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Technology Diffusion through Foreign Direct Investment:
A Unit-Level Analysis of the Indian Manufacturing Industry[$]

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Abstract
This study examines technology diffusion resulting from foreign direct investment (FDI) in the domestic manufacturing sector in India. We employ unit-level panel data (where a unit refers to an enterprise within the manufacturing sector) from 2000 to 2007, covering all medium- and large-size manufacturing enterprises in India, obtained from India's Central Statistics Office. We attempt to empirically capture evidence of FDI technology spillover effects through two key mechanisms: horizontal spillover (technology diffusion within the same industry) and vertical spillover (technology diffusion between foreign firms and their customer or suppliers). Vertical spillover effects can be further divided into backward linkages (technology diffusion from foreign firms to upstream industries), and forward linkages (technology diffusion from foreign firms to downstream industries). In addition, technology diffusion can be the result of both short- and long-term spillover effects. The results of the empirical analyses highlight the presence of short- and long-term horizontal spillover effects, both of which negatively affect the total factor productivity performance of domestic manufacturers. Moreover, we find an inverse relationship between the growth of FDI and total factor productivity in upstream industries in the short term; however, this changes to a positive relationship in the long term. Furthermore, the results show no evidence of FDI spillover effects to downstream sectors.

Keywords: Technology Diffusion; Foreign Direct Investment; Total Factor Productivity; Backward Spillover Effect; Manufacturing Industries; Unit-Level Data
JEL Classification: C81, F21, O53

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1 Introduction

The innovation and diffusion of technology is crucial for economic growth in developing countries. A key source of technology diffusion is through spillovers from foreign direct investment (FDI). FDI spillovers resulted in rapid economic growth in East Asian countries in the late 20th century, referred to as the East Asian Miracle (World Bank 1993). Several empirical studies have demonstrated the presence and effects of FDI spillovers by analysing aggregate industry-level data (e.g., Blomström and Persson 1983; Blomstrom 1986; Kokko 1994, 1996) and firm-level data (e.g., Javorcik 2004; Blalock and Gretler 2008; Javorcik and Spatareanu 2008, 2010; Liu 2008).

However, some empirical studies have not found significant FDI spillover effects, such as Akinlo's (2004) aggregate industry-level analysis and firm-level analyses by Haddad and Harrison (1993), Aitken and Harrison (1999), and Bosco (2001).

Considering these divergent findings, we examine FDI spillover effects in the manufacturing sector in India. FDI increased significantly in India after the 1991 Indian economic crisis and subsequent economic reform, supported by an International Monetary Fund stabilisation program. India became an attractive FDI destination due to its large labour force, low production costs, and high technological innovation potential. India attracted substantial FDI inflow following this period of reform and this inflow of FDI was a key factor in India's rapid economic recovery and growth (National Council of Applied Economic Research 2009).

Studies by Kathuria (2001, 2002) focus on the effects of FDI spillovers in Indian manufacturing industries using firm-level data from the Centre for Monitoring Indian Economy of companies traded on the National Stock Exchange of India and the Bombay Stock Exchange. A more comprehensive analysis is offered by Fujimori and Sato (2015), who present empirical evidence of FDI spillovers in India during the liberalisation period from 1995 to 2004 using aggregate industry-level data.

Following the arguments in previous studies, we analyse empirical evidence of technology spillovers from FDI within the Indian manufacturing industry with a focus on the causal relationship between the level of FDI and total factor productivity (TFP) of domestic enterprises in India from 2000 to 2008.

The remainder of this study is presented as follows: The theoretical background of the study is provided, followed by an analysis of the data, variables, and the empirical model. Next, the results of the analysis are presented, and the characteristics of spillover effects in Indian manufacturing industries are discussed. Finally, the results of the analysis are summarised together with policy-relevant conclusions.

2 Theoretical Background

Endogenous economic growth theory favours the acceptance of FDI; as Barro and Sala-i-Martin (2004) show, accepting FDI from developed countries raises the probability of technological innovation in host countries. Furthermore, technological innovation positively affects productivity and economic growth and micro foundation of this relationship are given by Fujimori and Sato (2015).

According to the Görg and Greenaway (2004), by accepting FDI from developed countries, domestic firms in the host country can reap benefits such as technology transfer, management expertise, and export market access. The process of technology diffusion begins, as Saggi (2002) and Keller (2010) suggest, when FDI accepting producers directly acquire advanced technology from foreign-affiliated companies, which increases their productivity.

This advanced technology then transfers to other non-FDI accepting producers in the same industry through imitation, reverse engineering, or the mobility of highly skilled personnel. Subsequently, advanced technology gradually spreads within the industry, which is known as the horizontal spillover effect.

In addition, advanced technologies also diffuse through inter-industry linkages. In developing countries, FDI accepting companies often purchase intermediate goods from local suppliers. In this situation, foreign-affiliated companies transfer advanced technology to these suppliers to improve the quality of their products. Conversely, FDI accepting companies can supply intermediate goods or services to local suppliers, facilitating the transfer of advanced technology to these suppliers by providing quality intermediate goods. This is referred to as the vertical spillover effect.

However, FDI can result in negative effects, one of the most typical being the crowding out effect, where FDI inflow displaces domestic investment. This phenomenon can suppress the activity of domestic manufacturing firms, reduce technological advancement in domestic industries, and negatively affect economic growth (Aitken and Harrison 1999). This is often criticised as the domination of developing country economies by foreign-affiliated companies.

Previous empirical studies that examined FDI spillover effects have captured both the positive and negative effects; however, the presence of a significant relationship between increasing FDI inflow and technological development has not yet been established.

3 Method

3.1 Data Sources

Our empirical analysis is based on census data for the manufacturing sector in India, divided into units, which represent the various sub-industries of the manufacturing sector. The unit-level data were obtained from the Annual Survey of Industries (ASI), which contains economic data for India's industrial sector and is published annually by the Central Statistics Office. The ASI contains unit-level data for India's 'organised' manufacturing enterprises, defined as enterprises with more than 10 employees (power-assisted) or more than 20 employees (non-power-assisted)[1]. All enterprises categorised as part of the organised sector are required to register under The Factories Act, 1948. The ASI data is divided into two categories: census sector, which contains large-scale enterprises with more than 100 employees, and sample sector, which contains small-scale manufacturing enterprises not categorised as census enterprises. For the purpose of constructing unit-level panel data, this study only employs the census category. Also, this study mainly focuses on the situation of medium and large size of manufacturing units.

Annual FDI stock data was unavailable; therefore, we approximated this variable using an accumulated value of FDI inflow from 1991. FDI inflow data were obtained from India's Ministry of Commerce. The sample underlying this empirical analysis is an unbalanced panel dataset from 2000/01 to 2007/08[2].

3.2 Empirical Model

To estimate FDI spillover effects on TFP, we employ a two-step procedure by first calculating the fitted value of TFP and then estimating the causality effect of FDI variables on TFP. To measure the fitted value of TFP, we consider the Cobb–Douglas production function in the logarithmic form as follows:

$$\ln Y_{i,j,t} = Constant + \beta_1 \ln K_{i,j,t} + \beta_2 \ln L_{i,j,t} + u_{i,j,t} \quad (1)$$

where $Y_{i,j,t}$ stands for gross value added, $K_{i,j,t}$ is the capital stock (the value of fixed capital in each unit), and $L_{i,j,t}$ is the labour input, which is the man-days of employment in each unit. The subscripts i, j, and t refer to the ith manufacturing unit operating j's sector at year t. Both $Y_{i,j,t}$ and $K_{i,j,t}$ are deflated to make real values. Regarding the deflation of Y, we employ the double deflation method as follows:

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1 Small manufacturing enterprises based on these definitions are categorised as part of the unorganised sector. Relevant economic data is included in the National Sample Survey, which is published by India's National Sample Survey Office.

2 Annual data is determined according to the Indian fiscal year (1 April to 31 March) rather than calendar years.

$$Y_{i,j,t} = \frac{Value\ of\ Output(Nominal)}{Wholesale\ Price\ Index} - \frac{Total\ Intermediate\ Goods\ Input(Nominal)}{Price\ Index\ of\ Intermediate\ Goods} \quad (2)$$

where the *Wholesale Price Index* is obtained from the Reserve Bank of India and the *Price Index of Intermediate Goods* is the weighted average of the price index of each intermediate good[3].

In the first step, we estimate the output elasticity of capital (β_1) and labour (β_2) from Eq. (1) and then obtain the TFP of each manufacturing unit as follows:

$$\widehat{TFP}_{i,j,t} = \frac{Y_{i,j,t}}{K_{i,j,t}^{\beta_1} \cdot L_{i,j,t}^{\beta_2}} \quad (3)$$

In the Cobb–Douglas production function regression, it is necessary to consider the endogenous problem between the observable inputs and unobservable elements such as productivity shocks. To manage this problem, we conduct a production function regression according to the methods of Ackerberg, Caves, and Frazer (2015), hereafter referred to as ACF; Levinsohn and Petrin (2003), hereafter referred to as LP; Olley and Pakes (1996), hereafter referred to as OP; and Wooldridge (2009), hereafter referred to as WRDG. Fuel cost is used in this estimation as a proxy variable of unobservable macroeconomic shocks.

In the second step, we estimate the spillover effects using the fitted values of TFP of unit i, which are obtained via the regression analysis in the first step. According to the estimation procedure of Liu (2008), the baseline regression equation is expressed in logarithmic form as follows:

$$\ln\widehat{TFP}_{i\ ,j,t} = Constant + \delta time + \vartheta_1 horizontal_{j,t} + \vartheta_2 backward_{j,t} + \vartheta_3 forward_{j,t} + \vartheta_4 horizontal_{j,t} * time + \vartheta_5 backward_{j,t} * time + \vartheta_6 forward_{j,t} * time + u_{i,t} \quad (4)$$

where unit i belongs to industry j, $horizontal_{j,t}$ is the short-term intra-industry spillover effect of j's sector, $backward_{j,t}$ is the short-term spillover effect from industries downstream of j's industry, $forward_{j,t}$ is the short-term spillover effect from industries upstream of j's sector, $horizontal * time$ is the long-term intra-industry spillover effect, and $backward * time$ is the long-term spillover effect from downstream industries. $horizontal_{j,t}$ represents the ratio of FDI stock to domestic capital in each industry and can be calculated as follows:

[3] The weights of each intermediate goods are calculated according to the 2003/04 Input–Output Tables.

$$horizontal_{j,t} = \frac{FDI_{j,t}}{Domestic\ \ Capital_{j,t}} \tag{5}$$

For *Domestic Capital*, we use the accumulated value of invested capital since 1991 in each industry, obtained from the ASI. $backward_{j,t}$ and *forward* are created according to Javorcik (2004) and Javorcik and Spatareanu (2008, 2010) as follows:

$$backward_{j,t} = \sum_{k \neq j} \sigma_{jk} * horizontal_{k,t} \tag{6}$$

$$forward_{j,t} = \sum_{l \neq j} \delta_{iljt} * horizontal_{l,t} \tag{7}$$

where σ_{jk} is the proportion of sector *j*'s output supplying to sector *k* in total output, and δ_{ilj} is the proportion of inputs purchased by unit *i* in sector *j* from sector *l* in total inputs sourced by unit *i* in sector *J*. σ_{jk} and δ_{iljt} are calculated using the 2003/04 input and output matrices published by the Central Statistics Office, and the ASI, respectively. To address the possible endogeneity of FDI, we use lagged FDI variables as explanatory variables in Eq. (4).

Each variable in the ASI is constructed based on the 2004 National Industrial Classification at the two-digit level and classified in terms of categories defined by the Secretariat for Industrial Assistance.

3.3 Descriptive Statistics

The descriptive statistics are presented in Table 1. We estimate that the average unit has 400 employees, assuming an average of 300 working days per year. We analyse only the ASI census sector; therefore, we expect the average unit size to be larger than the average size for the whole organised sector. The descriptive statistics for the fitted value of TFP are calculated by LP, OP, and WRDG and show similar results. The fitted value of TFP calculated by ACF is relatively lower but does not differ significantly from the other calculations.

horizontal represents the proportion of FDI stock to the total capital stock of the whole sector and shows an average value of 0.27, indicating that the percentage of FDI in domestic capital stock in the organised sector is around 30%. The vertical spillover FDI variables, *backward* and *forward,* are calculated as a weighted average of *horizontal*; therefore, the values of both variables should remain within the range of *horizontal*.

<Table 1>

4 Empirical Results

The results from the first-step regression of the Cobb–Douglas production function are shown in Table 2 and indicate that the coefficients of elasticities of both capital (β_1) and labour (β_2) are statistically significant across all cases. Moreover, the coefficients of each estimation method are different; in particular, the coefficients obtained from the OP and ACF estimations demonstrate an increasing return to scale in most of the sub-industries.

<Table 2>

Furthermore, $\ln\widehat{TFP}_{i,j,t}$ is strongly influenced by the estimation method as demonstrated by the large range of the standard deviation. Overall, the fitted values estimated by the ACF and OP methods are low relative to the results estimated by the LP and WRDG methods.

In Tables 3 and 4 we present the coefficients from the second-step estimation. The coefficient of the short-term horizontal spillover effect is negative and statistically significant at the 1% level, while the coefficient of the long-term horizontal spillover effect is also negative and statistically significant in all regression analyses except with the year dummy variable in the OP and LP methods. In the one-year lag model (Table 4), the coefficients of the short-term spillover effects are negative but not statistically significant across all the regression analyses.

In contrast, the results of the examination of backward spillover effects are more unified. The results of all the regression analyses show that short-term spillover coefficients are negative, long-term spillover coefficients are positive, and all are statistically significant. These results are replicated in the one-year-lag model, except when using the ACF method. These estimation results imply the existence of strong FDI backward spillover effects in the Indian manufacturing sector.

The analysis of forward spillover effects yields varying results depending on the estimation model. The coefficients are negative and significant in the short term and positive in the long term without the year dummy; however, the results are opposite when adding the year dummy; the coefficients are positive and significant in the short term and negative in the long term. Moreover, In the one-year-lag model, the coefficients are only significant when using the ACF method.

In sum, the non-lagged model results indicate that increasing FDI decreases the TFP level of intra-industry manufacturing units in both the short and long terms. The results of the one-year lag model also suggest that an increase in FDI has a negative effect on intra-industry TFP in the short term, and any evidence of long-term horizontal spillover effects are not captured. However, the coefficients of backward spillover effects in both models imply that increasing FDI enhances the TFP level of manufacturing units in upstream sectors in the long term. Robust evidence of FDI spillover is not detected in downstream sectors.

<Table 3>

<Table 4>

5 Discussion

The results of our empirical analyses highlight three key issues.

First, an increase in FDI appears to negatively affect TFP growth through horizontal linkages. We interpret this as an indication that the expansion of foreign affiliates' market share reduces the total output of local firms, resulting in relatively high fixed costs for local firms and a consequent reduction in TFP growth. Therefore, a negative spillover effect is observed (Aitken and Harrison 1999; Javorcik 2014).

Second, while backward linkages affect TFP growth negatively in the short term, positive significant spillover effects are captured in the long term. The short-term results indicate a gestation period of investment; however, the long-term results require a more detailed analysis. Final assembly sectors can procure their input materials locally or from overseas. In India, many foreign affiliate companies invest in local industries, traditionally as a result of strict local content requirements imposed by the Indian government until 2000. In this context, foreign subsidiaries created domestic supply chain networks in India and enhanced productivity and technology in the local manufacturing sector.

An example is provided by the automotive industry (Chatterjee 1990; Bhargava 2010). Suzuki Motors, one of the leading foreign companies to advance into India before economic liberalisation, broadly invested and transferred technology to local component industries in the 1980s. Following Suzuki's investment pattern, other foreign subsidiaries procured components from local suppliers. The quality of the final products was influenced by the technological capacity of local suppliers; therefore, foreign companies had an incentive to transfer technology to upstream suppliers. This evidence supports the results of our empirical analysis.

Finally, no significant evidence of forward spillover effects is detected in our results. This may be due to the timeframe of our data; the linkages between the manufacturing sector and the technology sector may have been relatively weak before the 2010s.

4 Conclusion

In this study we examined the channels of technology diffusion through FDI using a case study of the manufacturing sector in India during the liberalisation period from 2000 to 2008. The results of the empirical analyses posit a significant relationship between FDI and technological progress in the manufacturing sector. Importantly, we highlight the strong evidence of technology spillover from foreign firms to upstream suppliers.

Our findings are consistent with Fujimori and Sato (2015), who highlight the existence of long-term backward spillover effects. As an overall conclusion, the acceptance of FDI contributes to technological progress and, as such, is beneficial to India's long-term economic growth.

We find no evidence of technology diffusion to downstream industries in this study. We, however, expect future research that will examine FDI spillover effects after the 2010s. The amount of FDI inflows into information and communications technology (ICT) industries have been increasing since the 2010s. Therefore, the industrial linkages to the upstream sectors as well as downstream sectors must be more deepen than the 2000s.

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Table1 Descriptive Statistics

	Number of Obsevations	Mean	Std. Dev.	Min	Max
Gross Value Added: *Y* (Million Rupees)	87,629	165	1,030	0.0012	100,000
Man-Days of Employment: *L* (Days)	87,629	116,902	348,026	42	16,400,000
Fixed Capital: *K* (Million Rupees)	87,629	179	1,810	0.000001	176,000
ln *TFP* (LP)	87,629	6.2877	1.9047	-5.8312	13.3175
ln *TFP* (OP)	87,629	5.5448	1.7209	-10.7291	12.1199
ln *TFP* (WRDG)	87,629	6.5609	2.1314	-11.8082	15.2251
ln *TFP* (ACF)	87,629	3.7016	1.5857	-6.1942	11.6605
horizontal	87,629	0.2716	0.6777	0.0000	7.1225
backward	87,629	0.2825	0.2467	0.0438	1.2259
forward	87,629	0.5715	0.8349	0.1327	4.4515

Notes: Total Factor Productivity *(TFP)* is estimated by four methods denoted by the following: LP is the Levinsohn and Petrin (2003) method, OP is the Olley and Pakes (1996) method, WRDG is the Wooldrige (2009) method, and ACF is the Ackerberg, Caves and Frazer (2015) method.

Table 2 Results of First-Step Regression Analyses on the Indian Manufacturing Industry

Dependent Variable: ln *Y*			(1)		(2)		(3)		(4)	
			OP		LP		WRDG		ACF	
Code	Industries	Number of Observations	ln *L*	ln *K*	ln *L*	ln *K*	ln *L*	ln *K*	ln *L*	ln *K*
15	Food	19625	0.661***	0.263***	0.668***	0.248***	0.661***	0.248***	0.750***	0.385***
16	Tobacco	2232	0.786***	0.0822**	0.750***	0.0599***	0.749***	0.0655**	0.823***	0.218***
17	Textiles	15096	0.495***	0.369***	0.363***	0.406***	0.345***	0.388***	0.559***	0.399***
18	Apparel	6645	0.555***	0.306***	0.353***	0.352***	0.349***	0.339***	0.607***	0.276***
19	Leather	2598	0.561***	0.377***	0.535***	0.399***	0.532***	0.416***	0.659***	0.347***
20	Wood	1469	0.771***	0.215***	0.638***	0.231***	0.650***	0.239***	0.840***	0.244***
21	Paper	2294	0.612***	0.414***	0.448***	0.297***	0.431***	0.263***	0.626***	0.414***
22	Publishing	2227	0.715***	0.202*	0.475***	0.229**	0.473***	0.273***	0.793***	0.353***
23	Coke/Petroleum	905	0.790***	0.422***	0.613***	0.377**	0.613***	0.366***	0.943***	0.382***
24	Chemicals	11289	0.457***	0.260***	0.418***	0.226***	0.404***	0.214***	0.560***	0.461***
25	Rubber/Plastics	3614	0.604***	0.352***	0.390***	0.480***	0.386***	0.362***	0.659***	0.419***
26	Non-metallic mineral	9287	0.606***	0.180***	0.461***	0.210***	0.459***	0.207***	0.762***	0.174***
27	Basic metals	4256	0.544***	0.364***	0.607***	0.371***	0.602***	0.249***	0.769***	0.364***
28	Metal products	4195	0.625***	0.279***	0.401***	0.278**	0.418***	0.208***	0.728***	0.240***
29	Machinery	3607	0.719***	0.348***	0.628***	0.446***	0.628***	0.432***	0.775***	0.351***
30	Office machinery	377	0.283***	0.587***	0.365***	0.526***	0.334***	0.267**	0.643***	0.289*
31	Electrical machinery	3997	0.663***	0.457***	0.572***	0.471***	0.572***	0.513***	0.747***	0.346***
32	Television/Communication	1014	0.702***	0.365***	0.639***	0.465***	0.646***	0.361***	0.753***	0.365***
33	Medical/Watches	1492	0.604***	0.353***	0.595***	0.329***	0.585***	0.369***	0.691***	0.385***
34	Motor vehicles	285	0.714***	0.823***	0.503***	0.658***	0.494***	1.005***	0.789***	0.321*
35	Other transport	2450	0.589***	0.354***	0.509***	0.403***	0.488***	0.460***	0.602***	0.409***
36	Furniture	3297	0.704***	0.244***	0.610***	0.291***	0.602***	0.293***	0.796***	0.391***

Notes: Regression analyses are undertaken using four methods denoted by the following: LP is the Levinsohn and Petrin (2003) method, OP is the Olley and Pakes (1996) method, WRDG is the Wooldrige (2009) method, and ACF is the Ackerberg, Caves and Frazer (2015) method.

Standard errors are reported in parentheses. * Denotes significance at the 10% level, ** at the 5% level, and *** at the 1% level.

Table3 Results of Second-Step Regression Analyses on the Indian Manufacturing Industry

Dependent variable: ln TFP	(1) OP	(2) OP	(3) LP	(4) LP	(5) WRDG	(6) WRDG	(7) ACF	(8) ACF
horizontal	-0.0284***	-0.0270***	-0.0333***	-0.0320***	-0.0522***	-0.0518***	-0.0359***	-0.0353***
	(0.00725)	(0.00724)	(0.00743)	(0.00742)	(0.00769)	(0.00768)	(0.00719)	(0.00719)
horizontal×time	-0.00640***	0.00379	-0.00896***	0.00167	-0.0202***	-0.00980***	-0.0243***	-0.0151***
	(0.00235)	(0.00235)	(0.00241)	(0.00241)	(0.00250)	(0.00249)	(0.00233)	(0.00233)
backward	-2.075***	-1.345***	-2.624***	-1.892***	-3.009***	-2.318***	-1.082***	-0.261***
	(0.0817)	(0.0895)	(0.0838)	(0.0916)	(0.0866)	(0.0949)	(0.0810)	(0.0888)
backward×time	0.240***	0.0999***	0.282***	0.140***	0.318***	0.182***	0.190***	0.0460***
	(0.00694)	(0.00861)	(0.00711)	(0.00882)	(0.00735)	(0.00914)	(0.00688)	(0.00855)
forward	-0.125***	-0.0209*	-0.121***	-0.0144	-0.111***	-0.00611	-0.116***	-0.0137
	(0.0103)	(0.0111)	(0.0106)	(0.0114)	(0.0110)	(0.0118)	(0.0103)	(0.0110)
forward×time	0.0155***	-0.00110	0.0144***	-0.00251	0.0128***	-0.00353**	0.0139***	-0.00316**
	(0.00145)	(0.00155)	(0.00149)	(0.00159)	(0.00154)	(0.00164)	(0.00144)	(0.00154)
Constant	5.794***	5.585***	6.631***	6.419***	6.977***	6.779***	3.776***	3.560***
	(0.0145)	(0.0168)	(0.0148)	(0.0172)	(0.0153)	(0.0178)	(0.0144)	(0.0167)
Year Fixed Effect	NO	YES	NO	YES	NO	YES	NO	YES
Observations	87,629	87,629	87,629	87,629	87,629	87,629	87,629	87,629
R-squared	0.046	0.068	0.050	0.072	0.052	0.072	0.046	0.066
Number of Panel	28,117	28,117	28,117	28,117	28,117	28,117	28,117	28,117

Notes: Regression analyses are undertaken using four methods denoted by the following: LP is the Levinsohn and Petrin (2003) method, OP is the Olley and Pakes (1996) method, WRDG is the Wooldrige (2009) method, and ACF is the Ackerberg, Caves and Frazer (2015) method.

Standard errors are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level and *** at the 1% level.

Table 4 Results of Second-Step Regression Analyses on the Indian Manufacturing Industry with Lagged Explanatory Variables

Dependent vriable: ln TFP	(1) OP	(2) OP	(3) LP	(4) LP	(5) WRDG	(6) WRDG	(7) ACF	(8) ACF
horizontal (-1)	-0.0121	-0.0280***	-0.0134	-0.0295***	-0.0239**	-0.0395***	-0.0182*	-0.0313***
	(0.0104)	(0.0104)	(0.0106)	(0.0106)	(0.0109)	(0.0109)	(0.0104)	(0.0104)
horizontal (-1)×*time*	-0.00859**	-0.00247	-0.00873**	-0.00257	-0.00627*	-0.000238	-0.00496	0.000502
	(0.00356)	(0.00355)	(0.00362)	(0.00361)	(0.00373)	(0.00372)	(0.00356)	(0.00355)
backward (-1)	-1.909***	-0.338***	-1.986***	-0.408***	-2.082***	-0.525***	-1.714***	-0.149
	(0.107)	(0.122)	(0.109)	(0.124)	(0.112)	(0.128)	(0.107)	(0.122)
backward (-1)×*time*	0.228***	0.0342***	0.236***	0.0411***	0.242***	0.0500***	0.211***	0.0177
	(0.00914)	(0.0117)	(0.00930)	(0.0119)	(0.00957)	(0.0123)	(0.00915)	(0.0117)
forward (-1)	-0.123***	-0.0146	-0.120***	-0.0121	-0.117***	-0.0113	-0.126***	-0.0248*
	(0.0135)	(0.0145)	(0.0137)	(0.0148)	(0.0141)	(0.0152)	(0.0135)	(0.0145)
forward (-1)×*time*	0.0187***	0.000106	0.0180***	-0.000604	0.0175***	-0.000917	0.0199***	0.00150
	(0.00187)	(0.00201)	(0.00191)	(0.00205)	(0.00196)	(0.00211)	(0.00188)	(0.00202)
Constant	5.864***	5.627***	6.633***	6.395***	6.922***	6.687***	3.912***	3.668***
	(0.0170)	(0.0199)	(0.0173)	(0.0203)	(0.0178)	(0.0209)	(0.0170)	(0.0199)
Year Fixed Effect	NO	YES	NO	YES	NO	YES	NO	YES
Observations	54,915	54,915	54,915	54,915	54,915	54,915	54,915	54,915
R-squared	0.046	0.069	0.046	0.069	0.044	0.065	0.044	0.067
Number of Panel	17,762	17,762	17,762	17,762	17,762	17,762	17,762	17,762

Notes: Regression analyses are undertaken using four methods denoted by the following: LP is the Levinsohn and Petrin (2003) method, OP is the Olley and Pakes (1996) method, WRDG is the Wooldrige (2009) method, and ACF is the Ackerberg, Caves and Frazer (2015) method.

Standard errors are reported in parentheses. * denotes significance at the 10% level, ** at the 5% level and *** at the 1% level.