AN APPLICATION OF POST-DEA BOOTSTRAP REGRESSION ANALYSIS TO THE SPILL OVER OF THE TECHNOLOGY OF FOREIGN-INVESTED ENTERPRISES IN CHINA

by

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January, 2000

Abstract

It is now widely believed that Foreign Direct Investment (FDI) affects positively the productivity of individual enterprises in the host economy and this is a main argument in favour of FDI. Although China is the largest recipient of FDI after the USA, there has been little empirical research as to whether such productivity effects of FDI are present in China. In this paper we attempt to answer some of these questions using a data set constructed from the Third Industrial Census of China conducted in 1995. We employ a Data Envelopment Analysis (DEA) to estimate individual enterprise level relative productivity scores from an industry level nonparametric production technology. These individual results are then related to the level of FDI via a Bootstrap regression which is used to insure consistent estimates of the variance covariance matrix of the regression estimates. The results are decomposed by size of enterprise and industry and provide an insight to the manner in which such spillover effects may be operating in the Chinese Economy.

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Summary

It is now widely believed that FDI affects positively the productivity of individual enterprises in the host economy. Indeed, this is the main argument in favour of FDI.[1] In China, the new leadership of China under Deng Xiaoping in 1978 saw FDI as a critical component of the "modernisation" of the economy. The Joint Venture Law of 1979 recognised that the only way of achieving the goal of modernisation was to attract FDI which would provide the technology, management skills and capital that was lacking domestically (Kaiser, Kirby and Fan, 1996). However, there has been little empirical research on the productivity effects of FDI in China. As the largest recipient of FDI after the USA, China is a particularly important case study.

Section I discusses the nature of technology effects of FDI. It distinguishes between direct technology transfer from overseas parent companies to foreign-invested enterprises in China and spillovers from the foreign-invested enterprises in China to other Chinese enterprises. A number of studies have shown that enterprises with FDI have higher total factor productivity (for example, Haddad and Harrison, 1993) but few have tested for inter-enterprise spillovers. Section II provides a specification of the technologies of enterprises which incorporates spillovers (Saggi, 1999, surveys the literature). In Section III we present a novel method for the investigation of spillover effects in a sample of enterprises in the industrial sector of China for the year 1995. This method uses enterprise-level data and a set of new tests for the presence of spillovers by employing DEA based measures of nonparameteric efficiency measures and a Bootstrap based tests on the results. In Section IV we report the tests and discuss the implications of our findings.

I Introduction

The literature has recognised that FDI flows may affect production in a host economy. We can distinguish two primary effects[2]:

- the foreign technology has a higher total factor productivity which is transferred initially to the foreign-invested enterprise in the host economy
- knowledge of the foreign-invested enterprises spillovers to other enterprises in the same industries.

Each of these effects occurs within industries (appropriately defined), that is, they are intra-industry effects. They are both forms of technology transfer. The first will be called the direct technology transfer effect and the second the spillover effect.

The direct technology transfer effect derives from an old argument that foreign investors have a superior technology of production which is transferable to foreign affiliates. In recent years this effect has been incorporated in a number of models of technology catch-up or technology ladders. It views the technology difference as given. The technology differences across nations are the result of past R&D or other processes of technology acquisition and no attempt is usually made to explain these differences.

The notion that knowledge spills over from one enterprise to others has become popular in recent years (Blomstrom (1989) provides an early and influential statement, though the idea was put forward much earlier by Findlay (1978) who called it "contagion"). This notion has an intuitive appeal but it has been modelled in different ways.

One strand of the literature makes the total factor productivity of a enterprise a function of cumulative industry output because of learning-by-doing. Grossman and Helpman (1995, section 2) survey these models. In these models, it has been assumed for simplicity that labour is the only factor of production. Suppose there are only two countries, the home (= host) country and the foreign (= source) country. Then the output of a good (= industry), industry i, in some host country is given by the production function

$$Y_i \;=\; A_i(\cdot)\, L_i \,/\, a_i \qquad (1)$$

a_i is a labour coefficient which is fixed in each country but differs among countries and $A_i(\cdot)$ is the index of technical knowledge or know how in the country. $1/a_i$ measures intrinsic labour productivity. This is an industry production function as it is assumed that the same value of the coefficients A_i and a_i apply to all producers of the good in one country. Knowledge is transmitted among producers by making A_i some function of cumulative outputs. The index A_i can be a function of the cumulative national output of the good, or the cumulative world output or sometimes of a group of related outputs in an industry at the national or international level: that is, $A_i = \alpha_i Y_i + \beta_i Y_i^*$ where Y denotes the cumulative output in the country , * denotes the foreign country and α_i and β_I are constants. This generates a family of learning-by-doing spillovers models.

In these models, spillovers occur as a function of cumulative aggregate industry output at some level. It does not matter whether the output in a country is produced by home or by foreign enterprises. There is some kind of transfer among enterprises but the actual mode of transfer is not specified.

In this paper we want to investigate the possibility that spillovers are FDI-related. The technology and the mode of transfer will need to be generalised to accommodate multiple inputs and differences among types of enterprises and differences among enterprises of one type. This is done in the next section.

In China statistics of enterprises recognise several types. Foreign direct investment statistics distinguish between “foreign-funded” enterprises and “Hong Kong, Macao and Taiwan-funded” or Overseas Chinese enterprises as Hong Kong, Macao and Taiwan are regarded as part of China. For the purposes of economic analysis, direct investments from these three territories will be regarded as part of foreign direct investments.

Four distinct forms of “foreign-funded” and Overseas Chinese-funded organisations are recognised in China - equity joint ventures, contractual joint ventures, wholly foreign-owned enterprises and cooperative development, the last being chiefly in the exploration and development of offshore oil resources. These types are collectively known as foreign-invested enterprises. In 1979 joint ventures were the only permitted form but from April 1986 wholly-owned enterprises have been approved and have subsequently become much more important. Different laws and regulations apply to each form. For example, a wholly-foreign-owned enterprise must use advanced technology and equipment or export a large proportion of its output (APEC (1996, p. 115)). Equity joint ventures and contractual joint ventures are sometimes combined in Chinese statistics.

All Chinese enterprises are divided between state-owned and non-state enterprises in the Chinese reporting system. In state-owned enterprises the means of production are owned by the state. There is a wide variation in non-state enterprises; township and village enterprises, urban and rural collectives, individual enterprises and other types. They differ greatly in terms of the degree of autonomy and other organisation characteristics (see East Asian Analytical Unit (1997, chapters 10 and 11)). Township and village enterprises are the largest and most rapidly growing group of non-state enterprises and their exports have grown much faster than those of the state enterprises. Non-state enterprises are quasi-private. Some purely private ownership is permitted of small businesses and assets are increasingly traded privately; the laws relating to private ownership of factories are currently being revised. There has been much discussion in China of the desirability of increasing the productivity of Chinese enterprises, especially state-owned enterprises.

We know of no quantitative studies of technology transfer in China but there are qualitative analyses and case studies. Tsang (1994) considers the strategy for technology transfers. He considers that China has a low capacity for technology transfer because of the low supply of skilled, technical and managerial manpower following from an underdeveloped education system and the major interruptions to this system in the Cultural Revolution period. Characteristics of the transferor (e.g. whether it is a SME or multinational) and transferee affect the choice of mode of transfer. De Bruijn and Jia (1993) consider technology transfer in joint ventures. Lan and Young (1996) do a case study of FDI in the city of Dalian in North-east China by direct sampling of foreign investors. They use the standard official distinction between “hardware” (machinery and equipment), “software” (knowledge embedded in the experience and skills of individuals) technologies and also “mediumware” (documents that can only be used with certain hardware). They conclude that “the record of FDI in transferring technology to the local economy has been very varied... with technology flow dominated by hardware transplant and training in basic operations. The absence of R & D restricted development potential and encouraged hardware technology dependency, while lack of understanding and appreciation of skills such as marketing by local Chinese personnel constituted a barrier to transfer on the software side. The integration of FDI with the local economy was underdeveloped.” (Lan and Young (1996, p. 73). Papers in Feinstein and Howe (1997) review Chinese government policies towards science and technology and technology transfer, and some case studies.

The next section provides a specification of differences in technologies among enterprises in Chinese industries which might be used to test for systematic differences among enterprise types and for positive inter-enterprise spillover effects.

II Theory

Consider some industry. As we are concerned with variation among enterprises in the industry, we shall drop the industry subscript. Let f denote an individual enterprise (or enterprise) and t denote a type of enterprise in the industry. F is the set of all enterprises and T is the set of all types. There may be multiple types of Chinese enterprises and of foreign-invested enterprises. It is assumed that the technology differs among enterprise types in an industry.

The technology of each enterprise in the industry is given by its production function. It is assumed that the industry produces only a single (composite) good. For this good, the production function of an enterprise f of type t is

$$y_{ft} = A_{ft}\ \phi_{ft}(L_{ft},\ K_{ft},\ M_{ft}) \tag{2}$$

L_{ft}, K_{ft}, and M_{ft} are the inputs of labour, physical capital and intermediate inputs respectively. The capital and material inputs may be regarded as composites of domestically-produced and imported goods which are imperfect substitutes for each other. A_{ft} is an efficiency parameter which is enterprise-specific. It captures Hicks-neutral (output-augmenting) differences in technology among enterprises. ϕ_{ft} captures non-Hicks-neutral differences in technology among enterprises.

The aggregate output of the industry is then

$$\begin{aligned} y &= \sum_{t\in T}\sum_{f\in F} y_{ft} \\ &= \sum_{t\in T}\sum_{f\in F} A_{ft}\phi_{ft}(L_{ft},K_{ft},M_{ft}) \end{aligned} \tag{3}$$

From Equation (3), it is apparent that total factor productivity in an industry depends on both the mix of enterprise types and the total factor productivities of individual enterprises in each type.

With the specification in Equation (2), technology transfers can occur in two primary ways.[3] Direct technology transfers from a parent foreign-investing enterprise to a Chinese enterprise can be modelled by having the parameters A_{ft} and the functions ϕ_{ft} in Equation (2) differ among types of enterprises to reflect the superior technology of foreign enterprises. Direct technology transfer may be an output-augmenting (Hicks-neutral) factor which shifts output for all input combinations through the parameter A_{ft}. This is reasonable if knowledge transfers are not embodied in some input argument of the production function. It is possible that ϕ_{ft} may also vary systematically among enterprises such that, for two enterprise types *t* and *u*, $\phi_{ft} > \phi_{fu}$ for some input sets at least.

Spillovers from one set of enterprises to another set can be captured by shifting the efficiency parameter A_{ft} for the set of recipient (or transferee) enterprises. These parameters can be modelled as some function of the activities of the transferor enterprises. That is,

$$A_{ft} = A_{ft}(\cdot) \tag{4}$$

where $(\cdot)$ indicates there is some as-yet-unspecified argument of this shift function.
For example, in the case of spillovers via the creation of new enterprises, $A_{nt} > A_{ot}$ where *n* and *o* denote a new Chinese enterprise an old Chinese enterprise respectively. Alternatively, spillovers could be represented by factor-augmenting changes.[4]

Van and Wan (1999) model the idea that much technology transfer takes place through the establishment of new domestic enterprises staffed by workers who were previously employed by foreign enterprises and acquired work and production skills and knowledge of the technology of production from this employment. The new enterprises may be subcontractors for the foreign enterprise or competitors or even produce other goods which use a similar technology. New domestic enterprises have a technology which is superior to old domestic enterprises. This might be called the new enterprises effect. Their model may be regarded as one mode of technology transfer to the Chinese enterprises. Other models that have been suggested are demonstration effects and vertical links via upstream suppliers of intermediate inputs or downstream buyers of their own products (Saggi 1999 and Aitken and Harrison, 1999 p 607).

Alternatively, one may also observe a short-run drop in productivity for Chinese enterprises if the entry of the foreign enterprises means that the demand for the domestic enterprises falls a so called "market stealing effect" Aitken and Harrison (1999). This mechanism employs the assumption that domestic enterprises may be forced to spread their fixed costs over a smaller level of output thus making them less competitive in the short-run.

III Empirical Methods

The database for this study is taken from the unit records of the Third Industrial Census of China which was conducted by the State Statistical Bureau in 1995. This census covered the manufacturing and mining sectors of the Chinese economy. Data were used for 37 of the 2-digit industries and aggregated to 13 sectors. For these industries, the data cover outputs (value added) and inputs of labour and capital. Labour is the number of employees in the industry. Series of capital are notoriously bad in China. In this study Capital is the aggregate present value of fixed capital assets net of depreciation. The latter series was constructed by Zhang and Zhang (1998).

This database distinguishes between seven types of enterprises in Chinese industries:

- State-owned enterprises
- Collectives
- Private enterprises
- Public and Private Cooperatives
- Enterprises listed on the Stock Exchange
- Foreign Investor owned enterprises
- Hong Kong-Taiwan-Macao-owned enterprises

A number of empirical studies which investigate the presence of spillover effects using similar forms of data have appeared in the literature. Recently Aitken and Harrison (1999) conduct analysis of a data set for Venezuela similar to the one used here. Although their data included up to thirteen annual observations for each enterprise their data contained similar information for each. They employed a regression analysis in which total value of output is used as the dependent variable and the inputs, characteristics of the FDI in each industry, and the ownership of the enterprise are used as regressors. This was done to estimate a simple production function then to allow the characteristics of the level of FDI in the industry to determine the "residual" effect on production of the level of FDI in the industry. Obviously, a major assumption of this type of analysis is the correct specification of the production function so that the residual variation is in fact a measure of efficiency. If we specify a production function of the form (dropping the *t* subscript for type of enterprise here):

$$y_f = g(x_f) + \omega_f \qquad (5)$$

where y_f is the output, $g(\cdot)$ is the production function, and x_f is the vector of inputs then the productive inefficiency can be characterized by ω_f. This means thus the greater ω_f the higher the output over the expected amount or the higher the efficiency and the lower ω_f the smaller the output from the expected level or the lower the efficiency. However, if the function $g(\cdot)$ is not specified correctly the ω_f term may include the error of the specification as well which cannot be signed a priori.

One difficulty with the method employed in Aitken and Harrison (1999) is that a single Cobb-Douglas production technology is assumed for over 4,000 Venezuelan enterprises in all industries. They conclude that the impact of FDI on large domestic enterprises is negative or insignificant. However the results are different for smaller foreign owned enterprises. But on the whole they find little evidence that spillover effects are present. In the analysis that is described below we utilize a nonparametric determination of enterprise efficiency within each particular major industrial grouping. Then we employ a special estimation procedure to account for the dependency in the efficiency measures.

For each industry, the relative productive efficiency of individual enterprises has been estimated by Data Envelopment Analysis or DEA. This provides an estimate of the best technology of the industry. The DEA method of analysis has a number of advantages over other methods such as frontier production functions in the present context. It is non-parametric and, therefore, does not impose the restriction of any functional form or the restriction of constant returns to scale. To calculate efficiency, it uses individual observations in the neighborhood of the frontier rather than the whole population. It can accommodate either a cost minimizing or an output maximizing objective function. And it is not limited to the single output case proposed by the direct estimation of a production function.

We define the efficiency computations to be the output maximization version of DEA. DEA produces a single estimate of the efficiency of an enterprise relative to the frontier by estimating the minimum scalar adjustment to the level of output of an enterprise which would put it on the frontier. (For a description of the method of DEA, see Ali and Seiford 1993 and Färe, Grosskopf and Lovell 1994). In effect, this provides, for each enterprise, an estimate of y_f / y_f^* where y_f is the actual enterprise's output and y_f^* is the output produced if the technology of the enterprise were at the frontier level and the enterprise used the same level of inputs. This measure picks up both Hicks-neutral and non-Hicks neutral differences in technology among enterprises. If the only differences in technologies were in the parameter A_f (that is, $\phi_f = \phi$ for all f), then $E_f = A_f^* / A_f$ where A_f^* is the frontier level of the efficiency parameter. More generally, it will combine differences in both A_f and ϕ_f among enterprises.

One way to calculate this measure of technical efficiency is by solving the following linear programming problem once for each Decision Making Unit or DMU (here we assume these to be each enterprise in the data set) $f = 1,...,F$ (see Färe, Grosskopf and Lovell (1985)):

$$\underset{w.r.t.\ \mu_f\ \lambda_f}{\text{Max}(\mu_f)}$$

Subject to:

$$\begin{aligned} \lambda_f \bullet Y &\geq \mu_f \, y_f \\ \lambda_f \bullet X &\leq x_f \\ \lambda_f \bullet \iota_{(F\times 1)} &= 1 \\ \lambda_f &\geq 0_{(F\times 1)} \end{aligned}$$

where Y is the F by M matrix of the observed outputs of all DMUs, X is the F by N matrix of the observed inputs for all DMUs, λ_t is a one by F dimensional vector of weights which is specific to the particular DMU and $\iota_{(F\times 1)}$ is an F by one vector of ones. These weights form a convex combination of observed DMUs relative to which the subject DMU's efficiency is evaluated. The constraints in this problem simply describe the input requirement set as given by the observed data (i.e., the best-practice technology). This specification is the variable rate of return case for maximizing the output. Alternative problems can be defined for minimizing inputs and imposing constant returns to scale.

Zheng, Lui and Bigsten (1998) in a DEA analysis of similar data from China for the period 1986-1990 also used the output maximization version. They argue that due to the fixed nature of many of the inputs in the Chinese enterprises the appropriate models are ones in which the output is maximized versus the alternative input minimization version of DEA.

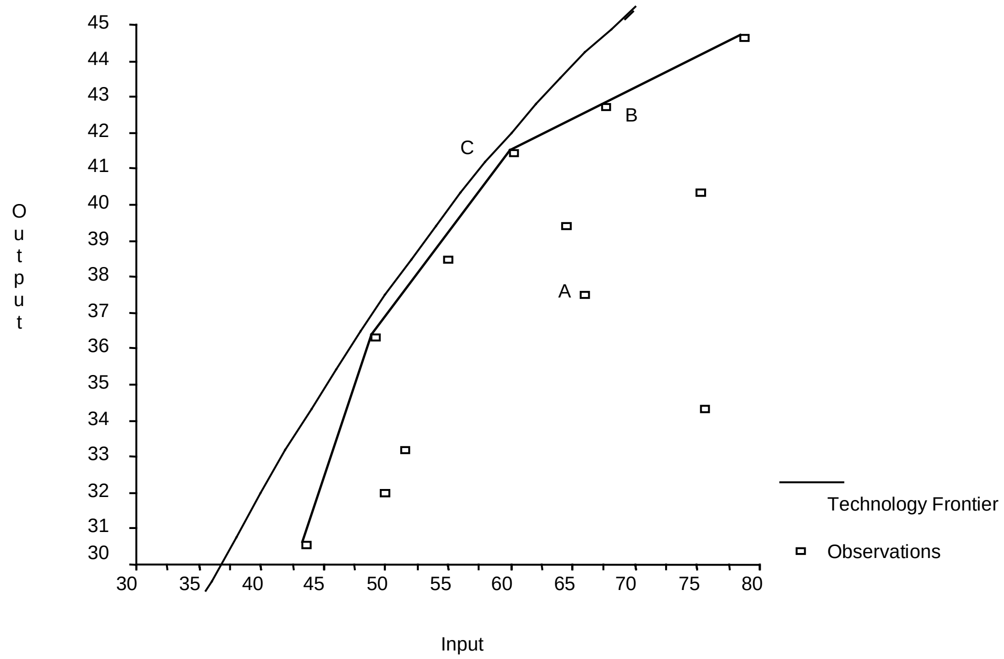

Figure 1. A one input one output technology

In the case where there is one input (x_f), one output (y_f) and output is maximized, the DEA measure of inefficiency (μ_t^*) is the inverse of the proportional increase in output that could be attained on the frontier with the same level of input. We perform a DEA analysis for a particular DMU using the (y_f, x_f) combination to define the technology of each DMU in the sample.

Instead of using the linear programming solution, we can demonstrate the process using the equivalent graphic solution to the one input one output case. In Figure 1 we can see an actual production frontier as the smooth curve which lies to the upper left-hand corner of the figure away from the data for a set of DMUs that are generated. The computation of the DEA score for DMU **A** (y_A, x_A) is defined by the ratio of the hypothetical value of y if **A** was on the estimated frontier $\hat{y}_A$ to the actual value of y_A. The estimated frontier will be defined by the set of line segments that connect the observed technology of those DMUs that are closest to the upper left-hand corner of the figure. Thus, in this case, the line connecting DMUs **B** and **C** will be the portion of the frontier from which we can compute the hypothetical value of y_A (given by $\hat{y}_A$) as the point on the line connecting DMUs **B** (y_B, x_B) and **C** (y_C, x_C) that corresponds to the level of input x_A. Note that DMU **B** is drawn from those cases where $x_A \le x_B$ and DMU **C** is drawn from those cases where $x_A \ge x_C$. This can include the DMU under consideration such as **A**. Algebraically, we can define the hypothetical level of $\hat{y}_A^*$ as a weighted average of the levels of input for the comparison DMUs. Thus the estimated efficiency score is formed as a ratio $\hat{\mu}_A = y_A/\hat{y}_A$ or in this example $\hat{\mu}_A \approx 37.5/43.5 = .862$. In order to compute the DEA efficiency score, it is necessary to find the set of reference technologies that result in the minimum value of $\hat{\mu}_A$ when computed from all the possible combinations of **B** and **C** that satisfy the conditions given above. Thus for any combination of alternative DMUs such as **B,** those with more or equal input than **A,** and alternatives such as **C**, those with less or equal input than **A**, an efficiency score can be computed for **A**. The score found by the DEA is defined as $\hat{\mu}_A^* = \min(\hat{\mu}_A)$ over all possible combinations of DMUs such as **B** and those such as **C** and in this case we find that the two DMUs identified as **C** and **B** are the ones for which $\hat{\mu}_A^* = \min(\hat{\mu}_A) \approx .862$.

Note that the estimated reference technology is not the same as the actual frontier technology and that if we drew a different sample of DMUs the reference technology would change. Furthermore, the efficiency score for DMU **A** as well as the score for the DMUs in close proximity will change. For example, the DMU just above **A** will have a different score if the reference technology is shifted and that shift is directly related to the shift in the score of DMU **A**. Thus two important observations can be made concerning DEA efficiency scores. First, they are subject to sampling variation just as statistics such as the sample mean and the variance are. And second, the scores of one DMU are going to be related to the scores for the other DMUs that are interior to the same portion of the reference technology. This means that if there is sampling variation in the reference technology the scores for a number of different DMUs will be correlated.

In this paper our objective is to determine if there are spillover effects from foreign-invested enterprises to Chinese enterprises. In order to perform this analysis, we propose to use the DEA score as the estimate of the residual effect (ω_f) as defined in equation (5). Thus we assume that there exists a monotonic relationship between ω_f and $\hat{\mu}_f^*$. Consequently, by conducting an analysis of the efficiency scores, we can determine if the spillover effects are present or not by establishing if the degree of FDI in an industry has a marginal effect on efficiency. These effects can be estimated by what is often referred to as a "post-DEA" analysis in which the relative efficiency scores are used as the dependent variables in a regression with variables that might influence the levels of these efficiency measures used as the regressors. Numerous examples of these studies can be found in the literature (i.e. Zheng, Lui and Bigsten 1998 for an example using a similar data set for China) and one might conclude that most applications of DEA involve such studies to summarize the results. In particular, the relative efficiency scores are some function of variables that might act as the mode of transfer of more efficient technology from the foreign-invested to the less efficient Chinese enterprises. For all the enterprises in the industry, we estimate an equation of the form

$$\hat{\mu}^{*}_{f} = f(z_{f}) + \varepsilon_{f} \qquad (6)$$

where z_f is a vector of explanatory variables for enterprise *f*. In this case we fit a series of models were the variables used include a quadratic (a linear and a squared value) of: the average wage rate, the total level of output in monetary value, the computed price index for capital assets, the average age of the capital of the enterprise, and a set of dummy variables for the particular form of ownership. In addition to these terms we also include two variables for the influence of FDI. In both we use the proportion of FDI in the three digit SIC as the indicator of the degree of FDI to which the enterprise is potentially subjected to. This indicator is multiplied by either a dummy variable indicating a Chinese owned enterprise or one that indicates a Non-Chinese owned enterprise. We do not distinguish levels of the degree of foreign control for each individual enterprise other than as a dichotomous value.

The proportion of FDI in the three digit SIC variable needed to test for the presence of positive spillover effects is the capital stock of foreign-invested enterprises in the industry, or perhaps the proportion of the capital stock of the industry which is foreign-owned. This stock is the cumulative (depreciated) value of foreign investment in the industry. A positive spillover from more efficient foreign-invested enterprises to less-efficient non-foreign invested enterprises will affect the distribution of relative efficiencies in the industry. The null hypothesis is that within an industry the mean score of the non-foreign-invested enterprises is affected positively by foreign investment in the industry. This is tested by pooling the data across industries. This test is based on the maintained hypothesis that the rate of spillover is constant across industries.

The DEA analysis was done for each of the 13 aggregated industries. Table 1 provides the distribution of the value of output among industries, the number of enterprises and in each industry the percent of total capital in the industry that is foreign owned.

Table 1. The Distribution Of The Value Of Total Output By Industry And Type Of Enterprise.

Industry	% of		Number of enterprises		
	Total Output	FDI of Capital	Foreign Control	Domestic Control	Total
Metals	14.4	2.33	127	1464	1591
Coal	2.7	0.06	1	324	325
Petrol Extraction	4.5	0.00	0	24	24
Petrol Processing	6.0	0.00	0	102	102
Chemicals	13.8	5.04	270	3052	3322
Machinery	26.0	7.59	511	5641	6152
Building Materials.	3.7	9.44	153	1715	1868
Wood	0.7	4.06	22	245	267
Processed Food	10.0	11.72	260	2176	2436
Textile & Clothing	9.5	6.06	301	2948	3249
Paper	2.1	7.79	88	919	1007
Misc. Manufacturing	0.4	5.71	16	176	192
Electricity & Water	6.4	11.15	32	1051	1083

A concern with running auxiliary regressions on the efficiency scores obtained from DEA is that the scores are estimated with a certain degree of sampling error that varies from DMU to DMU and that the scores for different DMUs may be dependent on each other. Consequently, $\varepsilon_t \sim (0,\Omega)$ and thus they do not conform to the assumption of identically and independently distributed random errors. Furthermore, a number of the DMUs may have efficiency scores equal to one and thus we are faced with a limited dependent variable problem. For, example from Figure 1 the scores for DMUs **B** and **C** would be estimated as equal to one because they are on the frontiers. This dependence and heteroskedasticity means that the use of simple regressions on these scores will not result in appropriately estimated standard errors.[5] The limited nature of the dependent variable will mean the parameter estimates are biased as well. To overcome this problem we use a method suggested by Xue and Harper (1999) that employs the bootstrap estimates as defined by Ferrier and Hirschberg (1997,1999).

The Bootstrap of the DEA scores procedure enables us to estimate a variance covariance matrix for the scores. Briefly, this is done by reestimating the DEA score for each DMU from a resampling of the set of DMUs (for an introduction to the Bootstrap method see Efron and Tibshirani 1993). Thus the reference technology is allowed to change and we can compute an estimate of the first two moments of the score estimates. Given the estimates of the covariance matrix derived from the Bootstrap procedure we obtain $\hat{\Omega}$ that can be used in the covariance estimation. In addition we can also use the average value of μ_f computed for each BS as the appropriate estimate for the efficiency score. Thus we estimate a linear model of the form:

$$\bar{\mu} = Z\beta + \varepsilon \tag{7}$$

where $\bar{\mu}$ is the vector of average DEA scores, Z is the matrix of enterprise characteristics, and β is the vector of linear coefficients. The estimate of β is given as:

$$\hat{\beta} = (Z'Z)^{-1}Z'\bar{\mu} \tag{8}$$

And the covariance matrix of $\hat{\beta}$ is estimated as:

$$\widehat{\mathrm{Cov}}(\hat{\beta}) = (Z'Z)^{-1}(Z'\hat{\Omega}Z)(Z'Z)^{-1}. \quad (9)$$

It can be shown that this specification is equivalent to reestimating the regression for each set of the bootstrapped scores and then using the variance covariance matrix from the estimated $\hat{\beta}$s as is suggested in Xue and Harper (1999). Note that because the number of bootstrap replications in this case is usually far less than the number of observations (in this application we used 75 bootstrap replications and with one industry with over 6,000 enterprises), the computation in (9) can be done by the decomposition of the $\hat{\Omega}$ matrix. This dimensionality problem also limits the estimation of β via a form of GLS procedure, due to a need for a form of $\hat{\Omega}^{-1}$, to those cases in which the number of bootstrap replications exceeds the number of enterprises.

The analysis proceeded in three steps.

1. The output maximizing DEA was run for enterprises within a particular industry. These efficiency scores are based on the use of a single output measured as the value of the total output and a set of three inputs: labour, measured by the number of workers, capital as measured by the value of capital, and the value of intermediate goods. Thus the efficiency score is the proportion of potential output achieved by the enterprise as compared to the best practice enterprise observed in the industry.

2. Apply the bootstrap method as described in Ferrier and Hirschberg (1997, 1999). Instead of the cost minimization problem set up in those papers, we are here solving the output maximization problem. Thus the bootstrap procedure is slightly different in that we change the level of outputs and make all enterprises efficient rather than the level of the inputs. Then we randomly select levels of inefficiency to establish the degree of variation in the efficiency score for each enterprise. This was done 75 times in this application which is on the low side for number of replications typically used in bootstrap studies. However this limitation on the number of bootstrap replications is due to the large number of enterprises in the entire sample (21,618). DEA requires that a linear programming problem be solved for each enterprise however, here we find that the number of enterprises in some industries is so large that repeating the DEA analysis 75 times required over 180 hours of computer time on a DEC workstation.

3. The post-DEA analysis was then performed by industry by estimating the parameters using (8) and the standard errors using (9). For the estimation of $\hat{\Omega}$ we determined that 75 replications was sufficient to correct the bias that would be introduced using the OLS estimates of the standard error. However one would be much more hesitant to use this number to construct confidence intervals. In simulations of Bootstrap regressions on highly dependent data it was found that 75 did offer fairly

good coverage for the standard error computations. However, these simulations were based on a smaller number of repressors and a well defined error structure. The other reservation about the use of regression - that the dependent variable is truncated - was considered unimportant in this case because of the very large number of DMUs in most industries and the fact that we only have one output. With this configuration, the number of DMUs for which the average score was 1 is less than one percent in most cases - thus we assumed that this had little impact on the results. The dependent variable was the logistic transformation of the efficiency measure defined as $\log\left[{}^{\mu_f}\!/_{(\mu_f - 1)}\right]$. This results in the creation of a new variable that is monotonically related to the efficiency scores and has an approximately unbounded range and it also removes the DMUs on the frontier from the analysis.

IV Results

Prior to investigating the impacts of FDI on enterprise productivity, we first determine if there are productivity differences between the various forms of the enterprises in these industries. The primary question is whether the domestic enterprises have lower productivity than the foreign owned enterprises. Table 2 lists the average DEA scores as computed over the mean of the bootstrap replications for each enterprise. Note that the overall averages are quite low in some industries. This is especially true for those industries with a large number of enterprises. The phenomenon that larger numbers of DMUs result in lower average efficiency scores a is a characteristic of DEA and is the primary a reason why cross-industry comparisons of DEA scores are inappropriate. The comparison across types within the same industry can be made and from this table and we find a number of cases in which the Foreign investor owned and Hong Kong, Taiwanese and other off shore Chinese holdings have higher average values than the State Owned enterprises. However, because one could be comparing quite different groups with this comparison this analysis should be based on conditional comparisons.

A more appropriate form of analysis uses conditional means to make this comparison. To accomplish this we estimate a series of regressions of the form of (6) using the logistic transformation of the efficiency score and all the regressors except, we do not multiply the domestic versus foreign ownership dummy by the proportion of FDI in the industry. We then construct a new parameter defined as the difference between the dummy on all forms of domestic enterprises from the dummy for all the types of foreign owned enterprises - here we drop the intercept in the estimation. The standard errors of these differences are then computed via the bootstrap procedure. Table 3 lists the differences as well as an indication of which are significant. A negative value indicates when the foreign owned enterprise is more efficient. All the significant differences are negative which indicate that the foreign control enterprises have a higher level of productivity all else being equal. However, it may be that only those enterprises acquired by foreign interests are those that are most productive. Given the limitations in the data we are not able to model the potential for such a simultaneity bias.

Table 2 The Average Of The Mean DEA Score For Each Type Of Enterprise.

Industry	Type of Enterprise								
	Duoyou (State Owned)	*Jiti* (Collective)	*Siying* (Private)	*Lianying* (Public/ Private Coop)	*Gufenzhi* (Listed On Stock Exchange)	*Sanzi* (Foreign Investor Owned)	Hk,T,M (Hong Kong, Taiwan +)	Other	All
Metals	0.027	0.008	#	0.003	0.010	0.019	0.031	#	0.021
Coal	0.096	0.013	-	#	0.934	-	#	-	0.103
C. Petrol	0.815	-	-	-	-	-	-	-	0.815
R. Petrol	0.361	0.405	-	-	#	-	-	-	0.356
Chem	0.025	0.020	-	0.032	0.018	0.028	0.067	#	0.026
Mech	0.031	0.018	-	0.024	0.013	0.054	0.047	0.016	0.030
B.M.	0.069	0.026	-	0.031	0.028	0.160	0.099	-	0.064
Wood	0.104	0.066	-	#	0.126	0.163	0.195	-	0.105
P. Food	0.016	0.018	-	0.110	0.002	0.053	0.059	-	0.020
T & C	0.065	0.044	#	0.042	0.023	0.054	0.098	#	0.058
Paper	0.114	0.085	-	0.027	0.047	0.292	0.169	#	0.116
M. Man	0.376	0.204	#	0.097	0.237	0.442	0.340	#	0.253
E & W	0.105	0.025	-	0.047	0.092	0.085	0.253	#	0.106

# Indicates that there were less than 5 enterprises in this group, - indicates that no enterprises are in this group.

Table 3 The Domestic Minus The Foreign Owned Coefficient.

Industry	Domestic - Foreign
Metals	**-0.744 ***
Coal	#
Chemicals	**-0.846 ***
Machinery	**-0.414 ***
Building Materials.	**-0.473 ***
Wood	0.426
Processed Food	**-0.572 ***
Textile & Clothing	**-0.355 ***
Paper	**-0.338 ***
Misc. Manufacturing	-0.316
Electricity & Water	-0.355

* Indicates a t-statistic with absolute value greater than 1.96, # Indicates that there were less than 5 enterprises in this group.

To establish which type of foreign enterprises are more efficient than state owned enterprises, we performed a more detailed analysis in which dummy variables for each of the 7 types of enterprises was used to estimate a model. The table below gives the results of these differences for Taiwan and Hong Kong based enterprises and for other foreign owned enterprises by sector. From Table 4 we see that for most industries the foreign owned enterprises are more efficient. The full set of differences is listed in Appendix C. Note these are all fit with the full set of regressors, but no indication of FDI.

Table 4. The Differences Between The State Owned Enterprise And The Two Forms Of Foreign Enterprises.

Industry	HK,T,M (Hong Kong, Taiwan +)	*Sanzi* (Foreign Investor owned)
Metals	-0.194	-0.557 *
Coal	#	N.A.
Chemicals	-0.985 *	-0.557 *
Machinery	-0.273 *	-0.281 *
Building Materials.	-0.292 *	-0.357 *
Wood	1.043 *	-0.016
Processed Food	-0.575 *	-0.466 *
Textile & Clothing	-0.369 *	0.068
Paper	0.051	-0.469 *
Misc. Manufacturing	-0.347	0.120
Electricity & Water	-0.397	-0.146

* Indicates a t-statistic with absolute value greater than 1.96, # Indicates that there were less than 5 enterprises in this group.

From this analysis we confirm that the domestically owned enterprises are less efficient than foreign owned enterprises. The question of spillover effects concerns the degree to which these more efficient operations have a influence on the domestic enterprises. In the analysis we perform next we determine the effect on domestic producers of being in an industry that has a higher degree of FDI than comparable other enterprises. We will do this by modifying our analysis by multiplying the dummies for domestic and foreign control by the proportion of FDI in the industry as well as including the regressors we used above and a set of dummy variables for the types of control.

There is a potential difficulty in interpretation of the parameter estimates in this model when including all of the enterprise characteristics in a single regression. The average age of capital , the average wage and the price of capital may all be a function of the degree of foreign investment in the industry. Therefore, the post-DEA analysis was performed with a series of different models. These are listed in Table 5. We do find that there is a positive correlation between these characteristics with the proportion of foreign ownership variable. Note that the average wage rate is a function of a number of factors. Both the mix of worker types and local wage rates will have an impact on the level of the average wage rate.

Table 5. The Model Specifications Estimated

Effects Included	**Model**					
	1	**2**	**3**	**4**	**5**	**6**
Intercept	●	●	●	●	●	●
Prop Cap Foreign Owned	●	●	●	●	●	●
Value of Output	●	●	●	●	●	
Ownership Type (Dummies)	●	●	●	●		
Average wage per worker	●	●	●			
Average age of capital	●	●				
Price index for fixed capital assets	●					

Table 6 provides the coefficient for the dummy that indicates all types of Chinese owned enterprises times the level of FDI in the same 3 digit SIC using all 6 models on enterprises of all sizes. A positive coefficient indicates a positive spillover effect and a negative coefficient indicates a negative spillover effect. Note that the different models are consistent in their results in that in no case do we find a reversal in sign to be significant. However, to avoid the possible bias from omitted variables we will concentrate on the results for Model 1. From this table one can see that the variable indicating the proportion of the industry was found to be significantly positive only for the Chemical Industry. But we also find that FDI has a significant negative impact on the Building Materials, Wood and the Electricity and Water industries. One possible interpretation is that the competition hypothesis may be at work in these industries if we follow the logic proposed in Aitken and Harrison (1999). The complete set of coefficient results from which this table is drawn is given in Appendix A.

Table 6. The Coefficients For The Chinese Times Foreign Investment Variable In Models 1 Through 6.

Industry	Model					
	1	**2**	**3**	**4**	**5**	**6**
Metals	0.346	0.308	0.319	0.284	-0.533	-0.956 *
Coal	16.908	17.301	12.755	14.134	18.467	15.161
Chemicals	**0.970 ***	**0.905 ***	**1.155 ***	**0.945 ***	0.304	0.385
Machinery	-0.031	-0.044	-0.432 *	-0.448 *	-0.635 *	-0.788 *
Building Materials.	-2.176 *	-2.141 *	-2.464 *	-2.428 *	-2.614 *	-2.968 *
Wood	-1.692 *	-1.702 *	-2.210 *	-3.640 *	-4.112 *	-4.156 *
Processed Food	0.122	0.111	-0.363	-0.342	-0.675 *	-0.664
Textile & Clothing	-0.190	-0.205	0.507	0.208	-0.552	0.009
Paper	0.015	0.062	0.241	0.297	-0.719 *	-0.824 *
Misc. Manufacturing	-0.202	0.145	1.589	1.885	2.171	6.457
Electricity & Water	-1.890 *	-1.679 *	-1.576 *	-1.662 *	-1.846 *	-3.984 *

*****t-statistics with absolute values greater than 1.96.

Aitken and Harrison (1999) find that the size of the enterprises appear to have an important influence on the degree to which FDI effects domestic enterprises. They found that smaller enterprises were more prone to the influence of spillover effects. In order to determine if this was also occurring in China we performed the same analysis as listed above using enterprises of various sizes as defined by the number of workers. Table 7 reports the size distribution of enterprises in these industries.

Table 7. The Industry Distribution Of The Number Of Enterprises By The Number Of Workers.

Industry	**Enterprise Size (Number of Workers)**				**Total**
	1-250	**251-500**	**501-1000**	**1001+**	
Metals	110	224	454	803	1591
Coal	4	13	23	285	325
Chemicals	263	609	1179	1271	3322
Machinery	260	756	2128	3008	6152
Building Materials.	104	246	702	816	1868
Wood	22	42	50	153	267
Processed Food	325	643	830	638	2436
Textile & Clothing	157	438	979	1675	3249
Paper	76	243	391	297	1007
Misc. Manufacturing	22	48	75	47	192
Electricity & Water	77	217	326	463	1083
Total	1422	3483	7154	9559	21618

Table 8. Summary Of Results For Model 1 For Coefficient For Chinese Owned Times FDI Using Model 1.

Industry	**Enterprise Size**				
	1-250	**251-500**	**501-1000**	**>1000**	**All**
Metals	**0.806** *	-0.148	-0.570 *	-2.029 *	0.346
Coal		-113.426	**89.836** *	10.545	16.908
Chemicals	-0.178	0.113	**0.439** *	-2.271 *	**0.970** *
Machinery	1.300	**1.428** *	**0.965** *	-1.131 *	-0.031
Building Materials.	-4.210	-1.086	0.008	-1.991 *	-2.176 *
Wood	3.408	-0.621	-1.782	-1.839	-1.692 *
Processed Food	**1.738** *	-0.578 *	0.421	0.417	0.122
Textile & Clothing	0.616	**1.074** *	0.333	-1.373 *	-0.190
Paper	-1.363	-0.254	**1.056** *	-1.450 *	0.015
Misc. Manufacturing	199.383	-2.292	-3.364	7.075	-0.202
Electricity & Water	2.926	0.634	-0.146	-3.627 *	-1.890 *

*****t-statistics with absolute values greater than 1.96.

In Table 8 we report the same coefficient on the level of FDI for domestic enterprises as computed in column 1 of Table 6. We observe that the positive spillovers effects seem to be in evidence for the smaller enterprises, and the larger enterprises are then negatively effected. This pattern seems to occur for Metals, Chemicals, Machinery, Processed Food, and Textiles and Clothing. Thus our initial results that implied little positive influences of FDI appear to change quite radically when we consider the relationship by enterprise size.

In conclusion, we find that domestically owned enterprises are less efficient than foreign-owned enterprises and there is some support for the hypothesis that the technology of foreign enterprises spills over to other enterprises. The proportion of the FDI capital in an industry has a positive impact on the relative productivity of enterprises in five of the eleven industries we study (Metals, Chemicals, Machinery, Processed Food, and Textiles and Clothing). However, it appears that this effect is determined by the size of the establishment. In fact we also observe negative significant impacts in seven out of the eleven industries when limiting our analysis to the largest enterprises. Does this imply that the hypothesis that local markets are lost to domestic enterprises when a high degree of FDI is present bares out for only large enterprises and that small enterprises adapt to the shift in technology faster thus are able to increase their productivity? Or, are small enterprises more receptive to receiving spillovers? This is the sort of question that further investigation may uncover.

Note that there are other potential explanations for these findings. Specifically they may be due to an inadequate specification of the spillover mechanism. For example, the spillover effect from foreign investors may differ if the mode of entry is joint ventures from that when the mode of entry is wholly-owned enterprises. Similarly, it may differ according to the type of Chinese enterprise which receives new technologies. Unfortunately, the existing theory gives little guidance on this issue.

FOOTNOTES

1. Foreign Direct Investment (FDI) affects the rate of growth of an economy in various other ways too. At the microeconomic level, it increases competition and improves marketing of the outputs. At the macroeconomic level, it supplements or stimulates domestic savings and capital formation, and promotes the development of new industries and export patterns (as in the Flying Geese effects in East Asian economies).
2. Conroy (1992) considers technology transfer along with other forms of technology imports through licensing and other non-equity forms of purchase of intellectual property, technology services, and co-production. As technology imports far exceeded FDI in value, Conroy concluded that "...it appears probable that the role of FDI, especially in advanced technology areas, has been extremely modest as a vehicle for technology flows" (Conroy (1992, p. 212)). This is a useful reminder of the importance of non-equity investments as a form of technology transfer. But Conroy's data relates to the Eighties, before the major surge in FDI.
3. Any capital- or labour-augmenting effects can be modelled by the specification of the inputs K_{ft} and L_{ft}.
4. In some studies, the term "spillover" is used in a more general sense to include other effects such as labour training and competition effects: for example, Blomstrom (1989). Labour training, may increase the supply of some types of labour or, more importantly, may make available some kinds of skilled labour which did not exist in the host countries before foreign investment; for example, engineers and supervisors. In some cases, foreign investors may send key local employers to plants in the source country for training. The immediate effect of labour training is limited to the enterprise which trains the workers. If human capital formation is considered to be labour-augmenting, the spillover is through the variable L_{ft} which becomes some function of FDI. This has a labour-augmenting effect which is an alternative to the assumption of an output-enhancing effect.
5. Note that simply using a procedure to produce standard errors that are consistent in the presence of heteroskedasticity will not help the problem caused by the dependence of the scores.

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Appendix A. The estimated coefficients for the set of 6 models fit to the entire set of enterprises in each industry. Note that all of these models have been estimated via the bootstrap method and that the coefficients with a * are those that have t-statistics with an absolute value greater than 1.96. If the coefficient is listed as a '.' then it was not estimated in the model.

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	Intercept	6.142 *	-6.593 *	-6.032 *	-6.331 *	-7.258 *	-7.035 *
Metals	Chinese owned times FDI	0.346	0.308	0.319	0.284	-0.533	-0.956 *
Metals	Non-Chinese owned times FDI	-0.531	-0.451	-0.390	-0.531	0.137	0.131
Metals	Value of Output	0.970 *	0.947 *	0.847 *	0.766 *	0.862 *	-
Metals	Output squared	-0.030	-0.029	-0.021	-0.015	-0.020	-
Metals	Duoyou (state owned)	-1.371 *	-1.134 *	-0.739	-0.631	-	-
Metals	Jiti (Collective)	-2.249 *	-2.028 *	-1.963 *	-1.834 *	-	-
Metals	Siying (Private)	0.855	1.972 *	1.565 *	1.702 *	-	-
Metals	Lianying (Public/Private coop)	-2.253 *	-1.950 *	-1.798 *	-1.714 *	-	-
Metals	Gufenzhi (Listed on stock exchange)	-1.552 *	-1.215 *	-1.051 *	-0.952 *	-	-
Metals	Sanzi (Foreign Investor owned)	-0.521	-0.175	-0.302	-0.286	-	-
Metals	HK,T,M (Hong Kong, Taiwan +)	-1.051 *	-0.729	-0.824 *	-0.761	-	-
Metals	Average wage per worker	-0.016	-0.016	-0.037 *	-	-	-
Metals	Wagerate squared	0.000 *	0.000 *	0.000 *	-	-	-
Metals	Age of Capital	-0.512 *	0.053 *	-	-	-	-
Metals	Age of Capital Squared	0.016 *	0.004 *	-	-	-	-
Metals	Price index for fixed capital assets	-25.387 *	-	-	-	-	-
Metals	Deflator squared	14.322 *	-	-	-	-	-
Coal	Intercept	-5.633	-1.787	-1.217	-2.844	-4.008 *	-3.809 *
Coal	Chinese owned times FDI	16.908	17.301	12.755	14.134	18.467	15.161
Coal	Non-Chinese owned times FDI	-76.633	-74.492	-75.241	-77.278	-40.063 *	-43.964 *
Coal	Value of Output	1.086	1.079	1.134	0.693	0.695	-
Coal	Output squared	0.026	0.034	0.007	0.122	0.124	-
Coal	Duoyou (state owned)	-1.511	-1.520	-1.192	-1.150	-	-
Coal	Jiti (Collective)	-1.934	-1.958	-2.003	-1.976	-	-
Coal	Average wage per worker	-0.379 *	-0.369 *	-0.450 *	-	-	-
Coal	Wagerate squared	0.023 *	0.022 *	0.024 *	-	-	-
Coal	Age of Capital	0.243	0.056	-	-	-	-
Coal	Age of Capital Squared	-0.003	0.001	-	-	-	-
Coal	Price index for fixed capital assets	7.672	-	-	-	-	-
Coal	Deflator squared	-4.298	-	-	-	-	-
C. Petrol	Intercept	59.755	-4.234	1.094	1.186	1.186	1.110 *
C. Petrol	Value of Output	0.066	0.066	-0.020	-0.162	-0.162	-
C. Petrol	Output squared	0.005	0.001	0.007	0.014	0.014	-
C. Petrol	Average wage per worker	0.352	1.254	0.033	-	-	-
C. Petrol	Wagerate squared	-0.023	-0.056	-0.009	-	-	-
C. Petrol	Age of Capital	-4.486	-0.423	-	-	-	-
C. Petrol	Age of Capital Squared	0.135	0.014	-	-	-	-

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
C. Petrol	Price index for fixed capital assets	-83.235	-	-	-	-	-
C. Petrol	Deflator squared	24.455	-	-	-	-	-
R. Petrol	Intercept	-5.610	-0.471	-0.857	-1.839 *	-1.232 *	-1.249 *
R. Petrol	Value of Output	-0.051	-0.054	-0.070	-0.166	-0.156	-
R. Petrol	Output squared	0.014	0.014	0.015	0.020	0.020	-
R. Petrol	Duoyou (state owned)	0.821 *	0.798 *	0.722 *	0.680 *	-	-
R. Petrol	Jiti (Collective)	0.484	0.439	0.316	0.151	-	-
. Petrol	Average wage per worker	-0.199 *	-0.201 *	-0.220 *	-	-	-
R. Petrol	Wagerate squared	0.007	0.007	0.008	-	-	-
R. Petrol	Age of Capital	0.186	-0.215	-	-	-	-
R. Petrol	Age of Capital Squared	0.003	0.017	-	-	-	-
R. Petrol	Price index for fixed capital assets	7.675	-	-	-	-	-
R. Petrol	Deflator squared	-3.267	-	-	-	-	-
Chem	Intercept	3.158 *	-5.897 *	-5.089 *	-5.803 *	-5.771 *	-5.830 *
Chem	Chinese owned times FDI	0.970 *	0.905 *	1.155 *	0.945 *	0.304	0.385
Chem	Non-Chinese owned times FDI	-2.056 *	-2.431 *	-2.369 *	-3.142 *	1.740	1.654
Chem	Value of Output	0.148	0.155	-0.070	-0.553	-0.607	-
Chem	Output squared	0.078	0.078	0.107	0.169 *	0.171 *	-
Chem	Duoyou (state owned)	0.004	0.036	-0.310	0.052	-	-
Chem	Jiti (Collective)	-0.256	-0.248	-0.622	-0.231	-	-
Chem	Lianying (Public/Private coop)	0.122	0.154	-0.168	0.079	-	-
Chem	Gufenzhi (Listed on stock exchange	-0.262	-0.238	-0.688 *	-0.409	-	-
Chem	Sanzi (Foreign Investor owned)	0.851 *	0.992 *	0.449	0.627	-	-
Chem	HK,T,M (Hong Kong, Taiwan +)	1.289 *	1.375 *	0.793	1.046 *	-	-
Chem	Average wage per worker	-0.061 *	-0.060 *	-0.078 *	-	-	-
Chem	Wagerate squared	0.001 *	0.001 *	0.001 *	-	-	-
Chem	Age of Capital	-0.498 *	-0.003	-	-	-	-
Chem	Age of Capital Squared	0.018 *	0.005 *	-	-	-	-
Chem	Price index for fixed capital assets	-16.479 *	-	-	-	-	-
Chem	Deflator squared	8.438 *	-	-	-	-	-
Mech	Intercept	-2.486 *	-6.274 *	-5.374 *	-6.137 *	-5.215 *	-5.291 *
Mech	Chinese owned times FDI	-0.031	-0.044	-0.432 *	-0.448 *	-0.635 *	-0.788 *
Mech	Non-Chinese owned times FDI	-0.431	-0.381	-0.146	0.267	-1.123 *	-2.131 *
Mech	Value of Output	-0.393 *	-0.402 *	-0.512 *	-0.863 *	-0.925 *	-
Mech	Output squared	0.044 *	0.044 *	0.051 *	0.071 *	0.075 *	-
Mech	Duoyou (state owned)	0.831 *	0.822 *	0.913 *	1.065 *	-	-
Mech	Jiti (Collective)	0.540 *	0.521 *	0.295	0.455 *	-	-
Mech	Lianying (Public/Private coop)	0.708 *	0.711 *	0.638 *	0.683 *	-	-
Mech	Gufenzhi (Listed on stock exchange	0.431 *	0.413 *	0.272	0.363	-	-
Mech	Sanzi (Foreign Investor owned)	1.196 *	1.244 *	0.891 *	0.540 *	-	-
Mech	HK,T,M (Hong Kong, Taiwan +)	1.174 *	1.166 *	0.779 *	0.540 *	-	-

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Mech	Average wage per worker	-0.084 *	-0.084 *	-0.121 *	-	-	-
Mech	Wagerate squared	0.001 *	0.001 *	0.002 *	-	-	-
Mech	Age of Capital	-0.142 *	0.045 *	-	-	-	-
Mech	Age of Capital Squared	0.007 *	0.003 *	-	-	-	-
Mech	Price index for fixed capital assets	-7.463 *	-	-	-	-	-
Mech	Deflator squared	4.105 *	-	-	-	-	-
B.M.	Intercept	1.831	-3.402 *	-3.154 *	-3.297 *	-3.419 *	-3.897 *
B.M.	Chinese owned times FDI	-2.176 *	-2.141 *	-2.464 *	-2.428 *	-2.614 *	-2.968 *
B.M.	Non-Chinese owned times FDI	-1.014	-0.768	-0.715	-0.918	0.090	-1.190
B.M.	Value of Output	-8.927 *	-9.036 *	-10.193 *	-10.870 *	-11.436 *	-
B.M.	Output squared	13.359 *	13.444 *	14.775 *	15.454 *	16.110 *	-
B.M.	Duoyou (state owned)	-0.243	-0.262	0.001	-0.028	-	-
B.M.	Jiti (Collective)	-0.706 *	-0.748 *	-0.646 *	-0.664 *	-	-
B.M.	Lianying (Public/Private coop)	-0.158	-0.160	-0.105	-0.177	-	-
B.M.	Gufenzhi (Listed on stock exchange	-0.616 *	-0.642 *	-0.447 *	-0.490	-	-
B.M.	Sanzi (Foreign Investor owned)	0.023	0.049	0.089	0.038	-	-
B.M.	Average wage per worker	-0.027 *	-0.028 *	-0.047 *	-	-	-
B.M.	Wagerate squared	0.001 *	0.001 *	0.001 *	-	-	-
B.M.	Age of Capital	-0.231 *	0.002	-	-	-	-
B.M.	Age of Capital Squared	0.009 *	0.004 *	-	-	-	-
B.M.	Price index for fixed capital assets	-10.747 *	-	-	-	-	-
B.M.	Deflator squared	6.092 *	-	-	-	-	-
Wood	Intercept	-3.025	-4.049 *	-3.533 *	-5.467 *	-3.802 *	-3.748 *
Wood	Chinese owned times FDI	-1.692 *	-1.702 *	-2.210 *	-3.640 *	-4.112 *	-4.156 *
Wood	Non-Chinese owned times FDI	-1.553 *	-1.593 *	-1.730 *	-0.964 *	-5.377 *	-5.552 *
Wood	Value of Output	3.202	3.262	2.567	-0.656	1.469	-
Wood	Output squared	-5.854	-6.032	-6.050	-0.420	-5.643	-
Wood	Duoyou (state owned)	0.805 *	0.762 *	1.098 *	1.899 *	-	-
Wood	Jiti (Collective)	0.155	0.119	0.361	1.059 *	-	-
Wood	Lianying (Public/Private coop)	-0.557 *	-0.573	-0.585	0.059	-	-
Wood	Gufenzhi (Listed on stock exchange	0.954 *	0.938	0.997 *	1.802 *	-	-
Wood	Sanzi (Foreign Investor owned)	0.939	0.906	0.934	1.051 *	-	-
Wood	Average wage per worker	-0.322 *	-0.321 *	-0.394 *	-	-	-
Wood	Wagerate squared	0.011 *	0.011 *	0.014 *	-	-	-
Wood	Age of Capital	0.004	0.049	-	-	-	-
Wood	Age of Capital Squared	0.001	0.000	-	-	-	-
Wood	Price index for fixed capital assets	-2.231	-	-	-	-	-
Wood	Deflator squared	1.296	-	-	-	-	-
P. Food	Intercept	-6.449 *	-8.336 *	-7.506 *	-7.698 *	-7.837 *	-7.913 *
P. Food	Chinese owned times FDI	0.122	0.111	-0.363	-0.342	-0.675 *	-0.664
P. Food	Non-Chinese owned times FDI	-0.465	-0.463	-0.264	0.123	0.397	0.283
P. Food	Value of Output	-0.017	-0.081	-1.188	-1.179	-1.259	-

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
P. Food	Output squared	0.630 *	0.651 *	0.986 *	0.990 *	1.024 *	-
P. Food	Duoyou (state owned)	-0.706 *	-0.754 *	-0.219	-0.117	-	-
P. Food	Jiti (Collective)	-1.248 *	-1.306 *	-0.979 *	-0.881 *	-	-
P. Food	Lianying (Public/Private coop)	-0.418	-0.485	-0.006	0.092	-	-
P. Food	Gufenzhi (Listed on stock exchange	-0.896 *	-0.935 *	-0.525 *	-0.432	-	-
P. Food	Sanzi (Foreign Investor owned)	-0.119	-0.107	-0.201	-0.100	-	-
P. Food	Average wage per worker	0.015	0.014	-0.024	-	-	-
P. Food	Wagerate squared	0.000	0.000	0.001 *	-	-	-
P. Food	Age of Capital	0.112 *	0.121 *	-	-	-	-
P. Food	Age of Capital Squared	0.000	0.002 *	-	-	-	-
P. Food	Price index for fixed capital assets	-5.518 *	-	-	-	-	-
P. Food	Deflator squared	3.781 *	-	-	-	-	-
T & C	Intercept	0.642	-3.741 *	-3.447 *	-3.792 *	-4.161 *	-4.579 *
T & C	Chinese owned times FDI	-0.190	-0.205	0.507	0.208	-0.552	0.009
T & C	Non-Chinese owned times FDI	-1.958 *	-1.737	-2.461 *	-2.407 *	-2.105 *	-2.298 *
T & C	Value of Output	-4.161 *	-4.222 *	-4.953 *	-5.627 *	-5.243 *	-
T & C	Output squared	3.041 *	3.073 *	3.395 *	3.715 *	3.444 *	-
T & C	Duoyou (state owned)	-0.850 *	-0.940 *	-0.240	-0.150	-	-
T & C	Jiti (Collective)	-1.140 *	-1.246 *	-0.842 *	-0.761	-	-
T & C	Siying (Private)	-1.751 *	-1.504 *	-1.544 *	-1.596 *	-	-
T & C	Lianying (Public/Private coop)	-1.313 *	-1.404 *	-0.840	-0.826	-	-
T & C	Gufenzhi (Listed on stock exchange	-1.007 *	-1.086 *	-0.719	-0.656	-	-
T & C	Sanzi (Foreign Investor owned)	-0.678	-0.777	-0.392	-0.532	-	-
T & C	HK,T,M (Hong Kong, Taiwan +)	-0.301	-0.408	0.009	-0.076	-	-
T & C	Average wage per worker	-0.048 *	-0.049 *	-0.078 *	-	-	-
T & C	Wagerate squared	0.001 *	0.001 *	0.002 *	-	-	-
T & C	Age of Capital	-0.127 *	0.072 *	-	-	-	-
T & C	Age of Capital Squared	0.006 *	0.002 *	-	-	-	-
T & C	Price index for fixed capital assets	-9.229 *	-	-	-	-	-
T & C	Deflator squared	5.280 *	-	-	-	-	-
Paper	Intercept	-3.028	-4.069 *	-3.351 *	-3.467 *	-2.660 *	-3.307 *
Paper	Chinese owned times FDI	0.015	0.062	0.241	0.297	-0.719 *	-0.824 *
Paper	Non-Chinese owned times FDI	-2.592 *	-2.720 *	-2.737 *	-1.979	0.060	-1.471
Paper	Value of Output	-14.281 *	-14.198 *	-15.013 *	-14.558 *	-14.788 *	-
Paper	Output squared	22.539 *	22.458 *	23.472 *	23.191 *	23.609 *	-
Paper	Duoyou (state owned)	0.876 *	0.874 *	0.833 *	0.824 *	-	-
Paper	Jiti (Collective)	0.466	0.451	0.255	0.241	-	-
Paper	Lianying (Public/Private coop)	0.427	0.460	0.180	0.162	-	-
Paper	Gufenzhi (Listed on stock exchange	0.610	0.608	0.451	0.417	-	-
Paper	Sanzi (Foreign Investor owned)	1.715 *	1.771 *	1.473 *	1.697 *	-	-
Paper	HK,T,M (Hong Kong, Taiwan	1.278 *	1.328 *	1.060 *	1.004 *	-	-

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
	+)						
Paper	Average wage per worker	-0.004	-0.007	-0.037	-	-	-
Paper	Wagerate squared	0.002 *	0.002 *	0.003 *	-	-	-
Paper	Age of Capital	0.050	0.040	-	-	-	-
Paper	Age of Capital Squared	0.001	0.002	-	-	-	-
Paper	Price index for fixed capital assets	-3.335	-	-	-	-	-
Paper	Deflator squared	2.431	-	-	-	-	-
M. Man	Intercept	-5.817	-1.983 *	-2.108 *	-1.910 *	-1.034 *	-2.451 *
M. Man	Chinese owned times FDI	-0.202	0.145	1.589	1.885	2.171	6.457
M. Man	Non-Chinese owned times FDI	1.141	0.682	-0.930	2.018	3.917	6.039
M. Man	Value of Output	-22.832 *	-22.584 *	-25.188 *	-24.454 *	-24.337 *	-
M. Man	Output squared	36.345 *	35.654 *	41.231 *	40.178 *	39.636 *	-
M. Man	Duoyou (state owned)	1.148 *	1.113 *	1.194 *	1.099 *	-	-
M. Man	Jiti (Collective)	0.833 *	0.819 *	0.917 *	0.795 *	-	-
M. Man	Siying (Private)	2.007 *	2.120 *	2.057 *	1.906 *	-	-
M. Man	Lianying (Public/Private coop)	0.641 *	0.647 *	0.627 *	0.597 *	-	-
M. Man	Gufenzhi (Listed on stock exchange	1.393 *	1.353 *	1.366 *	1.270 *	-	-
M. Man	Sanzi (Foreign Investor owned)	0.967	0.865	1.043 *	0.809	-	-
M. Man	HK,T,M (Hong Kong, Taiwan +)	1.453 *	1.421 *	1.670 *	1.400 *	-	-
M. Man	Average wage per worker	0.050	0.050	0.027	-	-	-
M. Man	Wagerate squared	-0.001	-0.001	0.000	-	-	-
M. Man	Age of Capital	-0.052	-0.123	-	-	-	-
M. Man	Age of Capital Squared	0.012	0.011 *	-	-	-	-
M. Man	Price index for fixed capital assets	9.888	-	-	-	-	-
M. Man	Deflator squared	-6.572	-	-	-	-	-
E & W	Intercept	5.468	-3.488 *	-3.587 *	-3.574 *	-2.692 *	-3.038 *
E & W	Chinese owned times FDI	-1.890 *	-1.679 *	-1.576 *	-1.662 *	-1.846 *	-3.984 *
E & W	Non-Chinese owned times FDI	8.534 *	9.350 *	9.330 *	9.367 *	1.534	-1.944
E & W	Value of Output	-4.663 *	-4.597 *	-4.622 *	-4.493 *	-4.508 *	-
E & W	Output squared	2.689 *	2.622 *	2.634 *	2.577 *	2.594 *	-
E & W	Duoyou (state owned)	1.052	0.963	0.891	0.896	-	-
E & W	Jiti (Collective)	0.263	0.216	0.205	0.218	-	-
E & W	Lianying (Public/Private coop)	0.713	0.641	0.589	0.611	-	-
E & W	Gufenzhi (Listed on stock exchange	0.343	0.361	0.335	0.335	-	-
E & W	Sanzi (Foreign Investor owned)	-0.697	-0.686	-0.668	-0.682	-	-
E & W	HK,T,M (Hong Kong, Taiwan +)	-0.532	-0.554	-0.553	-0.571	-	-
E & W	Average wage per worker	0.003	0.002	0.002	-	-	-
E & W	Wagerate squared	0.000	0.000	0.000	-	-	-
E & W	Age of Capital	-0.494 *	-0.047	-	-	-	-
E & W	Age of Capital Squared	0.013 *	0.003 *	-	-	-	-
E & W	Price index for fixed capital assets	-17.407 *	-	-	-	-	-

Industry	Coefficient	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
E & W	Deflator squared	9.383 *	-	-	-	-	-

*****t-statistics with absolute values greater than 1.96.

Appendix B. The tables listed below report the coefficient estimates for the variable defined as the dummy variable for Chinese owned enterprise times the industry FDI.

l <=250

Industry	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	0.806 *	0.024	0.353	0.596	0.071	1.003 *
Chem	-0.178	-0.149	0.070	0.089	-0.887	1.068
Mech	1.300	1.652	1.509	1.597	0.217	-1.058
B.M.	-4.210	-3.846	-4.100 *	-4.028 *	-4.530 *	-4.484 *
Wood	3.408	-0.850	-2.837	-3.426	-4.261	5.071
P. Food	1.738 *	1.967 *	1.690 *	2.256 *	1.178 *	0.870
T & C	0.616	0.574	0.325	-0.545	-0.532	0.343
Paper	-1.363	-1.238	-0.798	-0.802	-2.145 *	-2.376 *
M. Man	199.383	183.642	168.233	32.064	-4.744	11.254
E & W	2.926	3.767 *	3.708 *	3.555 *	3.640 *	-1.379

251-500

Industry	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	-0.148	-0.047	0.079	0.099	-0.260	0.272
Coal	-113.426	-40.813	3.082	-19.243	-9.931	14.186
Chem	0.113	0.078	0.250	0.095	0.091	0.538
Mech	1.428 *	1.459 *	1.449 *	1.608 *	1.594 *	1.560 *
B.M.	-1.086	-1.020	-0.871	-0.450	-0.674	-4.071 *
Wood	-0.621	-1.136	-0.739	-0.125	0.117	0.516 *
P. Food	-0.578 *	-0.619 *	-1.433 *	-1.449 *	-1.411 *	-0.986 *
T & C	1.074 *	0.981	1.355 *	1.003 *	1.314 *	1.993 *
Paper	-0.254	-0.248	-0.008	0.287	-0.310	-1.666 *
M. Man	-2.292	-2.486 *	-2.683 *	-1.662	-1.834	2.519
E & W	0.634	0.902	1.161	1.242	1.223	-0.924

501-1000

Industry	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	-0.570 *	-0.618 *	-0.848 *	-0.872 *	-1.199 *	-1.205 *
Coal	89.836 *	40.895	32.427	29.987	32.420	67.864 *
Chem	0.439 *	0.282	0.697 *	0.609 *	0.349	-0.096
Mech	0.965 *	0.957 *	0.853 *	0.933 *	0.970 *	0.068
B.M.	0.008	0.011	-0.208	-0.205	-0.232	-0.694 *
Wood	-1.782	-0.379	-0.358	-1.537	-1.965 *	-1.204
P. Food	0.421	0.410	0.054	0.112	-0.396	-0.202
T & C	0.333	0.372	1.038 *	0.876 *	0.249	0.733
Paper	1.056 *	1.101 *	1.104 *	1.125 *	0.531	-0.326
M. Man	-3.364	-2.874	0.357	-0.289	0.342	1.394
E & W	-0.146	0.396	0.585	0.555	0.291	-0.720

> 1000

Industry	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	-2.029 *	-2.037 *	-1.876 *	-1.841 *	-3.374 *	-4.378 *
Coal	10.545	10.682	3.950	2.325	2.546	-0.775
Chem	-2.271 *	-2.277 *	-1.816 *	-1.868 *	-2.827 *	-2.820 *
Mech	-1.131 *	-1.141 *	-1.738 *	-1.743 *	-2.205 *	-2.246 *
B.M.	-1.991 *	-1.938 *	-2.579 *	-2.505 *	-2.617 *	-2.481 *
Wood	-1.839	-1.556	-1.665	-4.831 *	-5.875 *	-5.894 *
P. Food	0.417	0.383	0.327	0.317	-0.514	-1.223 *
T & C	-1.373 *	-1.346 *	-0.745	-1.184 *	-2.627 *	-2.463 *
Paper	-1.450 *	-1.066 *	-0.357	-0.963 *	-2.008 *	-2.190 *
M. Man	7.075	6.372	18.603	15.419	14.575	3.864
E & W	-3.627 *	-3.590 *	-3.653 *	-3.619 *	-3.815 *	-4.404 *

All

Industry	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Metals	0.346	0.308	0.319	0.284	-0.533	-0.956 *
Coal	16.908	17.301	12.755	14.134	18.467	15.161
Chem	0.970 *	0.905 *	1.155 *	0.945 *	0.304	0.385
Mech	-0.031	-0.044	-0.432 *	-0.448 *	-0.635 *	-0.788 *
B.M.	-2.176 *	-2.141 *	-2.464 *	-2.428 *	-2.614 *	-2.968 *
Wood	-1.692 *	-1.702 *	-2.210 *	-3.640 *	-4.112 *	-4.156 *
P. Food	0.122	0.111	-0.363	-0.342	-0.675 *	-0.664
T & C	-0.190	-0.205	0.507	0.208	-0.552	0.009
Paper	0.015	0.062	0.241	0.297	-0.719 *	-0.824 *
M. Man	-0.202	0.145	1.589	1.885	2.171	6.457
E & W	-1.890 *	-1.679 *	-1.576 *	-1.662 *	-1.846 *	-3.984 *

Appendix C. The differences between the dummy variables for different types of organizational control. The negative numbers indicate that the sector has a higher conditional level of productivity than the state run enterprises. The * indicates that the absolute value of the t-statistic is greater than 1.96. Thus the difference between the state run enterprises and the Hong Kong and Taiwanese enterprises is negative and significant for most of the sectors except the Coal sector where there is only one such enterprise.

Table C.1 The difference in productivity for other enterprise types and the State run enterprises.

Industry	Difference with State Owned enterprise	
Metals	Gufenzhi (Listed on stock exchange)	0.141
Coal	"	#
R. Petrol	"	#
Chem	"	0.243 *
Mech	"	0.394 *
B.M.	"	0.383 *
Wood	"	0.057
P. Food	"	0.180 *
T & C	"	0.156 *
Paper	"	0.271 *
Misc. Man	"	-0.226
E & W	"	0.712 *
Metals	HK,T,M (Hong Kong, Taiwan +)	-0.194
Coal	"	#
Chem	"	-0.985 *
Mech	"	-0.273 *
B.M.	"	-0.292 *
Wood	"	1.043 *
P. Food	"	-0.575 *
T & C	"	-0.369 *
Paper	"	0.051
Misc. Man	"	-0.347
E & W	"	-0.397
Metals	Jiti (Collective)	0.858 *
Coal	"	0.446 *
R. Petrol	"	0.336 *
Chem	"	0.232 *
Mech	"	0.290 *
B.M.	"	0.468 *
Wood	"	0.727 *
P. Food	"	0.536 *
T & C	"	0.291 *
Paper	"	0.407 *
Misc. Man	"	0.310
E & W	"	0.871 *
Metals	Lianying (Public/Private coop)	0.853 *
Chem	"	-0.141
Mech	"	0.131 *
B.M.	"	-0.005
Wood	"	#
P. Food	"	-0.296
T & C	"	0.464 *
Paper	"	#
Misc. Man	"	0.466 *
E & W	"	#
Metals	Sanzi (Foreign Investor owned)	-0.725 *
Chem	"	-0.557 *
Mech	"	-0.281 *
B.M.	"	-0.357 *
Wood	"	-0.016
P. Food	"	-0.466 *
T & C	"	0.068
Paper	"	-0.469 *
Misc. Man	"	0.120
E & W	"	-0.146
Metals	Siying (Private)	#
T & C	"	#
Misc. Man	"	#

# Indicates that there were less than 5 enterprises in this group.