

Preliminary draft. Presented at the 11<sup>th</sup> Annual Conference on Global Economic Analysis,  
12-14 June 2008. Helsinki, Finland.

## **Productivity Spillover of Foreign Direct Investment: A Computable General Equilibrium Model of China**

**Ziliang Deng <sup>a \*</sup>, Rod Falvey <sup>a</sup>, Adam Blake <sup>b</sup>**

*<sup>a</sup> School of Economics, University of Nottingham, UK*

*<sup>b</sup> School of Services Management, Bournemouth University, UK*

### **Abstract**

A computable general equilibrium (CGE) model is constructed to capture the endogenous productivity spillover from foreign-invested firms to domestic firms in China. This paper summarizes the main results we have found so far. There are three contributions we have made to the knowledge. First and foremost, the endogenous productivity increase in manufacturing sectors caused by FDI spillover has been successfully introduced into a CGE model. The productivity spillover effects in both perfectly competitive and imperfectly competitive markets are also compared. This technique can be readily applied to a global dynamic CGE model embodying

trade-FDI-productivity spillover linkages. Second, we have estimated and compared the importance of four spillover channels in econometric analyses and the CGE model. Third, we have made a tentative assessment of Chinese FDI policies characterised by swapping market access for technology with the CGE prototype model. There are various directions worth future research, e.g. to estimate productivity spillover parameters by industries with firm-level data, to extend the research to include spillovers in services sectors, and to construct a global dynamic model capturing capital accumulation and trade-FDI-productivity interactions.

**Keywords:** productivity spillover, foreign direct investment (FDI), computable general equilibrium (CGE) modelling

*JEL* Classifications: O33, F21, C68

---

\* Corresponding author. Email: [LIXZD2@nottingham.ac.uk](mailto:LIXZD2@nottingham.ac.uk). Office address: School of Economics, Room A55A, University of Nottingham, University Park, Nottingham, NG7 2RD., UK.

This research has been sponsored by UK/China Postgraduate Research: Scholarships for Excellence. The authors are grateful to the constructive comments from Sourafel Girma, Yundan Gong, Aoife Hanley, Richard Kneller, Chris Milner, Chengqi Wang, Shujie Yao, Fan Zhai and the participants of the 19<sup>th</sup> Chinese Economic Association (UK) Annual Conference, 7<sup>th</sup> GEP International Postgraduate Conference hosted by the Leverhulme Centre for Research on Globalization and Economic Policy, University of Nottingham.

## **Introduction**

FDI plays a significant role in the global economic system for both the firms and the countries involved in FDI activities. Productivity spillover effect is arguably one of the most important aspects of FDI. The productivity spillovers are economic externalities which the presence of FDI brings to the host country's domestic firms. These spillovers take place through four channels, namely, labour mobility (Fosfuri, Motta, and Ronde 2001; Glass and Saggi 2002; Görg and Strobl 2005), industry linkages (Girma and Gong 2007; Javorcik 2004; Markusen and Venables 1999; Pack and Saggi 2001), exports (Aitken, Hanson, and Harrison 1997; Clerides, Lach, and Tybout 1998; Greenaway, Sousa, and Wakelin 2004), and demonstration effects (Findlay 1978; Koizumi and Kopecky 1977; Wang and Blomström 1992).

In exploring the spillover effects of FDI, there has been a rich emerging literature, both theoretical and empirical, on the FDI productivity spillover channels and effects since the 1990s. But the conventional econometric analyses tend to underestimate or ignore one of the most important features of spillover effects, i.e. the spillover is a nation-wide and cross-industry phenomenon rather than a region- and sector-specific one.

In addition, there have also been doubts as to whether spillovers have positive effects on host countries, which are supported by some recent empirical studies (Aitken and Harrison 1999). In host countries FDI might bring strong competitive effects and poses a serious threat to the survival of domestic firms whose capability to absorb the positive externalities brought by FDI is low.

By doing firm- and industry-level productivity spillover estimations, integrating Chinese input-output table with industry-level data by ownerships, and constructing a novel computable general equilibrium (CGE) model of China, we tried to answer the following research question: has the presence of multinational firms improved the productivity of domestic manufacturing firms via productivity spillovers? If yes, how?

## Methodology and Data

### Basic CGE modelling framework and data

The research on the productivity spillover effects of FDI is conducted in a CGE framework which involves estimating key FDI productivity spillover coefficients with econometric analysis first and then implementing computer-based simulations of various scenarios to evaluate the overall impact of productivity spillover.

This CGE model only contains China and the rest of the world as a single region. There are 31 industrial sectors (i.e. manufacturing, constructions and utilities) and 8 non-industrial sectors (i.e. agricultural and services).

The CGE model aims to providing a more complete and accurate measure of the productivity spillover effects of FDI on domestic firms in a structural way by scrutinizing all the four spillover channels, with a focus on the manufacturing sectors. The research is done in the China context given the success of China in attracting FDI with favourable “swap market access for technology” policies (Long 2005), and the fact that the inflow of FDI to China has fundamentally affected the development path of domestic firms (Yao and Wei 2007).

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 (1) to (4) and Figure 1.

*[Insert Figure 1 here]*

Level 1 (aggregation across sectors):

$$AG = \left[ \sum_{i=1}^{101} \alpha_i AR_i^{\frac{\rho_1-1}{\rho_1}} \right]^{\frac{\rho_1}{\rho_1-1}} \quad (1)$$

Level 2 (Armington aggregate):

$$AR_i = \left[ \sum_{j=1}^2 \beta_{i,j} DI_{i,j}^{\frac{\rho_2}{\rho_2-1}} \right]^{\frac{\rho_2-1}{\rho_2}} \quad (2)$$

Level 3 (aggregation across ownerships):

$$DI_{i,j} = \left[ \sum_{k=1}^3 \gamma_{i,j,k} MSO_{i,j,k}^{\frac{\rho_3}{\rho_3-1}} \right]^{\frac{\rho_3-1}{\rho_3}} \quad (3)$$

Level 4 (aggregation at firm level):

$$MSO_{i,j,k} = \left[ \sum_{f=1}^{N_x} \varphi_{i,j,k,f} Q_{i,j,k,f}^{\frac{\rho_4}{\rho_4-1}} \right]^{\frac{\rho_4-1}{\rho_4}} \quad (4)$$

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

The latest 122-sector China input-output table for 2002 is employed. Data from other sources (primarily various Chinese statistical yearbooks), e.g. total output, value added, and export of industry-level production by foreign invested enterprises and domestic firms are also used.

### Input-output table disaggregation

A benchmark CGE model is constructed at the first step to accommodate the input-output matrix among industries and the basic activity of multinational affiliates. Since the productivity spillover effect of FDI in manufacturing is the primary research target, each sector of manufacturing in the input-output table has been disaggregated into three sectors by ownership, namely state-owned enterprises (SOEs), foreign-invested firms (FIEs), and other domestic firms (PRIs), as shown in Figure 2 (Gillespie *et al.* 2001, 2002). The sectors in agriculture and services are not disaggregated by ownership.

[Insert Figure 2 here]

### TFP comparison

The TFP of FIEs, SOEs and PRIs are estimated with a firm-level database collected from a survey of 1000 manufacturing firms in 2000.

The following model specifications are employed:

$$\ln VA_i = \gamma_0 + \gamma_1 \ln K_i + \gamma_2 \ln L_i + \mu \quad (4)$$

where  $L_i$  will be measured in three different approaches, pure employment, human capital, and employment weighted by economy-wide average wage.

### FDI productivity spillovers

Then the benchmark CGE model is expanded to endogenously incorporate all the four possible productivity spillover channels.

If  $VA = TFP * G(K, L)$ , then  $TFP$  can be decomposed into:

$$TFP = TFP_{indigenous} + TFP_{spillover} \quad (5)$$

where  $TFP_{indigenous}$  captures all indigenous factors that contribute to the TFP of a firm, while  $TFP_{spillover}$  measures the FDI productivity spillover effects. Here we can estimate the TFP and spillover effects in 2-stage approach:

$$\begin{aligned} \ln(VA_i) &= \alpha_1 + \beta_1 \ln(K_i) + \beta_2 \ln(L_i) + \varepsilon \\ TFP &= \exp(\alpha + \varepsilon) = \alpha_2 + \beta_3 BL_i + \beta_4 FL_i + \beta_5 HZDS_i + \beta_6 EXCO_i + \phi \mathbf{DM} + \nu \end{aligned} \quad (6)$$

where four year dummy variables and thirty industry dummy variables are collectively denoted by a vector  $\mathbf{DM}$ .

$$BL_j = \sum_i (\beta_{i,j} * HZDS_i) \quad (7)$$

$$FL_i = \sum_j (\alpha_{i,j} * HZDS_j) \quad (8)$$

where  $\alpha_{i,j}$  and  $\beta_{i,j}$  are input-output coefficients.  $HZDS_j$  is the ratio of the gross output of

foreign-invested firms in sector  $j$ , which measures “horizontal demonstration” as a spillover channel.

$EXCO_i$  is the ratio of the export of foreign-invested firms in sector  $j$ , which measures “export concentration” as another spillover channel.

Thus we can employ econometric regression to estimate the ratio of TFP caused by spillovers over total TFP.

$$\frac{TFP_{spillover}}{TFP} = \frac{\beta * SPL}{(\alpha + \varphi * DM) + \beta * SPL} \quad (9)$$

where  $\beta * SPL = \beta_3 BL_i + \beta_4 FL_i + \beta_5 HZDS_i + \beta_6 EXCO_i$ .

In the CGE modelling all the spillover variables, i.e.  $BL_i$ ,  $FL_i$ ,  $HZDS_i$  and  $EXCO_i$  are all endogenously determined. Therefore, the ratio of productivity spillover over total TFP as measured by equation (9) is also endogenously determined.

### Monopolistic competition

The model is further upgraded to accommodate the imperfect competition underlying the strategic interplay of foreign invested enterprises and domestic firms. (Blake, Rayner, and Reed 1999; Francois and Roland-Holst 1997; Harrison, Rutherford, and Tarr 1994, 1995, 1997). The model employed here consists of three elements which differentiate itself from a classic model of general equilibrium: (1) increasing returns to scale (with fixed cost); (2) free entry and exit; (3) firm heterogeneity: firm produces differentiated goods (Dixit and Stiglitz 1977).

For a firm with a certain market power,

$$TR = P(Q) * Q$$

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

$$MR = MC \Rightarrow \frac{1}{|\varepsilon|} = \frac{P - MC}{P} = markup(\%) \quad (10)$$

With this key information of markup rate (%), it is then viable to include monopolistic competition in CGE modelling<sup>2</sup>. The next step is to identify the inverse of elasticity of demand

(see Appendix 1 for details), which is also the firm-level markup rate, as discussed in equation (10):

$$mk(\%) = \left| \frac{1}{\varepsilon_{Q(i,j,k,f)}} \right| = \frac{1}{\rho_4} + \frac{1}{N_{i,j,k,f}} \left( \frac{1}{\rho_3} - \frac{1}{\rho_4} \right) + \frac{\gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_2} - \frac{1}{\rho_3} \right) + \frac{\beta_{i,j} \gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_1} - \frac{1}{\rho_2} \right) + \frac{\alpha_i \beta_{i,j} \gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_1} - 1 \right) \quad (11)$$

Here a simplified assumption has been made for each ownership in every sector: the firm sizes are the same (*they produce heterogeneous products though*) in each sector and the market share of each firm in the corresponding sector is simply  $\varphi_{i,j,k,f} = \frac{1}{N_{i,j,k,f}}$ .

In the above equation, only the elasticities of substitution ( $\rho$ ) are exogenous.

## Basic Findings

### Econometric estimation of TFP spillover

The TFP level of foreign-invested firms (FIE) is the highest in this sample. The TFP level of SOE is higher than that of domestic private firms, as shown in Table 1. This estimation justifies the possible productivity spillover from FIEs to SOEs and other domestic firms. It is also possible that the absorptive ability of SOEs in benefiting from the FDI spillover is stronger than that of the other domestic firms (PRIs).

*[Insert Table 1 and Table 2 here]*

Due to the data constraint<sup>3</sup>, we can only estimate the spillover via labour turnover as the only spillover channel first (see Table 2). Spillover via labour turnover is generally negative, but the state-owned enterprises have gained positive benefits from recruiting those people with work experience in multinational firms. This is consistent with the higher absorptive ability of

SOEs shown in Table 1.

The estimated results of specification (6) are given in Table 3:

*[Insert Table 3 here]*

### CGE simulation of FDI productivity spillover and evaluations of FDI policies

With the estimated parameters in Table 3, we can know the ratio of average TFP spillover over average total TFP:

$$\frac{\text{spillover}}{\text{total TFP}} = \frac{\beta * SPL}{\alpha + \beta * SPL} = \frac{0.75}{6.09} = 12\% \quad (12)$$

which indicates that 12% of TFP of each sector or firm can be attributed to the FDI productivity spillover.

Furthermore, with the estimated spillover coefficients in Table 3,

$$TFP_i = \underbrace{5.34}_{\text{firm's intrinsic TFP}} + \underbrace{-8.16 * BL_i + 8.29 * FL_i + 1.56 * HZDS_i - 0.21 * EXCO_i}_{\text{spillover in benchmark}} \quad (13)$$

With this specification, four CGE experiments are done:

Experiment (a): benchmark “without” spillover:  $TFP = 5.34$ ;

Experiment (b): Benchmark with spillover: equation (13);

Experiment (c): FDI shock without spillover:  $TFP = 5.34$ , with FDI inflow shock;

Experiment (d): FDI shock with spillover: equation (13), with FDI inflow shock.

With this TFP decomposition denoted by equation (13), the results in Table (4) show that:

- (i) from experiment (a) to (d), the **national** gross output and value added increase monotonically; (ii) in experiment (c), **foreign** firms earn most because of the FDI is confined to the foreign sectors although the elasticity of substitution of products between FIEs and domestic firms are not equal to zero; (iii) from experiment (c) to (d), the increasing rates of gross output and GDP drop due to the spillover effect – a portion of the limited resources are attracted by more productive domestic firms. A similar proposition applies to the change of

FIEs from experiment (b) back to (a), because the FIEs could have produced more without spillover in the benchmark.

*[Insert Table 4 here]*

To compare the four spillover variables, we normalized all of the four spillover variables:

$$\tilde{x}_{j,i} = \frac{x_{j,i}}{\sum_i x_{j,i}}. \text{ After normalization, the range of every variable falls into the domain of } [0, 1],$$

which make the normalized variable comparable with each other.

Then we ran **experiment (g)** for each of these four normalized variables by “switching off” the other three spillover variables. The results are shown in Table 5.

$$TFP_i = \underbrace{1.00}_{\text{firm's intrinsic TFP}} + \underbrace{0.05 * \tilde{B}L_i + 0.05 * \tilde{F}L_i + 0.05 * H\tilde{Z}DS_i + 0.05 * E\tilde{X}CO_i}_{\text{spillover in benchmark}} \quad (14)$$

It is clear that they are almost symmetrically important. In each experiment, the gross output will decrease by about 0.6% and total value added will drop/increase by 0.1%.

*[Insert Table 5 here]*

The results (not shown in this paper) also tell us that basically the introduction of FDI can generate positive effect in terms of GDP increase, total exports and the upgrading of industry structure. However, the performance of domestic firms in certain industries e.g. electronics with the highest foreign presence in terms of gross output (over 80%) and export (over 90%), has been negatively affected by the presence of FDI due to the competition effect. In those industries the market share of domestic firms are shrinking although their total output volumes are still increasing.

When there is monopolistic competition, the average firm number increases by **2%**

(evenly distributed among FIEs, SOEs, and Private firms), while the average markup rate decreases by **0.01%** (evenly distributed among FIEs, SOEs, and Private firms as well). The increase percentages of gross output and value added now become less than those in the scenario of perfect competition (see experiment (e) in Table 4). This implies that the existence of monopolistic power and markup makes the economy benefit less from the FDI shock due to the waste of resources in the fixed cost, which can be understood as a necessary cost of the love of variety. But the last column of Table 6 shows that the average production scale of all the sectors increases by 0.2%, which means that the cost disadvantage ratio will be lower, and subsequently the efficiency of the whole economy will be higher.

*[Insert Table 6 here]*

Finally we introduce a tax reform to unify the existing differential corporate income taxes (taxes of FIEs are lower than those of domestic firms). The increased corporate income tax will make the overall tax burden of FIEs rise 0.5% (for example, to increase the portfolio tax rate on FIEs from 4.7% to 5.2% for electronics sector). The results shown in column (e) in Table 4 indicate that due to the removal of super-national treatment to foreign-invested firms, the FIEs are negatively affected while the productions of domestic firms are promoted. This removal is also beneficial to the national welfare – the removal of differential taxes bring to a 0.1% increase of the equivalence variation. This figure has a manifested policy implication, i.e. in some developing countries, the detrimental welfare impact of governments' efforts in desperately attracting FDI (especially in labour-intensive manufacturing) with super-favourable FDI taxes sometimes overweighs the productivity spillover benefit the presence of FDI can bring to them.

Thus with our preliminary projection, the side effect of FDI will continue due to the *de facto* province-level tax competition for FDI regardless of the unification of domestic and

foreign corporate taxes at the nation level<sup>4</sup>.

## **Concluding Remarks**

This paper summarizes the main results we have found so far. There are three contributions we have made to the knowledge. First and foremost, the endogenous productivity increase in manufacturing sectors caused by FDI spillover has been successfully introduced into a CGE model. The productivity spillover effects in both perfectly competitive and imperfectly competitive markets are also compared. This technique can be readily applied to a global dynamic CGE model embodying trade-FDI-productivity spillover linkages. Second, I have estimated and compared the importance of four spillover channels in econometric analyses and the CGE model. Third, I have made a comprehensive assessment of Chinese FDI policies characterised by swapping market access for technology with the CGE prototype model. The research shows that the FDI productivity spillover effects are eminent in China although some sectors are negatively affected by the foreign presence and the national welfare is slightly impacted by the differential corporate taxes.

Nonetheless there are still a lot of directions worth future research. The first one is to estimate productivity spillover parameters by industries with firm-level data, which will make the parameters more reliable. The second one is to model the spillover effects in services sectors after identifying the difference between the spillover mechanisms in manufacturing and services. The third one is to integrate productivity spillover into a global CGE model embodying important trade-FDI-productivity spillover nexus. The fourth one is to incorporate the latest development of international trade theory, i.e. firm-heterogeneity into the CGE model with the productivity distribution parameter estimated with firm-level data. This will greatly push the boundary beyond the international economics and CGE methodology. Finally, yet not least importantly, it is viable to construct a dynamic model incorporating capital accumulation and dynamic comparative advantage.

## Endnotes:

---

$$^2 \frac{P - MC}{P} = \frac{(P - MC) \times Q}{P \times Q} = \frac{TC - VC}{TC} = \frac{FC}{TC}$$

The markup rate is also equal to the proportion of fixed cost in total cost. This implies that in a monopolistic competitive market, each firm has to collect a markup to pay for the fixed cost. Collectively, the summed fixed cost can be understood as an “unrealized scale economy”. Thus, this markup ratio is also referred as “cost disadvantage ratio” (Pratten 1988). As the number in a certain market decreases, the production of surviving firms can gain rationalization benefit by expanding production scale and push their average cost curve downwards.

<sup>3</sup> The firm-level database only contains four manufacturing sectors, which renders the econometric estimation of TFP spillover inflexible.

<sup>4</sup> China's parliament, the National People's Congress, adopted the *Enterprise Income Tax Law* on 16<sup>th</sup> March 2007, a key signal of a phase-in end of superior treatments to foreign investors for two decades. The law, which sets unified income tax rate for domestic and foreign companies at 25%, came after years of criticism that the original dual income tax mechanism is unfair to domestic enterprises. The law is due to take effect on 1<sup>st</sup> January 2008.

## 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.
- 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 (400-424).
- 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.
- Dixit, Avinash K., and Joseph E. Stiglitz. 1977. Monopolistic Competition and Optimum Product Variety. *American Economic Review* 67 (3):297-308.
- 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 J. F. Francois and K. A. Reinert. Cambridge: Cambridge University Press.
- 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 N. 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 G. Hewings, M. Sonis and D. E. Boyce. Berlin: Springer-Verlag.
- Girma, Sourafel, and Yundan Gong. 2007. FDI, Linkages and the Efficiency of State-owned Enterprises in China. *Journal of Development Studies*.
- Glass, Amy Jocelyn, and Kamal Saggi. 2002. Multinational Firms and Technology Transfer. *Scandinavian Journal of Economics* 104 (4):495-513.
- Görg, Holger, and Eric A. Strobl. 2005. Spillovers from Foreign Firms through Worker Mobility: An Empirical Investigation\*. *Scandinavian Journal of Economics* 107 (4):693-709.
- 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.
- 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 W. Martin and L. A. Winters. Washington: World Bank.
- . 1997. Quantifying the Uruguay Round. *Economic Journal* 107:1405-1430.
- 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.
- Kamien, Morton I., and Nancy L. Schwartz. 1983. Conjectural Variations. *Canadian Journal of Economics / Revue canadienne d'Economique* 16 (2):191-211.
- 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.
- 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 M. Blomström. Washington D C: Institute for International Economics.
- Markusen, James R., and Anthony J. Venables. 1999. Foreign direct investment as a catalyst for industrial development. *European Economic Review* 43 (2):335-356.
- Pack, Howard, and Kamal Saggi. 2001. Vertical technology transfer via international outsourcing. *Journal of Development Economics* 65 (2):389-415.
- Pratten, Cliff. 1988. A Survey of the Economies of Scale. In *Research on the "Cost of Non-Europe: Basic Findings"*. Brussels and Luxembourg: Commission of the European Communities.
- Wang, Jian-Ye, and Magnus Blomström. 1992. Foreign Investment and Technology Transfer : A Simple Model. *European Economic Review* 36 (1):137-155.
- Yao, Shujie, and Kailei Wei. 2007. Economic Growth in the Present of FDI from a Newly Industrializing Economy's Perspective. *Journal of Comparative Economics* 35 (1):211-234.

## Appendix 1: monopolistic competition

With equation (1) to (4), and (10), we can construct a function for firm-level markup rate.

Starting from the 4th level aggregation denoted by equation (4), we can find the “inverse” demand function first.

$$P_{Q(i,j,k,f)} = \left( \frac{MSO_{i,j,k}}{Q_{i,j,k,f}} \right)^{1/\rho_4} \times P_{MSO(i,j,k)} \quad (A1)$$

Since all of the three variables on the right hand side are functions of  $Q_{i,j,k,f}$ , so if we take partial derivatives of equation (A1) w.r.t.  $Q_{i,j,k,f}$ , we can get:

$$\frac{\partial P_{Q(i,j,k,f)}}{\partial Q_{i,j,k,f}} = -\frac{1}{\rho_4} \frac{P_{Q(i,j,k,f)}}{Q_{i,j,k,f}} + \frac{1}{\rho_4} \frac{P_{Q(i,j,k,f)}}{MSO_{i,j,k}} \frac{\partial MSO_{i,j,k}}{\partial Q_{i,j,k,f}} + \frac{P_{Q(i,j,k,f)}}{P_{MSO(i,j,k)}} \frac{\partial P_{MSO(i,j,k)}}{\partial Q_{i,j,k,f}} \quad (A2)$$

We assume the “conjecture variation”(Kamien and Schwartz 1983) satisfies

$$P_{MSO(i,j,k)} \times \Delta MSO_{i,j,k} = P_{Q(i,j,k,f)} \times \Delta Q_{i,j,k,f}$$

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 firm type in its sector.

Then, we can get:

$$\frac{\Delta MSO_{i,j,k}}{\Delta Q_{i,j,k,f}} = \frac{P_{Q(i,j,k,f)}}{P_{MSO(i,j,k)}} \quad (A3)$$

The term  $\frac{\partial P_{MSO(i,j,k)}}{\partial Q_{i,j,k,f}}$  in (A2) can be transformed with the chain rule:

$$\frac{\partial P_{MSO(i,j,k)}}{\partial Q_{i,j,k,f}} = \frac{\partial P_{MSO(i,j,k)}}{\partial MSO_{i,j,k}} \frac{\partial MSO_{i,j,k}}{\partial Q_{i,j,k,f}} \stackrel{eq.(12)}{=} \frac{\partial P_{MSO(i,j,k)}}{\partial MSO_{i,j,k}} \frac{P_{Q(i,j,k,f)}}{P_{MSO(i,j,k)}} \quad (A4)$$

Substitute (A3) and (A4) back into (A2), and multiply both sides with  $\frac{Q_{i,j,k,f}}{P_{Q(i,j,k,f)}}$ :

$$\begin{aligned}
\frac{1}{\varepsilon_{Q(i,j,k,f)}} &= \frac{\partial P_{Q(i,j,k,f)}}{\partial Q_{i,j,k,f}} \frac{Q_{i,j,k,f}}{P_{Q(i,j,k)}} = -\frac{1}{\rho_4} + \frac{1}{\rho_4} \frac{P_{Q(i,j,k,f)}}{P_{MSO(i,j,k)}} \frac{Q_{i,j,k,f}}{MSO_{i,j,k}} \\
&+ \left( \frac{P_{Q(i,j,k,f)}}{P_{MSO(i,j,k)}} \frac{Q_{i,j,k,f}}{MSO_{i,j,k}} \right) \times \left( \frac{\partial P_{MSO(i,j,k)}}{\partial MSO_{i,j,k}} \frac{Q_{i,j,k,f}}{P_{MSO(i,j,k)}} \right) \\
&= -\frac{1}{\rho_4} + \frac{1}{\rho_4} \varphi_{i,j,k,f} + \varphi_{i,j,k,f} \times \frac{1}{\varepsilon_{MSO(i,j,k)}}
\end{aligned} \tag{A5}$$

From equation (A5), 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 the similar procedure:

$$\frac{1}{\varepsilon_{MSO(i,j,k)}} = -\frac{1}{\rho_3} + \frac{1}{\rho_3} \gamma_{i,j,k} + \gamma_{i,j,k} \times \frac{1}{\varepsilon_{DI(i,j)}} \tag{A6}$$

$$\frac{1}{\varepsilon_{DI(i,j)}} = -\frac{1}{\rho_2} + \frac{1}{\rho_2} \beta_{i,j} + \beta_{i,j} \times \frac{1}{\varepsilon_{AR(i)}} \tag{A7}$$

$$\frac{1}{\varepsilon_{AR(i)}} = -\frac{1}{\rho_1} + \frac{1}{\rho_1} \alpha_i + \alpha_i \times \frac{1}{\varepsilon_{AG}} \tag{A8}$$

For the aggregate product  $AG$ , assume  $P_{AG} \cdot AG = e$ , where  $e$  denotes the consumer's fixed expenditure.

Then we can get  $AG = \frac{e}{P_{AG}}$ . Thus we can get the elasticity of demand for this aggregate product:

$$\varepsilon_{AG} = \frac{\partial AG}{\partial P_{AG}} \frac{P_{AG}}{AG} = \left( -\frac{e}{P_{AG}^2} \right) \left( \frac{P_{AG}}{e/P_{AG}} \right) = -1 \tag{A9}$$

Substitute (A9) back to (A8), and then substitute (A8) to (A7), 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, as discussed in equation (10):

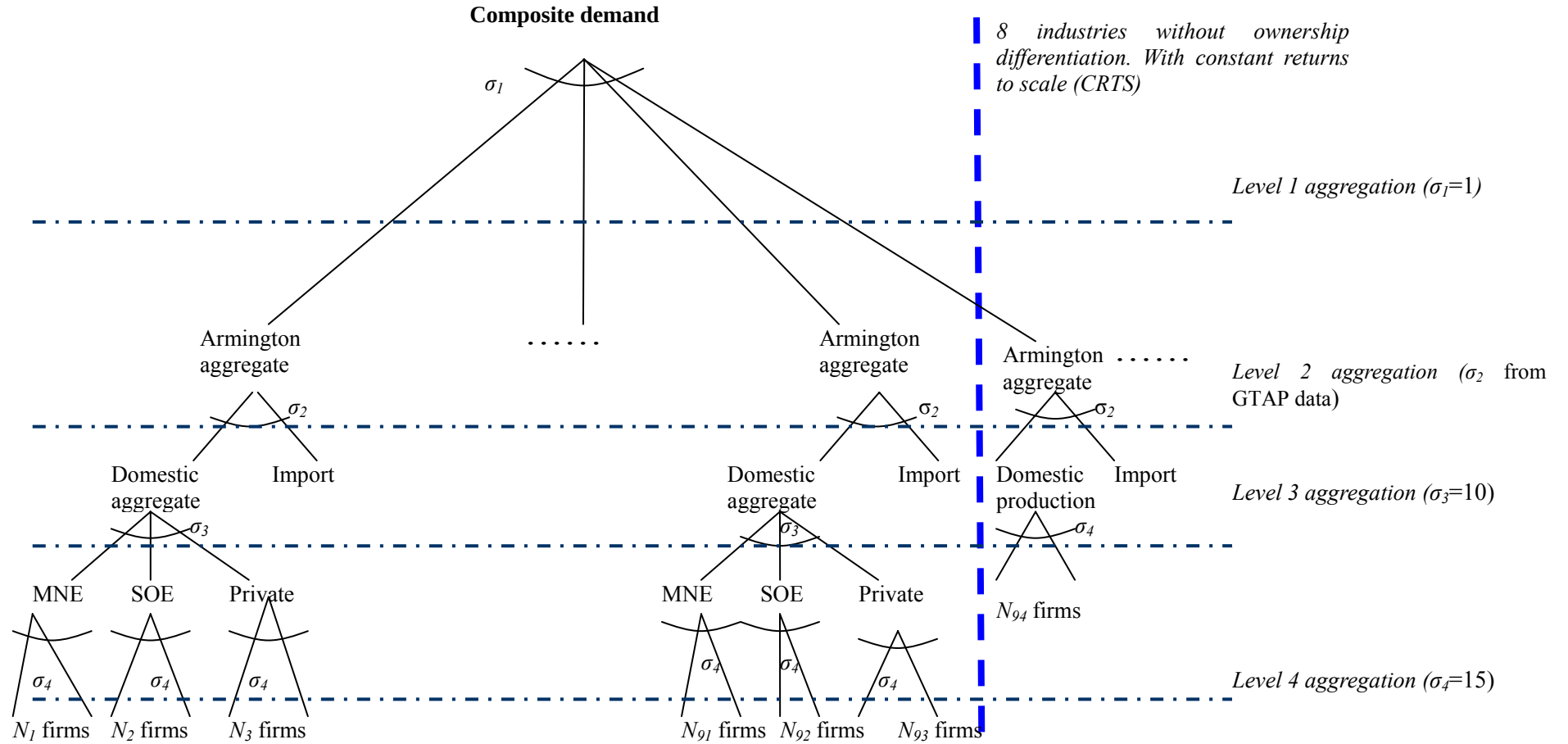
$$mk(\%) = \left| \frac{1}{\varepsilon_{Q(i,j,k,f)}} \right| = \frac{1}{\rho_4} + \frac{1}{N_{i,j,k,f}} \left( \frac{1}{\rho_3} - \frac{1}{\rho_4} \right) + \frac{\gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_2} - \frac{1}{\rho_3} \right) \\ + \frac{\beta_{i,j} \gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_1} - \frac{1}{\rho_2} \right) + \frac{\alpha_i \beta_{i,j} \gamma_{i,j,k}}{N_{i,j,k,f}} \left( \frac{1}{\rho_1} - 1 \right)$$

Here a simplified assumption has been made for each ownership in every sector: the firm sizes are the same (*they produce heterogeneous products though*) in each sector and the market share of each firm in the corresponding sector is simply  $\varphi_{i,j,k,f} = \frac{1}{N_{i,j,k,f}}$ .

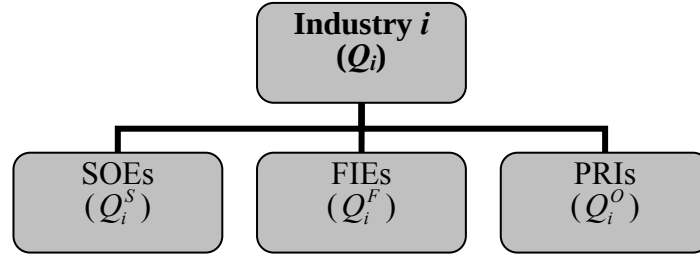
In the above equation, only the elasticities of substitution ( $\rho$ ) are exogenous. The value shares and firm numbers in each sector are endogenous, guaranteeing the properties of this model: free entry and exit, increasing returns to scale, and zero profit.

## Appendix 2: Tables and Figures

Figure 1: Consumption aggregation



**Figure 2: Disaggregate Output and Value Added by Ownerships**



**Table 1: A comparison of average TFP**

|      | <i>Pooled estimation</i> |             |             | <i>Separate estimation</i> |             |             |
|------|--------------------------|-------------|-------------|----------------------------|-------------|-------------|
|      | <i>L</i>                 | <i>HC</i>   | <i>HW</i>   | <i>L</i>                   | <i>HC</i>   | <i>HW</i>   |
| FIEs | <b>2.91</b>              | <b>2.41</b> | <b>1.85</b> | <b>3.63</b>                | <b>2.73</b> | <b>2.92</b> |
| SOEs | 2.59                     | 1.96        | 1.56        | 3.17                       | 2.72        | 2.11        |
| PRIs | 2.47                     | 1.80        | 1.42        | 2.51                       | 1.80        | 1.29        |

Note: Estimation specification is equation (4). *L* for pure labour input; *HC* for human capital with schooling years entered as weights; *HW* for human capital with economy-wide average wage entered as weights. In the “pooled estimation”, three types of firms are pooled to make estimations; while in the “separate estimation”, TFP of firms in each type of ownership are estimated separately.

**Table 2: FDI productivity spillover via labour turnover**

|                                                               | All four sectors (pooled)         |                                   |                                   | Electronics only                   |                                    |                                    |
|---------------------------------------------------------------|-----------------------------------|-----------------------------------|-----------------------------------|------------------------------------|------------------------------------|------------------------------------|
|                                                               | <i>L</i>                          | <i>HC</i>                         | <i>HW</i>                         | <i>L</i>                           | <i>HC</i>                          | <i>HW</i>                          |
| <b>Constant</b>                                               | 3.14<br>(0.11)***                 | 2.31<br>(0.11)***                 | 1.78<br>(0.12)***                 | 2.84<br>(0.14)***                  | 1.37<br>(0.14)***                  | 0.61<br>(0.14)***                  |
| <b><i>LT</i><sub>d,j</sub></b>                                | <b>-28.70</b><br><b>(8.85)***</b> | <b>-33.31</b><br><b>(9.24)***</b> | <b>-36.23</b><br><b>(9.52)***</b> | <b>-27.94</b><br><b>(8.70)***</b>  | <b>-27.69</b><br><b>(8.73)***</b>  | <b>-28.82</b><br><b>(8.74)***</b>  |
| <b><i>Training</i><sub>d,j</sub></b>                          | 0.01<br>(0.10)                    | -0.14<br>(0.10)                   | -0.18<br>(0.10)*                  | 0.02<br>(0.12)                     | -0.02<br>(0.11)                    | -0.03<br>(0.11)                    |
| <b><i>R&amp;D</i><sub>d,j</sub></b>                           | <b>-0.00</b><br><b>(0.00)**</b>   | <b>-0.00</b><br><b>(0.00)**</b>   | <b>-0.00</b><br><b>(0.00)**</b>   | 0.00<br>(0.00)                     | 0.00<br>(0.00)                     | -0.00<br>(0.00)                    |
| <b><i>LT</i><sub>d,j</sub>*<i>SOE</i><sub>d,j</sub></b>       | <b>93.47</b><br><b>(42.76)**</b>  | <b>89.77</b><br><b>(44.65)**</b>  | <b>87.20</b><br><b>(45.95)*</b>   | <b>180.77</b><br><b>(51.66)***</b> | <b>177.69</b><br><b>(51.85)***</b> | <b>170.69</b><br><b>(51.90)***</b> |
| <b><i>Training</i><sub>d,j</sub>*<i>SOE</i><sub>d,j</sub></b> | 0.04<br>(0.11)                    | 0.17<br>(0.12)                    | 0.21<br>(0.12)*                   | 0.02<br>(0.12)                     | 0.06<br>(0.12)                     | 0.08<br>(0.12)                     |
| <b><i>R&amp;D</i><sub>d,j</sub>*<i>SOE</i><sub>d,j</sub></b>  | 0.01<br>(0.01)                    | 0.01<br>(0.01)                    | 0.00<br>(0.01)                    | 0.01<br>(0.01)                     | 0.01<br>(0.01)                     | 0.01<br>(0.01)                     |
| <b>Observations</b>                                           | 743                               | 732                               | 732                               | 409                                | 401                                | 402                                |
| <b><i>R squared</i></b>                                       | 0.03                              | 0.03                              | 0.04                              | 0.05                               | 0.05                               | 0.05                               |

Notes:

- Dependent variable is logarithm of total factor productivity,  $\log(A_{d,j})=\log(TFP_{d,j})$ , which is estimated with equation (4);
- LT*, which denotes “labour turnover”, measures the number of **technicians** with foreign work experience, divided by the total employment number in the firm;
- “*L*” means the TFP data are estimated with data of capital and labour input; “*HC*” means the TFP data are estimated with data of capital and human capital (calculated with **schooling** years); “*HW*” means the TFP data are estimated with data of capital and human capital (calculated with economy-wide **wages**);

- d) Standard errors in parentheses. \*Statistically significant at 10%; \*\*significant at 5%; \*\*\*significant at 1%.

**Table 3: TFP Spillover estimated with industry-level data**

| $\alpha$ | $\beta_3$ | $\beta_4$ | $\beta_5$ | $\beta_6$ | <i>Obs.</i> | <i>R-squared</i> |
|----------|-----------|-----------|-----------|-----------|-------------|------------------|
| 0.46     | -8.16     | 8.29      | 1.56      | -0.21     | 155         | 0.90             |
| (0.89)   | (3.26)*** | (2.17)*** | (0.97)    | (0.17)    |             |                  |

Note: Estimation specification is given by equation (6). Standard errors in parentheses.

\*Statistically significant at 10%; \*\*significant at 5%; \*\*\*significant at 1%.

**Table 4: Changes of national aggregate output and value added (Δ%)**

|                     |                     | (a)                                 | (b)                            | (c)                               | (d)                                     | (e)                                              | (f)                                        |
|---------------------|---------------------|-------------------------------------|--------------------------------|-----------------------------------|-----------------------------------------|--------------------------------------------------|--------------------------------------------|
|                     |                     | Benchmark<br>“without”<br>spillover | Benchmark<br>with<br>spillover | FDI shock<br>without<br>spillover | FDI shock<br>with existing<br>spillover | FDI + spillover +<br>monopolistic<br>competition | FDI + spillover +<br>tax reform<br>(+0.5%) |
| <b>National all</b> | <b>Gross output</b> | <b>-4.3</b>                         | <b>0</b>                       | <b>-3.1</b>                       | <b>1.3</b>                              | <b>1.2</b>                                       | <b>0.9</b>                                 |
|                     | <b>GDP</b>          | <b>-6.6</b>                         | <b>0</b>                       | <b>-5.5</b>                       | <b>1.2</b>                              | <b>1.1</b>                                       | <b>0.7</b>                                 |
| FIEs                | Gross output        | 2.9                                 | 0                              | 5.4                               | 2.4                                     | 2.5                                              | -0.1                                       |
| (industry)          | Value added         | -0.2                                | 0                              | 2.2                               | 2.5                                     | 2.7                                              | -1.4                                       |
| SOEs                | Gross output        | -4.3                                | 0                              | -3.0                              | 1.4                                     | 1.1                                              | 1.8                                        |
| (industry)          | Value added         | 0.7                                 | 0                              | 1.9                               | 1.2                                     | 0.9                                              | 1.6                                        |
| Private             | Gross output        | -5.7                                | 0                              | -4.3                              | 1.6                                     | 1.6                                              | 2.4                                        |
| (industry)          | Value added         | -2.6                                | 0                              | -1.1                              | 1.6                                     | 1.7                                              | 2.3                                        |
| Non-industry        | Gross output        | -6.1                                | 0                              | -5.4                              | 0.7                                     | 0.6                                              | 0.4                                        |
|                     | Value added         | -9.4                                | 0                              | -8.6                              | 0.9                                     | 0.8                                              | 0.4                                        |

**Table 5: A comparison of four spillover channels**

|                     |                     | (g.1)          | (g.2)          | (g.3)            | (g.4)            |
|---------------------|---------------------|----------------|----------------|------------------|------------------|
|                     |                     | $\beta_{BL}=1$ | $\beta_{FL}=1$ | $\beta_{HZDS}=1$ | $\beta_{EXCO}=1$ |
| <b>National all</b> | <b>Gross output</b> | <b>-0.6</b>    | <b>-0.7</b>    | <b>-0.6</b>      | <b>-0.6</b>      |
|                     | <b>GDP</b>          | <b>0.0</b>     | <b>-0.1</b>    | <b>0.0</b>       | <b>0.1</b>       |
| FIEs                | Gross output        | 0.9            | 0.8            | 1.0              | 1.2              |
| (industry)          | Value added         | 0.9            | 0.7            | 1.2              | 1.5              |
| SOEs                | Gross output        | -1.4           | -1.2           | -1.3             | -1.0             |
| (industry)          | Value added         | 2.4            | 3.0            | 2.5              | 3.9              |
| Private             | Gross output        | -1.1           | -1.1           | -1.2             | -1.2             |
| (industry)          | Value added         | 2.3            | 2.9            | 2.1              | 2.8              |
| Non-industry        | Gross output        | -0.7           | -0.9           | -0.6             | -0.7             |
|                     | Value added         | -1.1           | -1.3           | -1.0             | -1.2             |

**Table 6: percentage changes (%) of some key variables in experiment (e)**

|                    | Export | wage | Production scale |
|--------------------|--------|------|------------------|
| Average            | 3.8    | 1.6  | 0.2              |
| Standard deviation | 1.3    | 1.1  | 0.1              |