Catching-up Process of Taiwan's Electronic Components Industry: A Frontier Analysis

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Abstract

Due to ownership advantages, the performance of foreign firms is generally better than local firms in the host market. However, this study empirically found that foreign firms in Taiwan's electronic components industry achieved relatively lower productivity efficiency during 1986-1996, when Taiwan's economy was liberalized. Putting extra efforts into improving technical efficiency, local firms gained higher technical efficiency and TFP growth, and this led to the conclusion that there was a trend towards a narrowing of the productivity gap between local firms and foreign firms.

INTRODUCTION

The theory of foreign direct investment (FDI) recognizes that as a disseminator of information and technology, as a supplier of new or better quality products and as a stimulator of competition and entrepreneurship, FDI plays a major role in improving the economic performance and competitiveness of local firms in the host country, as foreign subsidiaries generally possess property rights to technology and knowledge. Through the realization of externalities or spillovers, as Caves (1974) suggested, come mainly from the foreign subsidiaries' inability to capture all of the rents from their production activities.

The FDI spillover effects on the production efficiency of local firms in Australia were covered by Caves (1974); Globerman (1979) dealt with Canada; the effects on Mexico were reported by Blomstrom (1989); and Haddad and Harrison (1993) covered

Morocco. Each of these hypothesized that spillovers should stimulate the productivity of local firms by increasing competition, enhancing human capital formation and speeding up technology transfer. More specifically, they postulated that the inflow of FDI is a productivity-raising force. It is further suggested that if local firms were to put extra effort into capturing spillovers with market liberalization, there would be the potential for the local firms to catch up.

Many studies have proved that FDI had a positive effect on the development of Taiwan's electronic industryt, but the question remains as to whether foreign firms have actually achieved better performance when Taiwan's economy was liberalized. The object of this paper is to measure TFP growth in Taiwan's electronic components industry, in order to find evidence of shrinking productivity efficiency between foreign firms and local firms during the period 1986-1996. The stochastic frontier production function approach is used to separate out the two components of TFP growth.

The paper is organized as follows. The methodology and data used in this paper is presented in the next section, followed in the penultimate section by a description of the empirical results. The final section provides the conclusions to this study.

BACKGROUND

One of the major hypotheses supporting the existence of spillovers is the fact that foreign firms tend to pay higher wages, both to attract better quality workers and to reduce the disadvantages that foreign production might meet in the host country, such as difficulties in screening due to communication problems. Some empirical studies have provided evidence of this. For instance, Lim (1977) found that foreign subsidiaries in Malaysia paid higher wages than local firms. Kumar (1989) also found

that the proportion of high-income employees in India was significantly larger in foreign firms than in local firms.

Moreover, in order to ensure that operations move along smoothly, intensive training programs are provided by foreign firms. The accumulation of human capital and productivity growth are generally quicker for workers in foreign firms, as is the growth in wage rates. The mobility of these trained workers disseminates knowledge, skills and information to the host market, thereby accelerating the productiviy growth of local firms.

Many studies have proved that Taiwan's economy gained spillovers from FDI, but none attempt to examine whether foreign firms have actually achieved better performance since 1985, when Taiwan's economy was liberalized. This was clearly a period of dramatic change in Taiwan's economic environment, with the opening up of domestic commodity and financial markets, the relaxation of restrictions on holding and remitting foreign exchanges, and the reform of the labor market by the enforcement of the Labor Standards Law all helping to establish a more liberalized market in Taiwan. There was also rapid currency appreciation as well as a severe shortage of labor and industrial land. The harsh economic climate led many local firms to pursue overseas investment, in particular, relocating their labor- intensive production processes. At the same time, FDI faced restructuring challenges, especially where investments had focused on the utilization of cheap labor. Both foreign and local firms were forced to make adjustments, which leads us to the question of their comparative performance since that time.

Furthermore, A survey carried out by Lee (1991) to evaluate the impact of the Labor Standards Law on industrial development and on firms' recruitment strategies, found that there was only a minor impact on foreign firms because they were already

providing a high level of fringe benefits that were, in general, equivalent to their parent firms. However, when wage rates were compared, foreign firms seemed to be paying the 'going (local) rate' for unskilled and skilled workers, but a higher rate for managers, as Table 1 shows. The results demonstrated that foreign subsidiaries in Taiwan behaved, by and large, in very similar fashion to local firms, with the productivity growth of foreign firms being potentially equivalent to local firms. This implies that with the liberalization of the market, foreign firms would not perform better than their counterparts.

Table 1   Wage difference across occupation and gender

(unit:NT$000)

Gender	Occupation	Local firms		Foreign direct investment			
				US		Japanese	
		obs.	wage	obs.	wage	obs.	Wage
Male	Managers	4452	33.63	263	36.91	197	38.23
	Skilled	4921	25.72	283	24.64	186	24.77
	Semi-skilled	3716	19.71	219	20.23	133	19.63
	Unskilled	3582	16.21	220	19.48	153	16.66
Female	Managers	2872	23.42	181	27.63	131	26.86
	Skilled	2843	19.03	167	18.79	135	19.54
	Semi-skilled	2615	15.80	166	15.54	117	15.65
	Unskilled	3299	13.70	201	13.22	155	13.85

Notes: obs=observations
Source: Collected for this study.

Many studies have employed labor productivity as an indicator of productivity growth; however, use of labor productivity as a measure of a firm's productivity has its limitations. As Globerman (1979) suggested, an ideal indicator would be one that constructs the ratio of net output to an index of total factor inputs as a productivity measure, such as total factor productivity (TFP). Moreover, the impact of FDI is generally embodied in changes in input quality, management skills and know-how, as well as scale economies, which are the source of TFP growth rather than labor productivity growth. A change in TFP is approximately equal to that part of the change in outputs that is unexplained by changes in the inputs, thus TFP growth may provide a more appropriate method of evaluating FDI productivity and spillovers.

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This paper uses the TFP growth measure, decomposing it further into technical progress and technical efficiency.[1] Technical progress comes from innovation and the diffusion of new technology; therefore, the extent of technical progress is measured by the extent to which a firm's potential frontier shifts from one period to another. A change in technical efficiency, on the other hand, indicates the movement of the firm's actual output to its maximum possible output (frontier output), given the technology. Conventional growth accounting procedures for estimating TFP growth assume that all firms operate at full technical efficiency, thus TFP growth is often used synonymously with technological progress. However, high rates of technological progress can coexist with deteriorating technical efficiency, in the same way that improving technical efficiency can be achieved with low levels of technological progress. Different policy implications result from different sources of TFP variations.

METHODOLOGICAL FRAMEWORK

The hypothesis of this study assumes that a liberalized market encourages local firms to catch up with foreign firms in terms of their productivity levels. A TFP growth measurement is employed to represent the improvement in productivity efficiency. TFP growth is then examined for convergence of productivity between foreign firms and local firms.

In accordance with such definition, a change in TFP is then approximately equal to that part of the change in output that is not explained by changes in the inputs, TFP growth is then calculated as:

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[1] The decomposition was first introduced by Nishimizu and Page, (1982).

$$\text{TFP growth} = \text{Output growth} - \text{Input growth}$$

$$= (y_2 - y_1) - (y_2^* - y_1^{**})$$

$$= \left[(y_1^* - y_1) + (y_1^{**} - y_1^*) + (y_2 - y_1^{**})\right] - (y_2^* - y_1^{**})$$

$$= \left[(y_1^* - y_1) + (y_1^{**} - y_1^*) + (y_2^* - y_1^{**}) - (y_2^* - y_2)\right] - (y_2^* - y_1^{**})$$

$$= \left[(y_2 - y_2^*) - (y_1 - y_1^*)\right] + (y_1^{**} - y_1^*)$$

$$= \text{Change in TE} + \text{TP}$$

where y_1 and y_2 are logarithms of output in period 1 and period 2, respectively, y_1^* and y_2^* are the logarithms of the maximum possible frontier output in period 1 and period 2, respectively, and y_1^{**} is the logarithm of the maximum possible frontier output obtained by using the input levels of period 1 but the technology of period 2 that show the influence of inputs on output growth.

TFP growth is no longer calculated as a residual, as in the conventional growth accounting method, such as Gollop and Jorgenson (1980), but is given by the sum of changes in technical efficiency and technological progress.

The stochastic frontier analysis, which is adopted in this paper, allows us to separate out the two components of TFP. This approach to estimating frontiers, developed by Aigner, Lovell and Schmidt (1977) and Meeusen and van den Broeck (1977), uses a parametric representation of technology along with a two-part composed error term. One part of the composed error term represents statistical noise and is generally assumed to follow a normal distribution. The other part represents inefficiency and is assumed to follow a particular one-sided distribution, commonly assumed to be half-normal.[2] The frontier production function can be expressed mathematically as:

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[2] The one-sided disturbance term had been assumed differently in the literature, including half-normal and exponential distribution (Aigner, Lovell, and Schmidt 1977), a truncated normal distribution (Stevenson 1980), or a Gamma distribution (Richmond 1974; Greene 1990).

$$\ln Y_{it} = \ln F(x_{it}, t) + \varepsilon_{it} \ ,$$

and

$$\varepsilon_{it} = u_{it} + v_{it}$$

where i indexes firms, t indicates time, Y_{it} denotes output, and x_{it} denotes a vector of inputs. In terms of errors, u_{it} is a one-sided disturbance (negative for production frontier) capturing the effects of inefficiency,[3] which reflects the fact that each firm's output must lie on or below its potential output ($F(x_{it}, t) + v_{it}$); and v_{it} is distributed as $N(0, \sigma_v^2)$ capturing random output variation due to factors outside the control of the firm.

The density function of ε_{it} is given by:

$$f(\varepsilon_{it}) = \frac{1}{(2\pi\sigma)^{1/2}} \left[1 - F(\frac{\varepsilon_{it}}{\sigma_v^2}) \right] \exp(-\frac{1}{2}[(\frac{\varepsilon_{it}}{\sigma_u})^2 - (\frac{\varepsilon_{it}}{\sigma_v^2})^2])$$

where $\sigma^2 = \sigma_u^2 + \sigma_v^2$ and $F(\cdot)$ is the cumulative distribution function of the standard normal random variable. The likelihood function to be estimated can then be written as:

$$L(\theta; Y_{it}) = \frac{1}{2}(N_t T_i \ln\sigma^2 + \ln 2\pi - \frac{\varepsilon_{it}^2}{2(1-\gamma)\sigma^2} + \sum_i^N \sum_t^T \ln[1 - F(-z_{it})] + \frac{1}{2}\sum_i^N \sum_i^T (z_{it}^2)$$

where

$$\theta = (\beta, \sigma^2, \gamma)$$
$$\gamma = \sigma_u^2 / \sigma$$
$$z_{it} = -\gamma\varepsilon_{it} / [\gamma(1-\gamma)\sigma^2]^{1/2}$$

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[3] Owing to incomplete knowledge of the best technical practices or to other exogenous factors, favorable or unfavorable external events such as luck, topography and machine performance, that are beyond the control of the firm.

Derivation of the likelihood function allows the model to be estimated by maximum likelihood techniques in which the estimators are asymptotically efficient.[4] Meanwhile, this paper adopts the panel-data model with a translog specification of production function. The model can be expressed as:

$$
\begin{aligned}
\ln Y_{it} &= \ln F(x_{it}, t) + \mu_{it} + v_{it} \\
&= \beta_0 + \sum_{j}^{m} \beta_j \ln x_{hit} + \beta_T t + \beta_{TT} t^2 + \\
&\quad \sum_{j}^{m} \sum_{k \geq j}^{m} \beta_{jk} \ln x_{jit} \ln x_{kit} + \sum_{j} \beta_{Tj} t \ln x_{jit} + (v_{it} - u_{it})
\end{aligned}
\tag{1}
$$

where t denotes time trend; x denotes inputs; and v_{it} are random variables assumed to be $iid \sim N(0, \sigma_v^2)$. The technical inefficiency errors u_{it} are assumed to be distributed independently of v_{it} and non-negative truncation of the normal distribution. A half-normal distribution is assumed here. Given distributional assumptions for the two disturbance terms,[5] the model can then be estimated by the maximum-likelihood method.

The technical efficiency of production for the i-th firm at the t-th period, TE_{it}, is defined as the ratio of the actual output of firm I, Y_{it}, to its potential output, Y_{it}^*.

$$
TE_{it} = \frac{Y_{it}}{Y_{it}^*} = \exp(-u_{it})
\tag{2}
$$

and the rate of the technological progress, TP_{it}, is:

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[4] This model can also be estimated by corrected ordinary least squares (COLS), as in the estimation of Richmond (1974) and Bagi and Huang (1983), which uses the moments of residual term in OLS estimation to derive the expected value of the residual and then adjusts the intercept term. This estimation is easier than MLE, but many obtain inconsistent estimates.

[5] There are other assumptions for estimating the frontier production function (1):

$$
\begin{array}{ll}
E(u_{it} u_{i't'}) = 0 & \text{for all } i \neq i' \text{ and } t \neq t' \\
E(u_{it} u_{i't'}) = \sigma_u^2 & \text{for all } i = i' \text{ and } t = t' \\
E(v_{it} v_{i't'}) = 0 & \text{for all } i \neq i' \text{ and } t \neq t' \\
E(v_{it} v_{i't'}) = \sigma_v^2 & \text{for all } i = i' \text{ and } t = t' \\
E(u_{it} v_{i't'}) = 0 & \text{for all } i \text{ and } t
\end{array}
$$

$$TP_{it} = \partial \ln(Y_{it}) / \partial t = \beta_T + 2\beta_{TT}t + \sum_j \beta_{Tj} \ln x_j \qquad (3)$$

Once the *TE* and *TP* are estimated, TFP growth is obtained by the summation of the rate of technical efficiency change and the rate of technological progress. The rate of technical efficiency change is calculated as the deviation between two periods; i.e. $\dot{TE}_{it-1,t} = (TE_{it}/TE_{it-1}) - 1$, whilst the calculation of the rate of technological change needs to take the simple average between two periods to obtain the matching rate; i.e. $\dot{TP}_{it-1,t} = (TP_{it-1} + TP_{it})/2$. TFP growth is then calculated as

$$\dot{TFP}_{it-1,t} = \dot{TP}_{it-1,t} + \dot{TE}_{it-1,t} \qquad (4)$$

EMPIRICAL RESULTS

The frontier production is the maximum output of a group of economic decision-making units utilizing the best practice techniques at a given level of technology. Therefore, the empirical study focuses on Taiwan's electronic components industry, as opposed to the electronics industry, as discussed above. During their decision-making process, as firms in the electronic components industry face the same market environment, involving both factor and product markets, the practice techniques they choose may be similar.

The panel data adopted in this study, on the establishment of firms in Taiwn's electronic components industry, are from the manufacturing census conducted by the Directorate-General of Budget, Accounting and Statisitcs of the ROC for the years 1986, 1991 and 1996. The sample size totals 428 observations, with 401 local firms and 27 foreign firms.[6] A simple comparison of the performance between foreign

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[6] Firms with less than ten workers were omitted, since these firms generally provided incomplete or

subsidiaries and local firms are presented in Table 2. It shows that, on average, foreign firms had a larger scale of production and use more capital-intensive technology, either measured by net usage of asset value (capital) or by number of employee (labor) than their local counterparts.

Table 2 The performance of foreign firms and local firms

	1986		1991		1996	
	Local firms	Foreign firms	Local firms	Foreign firms	Local firms	Foreign firms
output	122077	520309	248818	806276	583284	1688026
capital inputs	17475	74199	85037	153135	323671	368834
labor inputs	145	523	166	489	184	463
material inputs	66757	282518	129800	466886	292316	1110580

Source：calculated

The model contains five variables: output, time, material, labor (numbers of full-time employees) and capital (net value of operating capital) inputs.[7] A Fortran program, FRONTIER 4.1, developed by Battese and Coelli (1996), was used to obtain the estimates of the frontier coefficients and firm-specific technical efficiencies.

Some of the tests are designed to select first of all, the form of production function and the type of technolgical change for the data, because the stochastic frontier model, Eq.(1), allows for testing of the specifications of production function and the type of technical changes by employing the likelihood ratio test. The functional form between the translog and the Cobb-Douglas ($\beta_{TT} = \beta_{Tj} = \beta_{jk} = 0$), the translog with neutral technical change($\beta_{Tj} = 0$ ($j = k, l, m$)) and the translog with no technical changes ($\beta_T = \beta_{TT} = \beta_{Tj} = 0$) are each tested. By so doing, the most suitable

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misleading reports.
[7] Calculation of TFP growth entails the deflation of the nominal values of materials, output and capital, to obtain real values, using deflators calculated from the real values for the series of output, capital stock and intermediate consumption within the electronics industry, at 1996 prices.

funcional form and type of technical changes are selected in order to improve accuracy in the estimation of technical inefficiency.

Note that FDI spillovers assume that foreign firms own a comparative advantage in technology, know-how and management skills, whilst the technology they employ may differ from local firms. Whether or not the two groups of firms apply the same technology in Taiwan's market is tested by including dummy variables in each input, that is, a translog production function defined as:

$$
\begin{aligned}
\ln Y_{it} &= \ln F(x_{it}, t) + \mu_{it} + v_{it} \\
&= \beta_0 + \sum_{j}^{m} (\beta_j + D) \ln x_{hit} + (\beta_T + D)t + (\beta_{TT} + D)t^2 + \\
&\quad \sum_{j}^{m} \sum_{k \geq j}^{m} (\beta_{jk} + D) \ln x_{jit} \ln x_{kit} + \sum_{j} (\beta_{Tj} + D)t \ln x_{jit} + (v_{it} - u_{it})
\end{aligned}
\tag{5}
$$

where D represents 0 for local firms and 1 for foreign firms. The maximum likelihood estimates of all dummies defined in Eq.(5) are insignificant and the likelihood ratio test applied also accepts that there is no significant difference between the technology of foreign firms and local firms in Taiwan's electronic components market.[8] It is appropriate to assume that the two groups are using the same technology; however, a dummy variable (1 for foreign firms and 0 for local firms) is included to represent the different economic environments faced by each firm. For instance, foreign firms may find it easier to obtain running capital or to recruit workers (due to the fringe benefits offered).

In addition to this model selection, other tests on model selection are undertaken, as shown in Table 3. The results of the tests led to the rejection of functional forms of

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[8] Respective log-likelihood values for Eq.(5) and Eq.(1) are 99.32 and 95.47. The likelihood ratio test statistic $-2 \log_e \lambda = 7.7$ accepts the null hypothesis of all dummies being equal to zero.

the Cobb-Douglas production function, as well as neutral and no technical change, concluding that the translog production function with non-neutral technical change was the best fit for the data.

Table 3   Results of the model selection and the type of technical change

Log-likelihood value under H_0	Test statistic χ^2	Selection
Translog production function excluding dummy variable		
95.47		
Cobb-Douglas production function with neutral technical change, $H_0 : \beta_{jk} = \beta_{TT} = \beta_{Tj} = 0$		
-186.81	564.56**	Rejected
Translog with neutral technical change, $H_0 : \beta_{Tj} = 0$		
66.42	58.10**	Rejected
Translog with no technical change, $H_0 : \beta_T = \beta_{TT} = \beta_{Tj} = 0$		
49.90	91.14**	Rejected

Note: ** indicates the null hypothesis is rejected at 5% significant level.
Source : calculated

The maximum likelihood estimates of the parameters for the selected frontier production function are summarised in Table 4.

Table 4   Maximum likelihood estimation parameter estimates

Parameters	Estimates	T-Ratio
Constant	3.1408	0.5499**
β_K	0.2387	0.1259**
β_L	0.7267	0.1330**
β_M	0.0824	0.0640*
β_T	0.2288	0.1425*
β_{KK}	0.0043	0.0060
β_{LL}	0.0421	0.0133**
β_{MM}	0.0949	0.0041**
β_{TT}	0.0316	0.0182**
β_{KL}	0.0837	0.0168**
β_{Km}	-0.0580	0.0107**
β_{Tk}	0.0253	0.0120**
β_{LM}	-0.1665	0.0109**
β_{TL}	0.0387	0.0179**
β_{TM}	-0.0678	0.0108**
σ^2	0.0492	0.0033**
γ	0.0512	0.0247**

Note: * indicates the test statistic at 10% level of significance
         ** indicates the test statistic at 5% level of significance
Source : calculated

The estimate of γ, which is the ratio of individual firm-specific variation to total variation, is significant at the 5% level, meaning that the inclusion of technical inefficiency related variable u_{it} in Eq.(1) is necessary in order to explain the variation in Taiwan's electronic components industry. The frontier production function is more suitable for analysis than a traditional production function which does not involve firm-specific effects.

All estimated coefficients are statistically significant. The significance of the time trend and time-related coefficients show that technological change does occur during the sampling periods and that it is appropriate to include these variables in the modeling in order to obtain accurate estimates.

The TFP growth calculations are summarized in Table 5, with the results showing that Taiwan's electronic components industry experienced a decline in technical efficiency over the periods 1986-1991 and 1991-1996, but an improvement in technological progress. As a result, there was only a minor change in TFP growth. Furthermore, changes in technical efficiency contributed more to TFP growth during the period 1986-1991, whilst technological progress improved significantly during the 1991-1996 period.

In a comparison of the performance of local and foreign firms, it was found that, on average, local firms enjoyed higher TFP growth than foreign firms in both of the two sampling periods. This suggests that within the more liberalized domestic market existinbg since 1985, there has been a 'catch-up' process taking place between local and foreign firms. This stems from the greater effort placed into the improvement of both technical efficiency and technological progress by local firms.

Similarly, changes in technical efficiency in the early period contributed more to TFP growth, with technological progress playing a relatively more significant role for

both local and foreign groups in the later period.

The downward trend in changes in technical efficiency suggests that, on average, firms exhibited lower technical efficiency improvement in 1991-1996 as compared to the 1986-1991 period. It seems that in Taiwan, the more liberalized economic environment in the latter half of the 1980s created a better functioning market for all firms, increasing market competitiveness and forcing firms to put greater effort into their utilization of input factors, particularly in terms of improving managerial techniques and the more efficient allocation of resources. The environmental changes placed greater pressure on local firms which are generally assumed to obtain market information imperfectly, as compared to foreign subsidiaries. This explains the greater improvement in technical efficiency amongst local firms.

Table 5   Decomposition of TFP growth

	TFP growth	Change in TE	TP
Total firms			
1986-1991	0.0736	0.0890	-0.0153
1991-1996	0.0701	0.0314	0.0387
Local firms			
1986-1991	0.769	0.0896	-0.0126
1991-1996	0.739	0.0316	0.0423
Foreign firms			
1986-1991	0.0229	0.0791	-0.0562
1991-1996	0.0134	0.0282	-0.0148

Source：calculated

Technological progress, on the other hand, showed an upward trend indicating a general improvement during both periods. The global electronics industry went through a period of revolutionary progress during the 1990s with for example, the introduction of PCs, mobile phones and other IT products. As new products and production processes continued to come on to the market, this substantially shortened the life-cycle of electronics products. Firms were forced to engage in ongoing product and process innovation and development in an effort to keep abreast of the rapid changes in demand. By so doing, firms made in-house technological advancements

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which led to considerable improvements in the technological progress of Taiwan's overall electronic components industry during the 1990s.

Although the adoption by local firms of rapid and flexible production systems, came in response to the competitive pressures of the world market, the results enhanced their ability to adjust to the environmental changes and hence, led to them gaining higher TFP growth. The higher TFP growth of local firms during both the 1980s and the 1990s leads us to the conclusion that there was a trend towards a narrowing of the productivity gap between local and foreign firms during that time.

CONCLUSIONS

This study of Taiwan's electronic components industry finds that foreign firms did not perform any better than local firms in either productivity or technical efficiency during the 1980s and 1990s. Since only TFP growth, and not absolute productivity levels, are estimated in this study, the results do not provide any confirmation that the productivity level of local firms is higher; however, it is possible to conclude that there is a narrowing of productivity between the two groups, since the literature suggests that foreign firms have, in general, a distinct comparative advantage over local firms in overcoming their 'foreignness' and benefiting the host economy through spillovers.

A worthwhile extension of this study would involve an empirical examination to determine whether the presence of FDI encourages higher productivity growth in the host market thorugh a cross-industry analysis, in order to provide important policy implications for reference by developing countries.

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