FEATURE ARTICLE

PRODUCTIVITY SPILLOVERS TO LOCAL MANUFACTURING FIRMS FROM FOREIGN DIRECT INVESTMENT

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EXECUTIVE SUMMARY

- This article examines if foreign participation in Singapore's manufacturing sector has led to productivity spillovers to local-owned firms. Three specific channels of productivity spillovers are considered – horizontal, backward and forward linkages.
- We find that foreign-owned firms tend to be more productive than local-owned firms in the various manufacturing clusters. We also find evidence that foreign direct investment (FDI) has led to productivity improvements in local-owned firms in clusters that have stronger vertical linkages with foreign-owned firms. This is particularly the case for local-owned firms supplying to foreign-owned firms in other clusters.
- However, the presence of foreign-owned firms has no clear productivity impact on local-owned firms in the same cluster.

BACKGROUND

Many developing countries and transition economies place attracting foreign direct investment (FDI) high on their agenda, as FDI is often seen as a means of increasing competition, obtaining technological transfers or achieving a more efficient allocation of resources in the domestic economy. Singapore is one of the pioneers in the use of this development strategy. Over the years, the multinational companies (MNCs) have brought many direct benefits to Singapore, especially in terms of (i) providing employment and higher wages for Singaporeans; and (ii) bringing in new technology and expertise to sustain Singapore's competitiveness.

Beyond such direct impact, FDI is also often seen to catalyse improvements in domestic firms' productivity through linkages between multinational and domestic firms. However, as Dani Rodrik (1999) remarked, "today's policy literature is filled with extravagant claims about positive spillovers from FDI but the evidence is sobering". Indeed, the empirical literature finds mixed support on the impact of MNCs on domestic firms' productivity.

This article examines whether foreign participation in the manufacturing sector (from FDI) has had an impact on the productivity of local-owned manufacturing firms.[1] We investigate this impact via three possible spillover channels – horizontal, backward and forward linkages.

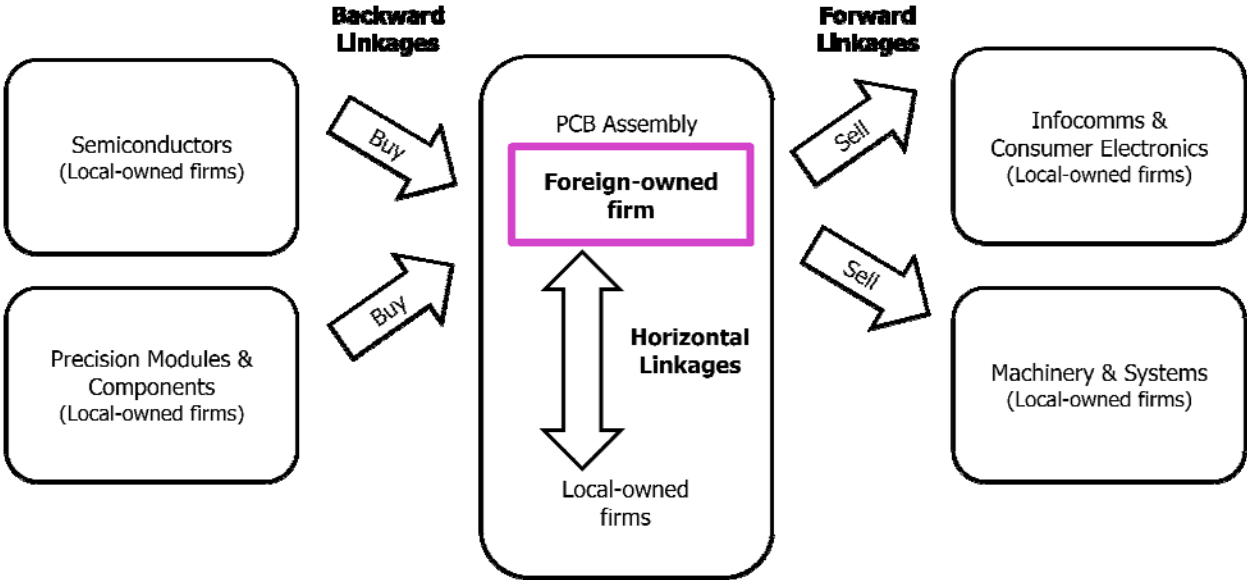
HOW PRODUCTIVITY SPILLOVERS CAN ARISE FROM FDI LINKAGES

To introduce the various forms of linkages, let us first consider a stylized electronics manufacturing value chain, with the foreign-owned firm in the printed circuit board (PCB) assembly sub-cluster as the point of reference [Exhibit 1].

[1] We measure the extent of foreign participation using the percentage of foreign shareholdings, with foreign-owned firms defined as firms with foreign shareholdings of 50 per cent or more, and local-owned firms as firms with local shareholding of more than 50 per cent.

The linkages between local-owned firms and their foreign-owned competitors in the same PCB assembly industry are known as horizontal linkages. When foreign-owned firms in the PCB assembly industry purchase inputs from local-owned firms in another industry, the linkages created are known as backward linkages.[2] Conversely, when the foreign-owned firms sell to local-owned firms in another industry, the linkages are known as forward linkages. As these backward and forward linkages refer to linkages outside the foreign-owned firms' industry, they are also commonly referred to as vertical linkages.

Exhibit 1: Horizontal, Forward and Backward Linkages – a Stylised Example



We next discuss the possible ways in which horizontal and vertical linkages may result in productivity spillovers from the foreign-owned firms to the local-owned firms.

Horizontal Linkages

To the extent that local-owned firms are able to imitate the more efficient technology, production processes and management of foreign-owned firms in their industry, their productivity may increase. This is often referred to in the literature as the 'demonstration effect'. Also, foreign-owned firms tend to provide valuable training to their employees, which results in a highly skilled and experienced labour pool that their local competitors can subsequently tap on.

However, given that foreign-owned and local-owned firms within an industry tend to be in direct competition with one another, the foreign-owned firms are likely to guard their technological and management practices closely to prevent local competitors from imitating them. This could work to restrict the extent of any positive learning spillovers on local-owned firms.

The effect of the competition posed by foreign-owned firms is also unclear. While greater competition may spur local-owned firms to use existing resources more efficiently, it may also reduce their market share, thereby reducing economies of scale. Furthermore, increased competition from the MNCs in the factor markets for labour, capital and intermediate goods may drive up wages, the borrowing costs of capital and the costs of intermediate goods, thus causing local-owned firms to switch towards the use of inferior substitutes that reduce their productivity.

[2] The backward and forward linkages are defined from the perspective of the foreign-owned firm, in line with the academic literature.

Backward Linkages

Increased local sourcing by MNCs is often highlighted as a key source of productivity gains for local-owned firms. The high technical standards set by MNCs for the intermediate inputs they use increase their incentive to improve the quality of their local suppliers through the sharing of technology and organisational processes (Javorick, 2004). However, even though the MNCs and their local suppliers tend to be in different industries, the increased competition in the factor markets for labour, capital and intermediate goods may still dampen the productivity of local suppliers, albeit to a lesser extent than if the firms were in the same industry.

Forward Linkages

The presence of MNCs may benefit local-owned firms to the extent that their supplier market becomes more competitive and the quality of their inputs improves. However, just as in the case for backward linkages, the productivity of local-owned firms may also be adversely affected because of increased competition in the factor markets. In the literature, this channel has generally been found to have an insignificant impact on local-owned firms' productivity (Smeets, 2008).

Exhibit 2 summarises the various sources of productivity spillovers that may arise from horizontal, backward and forward linkages.

Exhibit 2: Spillover channels through which local-owned firms' productivity may be affected by FDI

Horizontal Linkages	Vertical Linkages	
	Backward Linkages	Forward Linkages
Increase in foreign-owned competitors in the same industry	*Foreign-owned firms buy from local-owned firms in another industry*	*Foreign-owned firms sell to local-owned firms in another industry*
Sources of Positive Productivity Spillovers on Local-owned Firms		
• Imitation of technology and management practices • Larger experienced labour pool (with MNC experience) to hire from • Positive competition effect, as local-owned firms are spurred to use existing resources more effectively	• Increased incentive to share technological and organisational improvements with local suppliers • Increased local sourcing by foreign-owned firms may lead to greater economies of scale	• Local-owned firms benefit from a more competitive supplier market and higher quality inputs due to the entry of foreign-owned suppliers
Sources of Negative Productivity Spillovers on Local-owned Firms		
• Increased competition in factor markets (capital and intermediate goods) • Foreign-owned firms are able to pay higher wages to attract talent from local-owned firms		
• Negative competition effect, from reduced market share and economies of scale		

International Empirical Evidence

The empirical literature offers mixed evidence on the productivity spillovers from FDI to domestic firms. For horizontal linkages, Gorg and Greenaway (2004)'s review of 33 empirical studies done for a range of developing, developed and transition economies showed that most (19 out of 33) of the studies did not find a statistically significant FDI spillover impact on domestic firms' productivity, while the rest either reported a positive impact or a negative one.[3]

[3] Gorg and Greenaway (2004)'s review excludes earlier studies done using cross-sectional data. Gorg and Strobl (2001) argue that panel data analysis using firm-level data is the most appropriate estimation framework as i) it permits investigation of the development of domestic firms' productivity over a longer time period, and ii) it allows the investigation of spillovers after controlling for other factors. For example, higher productivity in the electronics sector compared to the food sector may attract MNCs into the electronics sector. In this case, cross-sectional data would show a positive and statistically significant relationship between the level of foreign investment and productivity consistent with spillovers even though the causation occurs in the reverse.

More recent literature considered the impact of vertical spillovers (from both backward and forward linkages) on domestic firms, in addition to horizontal spillovers. Javorcik (2004) found horizontal and backward spillovers to be positive and significant for Lithuania, while forward spillovers were not significant. In the case of Hungary, Bekes, Keinert and Toubal (2009) found horizontal spillovers to be positive and significant, but not for backward and forward spillovers. For the UK, Girma, Gorg and Pisu (2008) found positive backward and insignificant forward spillovers in aggregate as well as positive horizontal spillovers for exporters.

Closer to home, Blalock and Gertler (2005)'s study on Indonesia found positive and significant backward spillovers, but no horizontal spillovers. On the other hand, Blake et al (2009)'s study on China found that horizontal spillovers were generally negative for local firms but positive for large state-owned enterprises. They did not find any evidence of backward or forward spillovers.

DATA AND EMPIRICAL STRATEGY

To determine if FDI in the manufacturing sector in Singapore has led to productivity spillovers on local-owned manufacturing firms via horizontal, backward and forward linkages, we adopt the approach taken by Bekes, Kleinert and Toubal (2009).[4]

For the study, we use a panel dataset from EDB's Census of Manufacturing Activities survey covering about 2,650 to 3,400 manufacturing firms annually from 2001 to 2008.[5] We conduct a firm-level analysis of the impact of horizontal, backward and forward linkages on local-owned firms' productivity using a two-step approach.

First, we derive the total factor productivity (TFP) – which is the measure of productivity we use for this study – of each firm. This is done by estimating the production function of each of the 17 manufacturing sub-clusters (with capital being instrumented by expenditure on capital repairs), and then taking the firm-level residuals as the TFP of each firm in the sub-cluster. Second, we run a fixed-effects regression of the TFP of local-owned firms on variables that proxy the extent of their horizontal, backward and forward linkages to foreign-owned firms.[6] Our model also controls for industry concentration through the use of a Herfindahl index. The basic econometric model (Model 1) is shown below:

$$TFP_{ijt} = \alpha + \beta_1 H_{jt} + \beta_2 B_{jt} + \beta_3 F_{jt} + \gamma C_{jt} + v_i$$

For firm i, sub-cluster j and time t,
Where:

TFP_{ijt}	= Total factor productivity of local manufacturing firm
H_{jt}	= Sub-cluster's extent of horizontal linkages to foreign-owned firms
B_{jt}	= Sub-cluster's extent of backward linkages to foreign-owned firms
F_{jt}	= Sub-cluster's extent of forward linkages to foreign-owned firms
C_{jt}	= Herfindahl index of sub-cluster
v_i	= Firm fixed-effects

As it is highly possible that the productivity spillovers from FDI will vary by clusters, we also run an additional model (Model 2) where the coefficients of the various linkages are allowed to vary for five broad clusters, *viz*. electronics, chemicals, precision engineering, transport engineering and general manufacturing.[7]

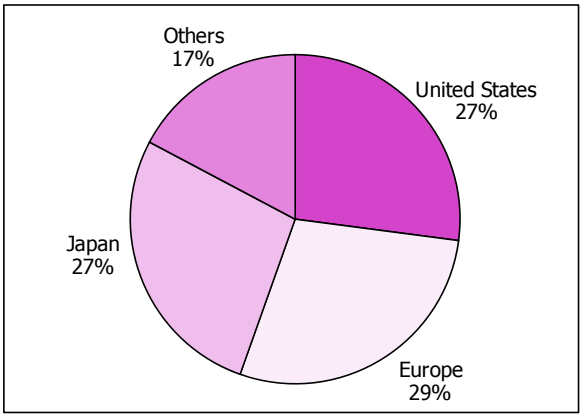
[4] Refer to Annex A for detailed methodology.
[5] Companies with less than 20 workers are randomly surveyed and appear in the dataset on a random basis.
[6] Ideally, we would like the linkages variables to be firm-varying for it to accurately represent the firm's exposure to foreign-owned firms. However, as no such data is available, we follow a commonly used method in the literature by using industry-varying linkages instead as proxies, constructed based on Javorcik (2004). Refer to Annex B for more details.
[7] Firms in the Biomedical Sciences cluster was excluded from both regression models due to the volatile and nascent nature of the cluster in the period studied.

Before discussing the results of the regressions, it is perhaps useful to first understand the characteristics of foreign-owned and local-owned firms in the various broad manufacturing clusters. These are provided in Box 1 below. In sum, we find that foreign-owned manufacturing firms across the broad clusters tend to be larger, employ more workers, and are more productive than local-owned firms. This suggests that foreign-owned firms are directly contributing to the Singapore economy in terms of providing good jobs for Singaporeans as well as enhancing the competitiveness of our manufacturing industries. It also suggests that there is scope for local-owned manufacturing firms to learn and benefit from the presence of foreign-owned firms in Singapore.

Box 1: Comparison between local-owned and foreign-owned manufacturing firms in Singapore

There has been a significant degree of foreign participation in Singapore's manufacturing sector over the past decade. The foreign-owned firms in Singapore are mostly global MNCs from G3 countries. Out of the 783 foreign-owned firms in the manufacturing sector in 2008, 83 per cent were from USA, Europe and Japan, while the remaining 17 per cent were from other countries [Exhibit 3].

Exhibit 3: Foreign-Owned* Manufacturing Firms in Singapore in 2008 by Capital Source, Per Cent of Establishments



Note: *Capital source determined using 50 per cent equity as cut off
Source: EDB Census of Manufacturing Activities

Exhibit 4 shows that foreign-owned firms were on average significantly larger than local-owned firms in terms of their value-added, labour and capital employed. Across the manufacturing clusters, foreign-owned firms were also substantially more productive than local-owned firms.

Exhibit 4: Comparison of Mean of Key Firm Characteristics by Clusters in 2008

Cluster	Ownership	TFP*	Value-added ($ Mil)	Labour (No.)	Capital ($ Mil)	No. of Estabs in 2008
General	Local	-0.018	1.0	19	0.8	3,986
	Foreign	0.208	12.2	116	12.6	110
Electronics	Local	-0.067	22.8	233	49.9	104
	Foreign	0.133	137.0	781	197.8	85
Chemicals	Local	-0.110	3.6	24	2.5	229
	Foreign	0.143	14.8	114	62.8	155
Precision Engineering	Local	-0.030	1.2	25	1.2	2,482
	Foreign	0.257	13.0	134	8.5	278
Transport Engineering	Local	-0.024	6.2	105	2.3	973
	Foreign	0.207	25.3	162	12.2	110

Note: *TFP values are centered around zero and averaged from 2001-2008. Foreign-owned firms are defined as firms with foreign shareholdings of 50 per cent or more.
Source: EDB Census of Manufacturing Activities

DISCUSSION OF RESULTS

Our findings on the impact of FDI on the productivity of local-owned manufacturing firms via the three spillover channels are shown in Exhibit 5.

Horizontal Linkages

We find that **FDI has no clear productivity impact on local-owned firms in the same sub-cluster.** While regression model (1) yields a negative and significant coefficient for horizontal linkages, regression model (2) shows that the coefficients for horizontal linkages for the various clusters are mostly insignificant with the exception of precision engineering.

Exhibit 5: Summary of Productivity Spillover Effects on Local-owned Manufacturing Firms, 2001-2008

Model	(1)	(2)				
Dependent Var	TFP	TFP				
Cluster	Overall	Gen	Elec	Chems	PE	TE
Horizontal	Negative***	Not sig.	Not sig.	Not sig.	Positive***	Not sig.
Backward	Positive***	Positive***	Positive***	Negative**	Positive***	Positive*
Forward	Not sig.	Positive***	Not sig.	Positive**	Not sig.	Positive**

*, ** and *** indicate significance at levels of 10%, 5% and 1% respectively.

Notes: The magnitude of the impact is not meaningful as the TFP measures are not comparable across clusters.
Refer to Annexes C and D for detailed results of the first step and second step respectively.
The Biomedical Sciences cluster was excluded from the regressions due to the volatile and nascent nature of the cluster in the period studied.

Our results differ from studies done in countries such as Hungary and Lithuania where horizontal spillovers were found to be positive and significant. This could be due to the fact that many of these countries are transition economies where the level of foreign participation in their economies is still low. By contrast, Singapore's policy of encouraging FDI has been in place since the 1960s. By 2001-2008, which is the sample period of the data used for our study, foreign participation in most clusters was already extensive. It is therefore likely that any productivity spillovers that could be gained by learning from foreign-owned firms would already have been reaped earlier, leaving the negative competition effect to dominate in most of the clusters during the sample period.

An exception is the precision engineering cluster, where foreign participation has led to significant positive horizontal spillovers on local-owned firms. As firms in the cluster tend to be highly specialised firms that deal in niche products, there could have been a much higher level of linkages between foreign- and local-owned firms within the cluster. For instance, precision component OEMs, which are mostly foreign firms selling specialised parts, are likely to outsource to local suppliers in the same cluster work such as electroplating and polishing. Akin to the case of backward linkages, these foreign-owned firms could have a greater incentive to share their technology or processes with their local suppliers within the cluster in order to raise the quality of their work.

Backward Linkages

In contrast to horizontal linkages, we find that **local-owned firms that supply to foreign-owned firms in another cluster are the most likely to experience productivity gains.** The coefficient for backward linkages in regression model (1) is positive and significant, suggesting that an increase in sales to foreign-owned firms in another cluster would increase the productivity of local-owned firms supplying to these firms. Such productivity gains from backward integration are not surprising, as foreign-owned firms that set up local supplier networks would be more willing to share technological and organisational improvements with their local suppliers. These local suppliers would also enjoy increased economies of scale with the entry of more foreign-owned customers.

For regression model (2), the impact of backward linkages on local-owned firms' productivity is positive and significant in all the clusters, except for chemicals. In the case of the chemicals cluster, the majority of the firms upstream are foreign-owned firms that purchase their intermediate inputs of crude oil from abroad. The extent of their backward linkages with local-owned firms thus tends to be weaker than is the case for the other clusters.

Given the potential benefits to be reaped from backward linkages, economic agencies in Singapore such as the EDB have implemented initiatives that encourage foreign-owned firms to engage in local sourcing. For instance, local precision engineering companies are listed in supplier directories that are provided to foreign companies in the machinery, aerospace, oil & gas and medical technology sectors. These directories enable the foreign-owned firms to easily identify local suppliers should they wish to source locally.

Forward Linkages

The productivity spillover impact from forward linkages is positive for most clusters, although it is insignificant at the overall level. In regression model (1), the coefficient for forward linkages is insignificant, which is similar to the findings of most other studies. However, regression model (2) suggests that local-owned firms in the general manufacturing, chemicals and transport engineering clusters may have reaped productivity gains as a result of the better-quality inputs they have been able to buy from their foreign-owned suppliers.

CONCLUSION

Our study has found evidence that FDI in Singapore's manufacturing sector has led to productivity improvements in local-owned manufacturing firms in clusters that have stronger vertical linkages with foreign-owned firms. This is particularly the case for those that have backward linkages with the foreign-owned firms. However, the presence of foreign-owned firms has no clear productivity impact on local-owned firms in the same cluster.

As backward and forward linkages appear to be the key channels through which foreign-owned firms can bring about productivity gains to local-owned firms, the government can do more to help link up local-owned firms to the MNCs as either their suppliers or customers. Such efforts will help to enhance the benefits of attracting FDI to the manufacturing sector in Singapore.

Contributed by:

Guo Jiajing
Economist
Economics Division
Ministry of Trade and Industry

Yuen Yi Leng
Senior Officer
Research and Statistics Unit
Economic Development Board

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ANNEX A: REGRESSION METHODOLOGY

We use a two-step regression procedure similar to Bekes, Kleinert and Toubal (2009).

The first step involves the estimation of a production function for each of the 17 manufacturing sub-clusters. As the capital variable is prone to measurement error, we use expenditure on capital repairs to instrument for capital.[8] All firms, regardless of whether they are local or foreign-owned, are included in the estimation for a particular sub-cluster. By running separate regressions for each sub-cluster, we allow the production technology to vary across sub-clusters. Time dummies are used to remove industry cycles specific to each sub-cluster.

The estimating equation for each EDB sub-cluster j is shown below:

$$VA_{it} = \beta_1 K_{it} + \beta_2 L_{it} + \alpha_t, \forall\ subcluster\ j \qquad (1)$$

For firm i, sub-cluster j and time t,
Where:

VA_{it}	= Natural log of real value-added, deflated by the GDP deflator
K_{it}	= Natural log of real capital, instrumented using the capital repair expenditure
L_{it}	= Natural log of total workers employed
α_t	= Time dummies

For each sub-cluster, the firm-level residuals are then used to derive the TFP – which is the indicator of productivity we use in this study – of each firm in the sub-cluster in each year.

In the second step, we analyse the impact of horizontal, backward and forward linkages with foreign-owned firms on the demeaned TFP of local-owned firms derived via equation (1). Foreign-owned firms are excluded in the second stage regressions as we are only interested in the productivity impact on local-owned firms.[9] We also exclude the top and bottom 5 percentile of the observations in terms of TFP to remove the effect of outliers.

Two models are used in the second stage regressions. Model (1) follows directly from Bekes, Kleinert and Toubal (2009). It assumes that productivity spillover effects do not vary across clusters – i.e., the impact that foreign-owned firms have on the productivity of a general manufacturing firm via each of the three spillover channels will be the same as their impact on an electronics firm. The model is shown below:

$$TFP_{ijt} = \alpha + \beta_1 H_{jt} + \beta_2 B_{jt} + \beta_3 F_{jt} + \gamma C_{jt} + v_i \qquad (2)$$

For firm i, sub-cluster j and time t,
Where:

TFP_{ijt}	= Total factor productivity of local manufacturing firm
H_{jt}	= Sub-cluster's extent of horizontal linkages to foreign-owned firms
B_{jt}	= Sub-cluster's extent of backward linkages to foreign-owned firms
F_{jt}	= Sub-cluster's extent of forward linkages to foreign-owned firms
C_{jt}	= Herfindahl index of sub-cluster
v_i	= Firm fixed-effects

Model (2) allows the productivity spillover effects to vary for each of the five broad manufacturing clusters. It entails interacting the spillover variables with cluster dummies so that we are able to obtain separate spillover effects for each cluster.

[8] The measurement error arises from the difference between the *use* of the capital by the firm in the production function (which is unobserved) and the *stock* of capital in the firm (which we observe, but does not vary in the short run with output). By instrumenting capital stock with the expenditure on capital repair, we obtain coefficients on capital that are more reasonable in general compared to those obtained using simple OLS. In the literature, other methods like the Olley-Pakes (OP) and Levinsohn-Petrin (2003) (Lev-Pet) methods are often used to obtain TFP – they are alternative versions of IV to account for similar endogeneity issues. We performed an alternative first-step regression using Lev-Pet, but elected to use our IV using capital repair as the instrument as the K and L coefficients were better behaved. We were unable to use the OP method due to the lack of the exit variable as well as data on capital investments.

[9] The two-step approach allows us to determine local-owned firms' productivity separately from foreign-owned firms', and enables us to subsequently exclude foreign-owned firms from the second stage regression. Although it is possible to do the same in a single step regression, the specification would be much more cumbersome.

ANNEX B: CONSTRUCTION OF LINKAGES VARIABLES AND TREATMENT OF DATA

We use 2001-2008 data from EDB's Census of Manufacturing Activity (CMA) survey with coverage of about 2,650 to 3,400 manufacturing firms annually. Based on the CMA sampling methodology, companies with less than 20 employees are surveyed on a random basis.

The various economic variables are deflated using price indices into real (or constant price) terms. Value-added (VA) is deflated using the GDP deflator for each manufacturing cluster (e.g., electronics, transport engineering). Capital stock is deflated using either the relevant sub-categories of the Wholesale Price Index or the Tender Price Index (for land buildings and structure). The firm's total real capital stock is obtained by summing up the various sub-categories of capital.

To derive the extent of backward and forward linkages among the manufacturing sub-clusters, an adapted version (mapped to EDB sub-clusters) of table 4 of the 2005 input/output tables is used. Linkages from the 2000 input/output tables are also compiled and found to be largely similar to the 2005 tables.

Observations which have negative VA or missing/zero values for key firm characteristics such as capital or total workers are dropped from the sample.

Construction of Linkages Variables

To obtain a measure of the extent of exposure that firms in an industry have to FDI within their own industry, and also in terms of backward and forward linkages with other industries[10], we follow the methodology in Javorcik (2004).

Horizontal linkages with foreign-owned firms are defined as:

$$H_{jt} = [\sum_{i \in j} share_{it} * Y_{it}] / \sum_{i \in j} Y_{it}$$

where $share_{it}$ is the share of the firm's total equity that is foreign-owned, and Y_{it} is the output of the firm i at time t.

Backward linkages with foreign-owned firms (local-owned firms supply to foreign-owned firms) are defined as:

$$B_{jt} = \sum_{k \neq j} \theta_{jk} H_{kt}$$

where θ_{jk} is the fraction of industry j's *output* shipped to sector k, constructed from the 2005 input-output tables from DOS.

As in Javorcik (2004), the output shipped within the sector is excluded in the computation due to its inclusion in the horizontal spillovers variable.

Forward linkages with foreign-owned firms are defined as:

$$F_{jt} = \sum_{m \neq j} \theta_{jm} H_{mt}$$

where θ_{jm} is the share of *inputs* purchased by industry j from industry m in total inputs purchased by industry j computed using input-output tables.

[10] Ideally, we would like the linkages variables to be firm-varying for it to accurately represent the firm's exposure to foreign-owned firms. However, as no such data is available, we follow a commonly used method in the literature by using industry-varying linkages instead as proxies.

As data on the foreign share of the output of services sectors are not available, the backward and forward linkages with services sectors are not captured in the linkages variables.

Herfindahl Index. To proxy for the level of competition in each sub-cluster, we calculate the normalised Herfindahl index for each sub-cluster j for each year t. The index ranges from 0 to 1, with 0 being highly competitive and 1 for a monopoly. To be more precise, the index is defined as:

$$C_{jt} = \frac{sum\ of\ squares\ of\ market\ share\ of\ top\ 50\ firms - \frac{1}{N}}{1 - 1/N}$$

where market share is proxied using total sales, while N is the number of firms in sub-cluster j at time t.

ANNEX C: RESULTS OF FIRST-STEP TFP REGRESSIONS

Dep. Var	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)
Cluster	Gen	Gen	Gen	Elec	Elec	Elec	Elec	Elec	Chems	Chems
Sub-cluster	Gen Misc	FBT	Printing	Semicon	Periphe-rals	Data Storage	Info-comms	Other Mods. & Comp.	Petrol-eum	Petro-chem
Ln(L)	0.719***	0.445***	0.451***	1.153***	0.378*	0.878***	0.621***	0.442	-0.0216	-0.206
	(43.77)	(7.78)	(7.32)	(4.66)	(2.12)	(5.69)	(5.32)	(1.66)	(-0.06)	(-1.15)
Ln(K)	0.308***	0.524***	0.509***	-0.0135	0.562***	0.381***	0.393***	0.477*	0.869**	0.784***
	(26.77)	(12.51)	(10.92)	(-0.08)	(4.22)	(2.37)	(4.77)	(2.52)	(3.28)	(7.60)
Constant	7.210***	4.926***	5.595***	10.65***	5.514***	6.554***	7.178***	6.192***	2.019***	3.345**
	(67.55)	(12.46)	(12.85)	(5.96)	(4.82)	(4.10)	(9.69)	(3.78)	(0.67)	(2.73)
Fixed Effects	Time	Time	Time	Time	Time	Time	Time	Time	Time	Time
R-Squared	0.804	0.7384	0.816	0.707	0.862	0.839	0.803	0.878	0.773	0.670
No. of obs	5,464	2,256	1,823	268	295	59	311	249	124	335

Dep. Var	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)	Ln(VA)
Cluster	Chems	Chems	PE	PE	TE	TE	TE
Sub-cluster	Specialty	Other Chems	Mach & Sys	Prec Mod Comp	Marine & Offshore	Aero-space	Land
Ln(L)	0.464***	0.643***	0.661***	0.483***	0.445***	0.660***	-0.292
	(5.45)	(7.96)	(11.66)	(14.31)	(18.46)	(3.39)	(-0.64)
Ln(K)	0.575***	0.400***	0.342***	0.494***	0.434***	0.348*	1.027**
	(9.74)	(8.14)	(7.27)	(18.17)	(17.47)	(2.21)	(3.23)
Constant	4.476***	6.186***	7.027***	5.406***	6.900***	7.740***	0.857
	(7.12)	(13.81)	(15.97)	(20.36)	(27.28)	(4.88)	(0.32)
Fixed Effects	Time	Time	Time	Time	Time	Time	Time
R-Squared	0.754	0.792	0.796	0.759	0.744	0.826	0.609
No. of obs	1,017	596	3,002	6,074	2,449	404	275

Note: t-statistics in parentheses, *, ** and *** indicate significance at levels of 5%, 1% and 0.1% respectively.
Capital was instrumented using capital repair in the first stage of the IV regression.
Each column estimates a production function for each of the 17 manufacturing sub-clusters.
All firms (local and foreign owned) included in the sample.
Firms with negative VA were excluded.
VA and K are in real terms.

ANNEX D: RESULTS OF SECOND-STEP REGRESSIONS, 2001-2008

Specification	(1)	(2)				
Dependent Var	TFP	TFP				
Cluster	Overall	Gen	Elec	Chems	PE	TE
Horizontal	-0.246***	-0.175	-0.183	-0.671	0.859***	-0.030
	(-2.85)	(-1.12)	(-0.47)	(-1.07)	(2.66)	(-0.11)
Backward	3.816***	7.107***	11.39***	-42.67**	4.604**	19.81*
	(5.48)	(3.11)	(2.92)	(-2.24)	(2.51)	(1.89)
Forward	-1.07	8.943***	5.124	82.70**	-3.197	8.187**
	(-0.06)	(2.69)	(0.65)	(2.39)	(-0.52)	(2.38)
Herfindahl	-0.203	-2.261***	0.732	-0.321	-11.88**	-0.590
	(-0.66)	(-3.40)	(1.26)	(-0.25)	(-2.33)	(-0.85)
Constant	-0.127	-0.596***				
	(-1.58)	(-3.60)				
Fixed Effects	Firm	Firm				
R-squared	0.749	0.750				
Observations	17,597	17,597				
No. of Firms	6,166	6,166				

Note: t-statistics in parentheses, *, ** and *** indicate significance at levels of 10%, 5% and 1% respectively.
Only local-owned manufacturing firms (>50% local shareholdings) were used in the second-stage sample.
Observations in the top and bottom 5 percentiles of local-owned firms in TFP in each cluster were dropped.