total products exported was entitled to claim 50% cut in corporate income tax. However, since such requirements and incentives were inconsistent with the provisions of WTO Agreement on Trade-Related Investment Measures (TRIMs), they were abolished in 2001 as China became a WTO member state.

The FDI policies were so effective in export promotion that the export propensity of FIEs and the contribution of FIEs to China's total exports have been astonishingly high. In 2004, the average ratio of export to total sales of FIEs was 46.1% in manufacturing, while the average ratio of other types of enterprises was only 10.2% (National Bureau of Statistics of China, 2006a). In 2007, the share of FIEs' export in China's total export hit a record high, 60%, which was much higher than 4% in the early 1980s (Ministry of Commerce of China). The strong export performance of FIEs set a good example for Chinese indigenous enterprises to enter the international market.

(b) *To transfer advanced technology*

China's laws on FIEs had specific technology requirements even after the removal (in 2001) of the clauses inconsistent with China's WTO commitments. According to the latest *Law on Chinese-Foreign Joint Ventures*, "the technology and equipment that serve as the investment of the foreign partner in a joint venture **must be** advanced technology and equipment that indeed suit China's needs." Both *Law on Wholly Foreign-owned Enterprises* and *Law on*

Chinese-Foreign Cooperative Enterprises also state that the State encourages the establishment of wholly foreign-owned enterprises and production-based Chinese-foreign cooperative enterprises with advanced technology.

7.3. COST AND BENEFIT OF PREFERENTIAL FDI TREATMENT

As discussed, most FIEs only needed to pay corporate income tax at an average rate of as low as 15% in the first seven years of operation. In contrast, the income tax rate (*i.e.* corporate income tax divided by total profit) of domestic firms is as high as 33%. Table 7.3 shows the actual corporate income tax rates for state-owned, private, and foreign-invested enterprises in 2004. The tax rates are calculated with the data from *China Economic Census Statistical Yearbook 2004*, as the data of the benchmark year (*i.e.* 2002) of this CGE model is not available. The average tax rates of SOEs and Private enterprises were 19.5% and 19.3% respectively. However, FIEs only paid income tax at 10.4%, almost half of those of their domestic rivals.

It is observed that there is much variation in these rates. Such variation is caused by various tax exemptions applicable to some enterprises as discussed in Section 7.2.2. Domestic enterprises in some industries collectively pay a tax at a rate higher than the upper limit 33%, which could be caused by accounting and measurement errors.

The preferential tax treatment had potentially encouraged foreign capital to flow to China, especially at the beginning of the marketisation (1980s) when the Chinese market was relatively closed and unknown to the rest of the world. The foreign capital increased the foreign reserves of China and helped it to import advanced equipment and technology. FDI also helped break the monopoly of SOEs and created a more competitive market environment. More importantly, preferential tax treatment had potentially promoted the productivity spillovers from foreign firms to domestic firms via backward and forward input-output linkages, cross-ownership labour mobility, the export of foreign firms, and horizontal effects.

Table 7.3: Corporate Income Tax Rate by Industry in 2004 (%)

Sectors	SOEs	Private	FIEs
Coal, petroleum and gas	12.8	21.1	1.4
Ferrous metals mining and dressing	19.6	27.2	15.5
Nonferrous metals mining and dressing	20.8	19.1	9.8
Mining of non-metal, other minerals, and other ores	32.2	20.7	23.7
Food, beverage, and tobacco manufacturing	30.3	14.9	14.5
Textile industry	n.a.	20.2	12.7
Garments and other fibre products	24.8	21.2	11.9
Leather, furs, down and related products	n.a.	14.7	13.3
Timber processing, bamboo, cane, palm fibre etc.	29.6	15.2	14.3
Furniture manufacturing	10.0	17.3	8.7
Papermaking and paper products	45.4	20.6	13.2
Printing and record medium reproduction	26.7	23.8	12.4
Cultural, educational and sports goods	47.7	18.5	15.6
Petroleum processing and coking	24.5	20.3	12.4
Raw chemical materials and chemical products	21.3	17.5	10.1
Medical and pharmaceutical products	19.7	17.9	12.5
Chemical fibre	55.7	18.6	13.8
Rubber products	35.7	20.8	13.0
Plastic products	24.6	19.1	12.5
Non-metal mineral products	29.1	20.7	10.3
Smelting and pressing of ferrous metals	24.8	18.9	6.7
Smelting and pressing of nonferrous metals	24.2	19.3	10.9
Metal products	28.2	20.6	11.1
Ordinary machinery	22.7	20.6	12.1
Special purpose equipment	29.2	21.3	9.4
Transport equipment	10.5	19.6	7.8
Electronic and electric products	22.6	19.6	10.3
Instruments, meters, cultural and office machinery	42.0	17.3	10.6
Production of electric power, steam and hot water	21.5	24.8	12.2
Production of gas	45.6	10.9	11.4
Production of tap water	n.a.	26.2	22.1
Average	**19.5**	**19.3**	**10.4**

Source: *China Economic Census Statistical Yearbook 2004*. Beijing: China Statistics Press. 2006.

Note: "SOEs", "Private", and "FIEs" denote the corporate income tax rate (=corporate income tax/total profits) of state-owned enterprises, private domestic enterprises, and foreign-invested enterprises, respectively.

However the benefits of such a preferential tax treatment seem to have diminished gradually due to the following two facts. First in recent years China's foreign reserves have been the highest in the world, reducing the necessity of accumulating reserves by attracting FDI (especially the export-oriented and labour-intensive foreign capital) simply with preferential tax treatment. Second, in manufacturing sectors, monopoly power of the SOEs has already been greatly restricted, and a more competitive market environment has already been fostered with the emergence of a variety of ownerships. As shown in Table 7.4, by 2007 the SOEs, private enterprises, and foreign-invested enterprises account for 9%, 23%, and 31% of national total output, respectively. So the benefit of the preferential tax treatment to the FIEs in breaking the monopoly of the SOEs is no longer so appealing.

Table 7.4: A Decomposition of National Total Output by Ownership, 2007

	Total output (RMB bn)	**Percentage (%)**
Total	**40518**	**100%**
Domestic Enterprises	**27755**	**69%**
-- SOEs	**3639**	**9%**
-- Limited Liability Company	9034	22%
-- Stock Company	4016	10%
-- Private Enterprises	**9402**	**23%**
-- Others	1664	4%
Foreign-invested Enterprises	**12763**	**31%**
-- Joint Venture	5410	13%
-- Solely Foreign Owned	6425	16%
-- Others	928	2%

Note: (a) Data source: *China Statistical Yearbook 2008*. Beijing: China Statistical Press. 2008; (b) statistics only covers the enterprises with annual sales above RMB 5 million in the MMU (mining, manufacturing, and utilities) sectors.

At the same time problems related to such preferential treatments also emerged so that the costs of the differential tax system have increased in recent years. The most critical one is *"round-tripping" FDI*, *i.e.* fake FDI. "Round tripping" FDI refers to cross-border investment motivated by the more favourable treatment of foreign as opposed to domestic capital. Domestic investors can transfer their capital out of, and then invest back into, the domestic market with a new label of "FDI". By 2003, about a quarter of FDI to China was round-tripping FDI (United Nations Conference on Trade and Development, 2003, pp. 45). Those enterprises invested by round-tripping FDI are not necessarily more productive than the firms registered as "domestic enterprises". However the former can enjoy a much lower corporate income tax rate (15%) for a maximum seven years. After this initial seven years, the investors could deliberately claim "bankruptcy" and re-register their fund as new "foreign-invested firms". By doing this, a domestic investor can circumvent the high corporate income tax forever. These tax evasion behaviour jeopardised the market environment and posed unfair competition against domestic enterprises.

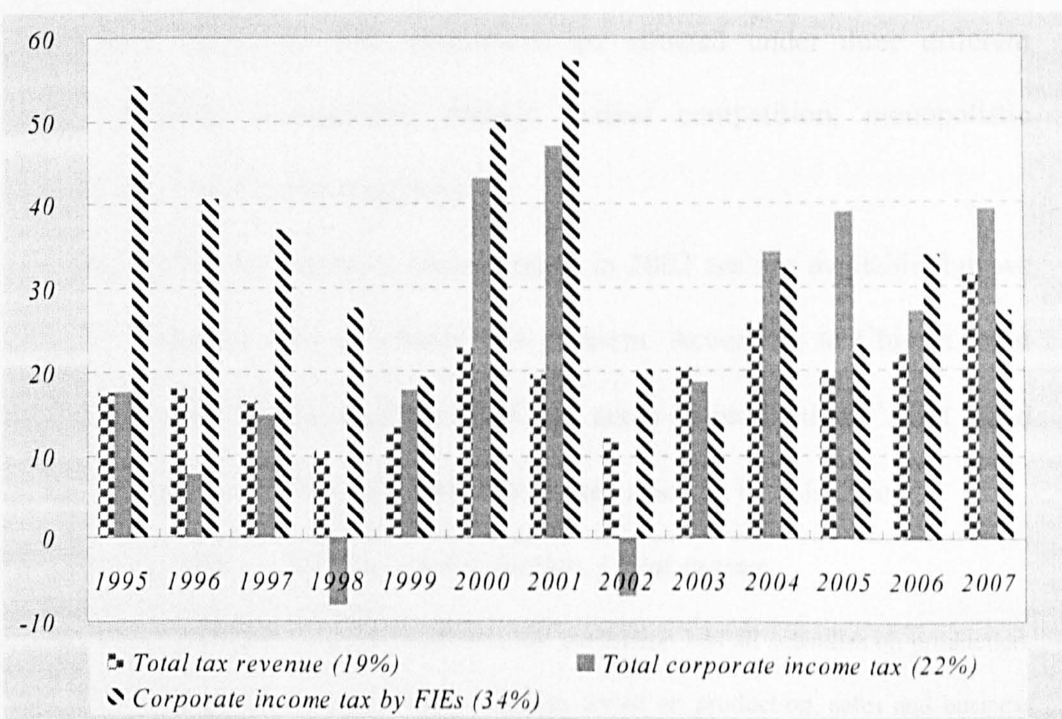
The second problem is related to the *technology content and origin of FDI*. FDI from Hong Kong, Macau, and Taiwan tended to remain in labour-intensive, low-technology manufacturing sectors, *e.g.* textiles, toys, and clothing. Some of those foreign-invested enterprises did not have any advantage in productivity, and the only advantage they held to beat domestic enterprises was the favourable corporate income tax rate. Empirical evidence suggests that once the presence of FDI in a certain sector exceeds a optimal point, foreign-invested enterprises may impose a negative impact on the performance of their domestic rivals (Buckley, Clegg and Wang, 2007).

The third problem of the preferential taxes is linked to the *survival of domestic firms in services* in China. The expansion of service sectors normally accompanies the industrialisation process. The percentage of services in China's GDP has been growing from less than 25% in late 1970s to around 40% in 2006. Also the employment in services accounted for 32% of total employment in China in 2006. These two figures in 2006 are still far below those in post-industrialisation economies, and indicate that the service sectors in the Chinese economy are far from well established. Facing the strong competition from mature foreign multinational firms in service industries *e.g.* banking, insurance, retail and wholesale, domestic enterprises do need a fair competitive environment where they can survive and sustain. A differential corporate income tax system will however threaten the development of domestic enterprises in service sectors.

The fourth problem is the *international competitiveness* of Chinese domestic enterprises. The average corporate income tax rate is 28.6% among all the 159 countries (or regions) around the world which have adopted a corporate income tax system. The average rate is 26.7% among the 18 countries (or regions) neighbouring China mainland (State Administration of Taxation of China, *http://www.chinatax.gov.cn/. 27 March 2007.*). A tax rate of 33% on domestic enterprises undoubtedly reduced the international competitiveness of the domestic enterprises.

The final possible problem is related to the *fiscal revenue*. Various empirical studies have found a negative relationship between corporate income tax and FDI inflows, *i.e.* with a lower corporate income tax rate on foreign firms, a country can generally attract more FDI (e.g. Grubert and Mutti, 1991; Hines and Rice, 1994; Cassou, 1997; Wei, 2000a, 2000b; Choi, 2003; Ang, 2008). If FDI is very elastic to the preferential corporate income taxes, then a lower tax rate could raise the fiscal revenue from foreign enterprises' taxes. However allured by the potential effectiveness of various tax incentives in attracting FDI, countries have "increasingly" relied on such policy instruments (United Nations Conference on Trade and Development, 2000, pp. 3). So compared with the corporate income tax rates (the *de facto* ones may be lower than the average 26.7% as discussed) in surrounding regions, the tax rate of 15% in China might not appear so attractive. Moreover, if FDI is attracted to China more by the cheap labour and raw materials and the market potential in China rather than the low tax rate, then a low tax rate will cause a net loss of fiscal revenue. The total tax revenue, total corporate income taxes, and corporate income taxes paid by the foreign enterprises in China have grown very fast since early 1990s, as shown in Figure 7.1.

Figure 7.1: Growth Rates of Tax Revenue in China, 1995-2007 (%)



Source: State Administration of Taxation of China (http://www.chinatax.gov.cn/).

The average annual growth rates of total corporate income taxes and corporate income taxes paid by FIEs are 22% and 34%, respectively, both higher than that of total tax revenue (19%). These figures indicated that the foreign enterprises performed well in the Chinese market, so a low corporate income tax on FIEs might have incurred a loss of fiscal revenue collected from foreign enterprises' income taxes.

In brief, the recent Chinese macroeconomic situation indicated that the costs of the dual corporate income tax system may have come to exceed the benefits in the recent years, and thus yielding an optimal time to harmonise the tax rates.

7.4. ASSESSMENT OF THE TAX HARMONISATION

The experiments conducted in this Section are aimed at evaluating whether a removal of preferential corporate income tax treatment will hamper the FDI productivity spillovers. The simulations are situated under three different market structure assumptions, namely perfect competition, monopolistic competition, and firm heterogeneity.

The data of the corporate income taxes in 2002 are not available, but we can use alternative data to remedy this problem. According to China's input output table, the only tax data are titled "net taxes on production"[11], and based on the tax data and total output data, a gross tax rate can be calculated:

$gross\ tax\ rate_i = net\ taxes\ on\ production_i\ /\ total\ output_i$

[11] "Net Taxes on Production" refer to all taxes on production less all subsidies on production. They include various taxes, extra charges and fees levied on production, sales and business activities as well as on the use of factors, such as fixed assets, land and labour. In contrast to taxes on production, subsidies on production refer to the government transfer to the production units and are therefore regarded as negative taxes on production.

where i indexes the sectors in mining, manufacturing, and utilities.

Then the data of corporate income taxes of foreign-invested enterprises, SOEs, and private enterprises in 2004 are collected from the *China Economic Census Statistical Yearbook 2004*, and are divided by total output to obtain the *transformed* version of corporate income tax rate:

$$income\ tax\ rate_i = income\ taxes_i\ /\ total\ output_i \tag{7.1}$$

The 2008 tax reform harmonised corporate income tax rate for domestic enterprises (previously 33%) and foreign enterprises (up to 15%) to 25%. This reform formula can be modelled by deflating the corporate tax rate of domestic enterprises' output by 24.2% [(25%-33%)/33%= -24.2%], while augmenting the tax rate of foreign enterprises' output by 66.7% [(25%-15%)/15%=66.7%].

It is necessary to endogenise the FDI flows by linking FDI with such a tax reform[12]. Here a parameter is taken from the paper of Wei (2000b) who estimates the responsiveness of FDI inflows to the statutory corporate income tax with a gravity FDI model. The details of the model are discussed in the Appendix to this Chapter. The responsiveness of FDI to tax can be specified as:

$$\frac{\partial \ln(FDI)}{\partial(tax)} = \frac{\Delta(FDI)}{FDI \times \Delta(tax)} = -0.032 \tag{7.2}$$

Wei's work covers bilateral FDI data from 14 source countries to 53 host economies (including China mainland), while other papers only examine the relationship between corporate income tax and FDI flows of a *single* FDI source country or recipient country (e.g. Grubert and Mutti, 1991; Hines and Rice, 1994; Cassou, 1997; Ang, 2008). More importantly, this work is one of the very few papers which estimate the tax responsiveness for the FDI flow to

[12] Such an endogeneity is similar to the practice adopted in a CGE model (Gooroochurn and Milner, 2005), where tourist arrival is endogenously linked to the tax reform.

China. Another paper also by Wei (2000a) which covers 12 FDI source countries and 45 host countries, and a paper by Choi (2003) employing the same database of Wei (2000b), have both obtained highly close tax sensitivity values. Thus it is reasonable to employ the parameter (-0.032) in this model to capture the endogenous link between corporate income tax rate and FDI inflow amount in China.

Four types of tax reforms are simulated. In the first scenario there are no FDI productivity spillovers, and only the corporate income tax rate for foreign firms increases by 40% (hereafter "*single-sided reform without spillovers*"). In the second scenario there are no FDI productivity spillovers, the corporate income tax rate for foreign firms increases by 40%, and the tax rate for domestic firms decreases by 24.2% (hereafter "*integrated reform without spillovers*"). In the third scenario there are FDI productivity spillovers, and only the corporate income tax rate for foreign firms increases by 40% (hereafter "*single-sided reform with spillovers*"). In the fourth scenario there are FDI productivity spillovers, the corporate income tax rate for foreign firms increases by 40%, and the tax rate for domestic firms decreases by 24.2% (hereafter "*integrated reform with spillovers*"). The above tax rate changes will be captured by changing the values of parameter $\overline{TAXREF}(a)$ in equation (A5.3.1). For example, this parameter value for the foreign enterprises in "electronic and electric products" sector can be obtained as:

(a) calculate the income tax rate using equation (7.1), and we get 0.75%;

(b) calculate the tax increment: 0.75%×40%=0.3%.

All of the above reforms are accompanied with endogenous FDI inflow reduction. From equation (7.2) we know that the percentage change of FDI inflow follows:

$$\frac{\Delta(FDI)}{FDI} = -0.032 \times \Delta(tax) \tag{7.3}$$

For example, in the "electronic and electric products" sector, FDI volume will decrease by 0.032×[25 (%, new tax rate)-10.3 (%, old tax rate)] = 0.47 (%).

This reduces FDI inflow, and will result in a lower foreign presence in terms of the proportion of output produced by foreign firms in the total output produced by all types of firms. This will make the channels (*i.e.* backward and forward linkages, export of the foreign enterprises, and horizontal effects) of FDI productivity spillovers shrink, and reduce the magnitude of FDI productivity spillovers, as captured by equation (5.8).

The domestic capital stock is assumed fixed in this static CGE model. As the output prices of products by foreign enterprises are higher after the reform, the cost of intermediate products used by domestic enterprises will also be higher. At the same time, facing higher corporate income taxes, the returns to capital and labour in foreign enterprises will be lower. This will consequently lead to a lower price of primary inputs of domestic enterprises due to the transformability between foreign and domestic capital. Therefore, the impact of single-sided reform on domestic enterprises will be jointly determined by the above three possible effects, namely a smaller magnitude of FDI productivity spillovers, higher intermediate input costs, and lower primary input costs. But overall, single-sided reform will increase the average national tax rate level, and therefore reduce the welfare level. This model adopts a fiscal-neutral government closure rule (see Section 5.3.2), i.e. the fiscal deficit is financed by borrowing a *fixed* amount of commodities from the households, and the government spending is endogenously determined subject to the exogenous tax rate level (to be changed in counterfactual simulations in this Section). The government closure is so designed that the change of welfare, measured by the total amount of consumption goods and services available for the households and government, can be *fully* attributed to the tax reform.

An integrated tax reform not only raises the taxes of foreign enterprises but also reduces the taxes of domestic enterprises. This will complicate the net impact of the tax reform on the total output of domestic enterprises in that it can increase the returns to the capital and labour used by domestic enterprises. In terms of the FDI productivity spillovers, the impact of such a tax reform still tends to be negative due to similar reasons. The sign of the national welfare change with an integrated tax reform can not easily be predicted.

Fiscal revenue will also change accordingly. In the model, the other tax rates, *i.e.* the average output overall tax rates, as denoted by `NTP(a)` in equation (A5.3.1), are assumed to be fixed. Due to the nonlinear relationship between tax rate and tax revenue suggested by the Laffer curve, the sign of tax revenue change can not be predicted *ex ante* either, and the different changing directions of tax rates over domestic (up) and foreign (down) enterprises also leave this as an empirical problem.

Table 7.5 reports the numerical results from scenario (a) only. To make the results from four scenarios more easily comparable, Table 7.6 reports only the signs of the results out of four scenarios.

Table 7.6 contains four panels. Panel (a) (b), (c), and (d) report the results from the scenarios of "*single-sided reform without spillovers*", "*integrated reform without spillovers*", "*single-sided reform with spillovers*", and "*integrated reform with spillovers*", respectively. By comparing the results in these four panels, we may have the following four main findings:

(1) The difference between the scenarios with single-sided and integrated reforms. The economy before the tax reform is already distorted with corporate taxes. Single-sided reform simply raises the tax rate on foreign enterprises, leaves the economy even more distorted, and reduces welfare. However the integrated reform not only raises the tax rate on foreign enterprises, but also lowers the tax rate on domestic enterprises and improves national welfare. The production scale of SOEs and Private enterprises are negatively impacted in the single-sided reforms, while positively affected in the integrated reforms.

Table 7.5: Effects of Corporate Income Tax Reform: Scenario (a)

(% changes, single-sided reform without spillovers)

		Perfect competition	***Monopolistic competition***	***Firm heterogeneity***
Output	*All*	-0.17	-0.18	-0.19
	FIEs	-0.72	-0.75	-0.83
	SOEs	0.04	0.04	0.02
	Private	0.05	0.04	0.06
Variety	*All*	*Not applicable*	-0.05	-0.10
	FIEs		-0.67	-0.40
	SOEs		0.09	-0.07
	Private		0.11	-0.05
Scale	*All*	*Not applicable*	-0.02	0.07
	FIEs		-0.11	-0.43
	SOEs		-0.01	0.12
	Private		-0.03	0.15
Productivity	*All*	*Not applicable*		0.02
	FIEs			0.01
	SOEs			0.02
	Private			0.02
Spillovers	*SOEs*	*Not applicable*		
	Private			
Total tax revenue		-0.19	-0.20	-0.21
Corporate income tax revenue		11.87	11.86	11.82
Welfare		-0.40	-0.42	-0.37
GDP		-0.14	-0.16	-0.14

Note: (1) "productivity" is industry-level productivity, measured by the denominator of fraction (5.8); (2) "spillovers" measures how the importance of productivity spillovers in domestic enterprises' TFP changes, as measured by equation (5.8); (3) Parameters of Pareto distribution (domestic firms) a=3.4, b=0.2, σ=3.8; parameters of Pareto distribution (foreign-invested firms) a=3.4, b=0.3, σ=3.8. Elasticity of transformation of capital and labour (τ_K, τ_L) = (2.0, 0.5). (4) "Not applicable" means that the values of the corresponding variables are not obtainable.

Table 7.6: Effects of Corporate Income Tax Reform (%)

(a) single-sided reform without spillovers

		Perfect competition	Monopolistic competition	Firm heterogeneity
Output	All	-	-	-
	FIEs	-	-	-
	SOEs	+	+	+
	Private	+	+	+
Variety	All	Not applicable	-	-
	FIEs		-	-
	SOEs		+	-
	Private		+	-
Scale	All	Not applicable	-	+
	FIEs		-	-
	SOEs		-	+
	Private		-	+
Productivity	All	Not applicable		+
	FIEs			+
	SOEs			+
	Private			+
Spillovers	SOEs	Not applicable		
	Private			
Total tax revenue		-	-	-
Corporate income tax revenue		+	+	+
Welfare		-	-	-
GDP		-	-	-

(b) integrated reform without spillovers

		Perfect competition	Monopolistic competition	Firm heterogeneity
Output	All	-	-	+
	FIEs	-	-	-
	SOEs	+	+	+
	Private	+	+	-
Variety	All	Not applicable	-	+
	FIEs		-	-
	SOEs		+	+
	Private		+	+
Scale	All	Not applicable	-	+
	FIEs		-	-
	SOEs		+	+
	Private		+	+
Productivity	All	Not applicable		+
	FIEs			+
	SOEs			+
	Private			+
Spillovers	SOEs	Not applicable		
	Private			
Total tax revenue		-	-	-
Corporate income tax revenue		-	-	-
Welfare		+	+	+
GDP		-	-	+

(c) single-sided reform with spillovers

		Perfect competition	Monopolistic competition	Firm heterogeneity
Output	All	-	-	-
	FIEs	-	-	-
	SOEs	+	+	+
	Private	-	-	-
Variety	All	Not applicable	-	-
	FIEs		-	-
	SOEs		+	-
	Private		+	-
Scale	All	Not applicable	-	+
	FIEs		-	-
	SOEs		-	+
	Private		-	+
Productivity	All	Not applicable		+
	FIEs			+
	SOEs	-	-	+
	Private	-	-	+
Spillovers	SOEs	-	-	-
	Private	-	-	-
Total tax revenue		-	-	-
Corporate income tax revenue		+	+	+
Welfare		-	-	-
GDP		-	-	-

(d) integrated reform with spillovers

		Perfect competition	Monopolistic competition	Firm heterogeneity
Output	All	-	-	+
	FIEs	-	-	-
	SOEs	+	+	+
	Private	+	+	-
Variety	All	Not applicable	-	+
	FIEs		-	-
	SOEs		+	+
	Private		+	+
Scale	All	Not applicable	-	-
	FIEs		-	-
	SOEs		+	+
	Private		+	+
Productivity	All	Not applicable		+
	FIEs			+
	SOEs	-	-	+
	Private	-	-	+
Spillovers	SOEs	-	-	-
	Private	-	-	-
Total tax revenue		-	-	-
Corporate income tax revenue		-	-	-
Welfare		+	+	+
GDP		-	-	+

Note: same as Table 7.5.

(2) The difference between the scenarios with and without spillovers. The results are almost the same with or without spillovers. The only difference is the total output of Private enterprises in Panel (a) and (c). Their output is negatively affected in the scenario with spillovers while positively affected in the scenario without spillovers. The reason for this seemingly counterintuitive result can be explained by the competition between the SOEs and Private enterprises. With a single-sided tax reform, the prices of intermediate inputs are higher while the prices of primary inputs become lower. When there are no productivity spillovers, Private enterprises appear to benefit from such a reform. However, when there exist spillovers, SOEs benefit more from the spillovers than the Private enterprises do, so that SOEs attract resources from the Private enterprises, making the latter lose from the spillovers.

(3) The comparison between the three alternative assumptions about industry structure. We need to keep in mind that any structure alone can not reflect the whole picture of an economy: some industries tend to be perfectly competitive as they produce highly homogeneous products, *e.g.* "petroleum processing and coking", and "textile"; some industries are more monopolistic competitive as their products are idiosyncratic and the number of firms is relatively small, *e.g.* "transport equipment"; and finally some industries could be closer to the assumption of monopolistic competition with heterogeneous productivity, such as the "electronic and electric products" industry hosting a very high level of product variety and the largest number of firms in China. Therefore, the main purpose of spotting the difference between the above three alternative market structure assumptions is not to identify which assumption is "superior" to the others, but to get a sense of the range of possible outcomes.

The simulations in the scenario of perfect competition can provide results of output, productivity of domestic enterprises, spillovers, welfare, and GDP. Simulations in the scenario of monopolistic competition can provide further details of variety and production scale. Simulations in the scenario of firm heterogeneity can capture not only the above variables, but also the productivity changes of both domestic firms and foreign firms.

The results of the productivity of domestic firms, output, productivity spillovers, welfare, and GDP are similar in the first two market structures. But the results under firm heterogeneity are different from those obtained in the previous two market structures to some extent. For example, in panel (a) and (c), the variety of SOEs and Private enterprises are positively affected under monopolistic competition while negatively affected under firm heterogeneity. Similar contrast applies to the changes of scale under monopolistic competition and firm heterogeneity. However, the above contrasts are consistent with those discussed in Section 6.4.2 and reflected in Table 6.14 in Chapter 6.

Another difference between the scenario of firm heterogeneity and the other two alternative market structures is the change of productivity of domestic firms under the above three scenarios. The productivity change is positive under firm heterogeneity while negative under the other two scenarios. Such an "inconsistency" can be explained by the different specification of "productivity". Under perfect and monopolistic competition, productivity is denoted by $\hat{\alpha}_1 + \hat{\boldsymbol{\beta}} \times \boldsymbol{SPL}$ in equation (5.8), so that the productivity of domestic firms is *directly dependent on* the presence of foreign firms. However under firm heterogeneity, productivity is an endogenous variable denoted by equation (5.30) in the partial equilibrium module, and it is only *indirectly* *linked* with the foreign presence. In this sense, the "productivity" denoted by $\hat{\alpha}_1 + \hat{\beta} \times SPL$ may not capture the actual information of domestic firms' productivity as fully as the "productivity" variable denoted by equation (5.30) under firm heterogeneity.

A comparison of panel (b) and (d) shows differences in total output and GDP. These two variables increase under firm heterogeneity while they decrease under the other two alternative market structures. This is also because the assumption of firm heterogeneity makes the model capture the productivity changes in a different way. *When there are no spillovers* (scenario (b)), firm productivity is endogenously modelled under firm heterogeneity and can affect the output and GDP explicitly, while productivity takes the benchmark value of 1 under perfect competition and monopolistic competition. *When there are spillovers* (scenario (d)), as discussed the productivity of domestic firms will decrease under perfect competition and monopolistic competition as it is *directly affected* by the weaker presence of foreign firms. But the productivity of all firms improves under firm heterogeneity, which is beneficial to total output and GDP.

Finally, total government tax revenue unanimously decreases in the above four scenarios. Although the corporate income tax revenue decreases in integrated reforms, but it increases in single-sided reforms. That is to say, given the model assumptions, a lower corporate income tax rate over foreign firms indeed reduced the tax revenue collected from the foreign firms.

(4) The relationship between corporate income tax reform and FDI productivity spillovers, *i.e.* the soundness of the strategy "swapping market access for technology". As reflected by the "spillovers" rows in panel (c) and (d), neither single-sided reform nor integrated reform can increase the proportion of the productivity spilt over from foreign firms to domestic firms in total productivity of domestic enterprises, as denoted by equation (5.8). This is because that, with a higher corporate income tax rate, the output of foreign firms decreases, so that their input-output linkages with domestic firms are also weakened. That is to say, all of the four spillover channels (backward linkages, forward linkages, export of foreign firms, and horizontal effects) shrink, via which FDI productivity spillovers take place. The above result also implies that the original dual corporate income tax system was indeed good for the FDI productivity spillovers to occur in that it helped strengthen the foreign presence, which is vital for FDI productivity spillovers.

However the above conclusion derived from this *static* CGE model might need to be modified if we situate this problem in a *dynamic* perspective. First of all, with the integrated corporate income tax reform, the productivity of domestic firms is higher than before under firm heterogeneity in all of the four scenarios. This implies that the domestic firms have acquired better absorptive capacity to exploit the FDI productivity spillovers (Girma, 2005; Blake, Deng and Falvey, 2009). Secondly, in scenario (b) and (d), the average productivity of the foreign firms surviving the integrated tax reform is higher. This implies a greater likelihood of productivity spillovers. Therefore, taking into consideration the changing pattern of productivity under firm heterogeneity, the tax reform will only temporarily lower the FDI productivity spillover effects. They can promote the speed and magnitude of spillovers later, *i.e.* a "*J*-curve" effect of tax reform on productivity spillovers may exist.

7.5. CONCLUSIONS

This Chapter simulates the impact of corporate income tax reform in 2008 on the FDI productivity spillover effect in China.

It introduces the major tax incentives to attract FDI in China, and discusses the cost and benefit of such preferential FDI treatment. The results of the tax reform simulations show that the original dual corporate income tax system was indeed good for the FDI productivity spillovers to occur in that it helped strengthen the foreign presence which is vital for FDI productivity spillovers.

A higher corporate income tax levied on foreign-invested enterprises alone distorts the economy's structure and lowers total output, welfare, and GDP. However an integrated tax reform formula can do a better job by increasing the output level of domestic enterprises and by promoting national welfare. Under firm heterogeneity, the spillover benefit of integrated reform is even more prominent, because the reform can raise the average productivity of all existing enterprises, and raises the possibility of productivity spillovers and the absorptive capacity of domestic enterprises. This is more beneficial to the productivity spillovers from foreign-invested firms to domestic enterprises.

Neither single-sided reform nor integrated reform can increase the proportion of the productivity spilt over from foreign firms to domestic firms in total productivity of domestic enterprises. Taking into consideration the changing pattern of productivity under firm heterogeneity, the tax reform will only temporarily lower the FDI productivity spillover effects, however it may promote the speed and magnitude of spillovers later.

APPENDIX: AN FDI GRAVITY MODEL BY WEI (2000b)

The Model

Wei (2000b) performed an analysis over whether local corruption levels will affect FDI inflows with an FDI gravity model:

$$log[FDI(k,j)]=\Sigma_i\alpha(i)D(i)+\beta_1 tax(j)+\beta_2 corruption(j)+\boldsymbol{X}(j)\boldsymbol{\delta}+\boldsymbol{Z}(k,j)\boldsymbol{\gamma}+e(k,j)$$

where $FDI(k,j)$ is the bilateral stock of FDI by source country k in host country j; $D(i)$ is a source-country dummy variable which takes the value of 1 if the source country is i, and 0 otherwise; $tax(j)$ is the corporate income tax rate in the jth host country; $corruption(j)$ measures the corruption level in the jth host country; $\boldsymbol{X}(j)$ is a vector of other characteristics of the jth host country *e.g.* GDP per capita, FDI incentives and restrictions, government deficit; $\boldsymbol{Z}(k,j)$ is a vector of characteristics specific to the source country-host country pair, *e.g.* geographic distance, exchange rate volatility, linguistic tie; $e(k,j)$ is an independently and identically distributed error that follows a normal distribution; and $\alpha(i)$, β_1, β_2, $\boldsymbol{\delta}$, and $\boldsymbol{\gamma}$ are parameters to be estimated.

Data Sources of Key Variables

BILATERAL FDI FLOWS: OECD. *International Direct Investment Statistics Yearbook 1998.* Average value over 1994-1996. In millions of Dollars, converted using yearly average exchange rates from annex III of the publication.

CORPORATE INCOME TAX RATE: It takes the percentage value, rather than the proportional value. For example, if the tax rate in country i is 28%, the corresponding variable takes 28 rather than 0.28 in the econometric regression. PricewaterhouseCoopers (2000). *Doing Business and Investing Worldwide*

(CD-ROM). New York.

FDI INCENTIVES AND RESTRICTIONS: PricewaterhouseCoopers (2000). *Doing Business and Investing Worldwide* (CD-ROM). New York. An "FDI incentive" index (dummy variable) is created to capture the following four disincentives specific to foreign firms: industry and geographic incentives, tax concessions, nontax concessions, export incentives. For example, China adopts three out of the above four incentives (with nontax concessions excluded), so the index takes the value of "3" for China. Similarly, an "FDI restriction" index (also dummy variable) is created to capture the following four disincentives specific to foreign firms: foreign exchange controls, exclusion from strategic sectors, exclusion from other sectors, and restrictions on ownership share. For example, China adopts all of the above four restrictions, so the index takes the value of "4" for China.

DISTANCE: Great Circle distance, in kilometres, between economic centres (usually the capital cities) of country pairs.

GCR CORRUPTION INDEX: *Global Competitiveness Report 1997* (World Economic Forum and Harvard Institute for International Development, 1997).

WDR CORRUPTION INDEX: World Bank, *World Development Report 1997* (World Bank, 1997)

GDP PER CAPITA: World Bank SIMA/GDF and WDI central database.

EXCHANGE RATE VOLATILITY: International Monetary Fund. *International Financial Statistics*.

Selected Estimation Results

As shown in Table A1, there exists a negative correlation between corporate income tax rate and FDI inflow in model (4-1) and (4-2). This correlation is robust against addition of a China dummy variable (model (6-1) and (6-2)). In the CGE model, $\dfrac{\partial \ln(FDI)}{\partial(tax)} = \dfrac{\Delta(FDI)}{FDI \times \Delta(tax)} = -0.032$ is taken as a parameter of the responsiveness of FDI flow to corporate income tax rate change.

Table A7.1: Selected Estimation Results

Model	**(4-1)**	**(4-2)**	**(6-1)**	**(6-2)**
Corporate income tax rate	**-0.028****	**-0.032****	**-0.035****	**-0.039****
	(0.011)	**(0.011)**	**(0.011)**	**(0.012)**
Corruption	-0.337**	-0.280**	-0.391**	-0.334**
	(0.068)	(0.070)	(0.071)	(0.076)
FDI incentives		0.410**		0.448**
		(0.093)		(0.059)
FDI restrictions		-0.337**		-0.316**
		(0.058)		(0.059)
Log GDP	0.864**	0.862**	0.911**	0.906**
	(0.049)	(0.053)	(0.053)	(0.057)
Log GDP per capita	-0.038	-0.019	-0.156*	-0.111
	(0.078)	(0.085)	(0.092)	(0.097)
Log distance	-0.577**	-0.553**	-0.585**	-0.563**
	(0.062)	(0.061)	(0.061)	(0.061)
Linguistic tie	1.516**	1.437**	1.454**	1.394**
	(0.216)	(0.210)	(0.217)	(0.211)
China dummy			-1.092**	-0.887*
			(0.442)	(0.459)
Adj. R^2	0.72	0.73	0.72	0.73
Obs.	658	628	658	628

Note: (a) Dependent variable is the logarithm of bilateral FDI value. (b) Standard errors in parentheses. ** denotes significance at 5% level, * denotes significance at 10% level. (c) The "corporate income tax rate" takes the percentage value, rather than the original value. For example, if the tax rate in country i is 28%, the corresponding variable takes 28 rather than 0.28 in the econometric regression.

CHAPTER 8: CONCLUDING REMARKS

8.1. SUMMARY

Research Questions

One of the most important aspects of foreign direct investment (FDI) is that it embodies advanced technologies and business practices which can spill over to domestic firms via various channels, *e.g.* labour mobility, backward and forward linkages, export of multinational affiliates, and horizontal effects. To pursue the benefit of FDI productivity spillovers, many developing countries adopt preferential FDI policies characterized by "swapping domestic market access for advanced foreign technology and productivity".

However it is debated in the literature on (a) how to quantitatively measure FDI productivity spillovers as an economy-wide and cross-industry phenomenon rather than a region- and sector-specific one; and (b) whether preferential FDI policies can help productivity spillovers. This research, which is provoked by the above two intriguing questions, has mainly addressed the following research questions: (a) how to quantify the FDI productivity spillovers in a CGE model; (b) how to model the spillovers under three alternative market structure assumptions, namely perfect competition, monopolistic competition with homogeneous firms and heterogeneous firms; and (c) how the 2008 corporate income tax reform has impacted the FDI productivity spillover effects.

Model Construction

The research combines computable general equilibrium (CGE) modelling and econometric techniques to quantify FDI productivity spillovers. This research is conducted in the context of the Chinese economy, considering the fact that China has been the largest FDI host country among the developing economies for the past 15 years.

A static 101-sector computable general equilibrium (CGE) model is constructed to measure the endogenous productivity spillovers of FDI in China. Spillover effects are analyzed under three different market structure assumptions, namely perfect competition, monopolistic competition, and monopolistic competition with heterogeneous firms.

First, the input-output flows of state-owned, private and foreign-invested enterprises are disaggregated from the original input-output table for China which did not contain ownership information. In the benchmark model four FDI spillover channels (backward linkages, forward linkages, MNE exporting, and horizontal demonstration) are endogenously incorporated in a perfectly competitive economy. When the model is simulated to counterfactuals, the spillover variables will change endogenously, making productivity spillovers change endogenously as well. Spillover parameters are estimated with Chinese industry-level panel data. Other parameters are taken from GTAP 6 database and the literature.

Second, in the intermediate model, monopolistic competition is modelled to explore how market competition affects the effects of FDI productivity spillovers.

Third, firm heterogeneity has also been incorporated into this model, examining how competition and intra-industry resource reallocation triggered by multinational firms improve industry-level aggregate productivities. The importance of firm heterogeneity, as a newly explored market structure, in modelling trade and FDI has been widely acknowledged.

Fourth, the CGE model is simulated in the above three market structure scenarios with an FDI shock, and the results are compared.

Finally, experiments of FDI policy reform counterfactuals are also conducted. The experiments simulate a harmonisation of corporate income tax rates over domestic and foreign-invested enterprises. These counterfactuals are of great policy significance not only to China but also to other economies, as countries have "increasingly" relied on tax incentives to attract FDI.

Methodologically, this research introduces three novelties. Firstly it is the first to endogenise the FDI spillovers by linking spillover effects to spillover channels. Secondly this research is the first to examine FDI spillovers under the market structures of monopolistic competition and firm heterogeneity. Finally, this research has also assessed the impact of corporate income tax harmonisation on FDI productivity spillovers.

Main Findings and Policy Implication

The research results show that the presence of FDI productivity spillovers has generally improved productivity and led to "spillover premium" effects of the total output of domestic enterprises in China. Spillovers make foreign firms' total output decrease. But collectively, spillovers exert positive impact on national aggregate variables, *i.e.* GDP, total output, and welfare.

The market structure assumptions of monopolistic competition and firm heterogeneity provide special insights (*e.g.* in terms of product variety and scale) for this research which the assumption of perfect competition can not do. Furthermore, the assumption of firm heterogeneity can provide a more comprehensive measurement of productivity change than perfect and monopolistic competition assumptions do.

A higher corporate income tax levied on foreign-invested enterprises alone distorts the economy structure and lowers total output, welfare, and GDP. However an integrated tax reform formula can do a better job by increasing the output level of domestic enterprises and by promoting national welfare. Under firm heterogeneity, the spillover benefit of integrated reform is even more prominent, because the reform can lift up the average productivity of all existing enterprises, and raises the possibility of productivity spillovers and the absorptive capacity of domestic enterprises. This is more beneficial to the productivity spillovers from foreign-invested firms to domestic enterprises.

Neither single-sided reform nor integrated reform can increase the proportion of the productivity spilt over from foreign firms to domestic firms in total productivity of domestic enterprises. Taking into consideration the changing pattern of productivity under firm heterogeneity, the tax reform will only temporarily lower the FDI productivity spillover effects, however it can promote the speed and magnitude of spillovers later.

In Chapter 2, we have reviewed the literature and found few papers studying the effects of FDI productivity spillovers with CGE models. The findings in this research are generally in line with those found in the broad literature. For example, the net productivity spillover effects of FDI can promote GDP, national output and welfare, which is consistent with the findings of van Meijl and van Tongeren (1998) and Lejour, Rojas-Romagosa and Verweij (2008). Another example is the tax reform experiments which imply that the "swapping market access for technology" policy was likely a success in China. This is also consistent with the stylised facts regarding this policy collected by Long (2005). However, as this research is methodologically novel and involves new research perspectives, many of its findings do not have their counterparts in the literature to compare with.

8.2. DIRECTIONS FOR FUTURE RESEARCH

Dynamic modelling. This research is based on a static computable general equilibrium model. However the accumulation of foreign capital and its subsequent productivity spillovers is a dynamic process. Therefore it would be more appealing to study the FDI productivity spillovers and their economic growth effects in a dynamic CGE model.

Social accounting matrix (SAM). The CGE model constructed here is based on a transformed Chinese input-output table containing an intermediate input-output block, a value added block, and a final demand block, as shown by Table 3.4. As the primary concern of this research is on the supply side rather than the demand side of the economy, the input-output table was not extended to a SAM to contain further information on transactions between non-producer agents. But with a SAM the CGE model could provide more detailed measurement of domestic consumption demand and investment demand, and thus making the simulation results more accurate.

Firm-level data. This CGE model mainly addresses the interaction between foreign enterprises and their domestic counterparts. More accurate spillover parameters (β in equation (5.6b)) and Pareto distribution parameters

(a and b in equation (5.29)) can be estimated with firm-level data. More importantly, firm-level data can be used to implement more interesting micro-simulation experiments under the assumption of firm heterogeneity. Rutherford and Tarr (2008) have used data from 55,000 Russian households and incorporated them into a CGE model. Their research shows the importance of incorporating the diversity of heterogeneous agents.

REFERENCES

Aitken, Brian, Gordon H. Hanson, and Ann E. Harrison. 1997. Spillovers, Foreign Investment, and Export Behavior. *Journal of International Economics* 43 (1-2):103-132.

Aitken, Brian J., and Ann E. Harrison. 1999. Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela. *American Economic Review* 89 (3):605-618.

Alvarez, Roberto, and Ricardo López. 2005. Exporting and Performance: Evidence from Chilean Plants. *Canadian Journal of Economics* 38 (4):1384 -1400.

Ang, James B. 2008. Determinants of Foreign Direct Investment in Malaysia. *Journal of Policy Modeling* 30 (1):185-189.

Antràs, Pol, and Elhanan Helpman. 2004. Global Sourcing. *Journal of Political Economy* 112 (3):552-580.

Arrow, Kenneth J., and Gerard Debreu. 1954. Existence of Equilibrium for a Competitive Economy. *Econometrica* 22 (3):265-290.

Balistreri, Edward J., Russell H. Hillberry, and Thomas F. Rutherford. 2007. Structural Estimation and Solution of International Trade Models with Heterogeneous Firms. Paper read at 10th Conference on Global Economic Analysis, at Purdue University.

Balistreri, Edward J., Christine A. McDaniel, and Eina Vivian Wong. 2003. An Estimation of US Industry-level Capital-labor Substitution Elasticities: Support for Cobb-Douglas. *North American Journal of Economics and Finance* 14 (3):343-356.

Bernard, Andrew B., Jonathan Eaton, J. Bradford Jensen, and Samuel Kortum. 2003. Plants and Productivity in International Trade. *American Economic Review* 93

(4):1268-1290.

Bitzer, Jürgen, Ingo Geishecker, and Holger Görg. 2008. Productivity Spillovers through Vertical Linkages: Evidence from 17 OECD Countries. *Economics Letters* 99 (2):328-331.

Blake, Adam. 1998. Computable General Equilibrium Modelling and the Evaluation of Agricultural Policy, Economics School, University of Nottingham, Nottingham, UK.

Blake, Adam, Ziliang Deng, and Rod Falvey. 2009. How Does the Productivity of Foreign Direct Investment Spill over to Local Firms in Chinese Manufacturing? *Journal of Chinese Economic and Business Studies* 7 (2):183-197.

Blake, Adam, A.J. Rayner, and Geoffrey Reed. 1999. A Computable General Equilibrium Analysis of Agricultural Liberalisation: The Uruguay Round and Common Agricultural Policy Reform. *Journal of Agricultural Economics* 50 (3):400-424.

Blomström, Magnus, and Ari Kokko. 1998. Multinational Corporations and Spillovers. *Journal of Economic Surveys* 12 (2):1-31.

Branstetter, Lee G., Raymond Fisman, and C. Fritz Foley. 2006. Do Stronger Intellectual Property Rights Increase International Technology Transfer? Empirical Evidence from U. S. Firm-Level Panel Data. *Quarterly Journal of Economics* 121 (1):321-349.

Buckley, Peter J. Jeremy Clegg, and Chengqi Wang. 2002. The Impact of Inward FDI on the Performance of Chinese Manufacturing Firms. *Journal of International Business Studies* 33 (4):637-655.

———. 2004. The Relationship between Inward Foreign Direct Investment and the Performance of Domestically-owned Chinese Manufacturing Industry. *Multinational Business Review* 12 (3):23-40.

———. 2007. Is the Relationship between Inward FDI and Spillover Effects Linear? An Empirical Examination of the Case of China. *Journal of International Business Studies* 38 (3):447-459.

Buckley, Peter J., Chengqi Wang, and Jeremy Clegg. 2007. The Impact of Foreign Ownership, Local Ownership and Industry Characteristics on Spillover Benefits from Foreign Direct Investment in China. *International Business Review* 16 (2):142-158.

Bussolo, Maurizio, and Jeffery I. Round. 2003. Poverty Reduction Strategies in a Budget-Constrained Economy: The Case of Ghana. Paris: OECD Development Centre.

Cassou, Steven P. 1997. The Link between Tax Rates and Foreign Direct Investment. *Applied Economics* 29 (10):1295 - 1301.

Ceglowski, Janet, and Stephen Golub. 2007. Just How Low Are China's Labour Costs? *The World Economy* 30 (4):597-617.

Choi, Changkyu. 2003. Does the Internet Stimulate Inward Foreign Direct Investment? *Journal of Policy Modeling* 25 (4):319-326.

Chow, Gregory, and An-loh Lin. 2002. Accounting for Economic Growth in Taiwan and Mainland China: A Comparative Analysis. *Journal of Comparative Economics* 30 (3):507-530.

Clerides, Sofronis, Saul Lach, and James Tybout. 1998. Is Learning by Exporting Important? Micro-dynamic Evidence from Colombia, Mexico, and Morocco. *Quarterly Journal of Economics* 113 (3):903-947.

Crespo, Nuno, and Maria Paula Fontoura. 2007. Determinant Factors of FDI Spillovers - What Do We Really Know? *World Development* 35 (3):410-425.

Das, Gouranga Gopal. 2007. Information Age to Genetic Revolution: Embodied Technology Transfer and Assimilation -- A Tale of Two Technologies. *Technological Forecasting and Social Change* 74 (6):819-842.

Das, Sanghamitra. 1987. Externalities, and Technology Transfer through Multinational

Corporations: A Theoretical Analysis. *Journal of International Economics* 22 (1-2):171-182.

Deng, Ziliang, Honglin Guo, and Yongnian Zheng. 2007. How East Asian Industry Transfer Affects the U.S.-China Trade Imbalance: Economic Mechanisms and Policy Implications. *Issues & Studies* 43 (3):165-197.

Dervis, Kemal, Jaime De Melo, and Sherman Robinson. 1982. *General Equilibrium Models for Development Policy*. New York: Cambridge University Press.

Dewatripont, Mathias, and Gilles Michel. 1987. On Closure Rules, Homogeneity and Dynamics in Applied General Equilibrium Models. *Journal of Development Economics* 26 (1):65-76.

Dixit, Avinash K., and Joseph E. Stiglitz. 1977. Monopolistic Competition and Optimum Product Variety. *American Economic Review* 67 (3):297-308.

Dunning, John H. 1977. Trade, Location of Economic Activity, and the Multinational Enterprises: A Search for an Eclectic Approach. In *The International Allocation of Economic Activity*, edited by B.; Hesselborn Ohlin, P.; Wijkman, P. New York: Holmes and Meier.

———. 1981. *International Production and the Multinational Enterprises*. London: George Allen & Unwin.

Falvey, Rod, Neil Foster, and David Greenaway. 2004. Imports, Exports, Knowledge Spillovers and Growth. *Economics Letters* 85 (2):209-213.

———. 2007. Relative Backwardness, Absorptive Capacity and Knowledge Spillovers. *Economics Letters* 97 (3):230-234.

Falvey, Rod, Neil Foster, and Olga Memedovic. 2006. The Role of Intellectual Property Rights in Technology Transfer and Economic Growth: Theory and Evidence. Vienna: United Nations Industrial Development Organization.

Falvey, Rod, David Greenaway, and Zhihong Yu. 2007. Market Size and the Survival of Foreign-owned Firms. *Economic Record* 83 (s1):S23-S34.

Falvey, Rod, and Udo Kreickemeier. 2005. Globalisation and Factor Returns in Competitive Markets. *Journal of International Economics* 66 (1):233-48.

Fan, C. Simon, and Yifan Hu. 2007. Foreign Direct Investment and Indigenous Technological Efforts: Evidence from China. *Economics Letters* 96 (2):253-258.

Fan, Ying, Hua Liao, and Yi-Ming Wei. 2007. Can Market Oriented Economic Reforms Contribute to Energy Efficiency Improvement? Evidence from China. *Energy Policy* 35 (4):2287-2295.

Farrell, Diana, Paul Gao, and Gordon R. Orr. 2004. Making Foreign Investment Work for China: McKinsey Global Institute, McKinsey & Company.

Feenstra, Robert, and Hiau Looi Kee. 2008. Export Variety and Country Productivity: Estimating the Monopolistic Competition Model with Endogenous Productivity. *Journal of International Economics* 74 (2):500-518.

Findlay, Ronald. 1978. Relative Backwardness, Direct Foreign Investment, and the Transfer of Technology: A Simple Dynamic Model. *Quarterly Journal of Economics* 92 (1):1-16.

Fosfuri, Andrea, Massimo Motta, and Thomas Ronde. 2001. Foreign Direct Investment and Spillovers through Workers' Mobility. *Journal of International Economics* 53 (1):205-222.

Francois, Joseph F., and David W. Roland-Holst. 1997. Scale Economies and Imperfect Competition. In *Applied Methods for Trade Policy Analysis: A Handbook*, edited by Joseph F. Francois and Kenneth A. Reinert. Cambridge: Cambridge University Press.

Fu, Xiaolan, and V. N. Balasubramanyam. 2005. Exports, Foreign Direct Investment and Employment: The Case of China. *The World Economy* 28 (4):607-625.

GAMS Development Corporation. 2008. *GAMS - A User's Guide*. Washington, DC: GAMS Development Corporation.

Gattai, Valeria, and Corrado Molteni. 2007. Dissipation of Knowledge and the

Boundaries of the Multinational Enterprise. *Review of World Economics* 143 (1):1-26.

Gillespie, Gary, Peter G. McGregor, J. Kim Swales, and Ya Ping Yin. 2001. A Regional CGE Analysis of the Demand and "Efficiency Spillover" Effects of Foreign Direct Investment. In *Inward Investment, Technological Change and Growth: The Impact of Multinational Corporations on the UK Economy*, edited by Nigel Pain. Basingstoke: Palgrave.

———. 2002. The Regional Impact of Foreign Direct Investment: Structure and Behavior in an Ownership-Disaggregated Computable General Equilibrium Model. In *Trade, Networks and Hierarchies: Modeling Regional and Interregional Economies*, edited by Geoffrey Hewings, Michael Sonis and David E Boyce. Berlin: Springer-Verlag.

Ginsburgh, Victor, and Michiel Keyzer. 1997. *The Structure of Applied General Equilibrium Models*. Cambridge (USA) and London (UK): MIT Press.

Girma, Sourafel. 2005. Absorptive Capacity and Productivity Spillovers from FDI: A Threshold Regression Analysis. *Oxford Bulletin of Economics and Statistics* 67 (3):281-306.

Girma, Sourafel, and Yundan Gong. 2008a. FDI, Linkages and the Efficiency of State-Owned Enterprises in China. *Journal of Development Studies* 44 (5):728 - 749.

———. 2008b. Putting People First? Chinese State-owned Enterprises' Adjustment to Globalisation. *International Journal of Industrial Organization* 26 (2):573-585.

Girma, Sourafel, Holger Görg, and Mauro Pisu. 2008. Exporting, Linkages and Productivity Spillovers from Foreign Direct Investment. *Canadian Journal of Economics* 41 (1):320-340.

Girma, Sourafel, Richard Kneller, and Mauro Pisu. 2005. Exports versus FDI: An

Empirical Test. *Review of World Economics* 141 (2):193-218.

Glass, Amy Jocelyn, and Kamal Saggi. 2002. Multinational Firms and Technology Transfer. *Scandinavian Journal of Economics* 104 (4):495-513.

Gooroochurn, Nishaal, and Chris Milner. 2005. Assessing Indirect Tax Reform in a Tourism-Dependent Developing Country. *World Development* 33 (7):1183-1200.

Görg, Holger, and David Greenaway. 2004. Much Ado about Nothing? Do Domestic Firms Really Benefit from Foreign Direct Investment? *World Bank Research Observer* 19 (2):171-197.

Görg, Holger, and Eric A. Strobl. 2001. Multinational Companies and Productivity Spillovers: A Meta-Analysis. *Economic Journal* 111 (475):723-739.

———. 2005. Spillovers from Foreign Firms through Worker Mobility: An Empirical Investigation. *Scandinavian Journal of Economics* 107 (4):693-709.

Greenaway, David, and Richard Kneller. 2004. Exporting and Productivity in the United Kingdom. *Oxford Review of Economic Policy* 20 (3):358-371.

———. 2007. Firm Heterogeneity, Exporting and Foreign Direct Investment. *Economic Journal* 117 (517):F134-F161.

———. 2008. Exporting, Productivity and Agglomeration. *European Economic Review* 52 (5):919-939.

Greenaway, David, Nuno Sousa, and Katharine Wakelin. 2004. Do Domestic Firms Learn to Export from Multinationals? *European Journal of Political Economy* 20 (4):1027-1043.

Grubert, Harry, and John Mutti. 1991. Taxes, Tariffs and Transfer Pricing in Multinational Corporate Decision Making. *Review of Economics and Statistics* 73 (2):285-293.

Halpern, Laszlo, and Balazs Murakozy. 2007. Does Distance Matter in Spillover? *Economics of Transition* 15 (4):781-805.

Harrison, Glenn W., Thomas F. Rutherford, and David Tarr. 1994. Product Standards, Imperfect Competition, and Completion of the Market in the European Union: World Bank Policy Research Working Paper 1293.

———. 1995. Quantifying the Uruguay Round. In *The Uruguay Round and Developing Economies (World Bank Discussion Papers 307)*, edited by Will Martin and L. Alan Winters. Washington: World Bank.

———. 1997. Quantifying the Uruguay Round. *Economic Journal* 107:1405-1430.

Helpman, Elhanan. 2006. Trade, FDI, and the Organization of Firms. *Journal of Economic Literature* 44 (3):589-630.

Helpman, Elhanan, Marc J. Melitz, and Stephen R. Yeaple. 2004. Export Versus FDI with Heterogeneous Firms. *American Economic Review* 94 (1):300-316.

Hertel, Thomas W., ed. 1997. *Global Trade Analysis: Modeling and Applications*. Cambridge and New York: Cambridge University Press.

Hines, James R., and Eric M. Rice. 1994. Fiscal Paradise: Foreign Tax Havens and American Business. *Quarterly Journal of Economics* 109 (1):149–182.

Hymer, Stephen H. 1976. *The International Operations of National Firms: A Study of Direct Foreign Investment*. Cambridge: MIT Press.

International Monetary Fund. 2004. *Annual Report on Exchange Arrangements and Exchange Restrictions*. Washington D. C.: International Monetary Fund.

Javorcik, Beata Smarzynska. 2004. Does Foreign Direct Investment Increase the Productivity of Domestic Firms? In Search of Spillovers through Backward Linkages. *American Economic Review* 94 (3):605-627.

Javorcik, Beata Smarzynska, and Mariana Spatareanu. 2008. To Share or not to Share: Does Local Participation Matter for Spillovers from Foreign Direct Investment? *Journal of Development Economics* 85 (1-2):194-217.

Jehle, Geoffrey A., and Philip J. Reny. 2001. *Advanced Microeconomic Theory, The Addison-Wesley Series in Economics*. Boston: Addison-Wesley.

Jiang, Dianchun, Jean Jinghan Chen, and David Isaac. 1998. The Effect of Foreign Investment on the Real Estate Industry in China. *Urban Studies* 35 (11):2101 - 2110.

Kamien, Morton I., and Nancy L. Schwartz. 1983. Conjectural Variations. *Canadian Journal of Economics* 16 (2):191-211.

Keller, Wolfgang. 1996. Absorptive Capacity: On the Creation and Acquisition of Technology in Development. *Journal of Development Economics* 49 (1):199-227.

———. 2004. International Technology Diffusion. *Journal of Economic Literature* 42 (3):752-782.

Kimura, Fukunari, and Kozo Kiyota. 2006. Exports, FDI, and Productivity: Dynamic Evidence from Japanese Firms. *Review of World Economics* 142 (4):695-719.

Kneller, Richard, and Mauro Pisu. 2007. Industrial Linkages and Export Spillovers from FDI. *The World Economy* 30 (1):105-134.

Knight, John, and Linda Yueh. 2004. Job Mobility of Residents and Migrants in Urban China. *Journal of Comparative Economics* 32 (4):637-660.

Koizumi, Tetsunori, and Kenneth J. Kopecky. 1977. Economic Growth, Capital Movements and the International Transfer of Technical Knowledge. *Journal of International Economics* 7 (1):45-65.

Krugman, Paul. 1980. Scale Economies, Product Differentiation, and the Pattern of Trade. *American Economic Review* 70 (5):950-959.

Kugler, Maurice. 2006. Spillovers from Foreign Direct Investment: Within or between Industries? *Journal of Development Economics* 80 (2):444-477.

Lai, Mingyong, Shuijun Peng, and Qun Bao. 2006. Technology Apillovers, Absorptive Capacity and Economic Growth. *China Economic Review* 17 (3):300-320.

Lejour, Arjan, Hugo Rojas-Romagosa, and Gerard Verweij. 2008. Opening Services Markets within Europe: Modelling Foreign Establishments in a CGE Framework. *Economic Modelling* 25 (5):1022-1039.

Liu, Zhiqiang. 2008. Foreign Direct Investment and Technology Spillovers: Theory and Evidence. *Journal of Development Economics* 85 (1-2):176-193.

Lóez, Ricardo A. 2008. Foreign Technology Licensing, Productivity, and Spillovers. *World Development* 36 (4):560-574.

Löfgren, Hans, Rebecca Lee Harris, and Sherman Robinson. 2002. *A Standard Computable General Equilibrium (CGE) Model in GAMS*. Vol. 5, *Microcomputers in Policy Research*. Washington DC: International Food Policy Research Institute.

Long, Guoqiang. 2005. China's Policies on FDI: Review and Evaluation. In *Does Foreign Direct Investment Promote Development?*, edited by Theodore H. Moran, Edward M. Graham and Magnus Blomström. Washington D. C.: Institute for International Economics.

Madariaga, Nicole, and Sandra Poncet. 2007. FDI in Chinese Cities: Spillovers and Impact on Growth. *The World Economy* 30 (5):837-862.

Mansur, Ahsan, and John Whalley. 1984. Numerical Specification of Applied General Equilibrium Models: Estimations, Calibrations, and Data. In *Applied general equilibrium analysis*, edited by Herbert E. Scarf and John B. Shoven. Cambridge: Cambridge University Press.

Markusen, James R. 2002a. MPSGE Examples. In http://www.mpsge.org/tutorial.pdf.

———. 2002b. *Multinational Firms and the Theory of International Trade*. Cambridge, Massachusetts: MIT Press.

Markusen, James R., and Natalia Trofimenko. 2009. Teaching Locals New Tricks: Foreign Experts as a Channel of Knowledge Transfers. *Journal of Development Economics* 88 (1):120-131.

Markusen, James R., and Anthony J. Venables. 1999. Foreign Direct Investment as a Catalyst for Industrial Development. *European Economic Review* 43 (2):335-356.

McCarl, Bruce A., Alex Meeraus, Paul van der Eijk, Michael Bussieck, Steven Dirkse, and Pete Steacy. 2007. McCarl GAMS User Guide (Version 22.7): Texas A&M University & GAMS Development Corporation.

McKenzie, Lionel. 1954. On Equilibrium in Graham's Model of World Trade and Other Competitive Systems. *Econometrica* 22 (2):147-161.

Melitz, Marc J. 2003. The Impact of Trade on Intra-Industry Reallocations and Aggregate Industry Productivity. *Econometrica* 71 (6):1695-1725.

National Bureau of Statistics of China. 2003a. *China Industrial Economy Statistical Yearbook 2003*. Beijing: China Statistics Press.

———. 2003b. *China Statistical Yearbook 2003*. Beijing: China Statistics Press.

———. 2004. *China Industrial Economy Statistical Yearbook 2004*. Beijing: China Statistics Press.

———. 2006a. *China Economic Census Statistical Yearbook 2004*. Beijing: China Statistics Press.

———. 2006b. *Input-output Tables of China, 2002*. Beijing: China Statistics Press.

———. 2007. *China Statistical Yearbook 2007*. Beijing: China Statistics Press.

Nocke, Volker, and Stephen Ross Yeaple. 2007. Cross-border Mergers and Acquisitions vs. Greenfield Foreign Direct Investment: The Role of Firm Heterogeneity. *Journal of International Economics* 72 (2):336-365.

———. 2008. An Assignment Theory of Foreign Direct Investment. *Review of Economic Studies* 75 (2):529-557.

Prasad, Eswar S., and Raghuram G. Rajan. 2006. Modernizing China's Growth Paradigm. *American Economic Review* 96 (2):331-336.

Rausch, Sebastian, and Thomas F. Rutherford. 2007. Computation of Equilibria in OLG Models with Many Heterogeneous Households.

Robinson, Sherman, and Hans Lofgren. 2005. Macro Models and Poverty Analysis: Theoretical Tensions and Empirical Practice. *Development Policy Review* 23 (3):267-283.

Robinson, Sherman, Zhi Wang, and Will Martin. 2002. Capturing the Implications of Services Trade Liberalization. *Economic Systems Research* 14 (1):3 - 33.

Round, Jeffery I. 2003. Constructing SAMs for Development Policy Analysis: Lessons Learned and Challenges Ahead. *Economic Systems Research* 15 (2):161-183.

Rutherford, Thomas F. 1995. Lecture Notes on Constant Elasticity Functions: University of Colorado.

———. 1999. Applied General Equilibrium Modeling with MPSGE as a GAMS Subsystem: An Overview of the Modeling Framework and Syntax. *Computational Economics* 14 (1):1-46.

Rutherford, Thomas F., and David G. Tarr. 2008. Poverty Effects of Russia's WTO Accession: Modeling "Real" Households with Endogenous Productivity Effects. *Journal of International Economics* 75 (1):131-150.

Saggi, Kamal. 2002. Trade, Foreign Direct Investment, and International Technology Transfer: A Survey. *World Bank Research Observer* 17 (2):191-235.

Sembenelli, Alessandro, and Georges Siotis. 2008. Foreign Direct Investment and Mark-up Dynamics: Evidence from Spanish Firms. *Journal of International Economics* 76 (1):107-115.

Sen, Amartya K. 1963. Neo-Classical and Neo-Keynesian Theories of Distribution. *Economic Record* 39 (1):54-64.

Shoven, John B., and John Whalley. 1984. Applied General-Equilibrium Models of Taxation and International Trade: An Introduction and Survey. *Journal of Economic Literature* 22 (3):1007-1051.

———. 1992. *Appling General Equilibrium*. Cambridge: Cambridge University Press.

Springer, Katrin. 1998. The DART General Equilibrium Model: A Technical Description. In *Kiel Working Paper No. 883*. Kiel, Germany: Kiel Institute for the World Economy.

Sue Wing, Ian. 2004. Computable General Equilibrium Models and Their Use in

Economy-Wide Policy Analysis: MIT Joint Program on the Science and Policy of Global Change, Massachusetts Institute of Technology.

Tomiura, Eiichi. 2007. Foreign Outsourcing, Exporting, and FDI: A Productivity Comparison at the Firm Level. *Journal of International Economics* 72 (1):113-127.

United Nations Conference on Trade and Development. 2000. *Tax Incentives and Foreign Direct Investment: A Global Survey*. New York and Geneva: United Nations.

———. 2003. *World Investment Report 2003*. New York and Geneva: United Nations.

———. 2006. *World Investment Report 2006*. New York and Geneva: United Nations.

van Meijl, Hans, and Frank van Tongeren. 1998. Trade, Technology Spillovers, and Food Production in China. *Review of World Economics* 134 (3):423-449.

Walmsley, Terrie L., and Csilla Lakatos. 2008. Regional Input-Output Data. In *Global Trade, Assistance, and Production: The GTAP 7 Data Base*, edited by Badri Narayanan G. and Terrie L. Walmsley. West Lafayette: Center for Global Trade Analysis, Purdue University.

Wang, Jian-Ye, and Magnus Blomström. 1992. Foreign Investment and Technology Transfer: A Simple Model. *European Economic Review* 36 (1):137-155.

Wei, Shang-Jin. 2000a. How Taxing is Corruption on International Investors? *Review of Economics and Statistics* 82 (1):1-11.

———. 2000b. Local Corruption and Global Capital Flows. *Brookings Papers on Economic Activity* 31 (2000-2):303-354.

Wei, Yingqi, and Xiaming Liu. 2006. Productivity Spillovers from R&D, Exports and FDI in China's Manufacturing Sector. *Journal of International Business Studies* 37 (4):544-557.

Whalley, John, and Bernard Yeung. 1984. External Sector "Closing" Rules in Applied General Equilibrium Models. *Journal of International Economics* 16

(1):123-138.

World Trade Organization. 2008. Secretariat Report. In *Trade Policy Review: China*. New York and Geneva: World Trade Organization.

Yao, Shujie, and Aying Liu. 2000. Policy Analysis in a General Equilibrium Framework. *Journal of Policy Modelling* 22 (5):589-610.

Yasar, Mahmut, and Catherine J. Morrison Paul. 2007. International Linkages and Productivity at the Plant Level: Foreign Direct Investment, Exports, Imports and Licensing. *Journal of International Economics* 71 (2):373-388.

Young, Alwyn. 2000. The Razor's Edge: Distortions and Incremental Reform in the People's Republic of China. *Quarterly Journal of Economics* 115 (4):1091-1135.

Zhai, Fan. 2008. Armington Meets Melitz: Introducing Firm Heterogeneity in a Global CGE Model of Trade. *Journal of Economic Integration* 23 (3):575 - 604.

Zhang, Kevin Honglin. 2005. Why Does So Much FDI from Hong Kong and Taiwan Go to Mainland China? *China Economic Review* 16 (3):293-307.

Zhao, Tonglu. 2004. Comparison between Industrial Classification in Chinese National Accounts and International Standard Industrial Classification for All Economic Activities. Paper read at 8th OECD - NBS Workshop on National Accounts, at OECD Headquarters, Paris.

Zhao, Yaohui. 2002. Earnings Differentials between State and Non-State Enterprises in Urban China. *Pacific Economic Review* 7 (1):181 - 197.