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

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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.

In empirical analysis of the FDI spillover, there are two kinds of analysis of spillovers from FDI, industrial-level analysis (using aggregate industry data) and micro-level analysis (using firm data). As a model study of industrial-level analysis, Borensztine et al. (1998) show a positive relationship between FDI accumulations and economic growth by an estimation of cross-country data, such as Blomstrom and Persson (1983) in the case of Mexico, Blomstrom (1986) in the case of Mexico, Kokko (1994; 1996) in the case of Mexico, and Li et al. (2001) in the case of China. There are also several kinds of micro-level analysis, such as Haddad and Harrison (1993) in the case of Morocco, Aitken and Harrison (1999) in the case of Venezuela, Blomstrom and Sjöholn (1999) in the case of Indonesia, Bosco (2001) in the case of Hungary, Djankov and Hoekman (2000) in the case of the Czech Republic, Kinoshita (2001) in the case of the Czech Republic, and Takii (2005) in the case of Indonesia.

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.[1] 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

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

$$\text{s.t.}\, \dot{A} = W - C + rA.$$

Here, C is aggregate consumption, W is income, A is assets, r is interest rate, and ρ 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

$$\frac{\dot{C}}{C} = r - \rho \qquad \cdots\cdots (1)$$

[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.

$$Y_i = AL_i^{1-\propto} \int_0^N (\tilde{X}_{ij})^{\alpha} dj \quad \cdots\cdots (2)$$

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 $\tilde{X}_{ij} = q^{\kappa_j} \cdot X_{ij}$. Here, q is a parameter of quality that takes a value larger than 1, and κ_j stands for intermediate goods on the quality ladder j. κ_j takes whole number beginning with 1 and increasing one by one. Thus, we could rewrite the equation (2) as follows.

$$Y_i = AL_i^{1-\propto} \int_0^N (q^{\kappa_j} \cdot X_{ij})^{\alpha} dj \quad \cdots\cdots (3)$$

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 κ_j.

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

$$\max \pi_i = Y_i - wL_i - \int_0^N P_j X_{ij}\ dj$$

$$\text{s.t.}\, Y_i = AL_i^{1-\propto} \int_0^N (q^{\kappa_j} \cdot X_{ij})^{\alpha} dj.$$

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

$$\frac{\partial \pi_i}{\partial X_{ij}} = 0 \Leftrightarrow X_{ij} = L_i \left(\frac{A \cdot \alpha \cdot q^{\kappa_j}}{P_j} \right)^{\frac{1}{(1-\propto)}} \quad \cdots\cdots (4)$$

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

$$X_j = L \left(\frac{A \cdot \alpha \cdot q^{\kappa_j}}{P_j} \right)^{\frac{1}{(1-\alpha)}} \quad \cdots\cdots (5)$$

Here, L is the aggregate input of labour in the final goods sector, and can be defined as $L = \int_0^n L_i di$.

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.

$$\max \pi(\kappa_j) = (P_j - 1)X_j$$

$$\text{s.t.} X_j = L\left(\frac{A \cdot \alpha \cdot q^{\kappa_j}}{P_j}\right)^{\frac{1}{(1-\alpha)}}.$$

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

$$P_j = \frac{1}{\alpha} \qquad \cdots\cdots (6)$$

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

$$\pi(\kappa_j) = \bar{\pi} \cdot q^{\frac{\kappa_j \cdot \alpha}{(1-\alpha)}}.$$

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.

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

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 ($p_{j\kappa_i}$) follows the Poisson distribution. Here, we define the factor to determine the level of $p_{j\kappa_i}$ as follows.

$$p_{j\kappa_i} = Z_{j\kappa_j} \cdot \varphi(\kappa_i, \iota) \qquad \cdots\cdots (7)$$

$$\frac{\partial p_{j\kappa_i}}{\partial Z_{j\kappa_j}} > 0$$

$$\frac{\partial p_{j\kappa_i}}{\partial \kappa_j} < 0$$

$$\frac{\partial p_{j\kappa_i}}{\partial \iota} > 0.$$

In equation (6), $Z_{j\kappa_j}$ is the total amount of R&D expenditure of firm j to obtain the $\kappa_i + 1$ th technology and ι 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 φ as follows.

$$\varphi(\kappa_i, \iota) = \iota \cdot q^{\frac{-\alpha(\kappa_j+1)}{(1-\alpha)}}.$$

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

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

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 $p_{j\kappa_i}$ 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.

$$p_{j\kappa_i} \cdot E\left[(V(\kappa_{j_j} + 1)\right] - Z(\kappa_j) = 0 \qquad \cdots\cdots (8)$$

Substituting equation (7) into equation (8), we can obtain the following equation.

$$Z(\kappa_j) \cdot \{\varphi(\kappa_j, \iota) \cdot E[(V(\kappa_j + 1)] - 1\} = 0.$$

Supposing each firm is willing to be a monopoliser on the $\kappa_i + 1$ th quality ladder engaged in R&D, the value of $Z(\kappa_j)$ should be positive. Thus, we can obtain the equation as follows.

$$\varphi(\kappa_j, \iota) \cdot E[(V(\kappa_j + 1)] - 1 = 0.$$

The above equation can be rewritten as follows.

$$Z(\kappa_j) = q^{\frac{(\kappa_j+1)\cdot\alpha}{(1-\alpha)}} \cdot \left(\frac{\bar{\pi} - r}{\iota}\right).$$

Aggregating the value of $Z(\kappa_j)$ in all kinds of intermediate goods markets, we can obtain the equation as follows.

$$Z \equiv \int_0^N Z(\kappa_j)dj = Q \cdot q^{\frac{\propto}{(1-\propto)}} \cdot \left(\frac{\bar{\pi} - r}{\iota}\right).$$

Here, Q is the summation of q in each intermediate good and can be defined as

$$Q = \int_0^N q^{\frac{\kappa_j \alpha}{(1-\propto)}} dj \qquad \cdots\cdots (9)$$

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.

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

The upgrade of the quality ladder in any intermediate goods j (increasing the value of κ_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.

$$\frac{\dot{Q}}{Q} = (\bar{\pi} \cdot \iota - r) \cdot \left[q^{\frac{\alpha}{(1-\alpha)}} - 1 \right] \qquad \cdots\cdots (10)$$

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

$$Y = C + X + Z.$$

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

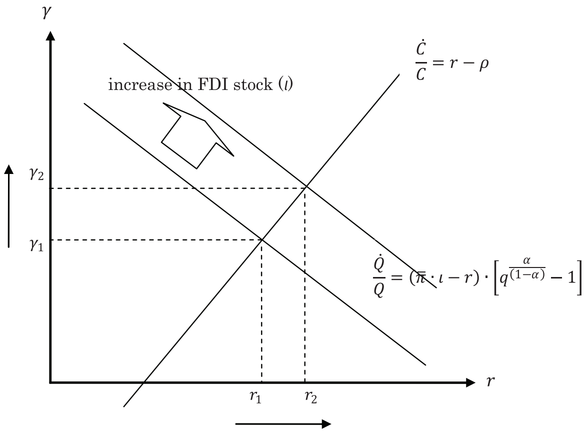
$$\frac{\dot{Y}}{Y} = \frac{\dot{C}}{C} = \frac{\dot{X}}{X} = \frac{\dot{Z}}{Z} = \frac{\dot{Q}}{Q} = \gamma \qquad \cdots\cdots (11)$$

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

$$r = \frac{\rho + \left[q^{\frac{\alpha}{(1-\alpha)}} - 1 \right] (\bar{\pi} \cdot \iota)}{\left[q^{\frac{\alpha}{(1-\alpha)}} - 1 \right]} \qquad \cdots\cdots (12)$$

$$\gamma = \bar{\pi} \cdot \iota - \rho \qquad \cdots\cdots (13)$$

Figure 1



We illustrate equation (1) and (9) in figure (1). In figure (1), γ 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 (ι) shifts $\frac{\dot{Q}}{Q}$

upwards and steady economic growth rate γ moves up from γ_1 to γ_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.

$$\widehat{TFP}_{i,t} = \frac{Y_{i,t}}{K_{i,t}^{\hat{\alpha}} \cdot L_{i,t}^{\hat{\beta}}}.$$

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.

$$\begin{aligned} ln\widehat{TFP}_{i,t} &= \beta_0 + \beta_1 time + \beta_2 horizontal_{i,t} + \beta_3 backward_{i,t} \\ &\quad + \beta_4 horizontal_{i,t} * time + \beta_5 backward_{i,t} * time + u_{i,t.} \end{aligned}$$

In the regression equation, time is the term of time trend. The *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.

$$horizontal_i = \frac{\text{ammout of FDI stock}}{\text{domestic capital stock}}.$$

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

$$backward_i = \sum_k \sigma_{ik} * horizontal_k.$$

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

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

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, *horizontal*time* and *backward*time*. From calculating the first difference of the regression model, we can obtain the equation as follows.

$$\ln\widehat{TFP}_{\mathrm{i,t}} = \beta_0 + \beta_1 time + \beta_2 horizontal_{\mathrm{i,t}} + \beta_3 backward_{\mathrm{i,t}}$$
$$+\beta_4 horizontal_{\mathrm{i,t}} * time + \beta_5 backward_{\mathrm{i,t}} * time + u_{\mathrm{i,t.}}$$

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

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

Table 1

Variable	Mean	Minimum	Maximum	Standard Deviation
Y	507,781	2,011	5,686,540	832,240
K	1,250,281	9,502	8,082,878	1,765,364
L	165,094	3,152	1,133,153	206,561
$horizontal$	0.251	0.005	1.503	0.247
$backward$	0.047	0.001	0.108	0.028

Table 2

Industry Description	Gross Value Added(price-adjusted): Y Unit: 100,000 Rupee				Capital Stock (price-adjusted): K Unit: 100,000 Rupee				Labour input: L Unit: Number of Employee			
	Mean	Minimum	Maximum	Standard Deviation	Mean	Minimum	Maximum	Standard Deviation	Mean	Minimum	Maximum	Standard Deviation
Production, Processing and Preservation of Meat, Fish, Fruit Vegetables, Oils and Fats	430,595	257,577	716,603	154,682	729,486	592,414	894,543	93,383	119,272	103,084	133,292	10,883
Manufacture of Grain Mill Products, Starches and Starch Products, and Prepared Animal Feeds	99,639	28,564	194,956	64,838	445,446	301,460	601,331	110,926	239,965	213,009	284,839	20,160
Manufacture of Other Food Products	778,038	480,195	1,130,819	237,275	1,800,735	1,376,700	2,148,510	285,923	545,285	517,998	569,730	15,246
Manufacture of Beverages	83,933	37,954	104,980	23,166	543,752	340,891	779,306	154,749	57,326	47,714	69,431	6,755
Manufacture of Tobacco Products	168,258	105,750	210,569	37,331	166,926	90,518	226,091	44,801	463,177	431,954	515,134	25,566
Manufacture of Textile	2,247,491	995,810	2,823,200	652,238	5,038,993	3,858,731	5,636,029	657,127	1,064,682	1,001,250	1,133,153	48,058
Manufacture of Apparel	323,585	208,636	487,701	87,278	344,955	231,432	458,045	84,815	260,822	218,748	327,509	34,328
Tanning and Dressing of Leather, Manufacture of Luggage, Handbags, Saddlery and Harnesses	58,166	32,735	94,343	18,722	110,158	95,538	126,546	11,309	40,131	31,784	44,680	3,838
Manufacture of Footwear	80,910	52,502	125,394	24,520	174,669	146,631	201,580	22,378	70,694	62,862	77,844	5,897
Saw Milling and Planing of Wood	3,287	2,011	5,439	1,151	11,003	9,502	15,400	1,777	9,710	7,396	14,498	2,586
Manufacture of Products of Wood, Cork, Straw and Plaiting Materials	25,923	17,072	36,274	6,904	105,230	88,103	119,860	10,992	34,495	28,964	43,922	6,298
Manufacture of Paper and Paper Products	249,284	184,436	326,518	47,813	1,368,288	1,075,841	1,634,594	180,876	136,213	131,751	139,745	3,270
Manufacture of Refined Petroleum Products	498,799	212,169	864,668	212,075	2,835,523	1,200,250	4,761,423	1,387,786	29,576	25,362	34,250	3,300
Manufacture of Basic Chemicals	1,156,501	861,877	1,319,425	155,476	6,244,717	5,136,716	7,095,846	719,795	159,919	130,832	212,251	23,372
Manufacture of Other Chemical Products	4,099,158	1,025,821	5,686,540	1,667,880	2,399,055	1,649,616	3,026,906	467,431	338,716	304,311	370,253	21,691
Manufacture of Rubber Products	333,231	169,216	450,928	96,213	689,544	576,035	764,491	65,864	88,998	79,154	98,314	7,581
Manufacture of Plastic Products	349,389	70,059	622,545	178,013	968,424	562,801	1,179,085	192,263	106,420	86,002	122,031	11,957
Manufacture of Non-Metallic Mineral Products	677,711	449,977	985,308	205,529	2,982,962	2,073,864	3,713,417	550,649	336,064	302,216	466,171	49,963
Manufacture of Iron Steel and Ferro Alloys	1,099,014	350,343	2,467,393	597,761	7,315,286	6,525,631	8,082,878	535,026	397,012	341,399	476,877	49,751
Manufacture of Basic Precious and Non-ferrous Metals	203,177	2,509	421,950	132,610	1,309,824	849,582	2,082,349	357,271	61,212	52,410	77,261	7,774
Manufacture of Structural Metal Products, Tanks, Reservoirs, Steam Generators and Special-purpose Machinery	818,188	638,258	1,228,850	172,261	1,182,644	1,077,047	1,260,851	62,519	221,394	180,286	283,644	39,047
Manufacture of Other Fabricated Metal Products; Metal Working Service Activities	359,893	209,345	608,316	127,977	540,683	395,231	649,197	89,322	127,101	108,659	148,369	15,119
Manufacture of General-purpose Machinery	598,703	430,337	843,325	126,129	794,991	625,712	892,735	93,858	160,093	122,615	207,924	40,797
Manufacture of Domestic Appliances	166,707	111,687	213,667	31,905	239,348	194,300	287,481	29,216	31,282	21,653	44,812	8,791
Manufacture of Electric Motors, Generators, Transformers, Electricity Distribution and Control Apparatus, Insulated Wire and Cable, Accumulators, Primary Cells, Primary Batteries, Electric Lamps, Lighting Equipment and Other Electrical Equipment	1,110,531	738,738	1,469,526	237,511	1,192,759	929,941	1,498,667	203,423	165,658	150,742	178,909	11,124
Manufacture of Electronic Valves and Tubes and Other Electronic Components	189,258	67,309	316,301	92,584	283,198	128,065	423,426	120,724	29,265	21,187	37,830	5,863
Manufacture of Television and Radio Transmitters, Apparatus for Line Telephony and Line Telegraphy, Television and Radio Receivers, Sound or Video Recording or Reproducing Apparatus and Associated Goods	321,221	212,045	432,638	81,038	577,899	457,886	861,421	116,295	49,618	31,463	70,785	16,087
Manufacture of Medical Appliances and Instruments and Appliances for Measuring, Checking, Testing, Navigating and Other Purposes except Optical Instruments	124,505	60,651	214,382	53,469	140,926	93,410	198,622	36,067	25,831	22,076	30,234	2,706
Manufacture of Optical Instruments and Photographic Equipment	18,016	12,808	25,876	4,038	35,059	26,249	83,378	18,303	3,915	3,152	5,760	767
Manufacture of Watches and Clocks	27,203	7,614	48,721	10,846	80,359	67,132	105,453	12,892	13,785	8,649	19,888	3,841
Manufacture of Motor Vehicles, Bodies (Coach Work) for Motor, Trailers and Semi-Trailers, Parts and Accessories for Motor Vehicles and their Engines	767,423	573,100	1,442,247	264,609	2,189,778	1,267,250	2,704,671	576,521	195,811	181,495	212,966	10,202
Building and Repair of Ships and Boats	35,249	23,952	48,461	7,486	77,507	65,192	87,275	7,670	20,338	13,436	27,884	4,862
Manufacture of Railways and Tramways Locomotives and Rolling Stock	58,880	25,335	145,720	39,837	223,081	172,655	314,315	52,313	50,715	14,650	143,714	49,287
Manufacture of Other Transport Equipment	170,480	84,869	283,122	59,918	552,301	362,353	737,444	137,902	106,059	89,142	180,517	28,942
Manufacture of Furniture	39,986	22,840	59,096	14,627	64,338	36,611	98,269	23,486	17,743	14,706	20,443	1,687
Total	507,781	2,011	5,686,540	832,240	1,250,281	9,502	8,082,878	1,765,364	165,094	3,152	1,133,153	206,561

Table 3

Industry Description	*horizontal*				*backward*			
	Mean	Minimum	Maximum	Standard Deviation	Mean	Minimum	Maximum	Standard Deviation
Food Products	0.165	0.103	0.237	0.042	0.089	0.075	0.095	0.007
Textile, Apparel and Leather Products	0.070	0.059	0.081	0.007	0.024	0.014	0.030	0.004
Timber Products	0.012	0.005	0.016	0.004	0.052	0.036	0.068	0.010
Paper and Paper Products	0.254	0.114	0.337	0.068	0.073	0.054	0.085	0.010
Petroleum and Natural Gas	0.874	0.512	1.503	0.310	0.025	0.019	0.030	0.004
Chemical Products	0.188	0.120	0.214	0.029	0.053	0.034	0.062	0.009
Drugs and Pharmaceuticals, Soaps, Cosmetics and Toilet Preparations	0.075	0.040	0.113	0.033	0.031	0.022	0.039	0.006
Rubber Products	0.202	0.043	0.327	0.093	0.038	0.031	0.046	0.005
Cementand Gypsum Products	0.058	0.038	0.082	0.019	0.002	0.001	0.004	0.001
Metallurgical Industry, Industrial Machinery and Machine Tools	0.171	0.091	0.230	0.044	0.041	0.021	0.051	0.009
Electrical Equipment	0.378	0.202	0.482	0.080	0.089	0.073	0.108	0.010
Miscellaneous Mechanical and Engineering Industries	0.314	0.113	0.509	0.111	0.071	0.038	0.107	0.022
Transportation Equipment	0.499	0.282	0.680	0.144	0.022	0.018	0.026	0.003
Total	0.234	0.005	1.503	0.200	0.052	0.001	0.108	0.028

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.

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 *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 residential 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 lnK is 0.33 and the coefficient of lnL 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 *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 *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.

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

On the other hand, the coefficients of *backward* and *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)

Variables＼Model	Fixed Effect	Random Effect	Pooled OLS
time	-0.175 (-2.49)**	-0.147 (-2.19)**	-0.147 (-2.17)**
horizontal	1.169 (0.92)	-0.827 (-0.96)	-0.899 (-1.06)
backward	-16.545 (-1.53)	-10.512 (-1.78)*	-10.617 (-1.82)*
*horizontal*time*	0.237 (1.53)	0.224 (1.49)	0.222 (1.47)
*backward*time*	2.035 (1.87)*	1.884 (1.77)*	1.905 (1.77)*
constant	10.725 (19.9)***	10.795 (29.94)***	10.813 (30.33)***
R_Square	0.0362 (Within)	0.0219 (Within)	0.019
	0.0001 (Between)	0.0073 (Between)	
	0.0068 (Overall)	0.019 (Overall)	
F-Statistic	2.07*		1.21
Wald-Statistic		6.17	
Number of Observation	315	315	315
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)

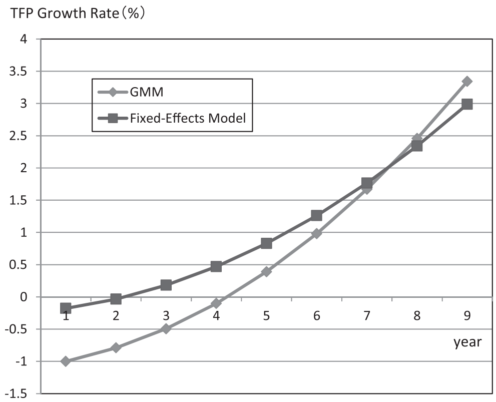
Variables＼Model	Fixed Effect	Random Effect	Pooled OLS
time	-0.245 (-2.99)***	-0.188 (-2.39)**	-0.184 (-2.31)**
horizontal（*lagged*）	1.772 (1.29)	-0.667 (-0.72)	-0.792 (-0.87)
backward（*lagged*）	-9.029 (-0.73)	-10.065 (-1.62)	-10.344 (-1.69)*
*horizontal*time*（*lagged*）	0.271 (1.5)	0.253 (1.42)	0.246 (1.36)
*backward*time*（*lagged*）	2.598 (2.14)**	2.251 (1.87)*	2.256 (1.84)**
constant	10.33 (17.49)***	10.8 (28.28)***	10.834 (28.73)***
R_Square	0.0568 (Within)	0.033 (Within)	0.022
	0.0016 (Between)	0 (Between)	
	0.0077 (Overall)	0.0215 (Overall)	
F-Statistic	2.89**		1.23
Wald-Statistic		6.83	
Number of Observation	280	280	280
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)

Variables＼Model	GMM	GMM(Robust-Standard Error)
time	-0.19 (-1.46)	-0.19 (-1.69)
lntfp (lagged)	0.143 (1.68)*	0.143 (1.72)*
horizontal	0.236 (0.11)	0.236 (0.10)
backward	-33.580 (-1.78)*	-33.580 (-1.57)
*horizontal*time*	0.058 (0.19)	0.058 (0.21)
*backward*time*	3.044 (1.67)*	3.044 (1.81)*
constant	10.470 (7.42)***	10.470 (7.41)***
Wald-Statistic	7.66	7.17
Number of Observation	245	245
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.

Figure 2



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.

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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 continuality by the line chart of variables. (3) If we cannot ensure the continuality 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.

$$Real\ Value\ of\ Y = \frac{Nominal\ Value\ of\ Output}{Whole\ Price\ Index} - \frac{Nominal\ Value\ of\ Total\ Intermediate\ Goods\ Input}{Price\ Index\ of\ Intermediate\ Goods}.$$

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.

$$I = \frac{B_t - B_{t-1} + D_t}{P_t^I}.$$

Here, B is the value of fixed capital, D is depreciation, and P^I 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 continuality of variables.