Spillovers from Foreign Direct Investment: Within or between Industries?*

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Abstract

This paper contributes an estimation framework to measure both technological and linkage externalities from foreign direct investment (FDI). Empirical research dealt mainly with intra-industry spillovers from FDI with restrictive treatment of inter-industry effects until recently. However, as optimal organization of the multinational corporation (MNC) involves minimization of profit losses due to leakage of technical information to competitors, host country firms within the MNC's sector experience limited productivity gains ensuing FDI. Host-country producers in other sectors may benefit. For example, MNCs transfer knowledge to local downstream clients, or outsource to local upstream suppliers. Hence, FDI substitutes within-sector domestic investment but complements it across sectors. The net impact on aggregate capital formation by host-country producers hinges on the interaction between linkages and spillovers. Estimations based on the Colombian Manufacturing Census yield the sectoral pattern of FDI spillovers displaying knowledge propagation between but not within industries. The findings reveal outsourcing relationships of MNCs with local upstream suppliers as a channel of diffusion.

JEL Codes: O41, F43, F21, F23, C52.

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1 Introduction

Foreign direct investment (FDI) by multinational corporations (MNCs) has grown without precedent recently, especially penetrating middle-income countries. During the 1990's, the growth of FDI flows trebled the growth in international trade. Most FDI flows occur among industrialized nations, as do international trade transactions. Yet, presently, the main source of international finance to developing countries is FDI. This trend has revitalized the ongoing debate over the economic impact of FDI on less developed countries.

In this paper we investigate empirically whether foreign direct investment (FDI) in a developing country generates positive externalities on local producers. Econometric evidence of their existence is rather scarce. Initial measurements of spillovers with panel data have yielded limited evidence of improvements in domestic productivity ensuing FDI partly because only *intra*-industry spillovers were considered, without allowance for *inter*-industry diffusion (e.g. Aitken and Harrison, 1999). Since MNC's locate their subsidiaries to avoid rent erosion due to local competition, other things equal, the MNC's deployment of subsidiaries via FDI is designed to minimize the risk of propagation of specific technical knowledge to potential competitors. In particular, *intra*-industry knowledge spillovers for host-country firms from manufacturing activities by subsidiaries are unlikely. Furthermore, evidence about spillovers from industrial R&D, as well as urban economic organization studies, reveals important technology diffusion between but not within industries. In a recent paper, Bloom, Schankerman and Van Reenen (2005) incorporate in the analysis of technology diffusion between firms, associated with R&D, both the positive spillover and the negative rivalry effect. The latter accounts for the loss of market share when R&D by other firms in the industry intensifies competition (i.e. business stealing by innovating firm).

In the context of FDI spillovers, the rivalry effect is more likely to dominate spillovers within the MNC's industry than between industries. Thus, the scarcity of empirical findings of *intra*-industry spillovers stemming from FDI is not surprising. If there is leakage of technical knowledge from the subsidiary to domestic producers, such spillovers are most likely to generate productivity improvements in non-competing and complementary sectors. The evidence of absence of *intra*-industry FDI spillovers in panel data studies is important because it suggests the excludability of technical knowledge. However, evidence in other contexts hints at the importance of considering *inter*-sectoral knowledge flows. Scherer (1982) finds R&D spillovers to diffuse across industries. In the context of knowledge diffusion in cities, Glaeser et al. (1992) found important spillovers between rather than within sectors suggesting returns to cross-fertilization of ideas in diverse instead of specialized environments.

To complement existing studies, measurement of technological externalities allowing for *inter*-industry spillovers requires a multisectoral dynamic set up. In the present paper, an econometric framework is developed to explore whether FDI generates externalities on manufacturing in the host country. One advantage of this approach is that, in contrast to other studies of FDI spillovers, the general equilibrium effects of FDI are identified and not only the benefits of knowledge sharing between MNCs and local suppliers. To apply this framework, a sectoral panel database was constructed merging data from the Colombian Manufacturing Census with FDI data, derived from Central Bank transaction records. We use the dataset (1) to estimate the extent of new technological opportunities for domestic manufacturers stemming from MNC operations, (2) to explore the determinants of whether ensuing adoption occurs, (3) to assess how FDI complements domestic capital formation through spillovers and linkages.

While *intra*-industry FDI spillovers are not to be expected, *inter*-industry spillovers are likely. First, if the MNC has domestic vertical linkages in the host country, subsidiaries will benefit from knowledge sharing with both clients and suppliers. On the one hand, local market penetration generates forward linkages and information flows between the subsidiary and the users of its output are beneficial to the MNC. On the other hand, outsourcing yields backward linkages leading to knowledge transfer to upstream sectors. Hence, the vertical propagation of knowhow that creates new technological opportunities for host-country producers induces *inter*-industry spillovers but industry–specific knowledge flows are bound to be limited in scope. Second, cost-reducing opportunities to producers in sectors other than the subsidiary's own do not induce rent losses to the MNC. The incentive to use resources for trade secrecy to avoid diffusion of generic knowledge is small. Therefore, generic technology, which can be deployed in production across sectors, is more likely to propagate than sector-specific technology. Third, the techniques that can be adopted from generic knowledge in manufacturing activities generally require less absorptive capacity than specialized high-tech processes.

Beyond increasing domestic technological opportunities, entry by MNC subsidiaries can cause productivity gains for host-country producers though increased competition. First, the setting up of the MNC subsidiary raises managerial incentives in host-country enterprises to make efficiency-enhancing investments because of the increased risk of a loss of market share. And second, there is a selection effect that increases average productivity of operating plants since only the fittest survive the subsidiary's competition. The pro-competitive impact of MNC entry is primarily *intra*-industry. It will tend to be deleterious to inefficient domestic producers who cannot challenge the MNC and lose market share until eventually closing down. To avoid rent loses, the MNC will target FDI to locations in which domestic competitors are unlikely to cope in the short-run even if in the very long-run the domestic industry might become more efficient.

The paper is organized as follows. After this introduction, Section 2 reviews and discusses the related literature. The theoretical and empirical research on FDI spillovers is surveyed. With regard to the sectoral pattern of spillovers, a synthesis of the implications of the literature is provided. In Section 3, the structural econometric framework and the background facts are provided, including a description of the data. Then, Section 4 contains the diagnostics and estimates from the multisector econometric framework that characterizes the impact of FDI. The results obtained from measuring the technological gap and quantifying the interaction among MNCs and domestic owned firms are used to analyze the extent and determinants of spillovers. Finally, Section 5 concludes.

2 Related Literature

This section starts with a review of the theoretical literature on MNC strategy and the implication for the impact of FDI on the host country. The general presumption about the sectoral pattern of spillovers to domestic manufacturing that emerges from these models is one of absence of *intra*-industry externalities but a likely positive impact at the *inter*-industry level. Then, a synthesis is provided of evidence from cross-section and panel data. The discussion of the econometric evidence documents that the higher expected propensity for *inter*-industry effects has not featured prominently in previous research on the impact of FDI on domestic manufacturing in the host country.

2.1 Theoretical Background

A survey of the theoretical literature about the impact of FDI on host-country industrial organization reveals that the modeled mechanisms are more likely to operate at the *inter*-industry rather than the *intra*-industry level. First, there is a body of literature on the choice by the MNC to use FDI as a mode of market penetration. The strategic considerations due to the risks of imitation and eventual replacement faced by the subsidiary are introduced (see e.g. Helpman, 1984; Ethier, 1986; Ethier and Markusen, 1996; Markusen and Venables, 1998). Second, there are models about the pecuniary externalities from FDI via the backward linkages to input markets that MNC entry can generate (see e.g. Rivera-Batiz and Rivera-Batiz, 1990; Rodriguez-Clare, 1996; Markusen and Venables, 1999). Finally, research has focused on the impact of entry by an enterprise with technological opportunities superior to local ones, such as a MNC, on incumbent domestic industry when different types of market structure prevail (see e.g. Bardhan, 1982; Varian, 1996).

First, the literature on the optimal market penetration strategy by the MNC emphasizes the minimization of the probability of imitation, especially under imperfect intellectual property rights in the host country. Organizational choices can be used to delay the emulation by domestic producers with absorptive capacity. In an incomplete contracts environment, resource and information transfer within the MNC minimize transaction costs (Ethier, 1986). Also, economies of scope stemming from product-specific R&D can explain the vertically integrated nature of MNCs (Helpman, 1984). Trade secrecy and efficiency wages are also used to mitigate technology leakage from FDI. Over time, the dissipation of technical knowledge rents if *intra*-industry spillovers materialized is mitigated as the MNC organizes production to maximize the imitation lag (Ethier and Markusen, 1996). The location of the MNC subsidiary minimizes rent erosion due to copying by local firms. Proximity to potential competitors with absorptive capacity to reverse engineer proprietary technology would be detrimental to the MNC, and subsidiaries will be set up where potential rivals cannot erode its market share (Markusen and Venables, 1998). Since the MNC can benefit from knowledge diffusion when it reaches downstream clients and upstream suppliers, it will encourage vertical flows of generic knowledge leading to *inter*-industry spillovers. Linkages can be a propagation mechanism for technological externalities above and beyond the pecuniary externalities highlighted by Hirschman (1977).

Second, some of the literature on backward linkages emphasizes the static effect of the increased demand by the MNC for local intermediate inputs (Rivera-Batiz and Rivera-Batiz, 1990). More recent models emphasize the dynamic effect on host-country productivity ensuing expansion of both the demand and supply of intermediate inputs and services (Markusen and Venables, 1999). Not only do incumbent upstream sector producers benefit but also the MNC, may start providing goods or services that were previously unavailable in the host country. Thus, MNC operations can induce local availability of new intermediate services and inputs, and thereby a nexus between FDI penetration and growth in the productivity of downstream manufacturers (Romer, 1994; Rodriguez-Clare, 1996).

Hence, the impact of FDI goes beyond the change in utilization of the host-country factor endowment that improves allocative efficiency, the type of static effect traditionally emphasized in trade theory, and may include improvements in technical efficiency. As the entry of the MNC induces the supply of new intermediate inputs, the productivity of downstream local firms can be enhanced due to a feasible increase in specialization. The direct demand effect on upstream sectors is primarily an *inter*-industry phenomenon. The indirect input-availability effect on downstream sectors is likely to be stronger at the *inter*-industry level than *intra*-industry. If outsourcing can benefit the competitive fringe in ways that cannot be avoided through exclusive contracts, in-house supply will be chosen.

Finally, whether the potential benefits of FDI materialize or not depends on the market structure in the host country. When demand in the host country is inelastic because of reduced availability of substitute goods, FDI yields higher rents for the MNC as local presence facilitates market penetration. Then, limited domestic competition relative to international competition means that FDI is more profitable to the MNC. Furthermore, competition from imports limits the attractiveness of imitation for domestic enterprises (Bardhan, 1982). Other things equal, the MNC will seek to set up subsidiaries in countries in which the market structure yields less direct competition within its industry but in which upstream sectors are competitive. Hence, FDI will be associated with situation in which there are few direct competitors and many input suppliers resulting in limited *intra*-industry spillovers but a positive impact at the *inter*-industry level.

The models in the literature imply that *inter*-industry positive externalities to host-country producers are much more likely than *intra*-industry gains in productivity ensuing FDI. For the MNC, technological spillovers from FDI represent a benefit when they diffuse downstream and upstream but a loss when they diffuse within the subsidiary's industry. Hence, the subsidiary will be deployed so as to minimize horizontal spillovers of industry specific knowhow to competitors while encouraging vertical flows of generic knowledge to complementary sectors. Yet, the higher expected propensity for *inter*-industry effects has not featured prominently in empirical research about the impact of FDI on domestic manufacturing in the host country. Furthermore, the large positive gap in terms of absorptive capacity required to adopt specific vis-à-vis generic technologies means that diffusion between rather than within sectors is more likely.

2.2 Empirical Evidence

Due to data limitations, until recently, empirical evidence on FDI spillovers was made up of case studies. The picture that emerged from the early literature has been important in guiding progress in the theory of FDI. The evidence has provided us with information about the mechanisms whereby MNC entry and presence can affect industrial organization in the host-country. This research emphasized linkages, labor turnover and demonstration effects. Recently database development has afforded the possibility of econometric testing on spillovers and dynamic analysis has been conducted as panel data has replaced cross-section data.

2.2.1 Evidence from Cross-Section Data

Initial efforts to conduct econometric testing of FDI spillovers were limited in scope due to lack of data. In particular, only cross-section databases were available, or in the best of cases collections of cross-sections for a few years. Therefore, it was not possible to follow over time what the impact of MNC entry and permanence was on domestic enterprises. Since technological diffusion is essentially a dynamic phenomenon, the conclusions that can be drawn in these studies based solely on contemporaneous effects have serious limitations. In particular, these findings are subject to simultaneity and endogeneity biases. Therefore, it is not possible to establish causality with any confidence. Yet, this early econometric literature is important as a first approximation to quantify the mechanisms documented in case studies.

The econometric examination of spillover patterns started with the use of cross-section sectoral data. Pioneering studies searched for intra-industry spillovers in Australia and Canada respectively (Caves, 1974; and, Globerman, 1975). The approach was to estimate sectoral production functions, with the share of MNC affiliates as an explanatory variable. In both cases, there is a positive correlation between domestic enterprise productivity and subsidiary productivity. Although this pattern is consistent with FDI externalities, the aggregated results lack statistical power to discern the causal nature and magnitude of spillovers. Mexican data reveal the same pattern (Blomstrom and Persson, 1983).

Subsequent analyses conjectured that spillovers are more likely in some industries than others. In concentrated industries, where there is a wide technology gap between local producers and MNCs, externalities from MNC presence are unlikely to materialize. Indeed, it is found that in Mexican manufacturing, there is a positive correlation between foreign presence and local productivity only in sectors where the market share of MNC affiliates is low (Kokko, 1994). A similar pattern for Uruguayan manufacturing is found (Kokko, Tansini and Zejan, 1996).

Finally, there is evidence that the incentives for the MNC to transfer state-of-the-art technology are higher when the host-country competitive fringe faces lower barriers to entry. Blomstrom, Kokko and Zejan (1992) find that in consumer good industries, with relatively low intensity in complex technology and with low capital requirements, MNCs deploy more advanced technologies to overcome the disadvantages of alien status. The way for MNCs to outdo competitors is to keep one step ahead. In principle, as the authors conclude, a more competitive local market structure leads to an increase in the potential for spillovers due to the increase in technology flows. However, the authors do not test whether it is the case that there is local adoption of these more advanced techniques.

2.2.2 Evidence from Panel Data

By and large the first panel studies about FDI spillovers in less developed countries, conducted in the 1990's, find the absence of a positive *intra*-industry productivity effect (Haddad and Harrison, 1993; Harrison, 1996; Hoekman and Djankov, 1998; Aitken and Harrison, 1999). The empirical findings are derived respectively from panel data of manufacturing plants in Morocco, Cote d'Ivoire, the Czech Republic and Venezuela. The empirical pattern uncovered where increases in MNC market share are detrimental to local producers in the subsidiary's industry is denoted "enclave formation." These results are not surprising in light of the above discussion of the theoretical literature, which predicts *inter*-industry rather than *intra*-industry spillovers. However, none of these studies considers the empirical possibility of *inter*-industry externalities in the econometric estimation. It is revealing that the one study that considers the diffusion of generic rather than industry-specific technology finds evidence consistent with FDI spillovers. The operation of export oriented MNC subsidiaries in Mexico is associated with a higher propensity for domestic enterprises to enter foreign markets (Aitken, Hanson and Harrison, 1997). The finding highlights the potential positive effect on host-country manufacturing of the diffusion of MNCs' generic knowhow about how to export, including information on standards, market access and distribution channels.

The reported findings about FDI spillovers in Cote d'Ivoire, the Czech Republic, Morocco and Venezuela constitute the first attempts to measure externalities from MNC activities using longitudinal data. The stylized fact of spillover absence emerging from these studies contrasts with previous evidence of spillovers in cross-sectional data. However, the exclusively *intra*-industry character of possible externalities allowed in the specification of the empirical estimations is limiting. While the positive contemporaneous correlation between highly aggregated sectoral productivity and sectoral FDI flows in cross-sectional data could reflect a causal relation in either direction, the nonpositive (i.e. negative or insignificant) correlation in panel data confirms one of the implications from the theoretical literature. [1]

The importance of inter-industry spillovers has been recognized and documented for a long time in studies about R&D and productivity (e.g., Romeo, 1974; Scherer, 1982). More recently Glaeser et al. (1992) have provided robust evidence showing that important knowledge spillovers occur between rather than within industries. The finding confirms Jacobs' (1969) conjecture that innovation is more likely to prosper in diverse rather than specialized environments. In the context of FDI spillovers, only recently, in Kugler (2000), was the need to allow for *inter*-industry effects in panel data studies recognized. Otherwise it is not possible to verify the sectoral pattern described above about the impact of FDI on host-country industrial organization. Since then, the finding of limited intra-sectoral spillovers but ample inter-sectoral effects from FDI via backward linkages has been documented also for Indonesia (Blalock, 2001), Lithuania (Smarzynska, 2004) and Mexico (Lopez, 2003).

The estimation of the extent of new technological opportunities for domestic manufacturers stemming from MNC operations includes potential effects within the subsidiary's sector as well as across other sectors, but is not limited to backward linkages. FDI impacts upon domestic producers both directly through backward linkages to suppliers, as documented in the papers mentioned above, and indirectly through enhanced input availability. By stimulating upstream sectors MNCs may also benefit other downstream local producers as cheaper inputs become available, as pointed out in Kugler (2000) and Blalock and Gertler (2004). The structural estimation framework specified next allows for not only for technological spillovers but also the latter pecuniary externalities. Hence, we will identify not only the direct benefit from FDI on the MNC's local suppliers but also the general equilibrium effect arising from enhanced intermediate input availability.

[1] In their study about the impact of FDI on domestic productivity using panel data for the UK manufacturing sector, Haskel, Pereira and Slaughter (2002) actually find evidence of a positive intra-industry effect when a sufficiently propagation lag is allowed for. This finding illustrates the importance of absportive capacity to make imitation, albeit with a delay, possible. More recently, Keller and Yeaple (2003) have documented evidence consistent with intra-industry spillovers.

3 Estimation Framework and Data Description

In this section a stochastic multisectoral dynamic general equilibrium model is set up in which firm-level investments can generate spillovers both within and across sectors. The characterization of externalities, in the model, is based on the Arrow-Romer specification of Marshallian externalities leading to aggregate increasing returns (Arrow, 1962, and Romer, 1986). But as suggested by Jacobs (1969), Scherer (1982) and Glaeser et al. (1992) productivity of manufacturing in any sector can be potentially influenced by investment in other sectors heterogeneously. The possible sectoral configurations of externalities from investment by MNC subsidiaries that results from our reduced form are very general. The analytic solution which leads to the structural estimation framework allows for both *inter*- and *intra*-industry externalities. The reduced form derived parameterizes the interaction of linkages and spillovers. First, the technology and preferences are set up. Then, the dynamic programming problem is solved and the competitive equilibrium with externalities is characterized. Finally, conditions to rule out indeterminacy are identified to derive the balanced growth path and the estimation framework.

The estimation framework is designed to analyze the dynamics of spillover diffusion and is based on the error correction model representation of a bivariate vector auto-regression of sectoral domestic productivity and sectoral capital formation by MNCs. The reduced-form set up is related to that used in Kugler and Neusser (1998) to analyze the link among financial development and productivity growth, and follows the methodology proposed by Johansen (1991). The analysis of short-run and long-run dynamics is used to estimate the persistent impact of FDI and to establish the causal link between capital formation financed through FDI and the productivity of domestic manufacturers in the host country.

3.1 A Model of Sectoral FDI Spillovers

The model is one of competitive equilibrium with endogenous technological change.[2] Knowledge is an input with increasing marginal productivity created as an observable by-product of investment by individual firms (Romer, 1986). The model is multisectoral and allows for both learning by doing and learning by observing, within as well as between industries. There are complementarities among the investment paths of various manufacturers because the knowledge from accumulated experience disseminates yielding cross-fertilization. Learning from production generates technological progress that diffuses and generates increasing returns external to the firm. When new knowledge is sector specific, the increasing returns are internal to the industry. If new knowledge is generic and can be deployed across industries, it can generate aggregate increasing returns and endogenous growth.

[2] The sectoral structure is based on the models of Long and Plosser (1983) and Neusser (2001).

Furthermore, backward and forward linkages appear when output from one sector serves as an input in building capital in another sector. These linkages provide a potential diffusion channel of sector-specific knowledge through both profitable knowledge exchange and embodied productivity enhancements.

3.1.1 Technology

Suppose that there are n sectors in the economy, with producers differentiated among domestic and foreign. There is perfect competition and the production function for each atomistic producer with headquarters in *h*, home or abroad, in each sector *i* is given by,

$$Y_{iht} = \xi_{iht} E_{ih} K_{iht}^{\alpha_i} H_{iht}^{1-\alpha_i} X_{iht} \qquad (1),$$

where the first term is a technology shock, E_{ih} is a fixed effect, K_{it} and H_{it} are the stocks of physical and human capital respectively, and X_{it} captures technological spillovers to be specified below. The motion equation for capital accumulation is given by,

$$K_{iht+1} = K_{iht}(1-d_{ih}) + \eta_{it+1} + \sum_{j=1}^{n} \delta_{ihj} I_{ijt}^{h} \qquad (2),$$

for i = 1,...,n, where K_{ih0} is given and I_{ijt}^{h} denotes gross investment in good j for accumulation of capital for production in sector *i* in a firm with headquarters in h, domestic or foreign.

Externalities are specified in the Arrow-Romer fashion as,

$$X_{iht} = \sum_{j=1}^{n} \gamma_{ijD} K_{jDt} + \sum_{j=1}^{n} \gamma_{ijF} K_{jFt} \qquad (3),$$

where the matrix $\gamma \equiv \{\gamma_{ijh}\} \geq 0$ and γ_{ijh} is a measure of the technological spillover emanating from investment in sector j by firms headquartered in h to productivity in sector i.

3.1.2 Preferences

The intertemporal preferences of the representative agent over the stochastic sequences of the consumption profile $\{C_t\}_{t>0}=\{(C_{1t},..,C_{nt})'\}$ are to choose the plan that maximizes the expected utility functional $E_0 \sum_{t=0}^{\infty} \beta^t U(C_t)$, with $\beta < 1$. Also, assume that instantaneous utility is separable over goods,

$$U(C_t) = \sum_{j=1}^{n} \theta_j \ln C_{jt}, \qquad (4),$$

with $\theta_j \geq 0$. If this condition is binding, then good j has no value for direct consumption. Suppose that at least some j has consumption value and $\theta_j > 0$. In particular, $\theta = (\theta_1,...,\theta_n)' > 0$.

3.1.3 Resource Balance

The model is closed with the appropriate resource balance conditions. We assume that the rate of transformation among consumption and investment is perfect so that,

$$C_{jt} + \sum_{i=1}^{n} I_{ijt} = Y_{jt} \qquad (5),$$

for each sector j. With respect to the initial capital stock $K_0 = (K_{10},..., K_{n0})$, an initial distribution among consumers is assumed.

The solution strategy we follow is the one proposed by Romer (1986). The competitive equilibrium is computed in two phases. First, the optimal policy rules for investment in each sector and the consumption profile chosen by the representative agent are derived taking the path of externalities as given. Second, the sectoral capital accumulation path, given the aggregate externalities implied by individual optimal decisions, is characterized on the basis of the policy rules derived in the first phase. It is then verified that the sectoral paths satisfy the resource balance conditions to insure that there is mutual consistency among the aggregate equilibrium and individual optimality.

The state of the economy in period t is given just by the sectoral capital stocks as the technology shocks of the preceding *p* periods are white noise, $S_t = (K_{1t},..., K_{nt})$'. The externality pattern in period t is given by, $X_{t+1} = X(K_{t+1}) = X(K_t, \eta_{t+1})$. With this notation in hand, the first step consists in solving the Bellman Equation of the representative agent's problem at each point in time. To solve the problem first we note that the above functional is stationary,

$$V(S;X) = \max_{(I_{ij}, H_i)} \left\{ \sum_{j=1}^{n} \theta_j \ln(C_j) + \beta EV(S';X') \right\} \text{ s.t. } \qquad C_j + \sum_{i=1}^{n} I_{ij} \leq Y_j \qquad (7),$$

where the expectation is formed with regard to the technology shocks and primed variables are next period's. In particular,

$$V(S_t;X_t) = \max_{(I_{ijt}, H_{it})_{1\leq i,j\leq n}} \left\{ \sum_{j=1}^{n} \theta_j \ln\left(Y_{jt} - \sum\nolimits_{i=1}^{n} I_{ijt}\right) + \beta \int V(S_{t+1};X_{t+1}) Q(S_t, X_t) dS_{t+1} \right\} \quad (8),$$

where *Q(.,.)* is the transition function implied by the Markov process of the shocks to production and accumulation. Note that in this problem, *X(.)* is exogenous.

Then, from the first order necessary conditions the following optimal policy rules for investment and consumption are obtained as,

$$I_{ij} = \frac{\beta b_i \delta_{ij}}{\theta_j + \beta \sum_{i=1}^{n} b_i \delta_{ij}} Y_j = \varphi_{ij} Y_j \qquad (9),$$

and

$$C_j = (1 - \sum\nolimits_{i=1}^{n} \varphi_{ij}) Y_j = \frac{\theta_j}{\theta_j + \beta \sum_{i=1}^{n} b_i \delta_{ij}} Y_j \qquad (10),$$

where $$b_i = \frac{\alpha_i \theta_i}{1 + d_i - \beta \sum_{j=1}^{n} \alpha_j \delta_{ij}} \qquad (11),$$

is the private shadow price of sectoral capital derived from the Benveniste-Scheinkman equation and which is completely independent of the extent of knowledge spillovers. Since agents take externalities as given, the private value of capital investment is lower than the social value. On the balanced growth path of the competitive equilibrium with externalities accumulation is suboptimal (Romer, 1986).

3.1.4 Equilibrium Path

These solutions imply the following reduced form for accumulation on the equilibrium path, future sectoral capital stocks are determined by the primitive parameters characterizing preferences and technology, by the capital vector from the previous period,

$$k_{\mathrm{iht+1}} = (1 - d_{ih}) k_{iht} + \eta_{\mathrm{iht+1}} + \sum_{i=1}^{n} \left[\delta_{ij} \left(\frac{\beta \delta_{ihj} b_{ih}}{\theta_j + \beta \sum_{i=1}^{n} \delta_{ihj} b_{ih}} \right) + \xi_{jht} + \alpha_{jh} k_{jht} + (1 - \alpha_{jh}) h_{jht} + \sum_{h=D,F} \sum_{l=1}^{n} \gamma_{jhl} k_{lht} \right] \qquad (12).$$

The Cobb-Douglas technology implies that the allocation of human capital is stationary. In particular, where the aggregate human capital stock is normalized,

$$h_i = \frac{(1 - \alpha_i)(\theta_i + \beta) \sum_{l=1}^{n} \delta_{lj} b_l}{\sum_{j=1}^{n} (1 - \alpha_j)(\theta_j + \beta) \sum_{l=1}^{n} \delta_{lj} b_l} \qquad (13).$$

Changes in productivity due to technology shocks are exactly offset by changes in prices that preserve the marginal revenue product unchanged.

The reduced form of the capital accumulation process can be viewed as an operator that transforms *X(.)* into the corresponding competitive equilibrium. Concavity guarantees that the operator has a unique fixed point. The fixed point is found identifying the path of the capital stock vector resulting from the optimal policy rules in (10) with the given externalities being replaced by the multisector effects from the actual capital accumulation choices. The logarithm of the state variable, namely the sectoral capital vector, with domestic stocks stacked up on top of foreign, can be characterized by the following first-order differential equation,

$$\Delta \underline{k}_{\mathrm{t+1}} = \underline{c}_k + (A - I_n) \underline{k}_t + \underline{\varepsilon}_{\mathrm{t+1}} \qquad (15),$$

in which $\underline{c}_k$ is a 2n-dimensional vector of constants, A is a 2n x 2n matrix of constants and $\varepsilon_{\mathrm{t+1}}$ is a 2n-dimensional vector of MA(1) processes.

Therefore, $\{k_t\}_{t>0}$ has the structure of a vector-autoregressive process except that the innovation is not white noise. In fact, the innovation is a MA (1) process and therefore $\{k_t\}_{t>0}$ is a vector autoregression (VAR) with components following ARMA (1,1) processes. In particular, aggregate growth depends on both sector-ownership *ih* specific incentives for investment, such as depreciation and the output elasticity with respect to capital, as well as on the structure of sectoral interdependence. The *inter*-industry effect arises potentially because of both linkages to upstream and downstream sectors as well as technological spillovers.

The matrix *A* determines the growth pattern of the system. For example, if for all *ih*, $\alpha_{ih} < 1$, balanced growth implies some technological externalities. Convergence to a balanced growth path requires that the diagonal elements of *A* are strictly positive,

$$a_{ihi} = d_{ih} + \delta_{ihi}\alpha_{ih} + \sum_{h=D,F}\sum_{l=1}^{n}\delta_{ihl}\gamma_{lih} > 0 \qquad (16).$$

This inequality is violated if and only if simultaneously there is instantaneous depreciation (d_{ih} = 0), there are no within industry intermediate inputs ($\delta_{ihi} = 0$), and for each sector j, either the sector does not any generate externalities ($\gamma_{lih} = 0$) or does not generate intermediate inputs for any other sectors ($\delta_{ihl} = 0$). Hence, the estimation framework does not rule out *intra*-industry spillovers.

The off diagonal elements are given by,

$$a_{ihj} = \delta_{ihj}\alpha_{jh} + \sum_{h=D,F}\sum_{l=1}^{n}\delta_{ihl}\gamma_{ljh} \qquad (17).$$

The first term captures the forward linkage effect, i.e. with $\delta_{iDj} > 0$, FDI in sector *j* enhances input supply for domestic firms in sector *i* and this induces more domestic investment. The later sum of terms captures the effect of FDI through the interaction of linkages and spillovers. For example, if $\delta_{iDl} > 0$ so that output from sector *l* is an input for domestic producers in sector *i* and $\gamma_{ljF} > 0$ so that there are spillovers from MNC's in sector *j* to producers in sector *l*, then FDI in sector *j* will indirectly benefit sector *i* domestic producers by making sector *l* more productive. Studies on backward linkages as a propagation mechanism for FDI spillovers concentrate solely on the information flow of the MNC subsidiary on its direct local suppliers. Here, we also consider the indirect effects of FDI due to the interaction between the upstream MNC supplier and other domestic producers.

In order to explore the impact of FDI on the technological opportunities of host-country manufacturing across sectors, it is necessary to tie the sectoral structures of capital accumulation and total factor productivity (TFP). To do so, the corresponding VAR and vector error correction representation (VECR) are derived to characterize both cointegrating and causal relations among investment and technical progress. The diffusion of externalities from FDI implies causation, in the

Wiener-Granger sense, of FDI inflows TFP growth in domestic manufacturing across sectors.

In particular, establishing long run co-integration between capital accumulation by MNCs in some sectors and productivity in others is not sufficient to conclude that spillovers take place. It could be that the high productivity of domestic manufacturers reflects abundance of factors in which the MNCs' technologies are intensive, thereby stimulating FDI inflows. To provide evidence corroborating the importance the diffusion of externalities from FDI, the causation of higher cross-sectoral local productivity by FDI must be shown.

3.1.5 Estimation Framework

For the estimation, we note that the stochastic process $\{y_t\}_{t>0}$ has the same number of stochastic and deterministic trends and therefore the same number of cointegrating relations as $\{k_t\}_{t>0}$. Furthermore, the total factor productivity process is given by $\{z_t\}_{t>0} \equiv \{ y_t - \alpha k_t - (1-\alpha) h \}_{t>0}$, and can be related to capital accumulation as follows,

$$\underline{z}_t = \underline{y}_t - \alpha \underline{k}_t - (1-\alpha)\underline{h} = \ln \xi_t + \underline{e} + \gamma \underline{k}_t \qquad (18),$$

where lower-case variables are vectors of logarithms of upper-case ones, with sectoral domestic values stacked up on top of foreign ones.

Furthermore, when the sectoral capital stock and TFP observations are combined, the system can be written as,

$$\begin{pmatrix} I_n - AL & 0 \\ -\gamma & I_n \end{pmatrix}\begin{pmatrix} k_t \\ z_t \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} I_n & \delta L \\ 0 & I_n \end{pmatrix}\begin{pmatrix} \ln \eta_t \\ \ln \xi_t \end{pmatrix} \qquad (19),$$

where $c_z \equiv e = (\ln E_{1D}, \ldots\ldots, \ln E_{nD}, \ln E_{1F}, \ldots\ldots\ldots, \ln E_{nF})'$, and in particular,

$$\begin{pmatrix} k_t \\ z_t \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} A & 0 \\ \gamma L^{-1} & 0 \end{pmatrix}\begin{pmatrix} k_{t-1} \\ z_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \ln \xi_t \end{pmatrix} \qquad (20).$$

This expression implies a cointegrating relationship among capital accumulation and productivity. The multisectoral structure of investment is linked to the dynamics of economic growth. In particular, in the VECR below it will be apparent that the reduced form of the structural model implies causation of higher domestic productivity growth by FDI inflows but not vice versa. Backward and forward linkages among sectors impact aggregate physical capital accumulation through pecuniary externalities. Also, both learning by doing and demonstration effects captured by *inter*-industry spillovers generate technological externalities, which drive productivity growth. These implications will be explored econometrically.

The causality analysis of the cointegrated system is based on the approach due to Johansen (1991). Assume that the 2n-dimensional stochastic process $\{X_t\}$ is generated by a Gaussian k-th order VAR. By making the appropriate definitions, the VAR derived in (19) above can be written as a VECR which is its Wold representation:

$$\Delta\Lambda_t = \kappa + \Psi(L)\Delta\Lambda_{t-1} + \Pi\Lambda_{t-k} + u_t = \begin{pmatrix} \Delta\Lambda_{1,t} \\ \Delta\Lambda_{2,t} \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} \psi_{11}(L) & \psi_{12}(L) \\ \psi_{21}(L) & \psi_{22}(L) \end{pmatrix} \begin{pmatrix} \Delta\Lambda_{1,t-1} \\ \Delta\Lambda_{2,t-1} \end{pmatrix} + \begin{pmatrix} \pi_{11} & \pi_{12} \\ \pi_{21} & \pi_{22} \end{pmatrix} \begin{pmatrix} \Lambda_{1,t-k} \\ \Lambda_{2,t-k} \end{pmatrix} + \begin{pmatrix} u_{1,t} \\ u_{2,t} \end{pmatrix} \quad (21),$$

where κ is a vector of constant drifts, $\pi_{ij}(L)$ are polynomials of order k-1 in the lag operator L, and Λ_1 and Λ_2 are the sectoral capital stock and productivity vectors. This can be used to assess the causal structure of the system. To establish that the comovement among the investment patterns of MNCs and the TFP of domestic manufacturers is due to the diffusion of externalities from FDI, the null hypothesis $H_0 : \pi_{21}(L) = 0$ must be rejected, and $H_0 : \psi_{21}(L) = 0$ for short-run causality.

3.2 The Data

Due to the dynamic nature of the diffusion process, FDI spillover estimation requires to follow sectors longitudinally. Consequently, the information needed to analyze FDI spillovers includes a panel database with sufficient variables for productivity measurement, and also information on foreign ownership structure. To construct such series, data from the Colombian Manufacturing Census were merged with Central Bank data on recorded FDI transactions. An interesting aspect about the Colombian case, beyond the availability of high quality data, is the liberalization of investment flows, which took place in 1991. Financial reform affected the FDI statute. Law 9 of 1991, eliminated restrictions affecting FDI, established national treatment, and eliminated the requirement of obtaining prior approval. Additionally, existing limits on the percentage of profits that foreign firms could transfer to headquarters were also eliminated.

In this section, the nature of the merged data is explained. Also, summary statistics are provided. Then, some industrial dynamics indicators are summarized on turnover rates and the age distribution of plants. Finally, the productivity measurement methodology is developed and discussed. The data set developed for the present study includes information from the Colombian Manufacturing Census and the records that those MNCs engaging in FDI in Colombia are legally bound to register at the Central Bank. The Census is based on annual surveys by the National Statistics Bureau of Colombia of firms with more than ten workers. Data are recorded on each plant's geographic location, industry, age, capital structure, investment flows, expenditures on labor and materials, and value of output sold. The variables in the plant-level panel database yield a wide range of observable characteristics. The records of individual FDI transactions are kept in the Central Bank and the variables derived from them are the amount of the transaction, the country of origin and the identity of the recipient firm.

3.2.1 The Manufacturing Census

The Census covers manufacturing plants since 1974 until 1998. For each plant there is information on (1) employment and employee compensation of different types of workers, (2) book values, purchases and sales of different types of capital inputs, (3) sales, production and value added and (4) information on other plant characteristics including location and age. Each plant has an identification code, which allows for plants to be tracked over time.

On average plants in the sample are small. Over the period of the Census, 58% of the plants have less than 50 employees and 34% have less than 20 employees. Only 7% of the plants have more than 200 employees. The smaller plants tend to exhibit the highest turnover. The plants continuously present in the sample account for an average share of the workforce over 1974-1991 of 63% and an average share of the product of 71%. This implies that larger plants are more stable and productive.

The geographic distribution of plants over metropolitan areas is also very stable. Plants are concentrated in the two largest cities, which are in the interior Andean region. On average over the years, 32% of plants have operated in Bogotá and 19% in Medellin. Of the remainder, Cali, the largest city in the Pacific region, has been host to 11% of the manufacturing plants and 7% of the plants have located in the two largest cities in the Caribbean region, Barranquilla and Cartagena. Hence, we have that 51% of the plants in the Census are in the two largest cities and 69% in the five largest metropolitan areas.

Over the period of study, the industries with the largest number of plants, according to the ISIC 3 digit groupings, have been food, beverages and tobacco (31), textiles and apparel (32) and metal products (38). However, the trend has a clear break in 1991 when international trade and foreign investment were liberalized. In the textile and metal products industries, there were widespread shutdowns. In textiles, foreign competition drove many local producers into bankruptcy. In basic metals, tariff-jumping FDI ceased because of the possibility of importing. Foreign owned operations were closed. In contrast, the number of establishments in the food industry grew in spite of the competition from foreign products. In fact, this industry was recipient of substantial inflows of FDI.

For the years from 1976 to 1979 we have a variable that reports the year in which operations began. For plants that are not observed over this period, we determine the age according to the first year in which the plant appears. The number and percentage of plants older than 20 years grows steadily from being about 16% of the total in 1974 to 38% in 1998. The proportion of plants younger than 5 years remains nearly constant about 29%. Therefore, the attrition rate for some plants has grown over time, especially of those between 5 and 20 years old. This rise in the failure rate beyond the initial stages of development of the plant is consistent with two mechanisms that select productive plants: firms learn about their own efficiency over time (see e.g. Jovanovic, 1982; and Hopenhayn, 1992) and stronger competition due to increasing openness of the Colombian economy.

The joint distribution of plants according to age and employment was characterized over five year intervals. The average plant employment rises with age. In particular, the plants with more than 100 employees are mostly older than 10 years. Also, 68% of plants older than 15 years have more than 50 employees. The pattern that emerges is one in which surviving plants grow over time. This is consistent with both selection mechanisms highlighted above.

3.2.2 The FDI Data

The series for sectoral FDI are built on the basis of transaction records kept at the Central Bank's International Exchange Department. These records contain information on all direct investments made by foreign corporations in Colombia since the 1970's. The information available includes the amount of the transaction in US dollars, the country where the investing firm is based and the identity of the firm in which the investment is being made. Hence, not only can the yearly inflows of FDI be classified by sector and country of origin but also the firms in the Manufacturing Census which have been recipients of FDI can be identified. This disaggregation is very important in the measurement of how MNC's impact domestic industrial organization.

The sectoral and geographical patterns of FDI inflows to Colombia have shown a fair amount of change during the period of study. This reflects both industrial evolution and important policy regime shifts over the past two decades. During the 1970's, an average of 73% of FDI inflows where targeted to manufacturing. Investment was concentrated in chemicals (35), equipment and machinery (38), basic metals (37) and food (31). About half of these inflows originated in the US with the remainder coming almost all from Europe. In the 1980's, mining attracted more than double the amount of FDI than did manufacturing. Within the manufacturing industry, FDI concentrated in the same four sectors as it had in the previous decade. The geographical pattern of FDI also changed. The source of most FDI was still the US with the rest originating in Europe but the US share rose to an average of 92%.

After the market oriented reforms of 1991, FDI inflows have risen. The industries that have registered the highest growth in FDI inflows are banking and manufacturing. The deregulation of the financial system coupled with the removal of restrictions in the transactions by MNCs lead to a substantial flow of investment by foreign banks. In manufacturing, the inflows of FDI grew exponentially over the five years after the reforms with a fourfold increase of FDI in 1998 relative to 1991. While investment from abroad disappeared in basic metals, it surged in the paper and publishing sector. Also, FDI increased rapidly in, chemicals, equipment and machinery as well as food processing.

The pattern of geographic origin of FDI changed substantially in the 1990's relative to the previous two decades. The share of FDI from the US fell although the level of FDI inflows to Colombia originating in the US rose somewhat. The fall in the US share of FDI, to its observed value in the 1970's, was made up by staggering increase in both the share and level of FDI originating in the Caribbean. The US share was 48%; the Caribbean share 31% and the European share 17%. Since the Caribbean share originates mainly from countries that are tax havens and which are used for purely financial transactions, it is not clear how the removal of barriers to FDI has induced changes to this geographic pattern.

3.3 The Measurement of Technical Efficiency

In the measurement of technical efficiency as a residual, we attempt to remove from the productivity estimate all contributions that are not technological. The contribution of various factors in the production of output is to be decomposed. Both the labor force and the capital stock contribute to production depending upon their quality. The quality of the inputs corresponds to attributes embodied in them and not strictly to the production technology in use but is not observed directly. Although the quality of inputs and the technology are distinct, there is an identification problem in discerning them quantitatively from the productivity residual because they both are decided as part of the plant's optimal plan.

But, even if human and physical capital are measured without error, to estimate technical efficiency from the productivity residual account must be taken for returns to scale and capacity utilization (See e.g. Hall, 1988). If these are not controlled for, changes in production may be wrongly attributed to changes in technology. Another potential source of bias in productivity measurement is the imputation of factor shares as elasticities normally performed in constructing Divisia indices.

When input markets are imperfect, factor shares do not necessarily reflect input product elasticities. Since labor and capital markets are not likely to be perfect in Colombia, technical efficiency is estimated from a production function framework. Indeed, average factor remunerations do not match elasticities. The labor share for various types of workers is such that the marginal revenue product of labor is greater than the wage plus other compensation.

3.3.1 Human Capital

We weigh workers in different categories by their relative wages to adjust for quality, thus obtaining a human capital index (See e.g. Griliches and Ringstad, 1971). The labor force of the plants in the Census is classified in five categories: management, nonproduction employees, local technicians, foreign technicians, and production workers.

The estimation of the human capital index consists of a weighted average of workers by categories where the weights are given by the ratio of per capita wages in the category to per capita wages for production workers. In estimating the index, an implicit assumption is that the labor market values workers according to their productivity or ability to transform inputs into value added. Even is the labor market is not perfectly competitive, it is plausible to assume that wages and productivity are linked.

3.3.2 Physical Capital

Throughout the period 1974-1998, we consider four types of physical capital: buildings and structures; transport equipment; machinery and equipment; and office equipment.[3] The perpetual inventory methodology was used to construct capital stocks. Constant depreciation rates were imputed based on assumptions about the useful lifetime of different types of capital. In particular, the expected lifetime of buildings was set to be 50 years, of transport equipment as well as machinery to be 20 years, and for office equipment the assumption was of 10 years before scrappage.[4] For the initial value of capital we used the book value reported in the first year of the sample.

The method assumes perfect substitutability across vintages of capital and constant decay of the capital stock. Therefore, the retirement rate of machinery is independent of the age distribution of the capital stock. Technical obsolescence induced by innovation is not taken into account. The physical stock of capital not only deteriorates due to wear and tear but also loses value as the vintage is older. However, as Hulten and Wykoff (1981) have shown, there is an identification problem in trying to separate these effects econometrically even if we had the asset prices of each vintage for different types of capital.

Thus, we use the plants' initial operations date to get an idea of the importance of the vintage effect. Other things equal, if the vintage effect were dominant, newer plants should have more modern capital in operation even taking into account retooling and scrapping by old firms, the older plants' machinery should still be older. And, if the vintage effect were strong enough, it would show up in the productivity differential across plants. Yet, it is not the case that productivity is higher among younger plants.

Our calculations reveal that since 1975 until 1996 there have been changes in the composition of investment. Out of total real net investment the share of machinery has risen steadily from 68% to 81%. The share of office equipment has also increased from 5 % to 11%. In contrast, the share of both transport equipment and structures has fallen. The former had a drop in participation from 13% to 2%. The investment in building and structures went from accounting for 14 % of real net investment by manufacturing plants in the census to account for 6 %. This pattern is revealing of the importance of

[3] Land is not used because its valuation is affected by aspects irrelevant to the production process, which are likely to introduce noise in our estimation.

[4] Harberger (1969) obtained these estimates for Colombian manufacturing. For the US, Hulten and Wycoff (1981) have estimated yearly depreciation rates of 0.036 for buildings and 0.1179 for equipment. Using a perpetual inventory methodology, expected lifetimes of 30 years for buildings and 8.5 years for equipment result. The respective figures derived by Harberger for Colombia are reasonable if we take into account that obsolescence sets in much slower in developing countries.

embodied technology. The intensity of use has shifted from physical plant and transportation to equipment and computers. Investments in the latter categories are the most likely to report productivity improvement and the distribution of investment suggests it.

4 Technological Opportunities and FDI

In this section, the empirical results with respect to the diffusion of externalities from FDI are analyzed. First, the stationarity of the sectoral series for productivity and capital formation is assessed. Then the evidence on cointegration among FDI and TFP across sectors is used to ascertain the configuration of spillovers. Next, follows a discussion of the implications of the evidence for absorptive capacity and diffusion. Finally, the findings on causality among FDI and *inter*-sectoral TFP are used to reject the alternative hypothesis to FDI spillovers, also consistent with the cointegration evidence, that FDI flows and sectoral productivity patterns are driven by a common factor but are not interdependent.

4.1 Capital Formation and Productivity Growth

In Table 1, the sectoral average growth rates in the 1974-1998 period of the capital formation and TFP series, for both domestic manufactures and MNCs, are presented. By and large the growth rates are positive. Among domestic producers, aggregate investment has grown yearly by more than 3% but TFP just over 1%. Average yearly investment has been even across sectors. In terms of productivity, the two domestic leading sectors have been paper products and food and beverages. The slowest sectors in productivity enhancement have been basic metals and textiles. Among MNCs, capital and especially productivity have grown much faster over the 25 years of the sample. FDI has been concentrated in four sectors, namely food and beverages, chemicals, basic metals and equipment and machinery.

The first stage in the estimation consists of assessing the stationarity of the series. If the series have unit roots, then it is appropriate to proceed with the co-integration analysis. The Dickey-Fuller statistics with a time trend are computed. The results are presented in Table 2. With few exceptions the null hypothesis of nonstationarity cannot be rejected. At the sectoral level, only for three series can this null hypothesis be rejected leading to the conclusion that the generating process is stationary.[5] Given the nonstationary nature of the capital accumulation and TFP series, the VAR analysis is based on Johansen's (1991) dynamic characterization of cointegration relationships. The motivation is that all sectors connected through spillovers and linkages share a stochastic trend. [6]

[5] The autoregression lag order was found using the procedure designed by Ng and Perron (1995). Starting with a high order, a conventional t-test is used to discard lags insignificant at the 10% level. This procedure is less biased than AIC.

[6] The length and frequency of the series do not permit a simultaneous analysis of all sectors, due to insufficient degrees of freedom. The implemented methodology consists of estimating all possible bivariate VARs and performing a cointegration test of the reduced system.

4.2 Spillover Configuration

In Table 3, the long run relationships between capital accumulation and productivity growth within and across sectors, among domestic plants only, are characterized empirically. It is surprising that there is complete absence of a common trend among capital formation in the chemical sector and productivity in the wood sector. This is perhaps due to the fact that the former is dominated by MNC subsidiaries. These industries together with the nonmetallic mineral sector seem isolated from the growth dynamics linking the other sectors.

In general, a common trend is observed linking capital formation and productivity growth within sectors. This observation could reflect a selection effect whereby capital intensive technologies exhibit the highest TFP growth. However, the comovement is also consistent with the existence of positive accumulation externalities among domestic producers in the same sector. On the other hand, the evidence rejects the possibility of external increasing returns across sectors.

Now that the nature of sectoral interdependence among domestic firms has been established, the impact of the presence of MNC subsidiaries can be established. In Table 4, the impact of FDI on domestic productivity is summarized both at the *intra-* and *inter-*industry levels. The observed pattern reveals that while MNC activities are substitutes for domestic manufacturing within the subsidiary's sector, they can complement manufacturing in other sectors. In particular, the hypothesis of no cointegration between FDI financed capital formation and domestic manufacturing TFP cannot be rejected at the *intra*-industry level but it is widely rejected at the *inter*-industry level. This finding corroborates the conjecture that FDI may crowd out domestic investment within the sector of the MNC but can provide positive externalities across other sectors.

The evidence on cointegration is consistent with *intra*-industry external increasing returns in domestic capital formation and *inter*-industry spillovers from FDI. To assess the generality of this finding, each sample is pooled and panel cointegration tests are performed. First, for investment by domestic manufacturers, each bisectoral pairing of the capital stock and TFP in each year is taken to be generated by a common process across sectors. Likewise, each bisectoral pairing of FDI financed capital formation and TFP across years is pooled in a common sample. The results in Table 5A show that the cointegration for domestic investment in *intra*-industry observations, which account for 12.5% of the sample, cannot be generalized. In contrast, the cointegration for FDI in *inter*-industry observations can be generalized. Across sectors there is evidence of comovement between investment by MNCs and the productivity of domestic manufacturing enterprises over the 25 years of the sample.

This is consistent with diffusion of externalities from FDI that is widespread across sectors. The FDI that generates positive spillovers in the greatest number of sectors is concentrated in the following industries: paper, chemicals, metallic machinery, and basic metals y nonmetallic minerals. The sectors that seem most prone to benefit from the presence of MNCs are: paper and printing as well as food, beverages and tobacco. Although the growing trend in the productivity of MNC subsidiaries indicates that they implement better techniques over time, domestic producers within the subsidiaries' sector seem unable to benefit from spillovers of sector specific technical knowledge deployed via FDI.

On the other hand, the evidence of *inter*-industry spillovers is consistent with the diffusion of generic knowledge. This pattern emerges when the absorptive capacity of domestic manufacturers lags behind that of MNCs. In this case, the adoption by host-country competitors of sector specific technologies deployed through FDI is not feasible. But, the adoption of generic technologies by host-country manufacturers, which does not represent a loss of market share to the MNC, is viable as the absorptive capacity requirement is modest.

4.3 Absorptive Capacity and the Diffusion of Externalities

In this section, the relative growth in the absorptive capacity of domestic manufacturers compared to that of MNCs is assessed. If the absorptive capacity of the host-country competitive fringe stagnates, the MNCs can use this lag to exclude others from using their sector specific knowledge by deploying sufficiently advanced technologies. When domestic competitors cannot reverse engineer and adopt profitably the MNCs' core technologies, they cannot appropriate benefits from FDI spillovers. Hence, the optimal strategy to deploy FDI will lead to choices of location and technology that limit *intra*-industry spillovers but allow for *inter*-industry spillovers. The MNC will avoid information flows to competitors by its location choice and also through trade secrecy. Below, an assessment is made as to whether the cointegration evidence of the latter diffusion pattern of externalities from FDI could indeed be due to a widening gap in absorptive capacity between host-country manufacturers and MNCs.

First, note that labor productivity growth will remain unaffected by TFP growth if physical capital and human capital per worker both stagnate. In particular, if increasing labor productivity is accounted for solely by TFP growth, then inputs per worker, namely physical and human capital, must be stationary. In particular, the level of labor productivity rises but it will not grow any faster. Without resources to transform technological improvements into value added, the adoption of new techniques has no impact on production opportunities for manufacturers. Absorptive capacity growth is reflected by the expansion of labor productivity beyond improvements in technology. The econometric properties the relation between physical and human capital accumulation per worker, on the one hand, and average labor productivity and TFP growth, on the other, entail that absorptive capacity is stationary if the logarithms of labor productivity and TFP are perfectly cointegrated. Both human capital per worker and physical capital per worker stagnate, and improvements in the state of technology do not yield higher growth of value added per worker.

In table 5B, the results of the panel cointegration tests for labor productivity and TFP within sectors reveal stationarity of absorptive capacity for host country manufacturers and nonergodicity for MNCs. While the domestic manufacturing capabilities to adopt new technologies have remained stagnant, those of MNCs have expanded over time. The evidence shows a widening gap in absorptive capacity that can account for the sectoral diffusion pattern of FDI spillovers apparent from the cointegration evidence. In particular, the absence of diffusion of sector specific technology that could result in *intra*-industry spillovers coupled with the prevalence of *inter*-industry externalities, likely due to the dissemination of generic knowhow, point to limits in absorptive capacity in host-country manufacturing.

4.4 FDI as a Source of New Technological Opportunities

The evidence on cointegration corroborated the presumption that the absence of *intra*-industry spillovers is consistent with presence of *inter*-industry externalities. Furthermore, the results from the panel cointegration test confirmed that the scope for within-sector knowledge flows is limited by absorptive capacity. The comparison between the technologies of foreign and domestic firms reveals a gap. Also, there appears to be an impact of the demand of MNCs for intermediate inputs on the productivity of local firms. The results are consistent with both the theoretical and empirical literature on externalities from FDI. Furthermore, by emphasizing the sectoral diffusion pattern of externalities, as well as the role of absorptive capacity, the empirical methodology developed contributes to the measurement of FDI spillovers by focusing on the neglected *inter*-industry externalities. The latter can reverse the conclusion from purely *intra*-industry studies that FDI crowds out domestic investment. In particular, the finding of comovement among sectoral FDI and productivity in other sectors is consistent not only with *inter*-industry externalities but also with some common factor stimulating FDI inflows and TFP growth. To assess whether FDI generates new technological opportunities across manufacturing, the causality from sectoral FDI to TFP across sectors is tested in terms of the predictive power of each variable on the other.

Wiener-Granger causality from $\{k_{it}\}$ to $\{z_{jt}\}$ amounts to a nonzero coefficient in the VECM in equation (20) emanating from the polynomial $\pi_{21}(L)$ in the bivariate VAR represented in equation (20). The null hypothesis of no causality can be tested by standard methods (e.g. by an F-test) if the VAR is stable. With integrated processes the situation becomes intractable because the asymptotic distribution of the test statistic is in general nonstandard and involves nuisance parameters (Toda and Phillips 1991; 1993). Fortunately, the problem simplifies as $\{k_{it}\}$ and $\{z_{jt}\}$ are both one-dimensional and cointegrated, so that bi-sectoral causality tests can be performed. In this circumstance, the conventional Wald test statistic converges to a χ^2 distribution under the null hypothesis of no causality (Toda and Phillips, 1993; Sims, Stock, and Watson, 1990) such that conventional testing procedures can be applied. The same hold for a test of reverse causality. To establish whether the comovement among the investment patterns and the TFP of domestic manufacturers is caused by external increasing returns from capital formation generally, and the diffusion of FDI externalities in particular, the issue of simultaneity must be dealt with.

The null hypothesis $H_0 : \pi_{12} = 0$ must be tested. If the latter hypothesis is rejected, causality from FDI to TFP across sectors implying *inter*-industry spillovers cannot be ascertained. In this case, all that would be known is that FDI and TFP can be used to predict each other in a cross-sectoral fashion. For example, domestic efficiency in one sector, indicated by a high TFP could be associated with FDI if the domestic sector provides an intermediate input to MNCs. However, if it the null hypothesis that domestic productivity in sector i cannot predict FDI inflows to sector j is not rejected, while FDI inflows to sector j predict TFP growth in sector i, then cross-sectoral comovement in FDI and TFP is likely to stem from the diffusion of externalities from the operations of MNCs.

First, the results reveal no causality from domestic capital formation to within sector TFP, with the sole exception of the nonmetallic minerals industry. Hence, the evidence points to higher technological development being associated with higher capital intensity rather than external increasing returns from domestic investment. Second, there is comovement among FDI and TFP in 59% of all possible bisectoral pairings. In these cases, when capital formation by MNCs in one sector is cointegrated with TFP in another sector, in 71% of the bivariate series FDI Granger-causes domestic productivity improvement.

Over time, FDI inflows generate TFP growth across sectors but not within sectors.[7] Although only generic and not specific technical knowledge from MNCs diffuses, FDI generates manufacturing productivity rises. To rule out simultaneity as an explanation for this pattern, reverse causality tests were performed. Of the bisectoral series in which FDI and TFP are cointegrated, only in 11% does domestic productivity predict FDI and in 9% there is evidence of Granger-causality in both directions. Hence, the evidence of generalized *inter*-sectoral TFP growth ensuing FDI cannot be explained away by simultaneity.

4.5 Sectoral Spillover Diffusion through Linkages

The evidence discussed so far strongly supports the conjecture that there is diffusion of *inter*-industry externalities from FDI. Here, technological spillovers are measured by estimation of the structural parameters of the production function. In particular, equation (17) can be expressed as,

$$z_{it} = e_i + x_{it}^D + x_{it}^F + \ln \xi_{it} = e_i + \sum_{l=1}^{n} \gamma_{li}^D k_{lt}^D + \sum_{l=1}^{n} \gamma_{li}^F k_{lt}^F + \ln \xi_{it} \,,$$

[7] Only in the machinery and equipment sector is there evidence of a positive *intra*-industry association among FDI and domestic TFP. The evidence points to simultaneity for generating this fact.

in which domestic TFP is decomposed in terms of a sectoral constant, FDI spillovers and a technological shock.[8] The matrix γ^F maps the sectoral allocation of FDI financed capital formation into the impact if spillovers on domestic sectoral TFP. It is estimated by the partial canonical correlations among the vector of deviations of domestic TFP from the sectoral average and the sectoral vector of capital financed with FDI.[9] The estimated matrix in Table 9 quantifies the spillovers already found through diagnostics tests. The fitted elasticities of TFP with respect to FDI range from 28% to 1.5% with several sectors close to 20%. All the significant positive estimates correspond to instances of *inter*-industry spillovers and constitute 41% of all potential cases.

Another interesting aspect of the diffusion of FDI externalities is to explore if the *inter*-industry spillovers found translate into higher manufacturing growth. To answer this question we can decompose the motion equation (15) of the state variable to differentiate the impact of the allocation of domestic investment from that of FDI. The impact across sectors of capital formation by MNCs in sector *j* on growth in sector *i* is given by,

$$a_{ij}^F = \delta_{ij}\alpha_j^F + \sum\nolimits_{l=1}^{n} \delta_{il}\gamma_{lj}^F = \frac{\partial k_i}{\partial I_{il}}\frac{\partial y_j}{\partial k_j} + \sum\nolimits_{l=1}^{n} \frac{\partial k_i}{\partial I_{il}}\frac{\partial x_l}{\partial k_j^F}.$$ [10]

Hence, spillovers translate into growth if the sectors to which externalities diffuse provide inputs to other industries. In other words, backward linkages and spillovers are complements in the generation growth. Note that if the sectors recipient of technical information from MNCs do not provide inputs to other sectors, then investment in other sectors is not affected. Hence, only to the extent that the sector benefiting from FDI spillovers is upstream will there be widespread inter-industry externalities. In other words, the establishment of backward linkages by MNCs plays a major role in facilitating diffusion of its technology. Without local outsourcing by MNCs, for example if all subsidiary inputs were either imported or produced in-house, widespread FDI spillovers would not materialize. The benefits from FDI technology diffusion include not only the direct effect to suppliers but more importantly to other local producers, which like the MNC are downstream from local input providers.

To quantify the effect of backward linkages combine the estimate of the intensity of cross-industry spillovers from the above expression of equation (17) with the coefficients of cross-sectoral demands, for both domestic and multinational producers, imputed entries from the from Input/Output (I/O henceforth) table available from national accounts until 1994. For the latter years in our sample, a new methodology was put in place for the national accounts, and I/O tables were replaced by output-use and output-supply matrices. Therefore, from 1994 to 1998, we rely on output-use matrices to determine cost

[8] Potential externalities from other domestic producers are not included as the cointegration and causality tests cannot reject the insignificance of external increasing returns, both within and across sectors, ensuing domestic investment.

[9] Johansen (1988) sets up the estimation as a reduced rank regression.

[10] The *intra*-industry effect is $a_{ii} = d_i + \delta_{ii}(\alpha_i + \gamma_{ii}) + \sum\nolimits_{l\neq i} \delta_{il}\gamma_{li} = d_i + \delta_{ii}(\alpha_i + \gamma_{ii}) + \sum\nolimits_{l\neq i} \frac{\partial k_i}{\partial I_{il}}\frac{\partial x_l}{\partial k_i}$.

and sales shares, and on output-supply matrices to determine sectoral output. It is also important to note that I/O tables do not use ISIC codes to classify industries. The level at which concordance could be created corresponds to the 2-digit ISIC codes.[11]

Table 10 shows that the positive impact of FDI in one sector on the productivity of domestic plants in some other industry may or may not spur investment. At the same time, FDI may complement capital formation in another sector even without affecting its productivity. While FDI technological spillovers and complementarity of FDI with domestic capital formation are clearly related, they are distinct processes. Absence of linkages can preclude new technological opportunities to be exploited through new investment projects. The evidence points to a crowding out effect of FDI on domestic competitors and in many cases *inter*-sectoral complementarity via backward linkages. When MNCs import some intermediate inputs, crowding out of local upstream suppliers also occurs. The estimates on the rows 3 and 4 and columns 3 and 4 for the wood and paper sectors in Tables 9 and 10, quantify how vertical spillovers operate while horizontal effects are absent. In particular, there is strong evidence in Table 9 that FDI in both sectors leads to substantial TFP improvement in the other sector (elasticities between 20% and 30%) but no significant intra-industry effect is apparent on TFP.

In contrast, in Table 10, there is a negative intra-industry effect on investment from FDI. At the same time, the inter-sectoral spillover on investment is strong, with an elasticity of 8%, from FDI in the paper sector to domestic producers in the wood sector but relatively weak, with an elasticity of 1%, from FDI in the wood sector to domestic producers in the paper sector. This pattern shows spillovers being transmitted along backward linkages but not along forward linkages and is consistent with other evidence in the literature. Table 10 reveals that the domestic row sectors that benefit most from FDI are in order metallic equipment, chemicals and wood. The first two of these sectors are primarily providers of intermediate inputs. As such the producers in these industries are upstream relative to MNC subsidiaries and most likely to be recipients of spillovers through backward linkages. As for the wood sector, it is also upstream to most industries via its linkage with the paper sector. The pulp, paper, and paperboard sector is a major end-user of raw materials. In particular, chemical processed and natural wood pulp represent approximately 45% of the total raw materials used by the sector. At the same time, the packaging industry is also a major end-user of paper. For example, approximately 11% of paper production is used for the manufacturing of paper bags for cement packaging. Packaging, both carton and paper, is also an important component in the food, beverages and textile industries, and others. These sectoral elasticities include not only the direct effect on sectors supplying MNCs but also the indirect effect due to enhanced widespread input availability associated with FDI. In particular, MNCs' technology transfer benefits upstream local suppliers, and also domestic plants which are downstream from those local suppliers. Most recent studies of inter-industry FDI spillovers only

[11] For further description on this methodology, the reader is referred to the account in Eslava, Haltiwanger, Kugler and Kugler (2004), pp. 344-345.

include the direct effect and neglect the latter (see e.g. Blalock, 2001, Lopez, 2003, and Smarzynska, 2004).[12] The evidence presented in Table 10 on backward linkages clearly demonstrates their importance in explaining inter-sectoral FDI spillovers. At the same time, forward linkages do not appear to channel information flows from MNCs.

5 Conclusions

In theory, there are three channels through which FDI can generate productivity growth for host-country producers. These are technical knowledge spillovers, linkage externalities and competition. Case studies show examples in which each of these channels impacts domestic manufacturing. Econometric analyses have tried to ascertain the generality of these examples. Empirical cross-country estimations reveal contemporaneous correlations among FDI inflows and domestic productivity consistent with the diffusion of externalities from MNC operations. However, this evidence is also consistent with the concentration of FDI in countries where productivity is high in general, and manufacturing TFP in particular, even if FDI had no impact on domestic producers. For example, this could happen if human capital abundance attracts FDI inflows.

To deal with this simultaneity problem, longitudinal econometric analysis was needed. The availability of panel databases has made it possible to explore in more detail the extent of spillovers. By and large, initially the new evidence focused on the rejection of *intra*-industry FDI spillovers. Then, a study found evidence of diffusion of generic knowledge, namely spillovers of exporting knowhow from MNCs to neighboring Mexican manufacturers (Aitken, Hanson and Harrison, 1997). This suggested that the absence of *intra*-industry FDI spillovers does not rule out the prevalence of *inter*-industry spillovers. On the basis of both the optimal location strategy by the MNC to minimize market-share loss and the low absorptive capacity requirement for the adoption of generic technical knowledge, theory predicts that in equilibrium only *inter*-industry FDI spillovers materialize. Externalities across sectors could explain evidence of contemporaneous correlation among FDI flows and TFP growth.

Ignoring the possibility of the diffusion of externalities across sectors may lead to the conclusion that FDI substitutes domestic investment. The evidence that there is no diffusion of externalities within sectors is important because it indicates that MNCs have some control to exclude use of their technology and thereby appropriate the benefits, in such countries as Cote d'Ivoire, the Czech Republic, Morocco and Venezuela. The evidence in the present paper shows not only that there are limited *intra*-industry externalities but also that there are widespread *inter*-industry spillovers from FDI. Hence, while FDI seems to afford excludability of its knowhow to the MNC, this excludability is partial in that it applies only to specific but not to generic technologies. The absence of a positive impact from FDI on the domestic competitors of MNCs stems from the lack of dissemination of

[12] The exceptions are Kugler (2000) and Blalock and Gertler (2004).

sector-specific technologies. The prevalence of a positive impact among other domestic producers in general is due to the diffusion of generic technical knowledge spurred partly by linkage effects. Hence, the structural econometric framework used to analyze Colombian manufacturing data in this paper delivers results that match the presumption of FDI spillovers in the literature as well as the recent findings of absent *intra*-industry externalities in many countries. Although some longitudinal analyses seemingly pointed in the opposite direction because of neglect of the possibility of externalities across sectors, the conjecture that FDI complements domestic investment through spillovers is borne out by the evidence in this paper.

It is important to identify the source for the absence of spillovers. The missing observable improvements on the productivity of host-country enterprises in the wake of FDI could be caused by lack of novel technique utilization by MNC subsidiaries, by successful MNC strategy to contain potential competitors to its subsidiaries, or by the lack of indigenous absorptive capacity necessary for new technology adoption. In the latter case, even if the domestic human capital stock is sufficient to absorb the new technique, limited access to specialized equipment and machinery, which partly embodies best practice, could preclude adoption by domestic producers. The probable cause limiting the ability for domestic entrepreneurs to adopt new technologies is the unfeasibility to acquire equipment and machinery. It may be due to restrictions in both financing and importing. As discussed above, this will be a problem mostly for specific as opposed to generic technologies. While generic technologies, such as computer-automated design (CAD) and local area networks (LAN), require some machinery, it is more accessible than the labs or high-accuracy equipment used with specialized technologies. For example, computer numerically controlled (CNC) equipment for assembly requires specifically tailored design, maintenance and training. But, generic production techniques such as just-in-time-inventories (JIT) and total-quality-management (TQM) do not require the acquisition of new equipment and machinery, and can be deployed with limited resources.

In this context, the implication of absence of *intra*-industry spillovers prevailing from less-developed country evidence is not that knowledge transfer associated with FDI is negligible. Neither should we conclude that a correlation among weighted FDI averages, using a host country input-output table, and domestic productivity implies that spillovers are *exclusively* present when MNCs outsource domestically. Such findings for Indonesia, Lithuania and Mexico do not rule other alternative mechanisms outright. FDI spillovers can be driven by the genericity of knowledge that facilitates *inter*-sectoral diffusion through low absorptive capacity requirement. Also, as pointed out by Scherer (1982) and Glaeser et al. (1991), one cause behind the spillovers between sectors is the cross-fertilization of ideas, while linkages provide incentives to share technical information. Finally, Rodriguez-Clare (1996) has argued that there can be an important indirect effect whereby domestic industry gains due to the emergence of high productivity input suppliers to MNCs. This is characterized in the estimation framework and measured in the current paper in Table 10 which provides estimates of the impact on capital accumulation associated with the spillovers documented in Table 9. Backward linkages and spillovers are complements in the generation growth. In particular, to the extent that direct FDI spillover recipients are primarily upstream suppliers of the MNC, there will also be indirect effects to other domestic producers utilizing intermediate inputs produced by these upstream suppliers. In this sense, the establishment of backward linkages when MNC subsidiaries outsource locally gives rise to potential widespread inter-sectoral FDI spillovers as the evidence in this paper shows for the Colombian manufacturing sector. The aggregate impact goes beyond the vertical spillovers typically identified in this literature, which refer to the rise in productivity for MNC input providers. The other component of the aggregate impact of FDI here characterized, namely the higher efficiency for all downstream domestic producers using these MNCs' new input providers, is shown to be quantitatively important. As in the case of the direct vertical FDI spillovers, the indirect impact due to new and better inputs takes place *between* rather than *within* sectors. Due to strategic considerations, MNCs optimally engage in exclusive supplier contracts in the case of specific inputs to avoid *intra*-industry FDI spillovers. At the same time, innovations in other inputs used across several industries will not hamper MNCs and thus generate indirect *inter*-industry spillovers, in addition to the vertical technology diffusion to upstream producers.

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Data

From plant-level data of the Annual Manufacturing Census a panel of 10 sectors (ISIC 3-digit level) for the period from 1974 to 1998 was constructed. Plants are classified as domestically-owned or MNC subsidiaries. The latter are those for which the financing from FDI constitutes a share above investment of at least 10%. The sectors are labeled as follows, where the first category encompasses all below:

(1) MAN = manufacturing

(2) FBT = food, beverages & tobacco;

(3) TEX = textiles;

(4) WOD = wood;

(5) PAP = paper & printing;

(6) CHE = chemicals, rubber, & plastics;

(7) NMM = non-metallic minerals (except oil);

(8) MTL = basic metals;

(9) MEM = Metallic equipment & machinery;

(10) OTR = other manufacturing

Table 1 - Average Growth Rates: 1974-1998

Sector	Domestic Capital Stock	Domestic TFP	MNC's Capital Stock	Foreign TFP
MAN	3.1 (0.6)	1.2 (0.4)	1.7 (0.9)	5.2 (1.4)
FBT	3.3 (0.5)	2.8 (0.5)	5.2 (1.1)	4.6 (0.8)
TEX	2.4 (1.1)	0.7 (0.6)	1.2 (1.2)	4.7 (1.0)
WOD	3.6 (0.7)	1.2 (0.9)	3.5 (1.1)	3.9 (0.9)
PAP	2.7 (1.0)	3.3 (0.4)	3.8 (1.0)	4.2 (0.5)
CHE	3.2 (1.9)	1.8 (1.0)	4.8 (1.5)	4.3 (0.6)
NMM	2.1 (1.1)	2.1 (0.7)	3.4 (0.9)	3.8 (0.6)
MTL	1.3 (0.8)	0.4 (0.7)	4.8 (1.1)	2.9 (0.8)
MEM	3.2 (0.7)	1.5 (0.6)	4.4 (0.9)	1.4 (0.5)
OTR	2.8 (0.5)	1.7 (0.4)	2.6 (0.8)	3.3 (0.4)

Notes: Percentage average growth rates with standard errors are reported in parenthesis. They are corrected for autocorrelation using the quadratic-spectral kernel with pre-whitening, as suggested by Andrews and Monahan (1992). Standard errors are reported in parenthesis.

Table 2 – Stationarity of the Series

Sector	Domestic Labor Productivity	Domestic Capital Stock	Domestic TFP	MNC's Labor Productivity	MNC's Capital Stock	MNC's TFP
MAN	-3.36* (2)	-3.76 (4)	-3.40* (2)	2.80 (3)	0.40* (2)	-2.31 (3)
FBT	-1.07 (1)	-2.46 (3)	-1.76 (2)	-1.75 (4)	-2.38 (4)	- 2.66 (2)
TEX	-2.32 (3)	-1.64 (2)	-2.10 (1)	-1.01 (4)	-2.84 (1)	-2.21 (4)
WOD	-1.60 (4)	-0.90 (2)	-3.17 (3)	-3.65* (1)	-2.23 (2)	-2.92 (3)
PAP	-1.95 (3)	-2.16 (4)	-1.37 (1)	-0.73 (3)	-3.28 (2)	-1.55 (3)
CHE	-3.46* (1)	-2.68 (3)	-3.20 (4)	-1.50 (2)	-2.56 (3)	-2.64 (4)
NMM	-2.69 (2)	-1.78 (2)	-2.48 (3)	-1.28 (1)	-3.00 (1)	-3.02 (1)
MTL	-2.07 (4)	-2.84 (3)	-1.98 (2)	-2.48 (3)	-3.05 (3)	-2.50 (2)
MEM	-1.97 (3)	-1.09 (1)	-1.75 (2)	-2.96 (4)	-1.27 (2)	-2.05 (4)
OTR	-3.23 (3)	-4.33* (2)	-2.86 (3)	-3.26 (1)	-2.32 (1)	-2.28 (2)

Notes: The Augmented Dickey-Fuller Test statistics here are for the null hypothesis that the series in question have no unit roots. * and ** indicate significance at the 10% and 5% significance levels respectively. The lag length selection is data dependant and yields the order of the autoregressive polynomial indicated in parenthesis, following Ng and Perron's (1995) procedure. All regressions include a constant and a linear time trend.

Table 3 - Cointegration between Investment and Technical Progress among Domestic Producers within and across Sectors

Domestic Sectoral TFP	Sectoral Capital Stock Financed Domestically							
	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**13.21***	12.75*	7.63	6.01	7.30	6.10	5.24	8.13
	(2)	(4)	(1)	(2)	(3)	(3)	(1)	(2)
TEX	8.28	**16.05****	7.15	8.04	6.66	5.54	1.66	10.24
	(1)	(3)	(4)	(2)	(1)	(2)	(4)	(2)
WOD	6.82	5.91	**11.47***	17.41**	7.99	8.38	9.35	7.71
	(2)	(4)	(1)	(3)	(2)	(4)	(3)	(4)
PAP	7.58	6.46	14.22*	**10.84**	6.33	6.14	8.07	7.90
	(3)	(3)	(2)	(2)	(4)	(3)	(2)	(1)
CHE	8.73	13.67*	13.08*	8.71	**12.29***	5.27	5.30	22.66**
	(4)	(1)	(4)	(3)	(4)	(3)	(2)	(3)
NMM	16.97**	7.36	13.29*	11.93	11.81	**14.54***	13.24*	19.93**
	(2)	(3)	(3)	(4)	(1)	(2)	(4)	(2)
MTL	6.89	16.32**	5.64	12.70*	9.09	20.31**	**15.30***	5.40
	(1)	(4)	(3)	(1)	(2)	(3)	(1)	(2)
MEM	12.75*	11.33	7.92	16.55**	4.67	15.24*	8.21	**19.64****
	(2)	(3)	(4)	(2)	(1)	(4)	(3)	(3)

Notes: The null hypothesis is that there is no cointegration. The order of the underlying VAR is in parenthesis. * and ** indicate significance at the 10% and 5% significance levels respectively. The critical values are taken from Osterwald-Lenum (1992).

Table 4 - Cointegration between FDI and Local Productivity Growth within and across Sectors

Domestic Sectoral TFP	Sectoral Capital Stock Financed through FDI							
	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**2.44** (3)	8.38 (4)	16.17** (2)	23.41** (2)	13.92* (1)	10.67 (3)	9.40 (2)	12.59* (1)
TEX	6.42 (2)	**8.41** (3)	13.90* (2)	12.73* (3)	14.06* (1)	8.41 (2)	11.10* (4)	7.07 (3)
WOD	13.58* (1)	18.92** (4)	**7.80** (4)	19.32** (3)	7.80 (2)	13.99* (1)	18.38** (3)	9.35 (3)
PAP	12.52* (3)	11.95* (3)	16.39** (4)	**7.03** (1)	16.56** (2)	16.04** (2)	8.92 (1)	12.33* (2)
CHE	12.68* (2)	15.74* (1)	16.07** (3)	13.79* (4)	**11.69** (3)	7.45 (4)	20.13** (1)	12.38* (4)
NMM	18.43** (4)	5.27 (2)	14.08* (3)	9.42 (2)	6.11 (4)	**5.02** (1)	11.68* (3)	13.13* (1)
MTL	15.24* (3)	17.49** (4)	9.74 (1)	8.25 (2)	12.64* (3)	8.02 (2)	**5.77** (3)	8.34 (2)
MEM	19.04** (2)	11.95* (2)	18.69** (4)	9.35 (3)	13.07* (1)	19.23** (3)	8.55 (4)	**14.34*** (3)

Notes: The null hypothesis is that there is no cointegration. The order of the underlying VAR is in parenthesis. * and ** indicate significance at the 10% and 5% significance levels respectively. The critical values are taken from Osterwald-Lenum (1992).

Panel Cointegration Evidence

Table 5A – Spillover Configuration

Test Statistic	Sectoral domestic capital formation and domestic TFP across all sectors	Sectoral FDI financed capital stock and domestic TFP across all sectors
Autoregression Test	-19.43	-31.53**
t-test	-7.04	-9.72**

Note: The null hypothesis is that there is no cointegration among the capital formation and productivity series for in the sample of all bi-sectoral possible pairings. The critical values are obtained by interpolation from the small sample Monte Carlo study in Pedroni (2004). The 5 and 10 % critical values for the autoregression test are -30.60 and -28.53 for the first column, and for the second column -30.37 and -28.32 respectively. For the t-test the 5 and 10 % critical values are -8.31 and -7.96 for the first column, and -8.46 and -8.09 for the second column. * and ** indicate significance at the 10% and 5% significance levels respectively.

Table 5B – Absorptive Capacity and Technology Diffusion

Test Statistic	Labor productivity and TFP within sectors among domestic firms	Labor productivity and TFP within sectors among MNCs
Autoregression Test	-25.25	-33.81**
t-test	-7.04	-8.69*

Note: The null hypothesis is that there is no cointegration among the labor productivity and TFP series within each sector for a sample pooling all sectors. The critical values are obtained by interpolation from the small sample Monte Carlo study in Pedroni (2004). The 5 and 10 % critical values for the autoregression test are -35.62 and -30.81 for the first column, and for the second column -32.78 and -29.34 respectively. For the t-test, the 5 and 10 % critical values are -9.08 and -8.25 for the first column, and -9.31 and -8.52 for the second column. * and ** indicate significance at the 10% and 5% significance levels respectively.

Table 6 – Evidence on whether Domestic Investment Generates External Increasing Returns

	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**4.04**	**3.52**	N/A	N/A	N/A	N/A	N/A	N/A
TEX	N/A	**2.38**	N/A	N/A	N/A	N/A	N/A	N/A
WOD	N/A	N/A	**1.70**	**7.96****	N/A	N/A	N/A	N/A
PAP	N/A	N/A	**4.22**	N/A	N/A	N/A	N/A	N/A
CHE	N/A	**2.03**	**1.67**	N/A	**2.68**	N/A	N/A	**5.36***
NMM	**1.41**	N/A	**3.44**	N/A	N/A	**5.02***	**2.69**	**1.93**
MTL	N/A	**1.56**	N/A	**2.30**	N/A	**3.27**	**4.11**	N/A
MEM	**1.72**	N/A	N/A	**3.45**	N/A	**2.19**	N/A	**3.83**

Note: The null hypothesis is that there is no causality from domestic investment in the column sector to domestic productivity in the row sector. When both series are cointegrated, the null hypothesis of no causality converges to Chi-square and can be tested with the F-statistic. If the series are not cointegrated, the test is not applicable. * and ** indicate significance at the 5% and 1% significance levels respectively.

Table 7 – Causal Evidence of *Inter*-Industry Spillovers from FDI

	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	N/A	N/A	**4.98***	**4.01**	**7.30***	N/A	N/A	**2.48**
TEX	N/A	N/A	**4.75***	**9.82****	**8.24****	N/A	**1.66**	N/A
WOD	**5.88***	**10.06****	N/A	**12.34****	N/A	**7.59***	**11.47****	N/A
PAP	**4.23***	**12.55****	**5.09***	N/A	**8.22***	N/A	N/A	**5.13***
CHE	**9.90***	**1.40**	**10.12****	**4.28***	N/A	**3.46**	**7.27***	**3.94**
NMM	**6.39***	N/A	**2.81**	N/A	N/A	N/A	**3.13**	**1.76**
MTL	**0.74**	**6.65***	N/A	N/A	**9.09***	N/A	N/A	N/A
MEM	**5.69***	**11.28****	**4.91***	N/A	**4.67***	**1.04**	N/A	**12.87****

Note: The null hypothesis is that there is no causality from FDI in the column sector to domestic productivity in the row sector. When both series are cointegrated, the null hypothesis of no causality converges to Chi-square and can be tested with the F-statistic. If the series are not cointegrated, the test is not applicable. * and ** indicate significance at the 5% and 1% significance levels respectively.

Table 8 – Evidence on Possible Simultaneity in the Relationship between TFP and FDI across Sectors

	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	N/A	N/A	**1.02**	**2.74**	**4.11**	N/A	N/A	**3.35**
TEX	N/A	N/A	**4.03**	**3.96**	**0.88**	N/A	**5.47***	N/A
WOD	**2.31**	**0.59**	N/A	**10.74****	N/A	**1.68**	**1.92**	N/A
PAP	**3.15**	**4.07**	**7.86***	N/A	**2.29**	N/A	N/A	**8.91***
CHE	**3.36**	**2.87**	**1.40**	**9.05***	N/A	**0.98**	**4.13**	**11.58****
NMM	**1.74**	N/A	**4.62**	N/A	N/A	N/A	**3.41**	**2.97**
MTL	**2.40**	**4.03**	N/A	N/A	**0.89**	N/A	N/A	N/A
MEM	**3.55**	**0.96**	**1.77**	N/A	**2.31**	**3.69**	N/A	**10.24****

Note: The null hypothesis is that there is no causality from domestic productivity in the row sector to FDI in the column sector. When both series are cointegrated, the null hypothesis of no causality converges to Chi-square and can be tested with the F-statistic. If the series are not cointegrated, the test is not applicable. * and ** indicate significance at the 5% and 1% significance levels respectively.

Table 9 – The Magnitude of Technological Spillovers

	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**.017**	**.008**	**.015***	**.024**	**.109****	**.066**	**.032**	**.178****
	(.021)	(.010)	(.006)	(.037)	(.046)	(.058)	(.029)	(.081)
TEX	**.023**	**.012**	**.020***	**.146****	**.086****	**.071**	**.044**	**.083**
	(.035)	(.011)	(.009)	(.028)	(.017)	(.063)	(.042)	(.076)
WOD	**.026***	**.041****	**.035**	**.218****	**.057**	**.069**	**.090***	**.074**
	(.012)	(.016)	(.028)	(.075)	(.081)	(.039)	(.037)	(.055)
PAP	**.063***	**.057****	**.283****	**.002**	**.119***	**.052**	**.061**	**.028**
	(.029)	(.018)	(.051)	(.063)	(.044)	(.074)	(.092)	(.026)
CHE	**.042**	**.083**	**.095**	**.131****	**.026**	**.019**	**.004**	**.057**
	(.089)	(.124)	(.063)	(.093)	(.021)	(.015)	(.013)	(.052)
NMM	**.017***	**.037**	**.022**	**.024**	**.013**	**.086**	**.079**	**.041**
	(.007)	(.048)	(.011)	(.035)	(.047)	(.052)	(.069)	(.028)
MTL	**.003**	**.064****	**.010**	**.048**	**.096****	**.008**	**.062**	**.018**
	(.052)	(.030)	(.019)	(.054)	(.034)	(.018)	(.072)	(.031)
MEM	**.026***	**.051****	**.072***	**.056**	**.047***	**.081**	**.016**	**.059****
	(.012)	(.017)	(.029)	(.038)	(.021)	(.055)	(.046)	(.014)

Note: The estimates are based on partial canonical correlations between domestic TFP in the row sector and FDI in the column sector. The procedure used is described by Johansen (1988). Standard errors are in parenthesis. * and ** indicate significance at the 5% and 1% significance levels respectively.

Table 10 – Elasticity of Domestic Capital Formation w.r.t. FDI

	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**-.012****	**.015**	**.016**	**.025**	**.026**	**.017**	**.016**	**.042**
	(.003)	(.022)	(.019)	(.034)	(.042)	(.059)	(.021)	(.057)
TEX	**.023**	**-.031****	**.031**	**.021**	**-.037**	**.019**	**-.005**	**-.013***
	(.042)	(.016)	(.048)	(.029)	(.042)	(.031)	(.027)	(.008)
WOD	**.016****	**-.038****	**-.023****	**.082****	**.021**	**.058**	**-.018***	**.065**
	(.009)	(.017)	(.028)	(.035)	(.031)	(.071)	(.010)	(.093)
PAP	**.008***	**.024**	**.009****	**-.024***	**.010***	**-.021**	**.039**	**.020***
	(.005)	(.038)	(.003)	(.011)	(.006)	(.047)	(.081)	(.012)
CHE	**.043***	**.015***	**.011***	**.128***	**.017**	**.013***	**.028***	**-.046**
	(.022)	(.008)	(.008)	(.076)	(.023)	(.007)	(.016)	(.071)
NMM	**.006**	**-.023**	**-.014**	**.045**	**.013**	**.064****	**.079**	**.029****
	(.013)	(.029)	(.018)	(.062)	(.047)	(.025)	(.068)	(.006)
MTL	**.031**	**.004***	**-.026**	**.031**	**.048**	**.008**	**.042****	**.073****
	(.064)	(.002)	(.039)	(.044)	(.041)	(.018)	(.014)	(.025)
MEM	**-.016****	**.012****	**.006***	**.036****	**.017***	**.059****	**.009****	**-.084****
	(.007)	(.005)	(.004)	(.017)	(.009)	(.027)	(.002)	(.037)

Note: The estimates are based on partial canonical correlations between domestic investment in the row sector and FDI in the column sector. The procedure used is described by Johansen (1988). Standard errors are in parenthesis. * and ** indicate significance at the 5% and 1% significance levels respectively.