Productivity Growth and Technology Diffusion in the Indian Manufacturing Industries: An Empirical Investigation into the Spillovers from Foreign Direct Investment

Azusa Fujimori, Takahiro Sato

1. Introduction

There are several discussions on how foreign direct investment (FDI) affects economic growth in developing countries. A large number of studies have examined the impact that FDI has on economic growth and in most cases, a positive relationship between the amount of FDI and economic growth has been identified. Here, we explain the concept of spillover from FDI. There are two FDI spillover channels. First, the technology of FDI source country spreads within the industry in the FDI host country, that is, a horizontal effect. According to Saggi (2002), manufacturers in the FDI host country will learn the advanced technology of FDI source countries through imitation, and this is called reverse engineering. Keller (2010) also explains the channel of spillover thorough the liquidity of the labour market. In other words, it should be possible to transfer engineers from a foreign affiliated company to a local company with the skills of the FDI source country.

The second channel of spillover is trans-industry spillover, which is called the vertical effect. The vertical effect can be explained by input-output relations. Keller (2010) believes that a the foreign affiliate company supplies intermediate goods from local companies, the foreign affiliate company may train these local companies through technological transfer from their home country in order to obtain intermediate goods of sufficient quality.


From most previous studies, the evidence of a positive relationship between accumulations of FDI and economic growth could be shown. On the other hand, some studies, such as Haddad and Harrison (1993), Kokko et al. (1996), Aitken and Harrison (1999), and Bosco (2001) could not
find any significant evidence from the empirical analysis.

Empirical studies in the case of India have been conducted by Kathuria (2001; 2002). However, he uses only few samples. Moreover, there has been no empirical analysis of the FDI spillover effect at the aggregated industry level for India as a case study. In this paper, we examine the relationship between technological progress and accumulations of FDI. In addition, we thoroughly analyse how the spillover from FDI could affect the productivity growth of the manufacturing industry.

2. The Model

Here, we consider the theoretical background to the relationship among FDI accumulation, technical innovation, and economic growth. We discuss this relationship according to the quality ladder model or QL model (Grossman and Helpman, 1991; Aghion and Howitt, 1992; Barro and Sara-i-Martin, 2004), which is based on the Schumpeterian innovation.

The key concept of the QL model is that technology upgrades step by step as if climbing up a ladder. In this model, production sector could be divided into two, the final goods sector and the intermediate goods sector, and there are five assumptions in this model: (1) the number of final goods-producing firms is \( N \) and the number of intermediate goods-producing firms is \( n \); (2) the final goods are assumed to be homogeneous; (3) the quality of final goods is assumed to be only influenced by the quality ladder level of intermediate goods; (4) each intermediate goods-producing firm invests in R&D to obtain the next level of technology and the firm could be the monopoliser until somebody succeeds in innovating the next technology on the quality ladder; (5) free entry to and exit from all intermediate goods production is ensured.

2.1. Households

Supposing that the instantaneous utility function is in logarithmic form, the dynamic optimisation problem of household could be described as

\[
\max U = \int_0^\infty e^{-\rho t} \ln C dt
\]

s. t. \( \dot{A} = W - C + rA \).

Here, \( C \) is aggregate consumption, \( W \) is income, \( A \) is assets, \( r \) is interest rate, and \( \rho \) is time preference. From the maximisation problem above, the Euler equation (equation (1)), that is, growth rate of consumption at steady state, could be derived as

\[
\frac{\dot{C}}{C} = r - \rho
\]

\[\text{(1)}\]

\[1\] Kathuria conducted empirical analyses with 368 samples in 2001 and with 487 in 2002.
2.2. Final Goods Producers

Considering the production function of a firm that produces final goods, we assume the Cobb-Douglas production function as follows.

\[ Y_i = AL_i^{1-\alpha} \int_0^N (\tilde{X}_{ij})^\alpha d\tilde{\alpha} \]  

\[ (2) \]

In this equation, \( Y_i \) is total output of final goods in firm \( i \), \( L_i \) is total labour input in firm \( i \), \( A \) is total factor productivity, \( \tilde{X}_{ij} \) is the adjusted input of intermediate goods of \( j \) in firm \( i \), and could be defined as \( \tilde{X}_{ij} = q^{kj} \cdot X_{ij} \). Here, \( q \) is a parameter of quality that takes a value larger than 1, and \( k_j \) stands for intermediate goods on the quality ladder \( j \). \( k_j \) takes whole number beginning with 1 and increasing one by one. Thus, we could rewrite the equation (2) as follows.

\[ Y_i = AL_i^{1-\alpha} \int_0^N (q^{kj} \cdot X_{ij})^\alpha d\tilde{\alpha} \]  

\[ (3) \]

Thus, the quality of final goods fully depends on summation of the quality ladders of all intermediate goods. Therefore, the \( q_k \) increases exponentially with upgrades of the quality ladders of \( k_j \).

Supposing perfect competition, the profit maximisation problem of firms can be written as follows.

\[ \max \pi_i = Y_i - wL_i - \int_0^N P_j X_{ij} \ d\tilde{\alpha} \]

s.t \( Y_i = AL_i^{1-\alpha} \int_0^N (q^{kj} \cdot X_{ij})^\alpha d\tilde{\alpha} \).

From the first-order condition of the profit maximisation problem above, we can obtain the demand function of intermediate goods of \( j \) as follows.

\[ \frac{\partial \pi_i}{\partial X_{ij}} = 0 \iff X_{ij} = L_i \left( \frac{A \cdot \alpha \cdot q^{kj}}{P_j} \right)^{\frac{1}{(1-\alpha)}} \]  

\[ (4) \]

Here, \( P_j \) is price of intermediate goods \( j \). Summarising the demand of all final goods in this economy, the aggregate demand function of intermediate goods \( j \) can be given as

\[ X_j = L \left( \frac{A \cdot \alpha \cdot q^{kj}}{P_j} \right)^{\frac{1}{(1-\alpha)}} \]  

\[ (5) \]

Here, \( L \) is the aggregate input of labour in the final goods sector, and can be defined as \( L = \int_0^N L_i \ d\tilde{\alpha} \).
2.3. Intermediate Goods Producers

Here, we think about the profit optimisation of the intermediate goods producers. First of all, we specify the production function of intermediate goods as

\[ X = Y. \]

This production function implies that it is necessary to input one unit of final goods to produce one unit of intermediate goods. Thus, the profit maximisation problem of intermediate goods producers could be defined as follows.

\[
\max \pi(\kappa_j) = (P_j - 1)X_j
\]

s. t. \[ X_j = L \left( \frac{A \cdot \alpha \cdot q^{k_j}}{P_j} \right)^{\frac{1}{1-\alpha}} \]

To solve the profit maximisation problem of intermediate goods producers, the optimum price of intermediate goods can be derived as

\[ P_j = \frac{1}{\alpha} \]

(6)

Substituting equation (6) into equation (5), we can express the profit of intermediate goods producers as follows.

\[ \pi(\kappa_j) = \bar{\pi} \cdot q^{\frac{k_j}{(1-\alpha)}} \]

Here, \( \bar{\pi} \) implies the profit of the initial level of the quality ladder (\( \kappa = 0 \)), and we can then define \( \bar{\pi} \) as follows.

\[ \bar{\pi} \equiv A^{\frac{1}{1-\alpha}} \cdot \left( \frac{1 - \alpha}{\alpha} \right)^{\frac{2}{(1-\alpha)}} \cdot L. \]

2.4. Determination of R&D Expenditure and Innovation

Intermediate goods producers are engaged in R&D to monopolise the intermediate goods market.

The probability of succeeding in innovation to obtain the \( \kappa_i + 1 \)th technology (arrival rate) of firm \( j \) (\( p_{jk_i} \)) follows the Poisson distribution. Here, we define the factor to determine the level of \( p_{jk_i} \) as follows.

\[ p_{jk_i} = Z_{jk} \cdot \varphi(\kappa_i, i) \]

(7)

\[
\frac{\partial p_{jk_i}}{\partial Z_{jk}} > 0
\]

\[
\frac{\partial p_{jk_i}}{\partial \kappa_i} < 0
\]

\[
\frac{\partial p_{jk_i}}{\partial t} > 0.
\]
In equation (6), \( Z_{jk_i} \) is the total amount of R&D expenditure of firm \( j \) to obtain the \( \kappa_i + 1 \) th technology and \( i \) is amount of the FDI stock of firm \( j \). Equation (6) implies that an increase in R&D expenditure raises the arrival rate of innovation. There is also a positive relationship between FDI stock and the arrival rate of innovation. On the other hand, the arrival rate of innovation decreases when the quality ladder goes up. In other words, it would be difficult to succeed in innovation with technology progress.

Then, we specify the function of \( \varphi \) as follows.

\[
\varphi(\kappa_i, i) = \frac{-\alpha(\kappa_i + 1)}{q^{(1-\alpha)}}
\]

Next, we think about the performance of the monopoliser of the \( j \) th intermediate goods market in the term of the \( \kappa_i \)th quality ladder. First, the expected profit of the monopolistic intermediate goods producer can be expressed as the current discount value as follows.

\[
E[(V(\kappa_i))] = \frac{\pi(\kappa_i)}{r + p_{jk_i}}.
\]

Here, \( \pi(\kappa_i) \) is the monopolistic profit of firm \( j \) and \( r \) is the interest rate. This equation implies that the expected monopolistic profit becomes lower as \( p_{jk_i} \) rises. In other words, the expected length of monopoly of firm \( j \) becomes shorter.

In addition, assuming the zero profit condition, the current discount value of the expected monopolistic profit of producers engaged in R&D at the \( \kappa_i + 1 \) th quality ladder is not to be zero. So, the equation below can be derived as follows.

\[
p_{jk_i} \cdot E[(V(\kappa_j + 1)] - Z(\kappa_j) = 0 \quad \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots \cdots 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Here, $Q$ is the summation of $q$ in each intermediate good and can be defined as

$$Q = \int_{0}^{N} \frac{k_{j}a}{q^{(1-\alpha)}} dj$$ ................................. (9)

### 2.5. Endogenous Growth

Summarising the production function of all financial goods producers, we can rewrite equation (2) using the definition of $Q$ (equation (9)) as follows.

$$Y = A^{\alpha(1-\alpha)} \cdot a^{2\alpha} \cdot L \cdot Q.$$  

The upgrade of the quality ladder in any intermediate goods $j$ (increasing the value of $k_{j}$) affects the level of total output positively through raising the value of $Q$. Therefore, we can express the growth rate of $Q$ as follows.

$$\frac{\dot{Q}}{Q} = (\bar{\rho} \cdot \bar{t} - \bar{r}) \cdot \left[q^{(1-\alpha)} - 1\right]$$ ................................. (10)

The resource constraint for the overall economy can be written as:

$$\bar{Y} = \bar{C} + \bar{X} + \bar{Z}.$$  

And the growth rate for all the economy at a steady state can be obtained as follows.

$$\frac{\dot{Y}}{\bar{Y}} = \frac{\dot{C}}{\bar{C}} = \frac{\dot{X}}{\bar{X}} = \frac{\dot{Z}}{\bar{Z}} = \frac{\dot{Q}}{Q} = \gamma$$ ................................. (11)

Substituting equations (1) and (10) into (11), we can obtain the equation of $r$ and $\gamma$ at a steady state as follows.

$$r = \frac{\rho + \left[q^{(1-\alpha)} - 1\right] (\bar{\rho} \cdot \bar{t})}{\left[q^{(1-\alpha)} - 1\right]}$$ ................................. (12)

$$\gamma = \bar{\rho} \cdot \bar{t} - \rho$$ .......................... (13)

We illustrate equation (1) and (9) in figure (1). In figure (1), $\gamma$ is displayed on the vertical and $r$ on the horizontal axis. From figure (1), the interest rate and economic growth rate at a steady state can be uniquely determined at the point of intersection between $\frac{\dot{Q}}{Q}$ and $\frac{\dot{C}}{C}$. Furthermore, we find that an increase in FDI stock ($\delta$) shifts $\frac{\dot{Q}}{Q}$.
upwards and steady economic growth rate \(\gamma\) moves up from \(\gamma_1\) to \(\gamma_2\).

3. Empirical Analysis

According to the theoretical analyses in the previous section, we estimate technological spillovers from FDI on a TFP of each industry from two different channels. The first channel of spillover is from FDI within an industry, which is called the ‘horizontal effect’. The other channel is spillover from FDI into other industries, which is related to input-output transactions, and is the so-called vertical effect.

Moreover, we distinguish the spillover of FDI into the ‘short-run effect’ and the ‘long run effect’. According to Liu (2008), the long-run spillover effect of FDI can be estimated by the coefficient of the interaction term of FDI stock and time trend.

The estimation process consists of two steps. In the first step, we calculate the fitted value of TFP by regression of a Cobb-Douglass type of production function. The estimation model can be described as follows.

\[
\widehat{TFP}_{it} = \frac{Y_{it}}{K_{it}^\alpha \cdot L_{it}^\beta}.
\]

In the regression of Cobb-Douglass-type production function, it would be necessary to take into consideration the endogenous problem between observable input elements (\(K\): capital input and \(L\): labour input) and unobservable input elements such as productivity shock. To deal with this problem, we conduct regression of the production function according to the method of Levinsohn and Petrin (2003) and Petrin, Poi, and Levinsohn (2004). In this regression, we substitute the invested capital of the ASI for \(K\) and total employees of the ASI for \(L\). We calculate the value of \(Y\) from the gross value of output of the ASI minus the total input of the ASI. As an instrument variable of unobservable shock, we use the value of the fuel consumed of the ASI.

In the second step, we analyse the relationship between the TFP and FDI stocks with the following equation.

\[
\ln \widetilde{TFP}_{it} = \beta_0 + \beta_1 \text{time} + \beta_2 \text{horizontal}_{i,t} + \beta_3 \text{backward}_{i,t} + \beta_4 \text{horizontal}_{i,t} \ast \text{time} + \beta_5 \text{backward}_{i,t} \ast \text{time} + u_{i,t}.
\]

In the regression equation, time is the term of time trend. The \textit{horizontal} variable represents the ratio of FDI stock and domestic capital stock of industries \(i\), which stands for the short-run horizontal spillover effect of FDI stock, and is described as follows.

\[
\text{horizontal}_i = \frac{\text{ammout of FDI stock}}{\text{domestic capital stock}}.
\]

Moreover, we insert \textit{backward} into the explanatory variable as short-run spillover effect from FDI stock in the backward (downstream) industries. According to Javorcik (2004), \textit{backward} is defined as the weighted average of FDI stock/domestic capital stock ratio of backward industries.
and can be described as follows.

\[ \text{backward}_i = \sum_k \sigma_{ik} \times \text{horizontal}_k. \]

Here, we suppose that the \( i \)th industry provides their products for each \( k \)th industry. \( \sigma_{ik} \) is the share of the amount of input to \( k \)th industry into total output of \( i \)th industry. We can define the \( \sigma_{ik} \) as follows.

\[ \sigma_{ik} = \frac{\text{intermediate goods from } i \text{th industry to } k \text{th industry}}{\text{total output of } i \text{th industry}}. \]

In addition, we insert the variables of the long-run spillover effect of FDI into the second-step regression equation. According to Liu (2008), it should be possible to estimate the long-run effect of FDI by inserting the transaction term of time trend and the variables of FDI spillover effect, \( \text{horizontal} \times \text{time} \) and \( \text{backward} \times \text{time} \). From calculating the first difference of the regression model, we can obtain the equation as follows.

\[
\ln TFP_{it} = \beta_0 + \beta_1 \text{time} + \beta_2 \text{horizontal}_{it} + \beta_3 \text{backward}_{it} \\
+ \beta_4 \text{horizontal}_{it} \times \text{time} + \beta_5 \text{backward}_{it} \times \text{time} + u_{it}.
\]

This equation implies the growth rate of output that we showed above as equation (13).

We estimate the second equation by four types of panel regression method: pooled ordinal least-square method, fixed-effects model, random-effects model, and the dynamic panel regression model (Arellano and Bond (1991)). Furthermore, we estimate the models which take one-year lagged FDI stock variables as explanatory variables in order to deal with the simultaneous problem.

4. Data

The empirical analyses of this paper are based on the panel data of Indian manufacturing industries from 1995 to 2004. We collected the data of the gross value added, capital stock, and labour input from the Annual Survey of Industries (ASI) which is data published by the Central Statistical Organisation (CSO). ASI covers the manufacturing factory belonging to the organised sector all over India, which combines census data and sample data. In this study, we use the aggregated data at the sector-wise level.

In addition, we collect FDI data from the website of the Department of Commerce and Industry.2 Because data on FDI stock in Indian industry is not available, we substitute the accumulated FDI inflow value from 1991 by the FDI stock data.

In this study, the classification of the sector of industry is based on the definition of the 1998

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2 The statistics of FDI can be downloaded from the newsletter of the Secretariat for Industrial Assistance (SIA) every month.
### Table 1

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>507,781</td>
<td>2,041</td>
<td>5,686,540</td>
<td>832,240</td>
</tr>
<tr>
<td>K</td>
<td>1,250,281</td>
<td>9,502</td>
<td>8,082,878</td>
<td>1,765,364</td>
</tr>
<tr>
<td>L</td>
<td>165,094</td>
<td>3,152</td>
<td>1,133,152</td>
<td>206,561</td>
</tr>
<tr>
<td>horizontal</td>
<td>0.251</td>
<td>0.005</td>
<td>1.503</td>
<td>0.247</td>
</tr>
<tr>
<td>backward</td>
<td>0.047</td>
<td>0.001</td>
<td>0.108</td>
<td>0.028</td>
</tr>
</tbody>
</table>

### Table 2

<table>
<thead>
<tr>
<th>Industry Description</th>
<th>Gross Value Added (price-adjusted): Y Unit: 100,000 Rupee</th>
<th>Capital Stock (price-adjusted): K Unit: 100,000 Rupee</th>
<th>Labour Input: L Unit: Number of Employee</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>Minimum</td>
<td>Maximum</td>
<td>Standard Deviation</td>
</tr>
<tr>
<td>Y</td>
<td>430,595</td>
<td>257,577</td>
<td>716,607</td>
</tr>
<tr>
<td>K</td>
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<td>8,082,878</td>
</tr>
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<td>0.108</td>
</tr>
</tbody>
</table>

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National Industry Classification (NIC) at the two-digit level. However, the industry classification was changed in 1998 and it is therefore difficult to use the ASI data both before and after 1998 in the same regression. Moreover, the industry classification is different depending on the source of each variable. To solve this problem, we made a new industry classification by ourselves according to the CSO and *EPW*. The industry classification of this study is shown in Table 2.

In order to estimate the production function using panel data, it is necessary to deflate the variables of output ($Y$) and capital input ($K$). In this study, to calculate the value of $Y$, we adopted the double-deflation method. In order to obtain a constant value of $Y$, we deflate the gross value of output (GVO) in the ASI by the wholesale price index (WPI)\(^3\) and total input in the ASI by the intermediate price index,\(^4\) and then deduct the adjusted total input from the adjusted GVO.

Here, we show the basic statistics of the variables in tables 1, 2, and 3. From Table 2, we can understand that the average of heavy and technology-intensive industries such as the steel or electrics equipment industry tends to be higher than the average of light industry such as the food production or textile industry. The average number of $K$ also takes a higher number in heavy industry and a lower number in light industry. Table 3 shows that statistics of the FDI variables are extremely high in the petroleum and natural gas industry. In addition, *horizontal* takes a relatively

\(^3\) We obtain the WPI data from the Reserve Bank of India’s website: (http://www.rbi.org.in/scripts/AnnualPublications.aspx?head=Handbook%20of%20Monetary%20Statistics%20of%20India). In the case of non-availability of the WPI, we use the index of the National Account Statistics (NAS).

\(^4\) The intermediate price indexes are calculated as the weighted average of WPI of each intermediate goods. The weight is the share of each intermediate good in the total input, which is calculated by the input-output table of 1998.

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**Table 3**

<table>
<thead>
<tr>
<th>Industry Description</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
<th>Mean</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Standard Deviation</th>
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<tbody>
<tr>
<td>Food Products</td>
<td>0.165</td>
<td>0.103</td>
<td>0.237</td>
<td>0.042</td>
<td>0.089</td>
<td>0.075</td>
<td>0.095</td>
<td>0.007</td>
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<td>Textile, Apparel and Leather Products</td>
<td>0.070</td>
<td>0.059</td>
<td>0.081</td>
<td>0.007</td>
<td>0.024</td>
<td>0.014</td>
<td>0.030</td>
<td>0.004</td>
</tr>
<tr>
<td>Timber Products</td>
<td>0.012</td>
<td>0.005</td>
<td>0.016</td>
<td>0.004</td>
<td>0.052</td>
<td>0.036</td>
<td>0.068</td>
<td>0.010</td>
</tr>
<tr>
<td>Paper and Paper Products</td>
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<td>0.114</td>
<td>0.337</td>
<td>0.068</td>
<td>0.073</td>
<td>0.054</td>
<td>0.085</td>
<td>0.010</td>
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<tr>
<td>Petroleum and Natural Gas</td>
<td>0.874</td>
<td>0.512</td>
<td>1.503</td>
<td>0.310</td>
<td>0.025</td>
<td>0.019</td>
<td>0.030</td>
<td>0.004</td>
</tr>
<tr>
<td>Chemical Products</td>
<td>0.188</td>
<td>0.120</td>
<td>0.214</td>
<td>0.029</td>
<td>0.053</td>
<td>0.034</td>
<td>0.062</td>
<td>0.009</td>
</tr>
<tr>
<td>Drugs and Pharmaceuticals, Soaps, Cosmetics and Toilet Preparations</td>
<td>0.075</td>
<td>0.040</td>
<td>0.113</td>
<td>0.033</td>
<td>0.031</td>
<td>0.022</td>
<td>0.039</td>
<td>0.006</td>
</tr>
<tr>
<td>Rubber Products</td>
<td>0.202</td>
<td>0.043</td>
<td>0.327</td>
<td>0.093</td>
<td>0.038</td>
<td>0.031</td>
<td>0.046</td>
<td>0.005</td>
</tr>
<tr>
<td>Cement and Gypsum Products</td>
<td>0.058</td>
<td>0.038</td>
<td>0.082</td>
<td>0.019</td>
<td>0.002</td>
<td>0.001</td>
<td>0.004</td>
<td>0.001</td>
</tr>
<tr>
<td>Metal/alurgical Industry, Industrial Machinery and Machine Tools</td>
<td>0.171</td>
<td>0.091</td>
<td>0.230</td>
<td>0.044</td>
<td>0.041</td>
<td>0.021</td>
<td>0.051</td>
<td>0.009</td>
</tr>
<tr>
<td>Electrical Equipment</td>
<td>0.378</td>
<td>0.202</td>
<td>0.482</td>
<td>0.080</td>
<td>0.089</td>
<td>0.073</td>
<td>0.108</td>
<td>0.010</td>
</tr>
<tr>
<td>Miscellaneous Mechanical and Engineering Industries</td>
<td>0.314</td>
<td>0.113</td>
<td>0.509</td>
<td>0.111</td>
<td>0.071</td>
<td>0.038</td>
<td>0.107</td>
<td>0.022</td>
</tr>
<tr>
<td>Transportation Equipment</td>
<td>0.499</td>
<td>0.282</td>
<td>0.680</td>
<td>0.144</td>
<td>0.022</td>
<td>0.018</td>
<td>0.026</td>
<td>0.003</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>0.234</td>
<td>0.005</td>
<td>1.503</td>
<td>0.200</td>
<td>0.052</td>
<td>0.001</td>
<td>0.108</td>
<td>0.028</td>
</tr>
</tbody>
</table>
high number in the electrical equipment, miscellaneous mechanical, engineering, and transportation equipment industries but a lower number in the drugs and pharmaceuticals, soaps, and cosmetics and toilet preparations industries. On the other hand, the average number of \textit{backward} becomes higher in the chemical products, electrical equipment, and miscellaneous mechanical industries, as well as in the light industries such as the food products, timber products, and paper and paper products industries.

5. Results

Here, we discuss the results of regressions of both the non-lag model and the one-year-lag model as shown in table 2. First of all, we have to specify the most adequate results estimated from three different methods. In the case of the non-lag model, the null hypothesis of the Hausman test where there are no differences between the coefficients of the fixed model and the random model could not be rejected at the 10% significance level. And neither could the null hypothesis of the Breusch and Pagan test where the variance of the error term is unbiased be rejected at the 10% significance level. So, we regard the results of pooled OLS as the most appropriate results. In the case of the one-year-lag model, we could not reject the null hypothesis of the Hausman test at the 1% significance level and neither could we reject the hypothesis of the F test where all the coefficients of individual-specific dummy variables are the same at the 5% significance level. Therefore, it could be said that the result of the fixed-effects model is the most adequate. In the regression of GMM, we examine the auto-correlation in the explanatory variables by the autoregressive (AR) test at the first difference (AR(1)) and second difference (AR(2)). The null hypothesis where there is autocorrelation in the residual term could be rejected at AR(1) at the 1% significance level but could not be rejected at AR(2) at the 10% significance level. Thus, it could be said that the estimator of GMM is not efficient but is consistent.

As the result of first-step regression (production function), the coefficient of $\ln K$ is $0.33$ and the coefficient of $\ln L$ is $0.45$. In addition, the sum of the coefficient of production elements is not different statistically from 1, so we can recognise a constant return to scale.

The estimated coefficients of \textit{horizontal} take a positive value in the results of the fixed-effects model and GMM, and take a negative value in the results of the random-effects model and the pooled OLS model. On the other hand, the coefficients of \textit{horizontal}*$time$ take a positive value in the results of all of the models. However, none of these coefficients are statistically significant at the 10% significance level. We could observe the same results in the one-year-lag model. Therefore, we cannot recognise significant intra-industry technological spillover from FDI either in the short run or in the long run.

On the other hand, the coefficients of \textit{backward} and

| Table 4 |
|-----------------|-----------------|
| Variables       | Coefficients(z-Statistics) |
| Capital Input(K)| 0.447 (1.92)*    |
| Labour Input(L) | 0.332 (3.36)**   |
| Number of Observations | 315             |
| Wald-Test for Constant Return to Scale | 1.00            |
backward*time are both significant and consistent. In the case of the coefficient of backward, we obtained a negative value in the results of all models, while the coefficient of backward*time takes a positive value in the results of each model. From these evidences, we can predict that FDI spillover from downstream industry affects TFP negatively in the short run. At the same time, FDI spillover from the downstream industry raises the TFP in the long run. After FDI inflow, restructuring of the industry, involving exit and new entry, may occur within a short period. Besides, it also takes a while to install a new technology in the local manufacturing industries, that is, the gestation period of capital.

Table 5(1)

<table>
<thead>
<tr>
<th>Variables \ Model</th>
<th>Fixed Effect</th>
<th>Random Effect</th>
<th>Pooled OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>-0.175 (-2.49)**</td>
<td>-0.147 (-2.19)**</td>
<td>-0.147 (-2.17)**</td>
</tr>
<tr>
<td>horizontal</td>
<td>1.169 (0.92)</td>
<td>-0.827 (-0.96)</td>
<td>-0.899 (-1.06)</td>
</tr>
<tr>
<td>backward</td>
<td>-16.545 (-1.53)</td>
<td>-10.512 (-1.78)*</td>
<td>-10.617 (-1.82)*</td>
</tr>
<tr>
<td>horizontal*time</td>
<td>0.237 (1.53)</td>
<td>0.224 (1.49)</td>
<td>0.222 (1.47)</td>
</tr>
<tr>
<td>backward*time</td>
<td>2.035 (1.87)*</td>
<td>1.884 (1.77)*</td>
<td>1.905 (1.77)*</td>
</tr>
<tr>
<td>constant</td>
<td>10.725 (19.9)***</td>
<td>10.795 (29.94)***</td>
<td>10.813 (30.33)***</td>
</tr>
<tr>
<td>R_Square</td>
<td>0.0362 (Within)</td>
<td>0.0219 (Within)</td>
<td>0.019</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>2.07**</td>
<td>6.17</td>
<td>1.21</td>
</tr>
<tr>
<td>Wald-Statistic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Observation</td>
<td>315</td>
<td>315</td>
<td>315</td>
</tr>
</tbody>
</table>

   Hausman-Test Statistic: 5.82
   F-Test Statistic (Null Hypothesis: all the coefficient of individual-specific dummy variables are same) : 1.31
   Breusch and Pagan Test Statistic: 0.34
   Selected Model: Pooled OLS

Table 5(2)

<table>
<thead>
<tr>
<th>Variables \ Model</th>
<th>Fixed Effect</th>
<th>Random Effect</th>
<th>Pooled OLS</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>-0.245 (-2.99)**</td>
<td>-0.188 (-2.39)**</td>
<td>-0.184 (-2.31)**</td>
</tr>
<tr>
<td>horizontal (lagged)</td>
<td>1.772 (1.29)</td>
<td>-0.667 (-0.72)</td>
<td>-0.792 (-0.87)</td>
</tr>
<tr>
<td>backward (lagged)</td>
<td>-9.029 (-0.73)</td>
<td>-10.065 (-1.62)</td>
<td>-10.344 (-1.69)*</td>
</tr>
<tr>
<td>horizontal*time (lagged)</td>
<td>0.271 (1.5)</td>
<td>0.253 (1.42)</td>
<td>0.246 (1.36)</td>
</tr>
<tr>
<td>backward*time (lagged)</td>
<td>2.598 (2.14)**</td>
<td>2.251 (1.87)*</td>
<td>2.256 (1.84)**</td>
</tr>
<tr>
<td>constant</td>
<td>10.33 (17.49)***</td>
<td>10.8 (28.28)***</td>
<td>10.834 (28.73)***</td>
</tr>
<tr>
<td>R_Square</td>
<td>0.0568 (Within)</td>
<td>0.033 (Within)</td>
<td>0.022</td>
</tr>
<tr>
<td>F-Statistic</td>
<td>2.89**</td>
<td>6.83</td>
<td>1.23</td>
</tr>
<tr>
<td>Wald-Statistic</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Number of Observation</td>
<td>280</td>
<td>280</td>
<td>280</td>
</tr>
</tbody>
</table>

   Hausman-Test Statistic: 9.69*
   F-Test Statistic (Null Hypothesis: all the coefficient of individual-specific dummy variables are same) : 1.53**
   Breusch and Pagan-Test Statistic: 1.07
   Selected Model: Fixed Effect Model
Table 5(3)

<table>
<thead>
<tr>
<th>Variables \ Model</th>
<th>GMM</th>
<th>GMM(Robust-Standard Error)</th>
</tr>
</thead>
<tbody>
<tr>
<td>time</td>
<td>-0.19 (-1.46)</td>
<td>-0.19 (-1.69)</td>
</tr>
<tr>
<td>lnTFP (lagged)</td>
<td>0.143 (1.68)*</td>
<td>0.143 (1.72)*</td>
</tr>
<tr>
<td>horizontal</td>
<td>0.236 (0.11)</td>
<td>0.236 (0.10)</td>
</tr>
<tr>
<td>backward</td>
<td>-33.580 (-1.78)*</td>
<td>-33.580 (-1.57)</td>
</tr>
<tr>
<td>horizontal*time</td>
<td>0.058 (0.19)</td>
<td>0.058 (0.21)</td>
</tr>
<tr>
<td>backward*time</td>
<td>3.044 (1.67)*</td>
<td>3.044 (1.81)*</td>
</tr>
<tr>
<td>constant</td>
<td>10.470 (7.42)***</td>
<td>10.470 (7.41)***</td>
</tr>
<tr>
<td>Wald-Statistic</td>
<td>7.66</td>
<td>7.17</td>
</tr>
<tr>
<td>Number of Observation</td>
<td>245</td>
<td>245</td>
</tr>
</tbody>
</table>

Sargan J-Statistic 16.170
AR(1)-test Statistic -4.32***
AR(2)-test Statistic 0.79

We can illustrate the total FDI spillover (summarising the short-run effect and long-run effect) effects from the downstream sector in figure 2. From figure 2, we can explain that the growth rate of TFP (lnTFP) falls in the first three or four years after FDI inflow, and TFP then starts to grow.

6. Conclusion

In this paper, spillover from FDI stock to manufacturing industry growth was examined for India from 1995 to 2004 mainly using ASI and SIA data. We separate spillover from FDI stock into the horizontal effect and the backward effect. Moreover, we also take the length of spillover to distinguish the short-term effect from the long-term effect.

The empirical results suggest that spillover from FDI stock tends to be stronger from the downstream sector than intra-industry. In India, some examples of spillover from the assembly sector to local intermediate goods producers can be observed. For example, Suzuki Motors, which is an automobile company in Japan, started up production in India in 1982 as a joint venture with the Indian government named Multi Udoyog. At that time, Suzuki Motors offered training and transferred certain techniques to local suppliers of automobile parts near their factory. Finally, Suzuki contributed to technical development in local industries in India.

It is necessary to analyse FDI spillover by using micro-data and it is also important to consider the location of the factory or the geographical condition. Since economic liberalisation, India has been enjoying rapid economic growth. Furthermore, India will attract more FDI from developed countries in the near future. In this case, we can say that FDI might be the engine of economic growth under the globalisation scheme.
References


**Appendix**

1. **Processing ASI Statistics**

The Annual Survey of Industries (ASI) is an official industry statistics source concerning the Indian organised manufacturing sector published by the Central Statistical Organisation (CSO) every year. ASI statistics are created by a census survey for organised manufacturing factories that employ more than 100 workers and a sample survey for organised manufacturing factories that employ fewer than 100 workers. In this paper, we used industry-wise aggregate data according to the National Industry Classification code of 1987 (NIC87). However, continual industry-wise aggregated data from 1991 to 2004 is not available because the NIC code was changed in 1998 (NIC98). In order to conduct panel analysis beyond 1998, we combine the classification code of NIC87 and NIC98. In the process of combining the classification code of both NIC87 and NIC98, we refer to the merger code suggested by the CSO and the *Economic and Political Weekly* (EPW) research foundation. We then draw a line chart of variables to confirm the continuity of the variables through the sample period.

Our data-creating process can be described as follows. (1) We merged the classification code on the basis of the merger code suggested by the *EPW*. (2) We check the continuity by the line chart of variables. (3) If we cannot ensure the continuity of a variable, we merge the classification of the industry with the classification referring to the merger code suggested by the CSO, or otherwise merge with a similar industry in the same industry category. Because of the above process, the number of our industry classification of ASI is smaller than the classification of the *EPW* and the CSO.

2. **Deflation**

In terms of panel data regression, it is necessary to deflate the value of \( Y \) and capital stock \( K \) to eliminate the influence of price fluctuation. Here, we show the process of deflation in terms of \( Y \) and \( K \).

(1) **Deflating \( Y \)**

To obtain the real value of \( Y \), we deflate the nominal value of \( Y \) adapted to the double-deflation method
as follows.

\[
\text{Real Value of } Y = \frac{\text{Nominal Value of Output}}{\text{Whole Price Index}} - \frac{\text{Nominal Value of Total Intermediate Goods Input}}{\text{Price Index of Intermediate Goods}}
\]

Here, we obtain the whole price index from the website of the Reserve Bank of India (RBI). The price index of intermediate goods is calculated by the weighted average of the price index of each intermediate good. The weight of each intermediate good is calculated from the input-output table of 1998-99. For the price index of service industries that is not available on the RBI website, we calculate the price index from the National Account Statistics (NAS). We divide intermediate goods cost into three categories: raw material cost, fuel cost, and other service cost. Finally, we calculate the price index of intermediate goods by adjustment by the share of the total cost of intermediate goods.

(2) Deflating \( K \)

Here, we explain the deflation process of \( K \) by the perpetual inventory method. The real value of capital stock can be calculated as the following process.

\[
I = \frac{B_t - B_{t-1} + D_t}{P^t}
\]

Here, \( B \) is the value of fixed capital, \( D \) is depreciation, and \( P^t \) is the price of invested capital that is the implicit deflator of gross domestic fixed capital formation of the NAS (categorised into the organised manufacturing sector).

In the next step, we calculate real capital stock at time \( t \) by the equation as follows.

\[
K_t = (1 - d)K_{t-1} + I_t.
\]

In the equation above, we substitute the book value \((B_0 + D_0)\) as the initial value of \( K \) \((K_0)\) and we fix the depreciation rate at 5%.

3. Processing of FDI Variables

In this paper, we use FDI statistics in the newsletter of the Secretariat for Industrial Assistance (SIA) published by the Department of Commerce and Industry as a variable of FDI inflow (approval basis). In the next step, we calculate the accumulated value of FDI inflow from 1991 to the end of each fiscal year and substitute as the value of FDI stock.

Using the value of FDI stock from 1991, we calculate two variables, horizontal and backward, to stand for FDI stock. As we mentioned in the main part, horizontal is the ratio of FDI stock to domestic capital stock. In this paper, we adopted invested capital stock from 1991 in the ASI as a variable of domestic capital stock. The second variable, backward, is the weighted average of horizontal of each industry in the downstream sector. In order to calculate backward, it is necessary to obtain the weight of each industry in the downstream sector. In this paper, we calculate the weight from the input-output table of 1998-99. In addition, we include backward of the service industries. In the process of calculating the ratio of FDI stock and domestic capital stock of the service industries, we substitute the value of net capital formation of the NAS instead of the ASI stock data because ASI does not cover all of the service industry.

In the final step, we merge the industry classification of the SIA and the ASI. However, classification of the SIA is occasionally changed through the sample period. To address this problem, we combine certain classifications of the SIA to ensure the continuity of variables.