

Foreign direct investment and technology spillovers: Theory and evidence

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Introduction

Low- and middle-income countries, especially, attract FDI by offering foreign investors special incentives:

- Tax holidays
- Tariff reductions or exemptions
- Subsidies for infrastructure, etc.

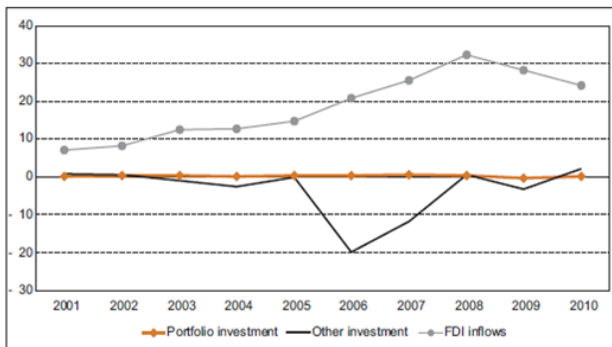
Justification for the favorable policies toward FDI rest on:

- 1 the assumption that FDI generates externalities in the form of technology transfer, including advanced technology, management methods, new products and new processes.
- 2 other benefits to recipient countries—employment, financing savings gap and balance of payments deficit, etc.

Introduction

FDI inflows have been the most important external private capital flows to LDCs, exceeding foreign portfolio and other investments combined.

Figure I.1. Private capital flows to LDCs, 2001–2010
(Billions of dollars)



Source: UNCTAD, FDI/TNC database (www.unctad.org/fdistatistics) (for FDI inflows) and IMF (for portfolio and other investments).

Note: Data for 2010 are estimates. Other investment includes mainly bank lending.

Spillover Channels

- Intraindustry or horizontal spillover
 - Through improved efficiency by coping technologies of foreign affiliates.
 - Labour turnover
 - Severe competition, which forces local firms to use resources efficiently and/or search for new technologies.
- Interindustry or vertical spillover
 - Backward Linkages: contacts between foreign firms and their local suppliers.
 - Forward Linkages: sales of intermediate inputs by foreign firms to local firms. May come with complementary services that may improve efficiency.

Previous works

- Aitken and Harrison (1999) using panel data on Venezuelan plants, find that FDI affects adversely the productivity of domestic firms. To explain their results, they put forward a "market-stealing" hypothesis arguing that, while FDI may promote technology transfer, foreign-invested firms gain market shares at the expense of domestic firms and force the latter to produce smaller outputs at higher average costs. Thus, overall benefit (horizontal spillover) of FDI is small.
- Javorcik (2004) reports evidence for positive productivity spillover from foreign firms to their local suppliers in Lithuania—backward linkage.

Liu's work

- Distinction between short-term level effect and long-term rate effect of FDI on the productivity of domestic firms.
- Spillovers have negative effect on the productivity of domestic firms (there's cost to learning) in the short run yet a positive effect on the productivity of domestic firms in the long run (learning enhances firm's future productivity capacity).
- Possible explanation in the context of a model of endogenous growth at the firm level.

Liu's work

- To test the theory, he uses a large panel of Chinese manufacturing firms.
- Finds suggestive evidence that FDI lowers the short-term productivity level but raises the long-term rate of productivity growth of domestic firms in the same industry.
- Backward and forward linkages between industries have similar effects on the productivity of domestic firms.
- Backward linkages seem to be statistically the most important channel through which spillovers occur.

The model

Productivity growth is firm specific. The engine of growth is firm-specific organizational capital, which augments the productivity of all inputs.

Firm's production function:

$$Q_t = A_t B_t L_t^\alpha K_t^\beta [H_t M_t]^\gamma \quad (1)$$

where A_t represents exogenous, common technical factors, and B_t is the productivity parameter relating to the superior technology to a joint venture by the foreign partner. B_t is assumed to be greater for foreign-invested firms than for domestic firms. L_t and K_t are labor and capital inputs.

The model...

H_t is the stock of firm-specific organization capital ¹, M_t is the fraction of managerial time (normalized to be one) devoted to directing current production.

$$\dot{H} = rH_t[1 - M_t]^\delta G^\varphi \quad (2)$$

where r is an efficiency parameter of the production, $0 < \delta < 1$ indicates whether managerial inputs are subject to diminishing returns, G denotes public information on technology and management methods associated with foreign-invested firms, $\varphi \geq 0$ represents the intensity of spillovers. If there are no spillovers, φ takes the value of zero.

¹See Prescott and Vischer (JPE, 1980) for a discussion on organization capital. Organization capital is the product of organization learning

The model...

The firm chooses M^*, L^*, K^* to maximize the present value of future profits:

$$\text{Max } \Pi = \int_0^{\infty} e^{-\rho t} \{pA(t)B(t)L(t)^{\alpha}K(t)^{\beta}[H(t)M(t)]^{\gamma} - \omega' L(t) - c' K(t)\} dt \quad (3)$$

$$\text{Subject to : } \dot{H} = rH(t)[1 - M(t)]^{\delta} G^{\varphi} \quad (4)$$

$p = \phi Q_m^{-\epsilon}$ is the market demand function, $1/\epsilon$ is the price elasticity of demand, $Q_m = nQ$ the industry's output, and n the industry's steady-state number of firms.

Steady-state solutions

$$\hat{L} = \hat{K} = \eta \hat{Q} + \hat{\phi} \quad (5)$$

$$\hat{Q} = \frac{\frac{1}{\eta} \gamma \hat{H} + \frac{\hat{\phi}}{\eta} (\alpha + \beta)}{\frac{1}{\eta} - \alpha - \beta} > 0 \quad (6)$$

$$\hat{H} = \frac{(rG^\varphi \xi - \rho)(\frac{1}{\eta} - \alpha - \beta) + \frac{\hat{\phi}}{\eta}}{\frac{1}{\eta} - \alpha - \beta - \gamma} > 0 \quad (7)$$

provided $(rG^\varphi \xi - \rho) > 0$, $\frac{1}{\eta} - \alpha - \beta - \gamma > 0$, $\eta = 1 - \epsilon$ and $\xi = (1 - M)^{\delta-1} [1 - M(1 - \delta)] > 0$.

$$\frac{dM^*}{dG} < 0 \quad (8)$$

Firm's Total Factor Productivity

At time t:

$$TFP_t = \frac{Q_t}{L_t^\alpha K_t^\beta} = A_t B_t [H_t M_t]^\gamma \quad (9)$$

$$\hat{TFP} = \hat{A} + \hat{B} + \gamma \hat{H} \quad (10)$$

$$\hat{H} = r(1 - M^*)^\delta G^\varphi \quad (11)$$

$$\frac{d\hat{H}}{dG} > 0 \quad (12)$$

$$\frac{d\hat{TFP}}{dG} = \frac{\partial \hat{TFP}}{\partial \hat{H}} \frac{\partial \hat{H}}{\partial G} > 0 \quad (13)$$

$$\frac{dTFP}{dG} = \frac{\partial TFP}{\partial M^*} \frac{\partial M^*}{\partial G} < 0 \quad (14)$$

Empirical methodology

$$ltp_{ij} = \alpha_0 + \alpha_1 FDI_firm_{ij} + \alpha_2 FDI_sector_j + \alpha_3 Time + \alpha_4 Time * FDI_sector_j + \alpha_5 X_{ij} + \mu_i + \epsilon_i \quad (15)$$

ltp_{ij} = logarithm of firm i 's productivity.

FDI_firm_{ij} = foreign equity share in firm i .

FDI_sector_j = foreign investments in industry j

$Time$ = time trend.

μ_i = unobservable firm specific effect

ϵ_i = stochastic disturbance

Data

Data obtained from the National Bureau of Statistics of China (NBSC). Sample, randomly drawn from the database, is an unbalanced panel consisting of 17,675 manufacturing firms over a period of 5 years from 1995 to 1999 with a total of 50,667 observations.

Real capital stock in year t :

$$K_t = (1 - d)K_{t-1} + I_t \quad (16)$$

where d is the rate of depreciation.

Proxies for spillovers

At the four-digit level:

$$FDI_sector_j = \sum_i OS_{ij} \times FDI_firm_{ij} \quad (17)$$

OS_{ij} = firm i 's share in sector j 's output.

At the two-digit level:

$$FDI_downstream_sector_j = \sum_k \theta_{jk} \times FDI_sector2_k \quad (18)$$

θ_{jk} = share of sector j 's output used as an intermediate input by sector k taken from the 1997 input-output matrix.

Proxies for spillovers

$$FDI_upstream_sector_j = \sum_l \tau_{jl} \times FDI_sector2_l \quad (19)$$

τ_{jl} = share of intermediate inputs purchased by industry j from industry l in total inputs sourced by sector j , and $l \neq j$.

Estimating total factor productivity

Consider the following Cobb-Douglas production function:

$$q_{it} = \alpha + \beta_l l_{it} + \beta_k k_{it} + \omega_{it} + \epsilon_{it} \quad (20)$$

where q , l , and k are the logarithm of output (in value added terms), labor and capital inputs, respectively, ω is total factor productivity which is known to the firm but not to the researcher, ϵ is the random productivity shocks.

$$i_{it} = i(\omega_{it}, k_{it}) \quad (21)$$

By inverting (21), the unobservable productivity can be expressed as a function of observable investment and capital:

$$\omega_{it} = h(i_{it}, k_{it}) \quad (22)$$

Estimating total factor productivity

Substituting (22) into (20), we obtain the production function to be estimated in the first step of the Olley and Pakes (1996) procedure:

$$q_{it} = \alpha + \beta_l l_{it} + \beta_k k_{it} + h(i_{it}, k_{it}) + \epsilon_{it} \quad (23)$$

Approximate $h(i_{it}, k_{it})$ by a third-order polynomial in investment and capital, we can obtain consistent estimates for β_l and the third-order polynomial function, ψ_{it} , which is:

$$\psi_{it} = \alpha + \beta_k k_{it} + h(i_{it}, k_{it}) \quad (24)$$

Accordingly,

$$h(i_{it}, k_{it}) = \psi_{it} - \beta_k k_{it} - \alpha \quad (25)$$

Estimating total factor productivity

The second step of the procedure involves estimating the following nonlinear regression model:

$$q_{it+1} = \beta_l l_{it+1} = \beta_k k_{it+1} + g(\psi_{it} - \beta_k k_{it} - \alpha) + \xi_{it+1} + \epsilon_{it+1} \quad (26)$$

where g is a third-order polynomial of $\psi_{it} - \beta_k k_{it} - \alpha$ and ξ_{it+1} is mean independent of k_{it+1} . A nonlinear least squares method can be used to obtain a consistent estimate for β_k . We estimate (24) and (26) for each two-digit industry to obtain consistent estimates. These estimates are then used to compute firm-specific total factor productivity, which is the difference between the actual and predicted outputs.

Summary statistics

Table 1
Definitions and summary statistics of key variables used

Variable	Definition	Mean (standard deviation)
Output (million yuan)	Value-added in constant price	453.29 (1842.21)
Capital (million yuan)	Real values of capital stock	110.06 (699.85)
Labor (persons)	Total number of employees	1453 (3983)
ltfp	Log of total factor productivity	2.647 (1.529)
FDL_firm (%)	The percentage of firm's equity owned by foreign investors	10.33 (23.93)
FDL_sector (%)	The weighted average of the percentage of firm's equity owned by foreign investors among firms in the same four-digit industry ^a	11.83 (20.03)
FDL_sector2 (%)	The weighted average of the percentage of firm's equity owned by foreign investors among firms in the same two-digit industry ^a	13.12 (17.15)
FDL_downstream_sector (%)	The weighted average of FDL_sector2 of upstream two-digit industries ^a	5.69 (7.36)
FDL_upstream_sector (%)	The weighted average of FDL_sector2 of downstream two-digit industries ^a	5.67 (6.51)
HI	Herfindhal index	0.10 (0.133)
Sample size		50,667

Firms included in the sample come from the following two-digit manufacturing sectors: food processing, food manufacturing, beverage manufacturing, tobacco processing, textile, garments and other fiber products, leather (including furs and related products), timber processing, furniture, paper and paper products, printing and record medium, educational and sports goods, petroleum processing, chemical material and products, medical and pharmaceutical products, chemical fiber, rubber products, plastic products, nonmetal mineral products, processing of ferrous metals, processing of nonferrous metals, metal products, ordinary machinery, special purpose equipment, transportation equipment, electric equipment and machinery, electronic and telecommunications equipment, instruments, and other manufacturing.

^a See discussions about Eqs. (8)–(10) for the specific weight used.

Replicating empirical models of previous studies

Table 2
Estimating the level effect of intraindustry spillovers

Variables	(1)	(2)	(3)	(4)
FDL_firm	0.00605*** (0.000530)	-0.00173*** (0.000384)	-0.00166** (0.000350)	-0.00386*** (0.000484)
FDL_sector	0.00517*** (0.000546)	-0.00174*** (0.000355)	-0.00199*** (0.000351)	-0.00191*** (0.000382)
FDL_firm * FDL_sector	-0.0000431*** (0.0000103)	0.0000670*** (0.00000779)	0.0000721*** (0.00000750)	0.000102*** (0.00000858)
Firm dummy	No	No	Yes	No
Industry dummy	No	Yes	No	No
Year dummy	Yes	Yes	Yes	No
Adj- R^2	0.02	0.91	0.91	0.005
Sample size	50,667	50,667	50,667	30,225

Figures in parentheses are standard errors corrected for heteroskedasticity. The dependent variable is $ltfp_t$ for columns (1) through (3). For column (4), the dependent variable is $ltfp_t - ltfp_{t-1}$ and independent variables are in first-difference form.

*Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Estimating the level and rate effects of intraindustry spillovers

Table 3

Estimating the level and rate effects of intraindustry spillovers, dependent variable: $\ln f_{it}$

Variables	(1) Full sample	(2) Full sample	(3) Domestic sample	(4) Domestic sample
FDL _{firm}	0.000256 (0.000374)			
FDL _{firm} (lagged)		0.000359 (0.000425)		
FDL _{sector}	-0.00116*** (0.000408)		-0.00346*** (0.000573)	
FDL _{sector} (lagged)		-0.00140** (0.000607)		-0.00375 (0.000915)
Time * FDL _{sector}	0.000374*** (0.000107)		0.000292* (0.000159)	
Time * FDL _{sector} (lagged)		0.000324** (0.000158)		0.000356 (0.000257)
Time	0.0122*** (0.00185)	0.0139*** (0.00267)	0.0123*** (0.00196)	0.0139*** (0.00288)
HI	-0.0359 (0.0472)	-0.000589 (0.0608)	-0.120** (0.0531)	-0.0823 (0.0700)
Firm dummy	Yes	Yes	Yes	Yes
Obs.	50,667	30,225	39,140	23,555
Adj- R^2	0.91	0.93	0.91	0.93

Figures in parentheses are standard errors corrected for heteroskedasticity. Lagged indicates the independent variable is lagged by 1 year. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Estimating the level and rate effects of intraindustry and interindustry spillovers

Table 4
Estimating the level and rate effects of intraindustry and interindustry spillovers, dependent variable: $\ln y$

Variables	(1) Full sample	(2) Full sample	(3) Domestic sample	(4) Domestic sample	(5) Domestic sample	(6) Domestic sample
FDI_firm	0.000312 (0.000375)					
FDI_firm (lagged)		0.000412 (0.000438)				
FDI_sector	-0.000990** (0.000416)		-0.00338*** (0.000580)			
FDI_sector (lagged)		-0.00102 (0.000643)		-0.000404 (0.000927)		
Time * FDI_sector	0.000231** (0.000118)		0.000212 (0.000169)			
Time * FDI_sector (lagged)		0.000196 (0.000179)		0.0000613 (0.000266)		
FDI_downstream_sector	-0.00289** (0.00128)		-0.000963 (0.00146)		-0.000468 (0.00146)	
FDI_downstream_sector (lagged)		-0.0101** (0.00462)		-0.00833*** (0.00197)		-0.00824*** (0.00198)
Time * FDI_downstream_sector	0.000696*** (0.000272)		0.000421** (0.000209)		0.000632** (0.000316)	
Time * FDI_downstream_sector (lagged)		0.00107 (0.000821)		0.000689*** (0.000445)		0.000963** (0.000451)
FDI_upstream_sector	-0.000480 (0.00145)		0.00160 (0.00157)		0.000908 (0.00158)	
FDI_upstream_sector (lagged)		-0.00581 (0.00379)		-0.00446** (0.00232)		-0.00434* (0.00234)
Time * FDI_upstream_sector	0.000324 (0.000346)		0.000156 (0.000389)		0.000243 (0.000404)	
Time * FDI_upstream_sector (lagged)		0.00131* (0.000819)		0.000761 (0.000600)		0.000697 (0.000625)
Time	0.00857*** (0.00227)	0.00827** (0.00467)	0.0104*** (0.00257)	0.0104*** (0.00360)	0.0116*** (0.00257)	0.0102*** (0.00361)
III	-0.0344 (0.0473)	-0.00655 (0.257)	-0.118** (0.0532)	-0.0840 (0.0702)	-0.112** (0.0531)	-0.0644 (0.0703)
FDI_sector2					-0.000979 (0.000536)	
FDI_sector2 (lagged)						-0.000144 (0.000872)
Time * FDI_sector2					-0.000383 (0.000365)	
Time * FDI_sector2 (lagged)						0.0000255 (0.000256)
Firm dummy	Yes	Yes	Yes	Yes	Yes	Yes
Obs.	50,667	30,225	39,140	23,555	39,140	23,555
Adj-R ²	0.914	0.932	0.914	0.932	0.914	0.93

Figures in parentheses are standard errors corrected for heteroskedasticity. Lagged indicates the independent variable is lagged by 1 year. *Significant at the 10% level. **Significant at the 5% level. ***Significant at the 1% level.

Conclusion

- ▶ Within the endogenous growth framework, technology spillovers take place at the firm level—level effect and rate effect.
- ▶ Empirical evidence is consistent with the theoretical predictions.
- ▶ FDI lowers short-term productivity level but raises the long-term rate of productivity growth of domestic firms.
- ▶ Backward linkages are statistically the most important spillover channel.

Extension

- To confirm the findings of this paper using data from other countries: India, Thailand, etc.
- To see if the same idea in the paper can be used to understand the impact of foreign aid on domestic firms—positive short-term and negative long-term impacts.