Externalities from Foreign Direct Investment: The Sectoral Pattern of Spillovers and Linkages*

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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 to date has dealt only with intra-industry spillovers from FDI without allowance for inter-industry effects. 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. Other producers may benefit, especially when MNCs transfer knowledge to local clients, or outsource to local upstream suppliers. FDI substitutes within-sector domestic investment but complements it across sectors. Hence, FDI can potentially induce not only exit and entry but also changes in incumbents' market shares across industries. 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 externality diffusion and measurement of spillover and linkage effects from FDI.

Keywords: Foreign direct investment, generic technology; *inter*-industry spillovers; absorptive capacity.
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 industrialised nations, as do international trade transactions. Yet, presently, the main source of international finance to developing countries is FDI. This trend has revitalised 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. It is conjectured that this is because previous efforts to measure spillovers have not been comprehensive enough. Existing studies have not found evidence of improvements in domestic productivity ensuing FDI partly because no allowance has been made for *inter*-industry diffusion. Industrial organization considerations imply that externalities in the form of static *intra*-industry productivity improvements for host-country firms from manufacturing activities by multinational corporations (MNCs) should not be expected. Other things equal, MNC's locate their subsidiaries where rent erosion due to local competition is least likely. In general, the MNC's optimal organizational strategy is designed to minimize the risk of propagation of specific technical knowledge to potential competitors.

Hence, 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 diffusion of generic knowhow, namely technical information that can be deployed across sectors, probably does not represent a loss of rents to the MNC. It may even be beneficial if potential upstream suppliers become more efficient. In contrast, *intra*-industry productivity improvements for domestic producers would be observed, if at all, with a substantial lag. Thus, the scarcity of empirical findings of *intra*-industry spillovers stemming from FDI is not surprising. Proper measurement of technological externalities, allowing for *inter*-industry spillovers, requires a multisectoral dynamic framework, which has been lacking in the literature. An econometric framework is developed to explore whether FDI generates externalities on manufacturing in the host country. The sectoral panel database used 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 asssess whether FDI complements domestic capital formation through either spillovers or linkages.

Efforts have been made to understand and measure the potential effects of subsidiary operations by MNCs on the productivity of domestic enterprises in host less-developed countries. Existing studies, however, have failed to emphasize some crucial elements in the inquiry of the technological spillovers of FDI. In particular, the degree to which the use of the MNC's proprietary technological information by indigenous competitors is excludable has not featured as a major determinant of spillover configuration. The latter has been primarily characterized as resulting from externalities beyond the control of those possessing technology and its recipients. Hence, the effect on domestic production possibilities, as well as industrial organization, regarding the appropriability afforded by FDI has not been incorporated in the analysis of the MNC's decision of what techniques to deploy. And, the adoption potential by enterprises in the host country has been presumed automatic, subject to skilled labor availability, and thus not included as a determinant in the industrial pattern of spillover diffusion.

There is a widespread opinion that one of the most efficient channels through which developing countries can gain access to superior technology is FDI (see e.g., Romer, 1993). However, econometric evidence that the activities of MNCs generate a positive externality on the efficiency of host-country producers is scarce. We argue that this could well be due to insufficient theory ahead of measurement. The MNC's strategy that minimizes rent erosion consists of limiting specific knowledge leakages to producers within its own industry. Yet, empirical studies have searched mainly for domestic *intra*-industry productivity enhancements in the data. Indeed, most recent empirical studies have found that local producers fare badly in the aftermath of FDI in their own sector. The result is not surprising if we take into account that the MNC requires incipient monopoly power to recover its sunk investment and will, thus, avoid strong competition. In equilibrium, the sectoral pattern of FDI is likely to feature concentration in industries where local firms in the subsidiary's own industry have limited *absorptive capacity* to adopt advanced techniques that could be imitated given the proximity of the MNC operation. As FDI is targeted to sectors in which the domestic competitive fringe is restricted by the scarcity of specific human capital and by limited access to equipment and machinery embodying frontier technology, *intra*-industry spillovers to domestic producers are unlikely even if MNC affiliates deploy novel techniques.

While theory suggests that *intra*-industry technological externalities stemming from FDI are very unlikely, at least in the short-run, it also suggests that *inter*-industry spillovers are likely to materialize. First, 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 purposes so as to limit the diffusion of generic knowledge is small. Therefore, generic technology, which can be deployed in production across several sectors, is more likely to propagate than sector-specific technology. Second, the techniques that can be adopted from generic knowledge in manufacturing activities generally require less absorptive capacity than specialized high-tech processes.

For example, 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. Some generic technologies, such as computer-automated design (CAD), need complementary equipment investments modest reltive to product-specific manufacturing technologies (see e.g. Kaplinsky, 1995). Third, if outsourcing is profitable for the subsidiary, MNC management will encourage knowledge sharing with suppliers. This process yields *inter*-industry spillovers that should be observed as productivity improvements in upstream sectors. Hence, the technical knowhow that is most likely to generate new technological opportunities for host-country producers is not industry-specific.

Beyond increasing domestic technological opportunities, there are several ways in which entry by MNC's can generate observed productivity gains for host-country producers. In particular, there are two types of pecuniary externalities stemming from the increased competition facing domestic producers. 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 obviously *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 sectors in which this scenario is likely. Finally, there are linkage externalities. The expansion in the variety of available inputs, due to both the demand and supply effects of MNC entry, can induce efficiency gains for both input users and providers. Clearly, the process that establishes backward and forward linkages is multisectoral since upstream and downstream producers will generally operate in different industries.

These considerations imply that proper measurement of technological externalities arising from FDI requires a multisectoral dynamic framework that allows for *inter*-industry spillovers. The wide technological gap among producers in the home-country and host-country of FDI implicit in the above analysis is not strictly relevant to industrialized host-countries. Although the same strategic considerations highlighted in the present study could be relevant to analyze some aspects of FDI between industrialized nations, we focus on the case in which the host-country is less developed. Rather than doing an aggregated cross-country study as Borensztein, De Gregorio and Lee (1998) already have done, we analyze industrial dynamics, in the presence of FDI, in a developing country using industrial panel data to derive aggregate behavior from heterogeneous sectoral adjustment.

Due to the dynamic nature of the diffusion process, we need 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. We merged the data from the Colombian Manufacturing Census 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 foreign direct investment 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.[1]

The paper is organized as follows. After this introduction, Section 2 reviews and discusses the related literature. The theoretical, qualitative 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 is derived. Section 4 provides the background facts, including a description of the data. Then, Section 5 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 producers are used to analyze the extent and determinants of spillovers. Finally, Section 6 draws conclusions and suggests directions for further research.

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[1] The present paper is the only one using plant data derived from the Colombian Manufacturing Census after 1991. Due to statistical reserve and confidentiality restrictions only sectoral analyses have been possible. By becoming a sworn agent

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, the classic paradigm about the determinants of FDI is presented and the prediction is borne out that the knowhow and designs that disseminate to domestic firms will be mostly *generic*, that is deployable in a wide range of sectors, and not *specific* to the MNC's subsidiary industry. At the end of the section, a synthesis is provided of evidence from case studies, cross-section and panel data. The discussion of the econometric evidence documents how the higher propensity for *inter*-industry effects has not featured prominently in previous research efforts about 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 strategic considerations underlying optimal decision-making by the MNC shows that an important feature of the choices made by management is the minimization of the probability of imitation. With imperfect intellectual property rights, it is crucial for the MNC to exclude competitors in its industry from access to its technology. Organizational choices can be used to delay the possibility for enterprises with sufficient absorptive capacity to emulate the technology deployed through FDI. There are efficiency gains from transaction cost minimization afforded by resource transfer within the MNC in an incomplete contracts environment (Ethier, 1986). Also, economies 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. The dissipation of rents from knowledge capital when *intra*-industry spillovers materialize cannot

of the Colombian Bureau of Statistics, the author was able to access plant-level information to build the database.

be avoided but the MNC organizes production to maximize the imitation lag (Ethier and Markusen, 1996).

Another important decision by the MNC once it has chosen FDI into a wholly owned affiliate, rather than licensing or setting up a joint venture, is location. The MNC entry pattern that minimizes the probability of rent erosion due to imitation will be such that *intra*-industry spillovers are unlikely. The optimal location of production avoids proximity to potential competitors with absorptive capacity to copy the production process. The MNC will locate where potential rivals cannot erode its market share (Markusen and Venables, 1998). Since the MNC can benefit from knowledge diffusion when it reaches upstream suppliers, and it will not lose when generic knowledge reaches producers of non-competing goods, *inter*-industry spillovers to complementary and non-competing sectors are more likely.

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). Other models that concentrate on the impact of MNC operations on the production possibilities of host country producers emphasize dynamic effect of the ensuing expansion of the demand for intermediate inputs and services. Not only do incumbent upstream sector producers benefit but also new firms may start providing goods or services that were previously unavailable in the host country. FDI fosters specialization by local suppliers. 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 (Markusen and Venables, 1999).

Hence, the impact of FDI goes beyond the change in utilization of the host-country factor endowment that improves allocative efficiency, the type of effect typically 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 (Romer, 1994; Rodriguez-Clare, 1996). 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.

If the number of incumbent competitors for the MNC in the host country is sufficiently large, the pro-competitive impact of MNC entry will be small. The survival-of-the-fittest effect and the managerial incentives effect tend to be large only when there are few incumbents. The potential impact on cost reduction embedded by these two effects is important only for incumbent firms within the entrant's industry. When the gap among domestic and foreign technology is wide, local producers lose market share and profits, and may eventually have to shut down. The most likely empirically observable pattern when competition is scarce is a fall in productivity due to excess capacity initially and closure eventually.

However, the possibility of adoption of cost-reducing production processes afforded by the entry of a new subsidiary can represent important gains for incumbents. This imitation effect materializes only if rents can be generated before spillovers occur to cover the entry costs of the MNC. If the copying of its technology by local producers limits the appropiability of rents from its technology, the MNC will not enter (Varian, 1996). MNC entry leading to imitation is profitable to the subsidiary only if spillovers are *inter*-industry but not *intra*-industry.

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 upstream but a loss when they diffuse within the subsidiary's industry. Similarly, given the choice of an optimal market penetration strategy by the MNC, pecuniary externalities in both input and output markets are likely to benefit producers in sectors different than the subsidiary's. As outlined in the introduction, and as will be evident from the following discussion of the empirical evidence, the higher propensity for *inter*-industry effects has not featured prominently in previous research efforts about the impact of FDI on domestic manufacturing in the host country.

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 host-country 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, only very recently, 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 plagued by 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 analysis 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 in sectors where the market share of MNC affiliates is not too high (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 adoption of these more advanced techniques.

2.2.2 Evidence from Panel Data

By and large the few panel studies about FDI spillovers in less developed countries find the absence of a positive *intra*-industry productivity effect (Haddad and Harrison, 1993; Harrison, 1996; Hoekman and Djankov, 1998; Aitken and Harrison, 1999).[2] 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

[2] The empirical findings are derived respectively from panel data of manufacturing plants in Morocco, Cote d'Ivoire, the Czech Republic and Venezuela.

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 "export quality" production, including information on standards, market access and distribution channels.

There is a failure in the literature 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.[3] 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.

For example, as the domestic human capital stock rises, the MNC will be able to produce at a relatively lower cost. But also, rent losses become more likely due to the possibility of technological diffusion to competitors. To the extent that excludability of technical knowledge is costly, only if the competitive fringe is constrained in some aspect of absorptive capacity, will the MNC find it profitable to deploy its specialized production processes. In the countries where there is evidence for absence of spillovers scarce absorptive capacity is likely to be a binding constraint in the adoption of specialized techniques.

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.[4] As discussed above, this will be a problem mostly for specific as opposed to generic technologies.[5] In this context, the implication of absence of *intra*-industry spillovers is not that knowledge transfer associated with FDI is negligible but rather that there is a need to facilitate access to domestic investment in equipment and machinery. While the policy recommendation not to subsidize FDI is not necessarily wrong, it is more appropriate to recommend capital and labor market policies that facilitate absorptive capacity build-up. Therefore, it is important distinguish why we do not observe FDI spillovers beyond pointing out their absence.

The reported evidence about FDI spillovers in Cote d'Ivoire, the Czech Republic, Morocco and Venezuela constitutes the first systematic effort to measure externalities from MNC activities using longitudinal data. The general finding of spillover absence 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 very limiting. While the positive contemporaneous correlation between sectoral productivity and sectoral FDI flows in cross-sectional

[3] Borensztein et al. (1998) found that FDI is associated with higher productivity only when the host-country has human capital above a threshold level. Also, evidence on aggregate productivity consistent with FDI spillovers found for Australia (Caves, 1974) and Canada (Globerman, 1975) may stem from availability of absorptive capacity.

[4] This may partly explain why otherwise identical software engineers working in Bangalore, India, earn about 10% of the salary of those working in Palo Alto, California; or, why the same type of employees in Intel Corp. earn 20% in Malaysia of what they would be paid if based in the US.

data could reflect a causal relation in either direction, the negative correlation in panel data confirms one of the implications from the theoretical literature.

However, it would be even more informative to allow for *inter*-industry spillovers to verify empirically whether panel data confirms the sectoral pattern predicted by theory about the impact of FDI on host-country industrial organization. When spillovers are not found at all, it is also informative to explore the cause of their absence. In contrast to previous empirical research about FDI spillovers based on longitudinal data, in this paper, the estimation of the extent of new technological opportunities for domestic manufacturers stemming from MNC operations includes potential effects both within the subsidiary's sector and across other sectors. The structural estimation framework allows for the both the technological spillovers and the pecuniary externalities highlighted in the discussion of the related literature. Furthermore, once the extent of spillovers in each sector is measured, an exploration of the determinants of whether ensuing adoption occurs is performed.

3 The Model and the Estimation Framework

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. 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. While the microfoundations of the diffusion pattern of FDI spillovers laid out in the last section are not directly built into the model, the analytic solution which leads to the structural estimation framework allows for both *inter*- and *intra*-industry externalities. The reduced form derived parametrizes the impact of both linkage and technological externalities. 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 analyse 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 set up is similar to that used in Kugler and Neusser (1998) to analyse the link among financial development and productivity growth, and follows the methodology proposed by Johansen (1991a, 1991b). The analysis of short-run and long run dynamics is used to estimate the permanent 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.

[5] 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 e.g. computer numerically controlled (CNC) equipment for assembly requires specifically tailored design, maintenance and training.

3.1 Building Blocks

The model is one of competitive equilibrium with endogenous technological change.[6] 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 across industries. There are complementarities among the investment paths of various manufacturers because the knowledge from accumulated experience disseminates. 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. 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 embodied aggregate productivity rises.

3.1.1 Technology

In each period t, with t$\in \{1,...,\infty\}$, n sectors manufacture distinct products indexed by i$\in \{1,...,\mathrm{n}\}$. There is perfect competition and the production function for each product is given by,

$$Y_{it} = F(K_{it}, H_{it}, X_{it}, \xi_{it}) = \xi_{it} E_i K_{it}^{\alpha_i} H_{it}^{1-\alpha_i} X_{it} \qquad (1),$$

where K_{it} and H_{it} are the stocks of physical and human capital respectively. The human capital stock is fixed and X_{it} captures technological spillovers to be specified below. At each time *t*, there is a realization of the technology shock vector $\xi_t = (\xi_{1t},...,\xi_{nt})'$. The assumption with respect to factor shares is that 0 $> \alpha = diag(\alpha_1,.....,\alpha_n) > I_n$.[7]

The motion equation for capital accumulation is given by,

$$K_{it+1} = G(K_{it}, I_{i1t},....., I_{int}, \eta_{it}) = D_i K_{it}^{d_i} \prod_{j=1}^{n} I_{ijt}^{\delta_{ij}} \eta_{it+1} \qquad (2),$$

for *i* = 1,...,n, where K_{i0} is given and I_{ijt} denotes gross investment in good j for accumulation of capital for the production of good *i.* The production function for the capital stock G(.) is linearly homogeneous in { I_{ijt} }$_{j=1,...,n}$ and the current capital stock K_{it} .[8] Accumulation is also subject to

[6] The sectoral structure is based on the models of Long and Plosser (1983) and Neusser (1997).

[7] Note that A$\leq$B if $a_{ij} \leq b_{ij}$ for all (i,j); A<B if A$\leq$B and A$\neq$B; and, A<<B if $a_{ij} < b_{ij}$ for all (i,j).

[8] Hence, $d_i + \sum_{j=1}^{n} \delta_{ij} = 1$ for all i.

productivity shocks represented by a n-dimensional stochastic process $\eta_{it} = (\eta_{1t},...,\eta_{nt})'$.

Define the matrices $\boldsymbol{d} \equiv diag(d_1,..., d_n)$ and $\delta \equiv \{\delta_{ij}\}$. Hence, constant returns in accumulation imply that $d + diag(\delta\iota) = I_n$ where $\iota = (1,....,1)'$. If $\delta_{ij} = 0$, good j is not needed to construct capital in sector i. The matrix δ characterizes the structure of backward and forward linkages among sectors. A large δ_{ij} magnifies the benefit of higher efficiency in production sector j for capital accumulation in sector i. The assumption is that for each i, there is at least some j such that $\delta_{ij} > 0$. Therefore, $\delta > 0$ and $\iota >> d\iota = \iota + \delta\iota \geq 0$. If for some j, $\delta_{ij} = 0$ for all i, then j is a pure consumption good.

The accumulation specification follows Lucas and Prescott (1971), and as a reduced form allows for decreasing returns, say due to adjustment costs. The parameter family δ can also be interpreted as measures of the relative quality between newer and older capital.[9]

Externalities are specified in the Arrow-Romer fashion as,

$$X_{it} = \prod_{j=1}^{n} (K_{jt}^{D})^{\gamma_{jt}^{D}} \prod_{j=1}^{n} (K_{jt}^{F})^{\gamma_{jt}^{F}} \qquad (3),$$

where the matrix $\gamma \equiv \{\gamma_{ij}\} \geq 0$ and γ_{ij} is a measure of the technological spillover emanating from investment in sector j 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,

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

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, $\theta = (\theta_1,...,\theta_n)' > 0$.

[9] If $\boldsymbol{d} = 0$, so that $\sum_{j=1}^{n} \delta_{ij} = 1$ for all i, obsolescence sets in one period, as in the case analyzed by Long and Plosser (1983).

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,

$$C_{jt} + \sum_{i=1}^{n} I_{ijt} = Y_{jt} \qquad (4),$$

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

Human capital is normalized so that,

$$\sum_{i=1}^{n} H_{it} = 1 \qquad (5).$$ [10]

Both technology shocks follow Markov processes. Specifically, their joint evolution is subject to a stable autoregressive process of order p:

$$\Phi(L)\begin{pmatrix} \ln \xi_t \\ \ln \eta_t \end{pmatrix} = (I_{2n} - \phi_1 L - ... - \phi_p L^p)\begin{pmatrix} \ln \xi_t \\ \ln \eta_t \end{pmatrix} = \mu + \omega_t \qquad (6),$$

where ω_t has distribution $WN(0, \Psi)$ (i.e., a vector of white noise perturbations with a joint normal distribution) . The set $\{\phi_k\}_{1 \le k \le p}$ is a collection of 2n x 2n matrices and $\mu \ge 0$ is a vector of constants with 2n elements, and L is the lag operator (e.g., $L^\tau Z_t = Z_{t-\tau}$).

3.2 The Competitive Equilibrium with Externalities

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 fisrt phase. It is verified that the sectoral paths satisfy the resource balance conditions to insure that there is mutual consistency among the aggregate equilibrium and individual optimality. [11]

The state of the economy in period t is given by just by the sectoral capital stocks as the technology shocks of the preceding *p* periods are white noise,

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[10] Human capital is not accumulated and is supplied inelastically.

[11] The log-linear structure of the problem implies that expectational indeterminacy is not an issue. See e.g. Boldrin and Rustichini, (1994) and Benhabib and Farmer (1994).

$$S_t = (K_{1t},\dots,K_{nt})'.$$

The externality pattern in period t is given by,

$$X_t = (X_{1t} ,\dots, X_{nt})' ,$$

where X(.) is a function of the capital stock vector which depends of the state of the economy and the technology shock to accumulation,

$$X_{t+1} = X (K_{t+1}) = X (K_t , \eta_{t+1})$$

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,

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

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

In particular,

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

where $Q(.,.)$ is the transition function implied by the Markov process of the shocks to production and accumulation.[12]

A log-linear solution is conjectured in terms of the variables in S_t ,

$$V(S;X) = b_0 + b_1 \ln K_1 + \dots + b_n \ln K_n \qquad (9),$$

to verify that it satisfies the first order necessary conditions of the Bellman Equation.

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

12 Note that in this problem, *X(.)* is exogenous.

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

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

From the Benveniste-Scheinkman equation we can obtain the private shadow price of sectoral capital as,[13]

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

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). These solutions imply the following reduced form of the accumulation path,

$$K_{\mathrm{it}+1} = D_i \prod_{j=1}^{n} \left(\frac{\beta \delta_{ij} b_i}{\theta_j + \beta \sum_{i=1}^{n} \delta_{ij} b_i} \xi_{jt} K_{jt}^{\alpha_j} H_{jt}^{1-\alpha_j} X_{jt} \right)^{\delta_{ij}} K_{it}^{d_i} \eta_{\mathrm{it}+1} \tag{12).}$$

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

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

Changes in productivity due to technology shocks are exactly offset by changes in prices that preserve the marginal revenue product unchanged.[14]

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.

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[13] See e.g. Lucas, Stokey and Prescott (1989).
[14] See e.g. Long and Plosser (1983).

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,

$$K_{\mathrm{it}+1} = D_i \prod_{j=1}^{n} \left[\left(\frac{\beta \delta_{ij} b_i}{\theta_j + \beta \sum_{i=1}^{n} \delta_{ij} b_i} \right)^{\delta_{ij}} \xi_{jt}^{\delta_{ij}} \quad K_{jt}^{\delta_{ij}\alpha_j} H_{jt}^{\delta_{ij}(1-\alpha_j)} \prod_{l=1}^{n} K_{lt}^{\delta_{ij}\gamma_{jl}} \right] K_{it}^{d_i} \eta_{\mathrm{it}+1} \qquad (14),$$

for each *i*.

Proposition 1 The logarithm of the state variable, namely the sectoral capital vector, can be characterized by the following first-order differential equation,

$$\Delta k_{\mathrm{t}+1} = c_k + (A - I_n) k_t + \varepsilon_{\mathrm{t}+1} \qquad (15),$$

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

Proof: See the Appendix.

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. Since the physical capital stock is the only reproducible factor of production, its motion equation determines the dynamics of the economy. In particular, aggregate growth depends on both sector specific incentives for investment, such depreciation and the ouput elasticity with respect to capital, as well as on the structure of sectoral interdependence. The *inter*-industry effect arises because of both linkages to upstream sectors and technological spillovers.

The characteristics of the matrix A determine the growth pattern of the system. For example, if A is a negative matrix, the economy will converge to a stagnation equilibrium. Analogously, if the elements of A were of such magnitude that Δk_t expands without bounds, the economy would go on an explosive path. The strength of mutisectoral externalities has to be limited. For example, if $\alpha_i = 1$ for some sector i, so that it has an AK technology, nonexplosive equilibrium is possible only in the absence of externalities. But, if $\alpha_i < 1, \forall i,$ balanced growth implies the existence of some technological externalities.[15]

[15] The algebraic properties of the growth process are discussed in detail in the appendix. In the proof of Proposition 1, it is shown that $A \equiv d + \delta(\alpha + \gamma)$.

To insure that there is convergence to a balanced growth path, we need that the diagonal elements of A are strictly positive,

$$a_{ii} = d_i + \delta_{ii}\alpha_i + \sum_{j=1}^{n} \delta_{ij}\gamma_{ji} > 0 \qquad (16).$$[16]

This inequality is violated if and only if simultaneously there is instantaneous depreciation ($d_i = 0$), the good is not needed for its own production ($\delta_{ii} = 0$), and for each sector j, either the good either does not any generate externalities ($\gamma_{ji} = 0$) or is not necessary in capital accumulation ($\delta_{ij} = 0$).

3.3 The Balanced Growth Path

In order to explore the impact of FDI on the technological opportunities of host-country manufacturing across sectors, it is necessary to tie capital accumulation and total factor productivity (TFP) dynamics. 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 its causation, in the Wiener-Granger sense, of TFP growth in domestic manufacturing across sectors.

In particular, establishing a long run pattern of coevolution 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.

3.3.1 Cointegration

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 in logarithmic form,

$$\{z_t\}_{t>0} \equiv \{y_t - \alpha k_t - (1-\alpha)h\}_{t>0},$$

where $h = (\ln H_1, \ldots\ldots, \ln H_n)'$ can be related to capital accumulation as follows,

$$z_t = y_t - \alpha k_t - (1-\alpha)h = \ln \xi_t + e + \gamma k_t \qquad (17),$$

[16] The off diagonal elements are given by $a_{ij} = \delta_{ij}\alpha_j + \sum_{l=1}^{n} \delta_{il}\gamma_{lj}$.

where lower-case variables are logarithms of upper-case ones.

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

$$\begin{pmatrix} I_n - AL & 0 \\ -\gamma & I_n \end{pmatrix}\begin{pmatrix} k_t \\ z_t \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} I_n & \delta L \\ 0 & I_n \end{pmatrix}\begin{pmatrix} \ln\eta_t \\ \ln\xi_t \end{pmatrix} \quad (18),$$

where $c_z \equiv e = (\ln E_1, \ldots\ldots, \ln E_n)'$, and in particular,

$$\begin{pmatrix} k_t \\ z_t \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} A & 0 \\ \gamma A L^{-1} & 0 \end{pmatrix}\begin{pmatrix} k_{t-1} \\ z_{t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_t \\ \ln\xi_t \end{pmatrix} \quad (19).$$

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 viceversa. 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.

3.3.2 Causality

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 (20) above can be written as:

$$\Lambda_t = \kappa + \Pi(L)\Lambda_{t-1} + u_t = \begin{pmatrix} \Lambda_{1,t} \\ \Lambda_{2,t} \end{pmatrix} = \begin{pmatrix} c_k \\ c_z \end{pmatrix} + \begin{pmatrix} \pi_{11}(L) & \pi_{12}(L) \\ \pi_{21}(L) & \pi_{22}(L) \end{pmatrix}\begin{pmatrix} \Lambda_{1,t-1} \\ \Lambda_{2,t-1} \end{pmatrix} + \begin{pmatrix} u_{1,t} \\ u_{2,t} \end{pmatrix} \quad (20),$$

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. From this expression we can obtain the VECR, which is the Wold representation,

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

and can be used to establish the causal structure of the system. The structural model implies that FDI spillover diffusion will lead to Wiener-Granger causality by FDI inflows of productivity across sectors.

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.[17] Before describing the data below and performing the cointegration and causality analysis, a further decomposition provides insight into the nature of capital accumulation.

Proposition 2 Balance growth induces unit roots in the process{ k_t } so that it is I(1). Hence, after a Beveridge-Nelson decomposition, the evolution of { k_t } can be represented as,

$$k_t = k_0 + Cc_k t + C\sum_{\tau=1}^{t}\varepsilon_\tau + \Theta(L)\varepsilon_t - \Theta(L)\varepsilon_0 \qquad (22),$$

where $\Theta(L)u_t$ is stationary, as u_t is I (0).

Proof: See the Appendix.

In synthesis, { k_t } has three parts: a deterministic linear trend; a multivariate random walk with a stochastic trend; and, a stationary component. When $b'C = 0$, { b' k_t } is a stationary process as the stochastic and deterministic trends disappear with the transformation. In the terminology of Engle and Granger (1987), *b* is a cointegration vector. Also, the mean growth rate is thus given by Cc_k . Let the vectors α and β be 2n dimensional and both different from zero such that Π = αβ´. If $\alpha'_\perp\mu$ equals zero no growth occurs. If equation (23) is multiplied by ß´ from the left both the linear trend and the multivariate random walk vanish because ß´C equals zero, demonstrating the stationarity of {ß´X_t}.

Finally, under the assumptions that imply balanced growth, when the matrix *A* is expressed in block diagonal form a number of the block matrices will have unit characteristic roots. The sectors corresponding to such blocks constitute the engine of growth. The nature of economic growth is determined by the structure of the matrix *C*. In particular, a necessary condition for the jth sector to expand in equilibrium is that the jth row of the matrix is positive.[18] If FDI finances investment in sectors that are part of the engine of growth, there will be *inter*-industry spillovers to those sectors that are not isolated.

4 Industrial Evolution and MNC Operations in Colombia

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.

4 Industrial Evolution and MNC Operations in Colombia

[17] A test of short-run causality would use $H_0 : \psi_{21}(L) = 0$ as the null hypothesis.

[18] In the set of Eigen vectors of the unit characteristic root { $x^{(1)},\ldots, x^{(o)}$ }, $x^{(k)} \neq 0$ iff sector *k* accesses sector *j*.

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.

4.1 The Data

The data set developed for the present study merges information from two sources: 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. These manufacturing data have been used by Clerides, Lach and Tybout (1998) and Roberts and Tybout (1996) to explore Colombian export dynamics. 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.

4.1.1 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 tend to have higher production per worker.

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 Bogota 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 some plants has grown over time, especially of those between 10 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 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.

4.1.2 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 tidal wave 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.

4.2 The Measurement of Technical Efficiency

In the measurement of technical efficiency as a residual, we have 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.[19]

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.

4.2.1 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

[19] The technique used fits a quadratic time trend for the productivity process and the estimation follows Tybout (1992).

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.

4.2.2 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.[20] 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.[21] 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%.

[20] 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.

[21] 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.

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 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.

4.2.3 Capacity Utilization and Returns to Scale

Slackness in the use of installed capacity should be associated with lower than usual energy consumption. Deviations form the secular quadratic trend give an indication of the intensity of production for the year in consideration. We use this observation to control for capacity utilization by detrending on the basis of energy use. Production is adjusted multiplying output by the ratio of actual energy use over energy use predicted from the quadratic trend.

In order to measure returns to scale, we estimate the product elasticities of human capital, physical capital and materials. We cannot reject the restriction that the elasticities add up to one in any given year at the 1 % level. Hence, there is no adjustment made for returns to scale. The maintained assumption is that the production function is homothetic with respect to plant size in input use. Our point estimates based on a loglinear production function are that the capital elasticity is 0.258, the labor elasticity 0.412, and the intermediate input elasticity 0.356.

The estimated elasticities are very important because we will not use factor shares to estimate technical efficiency as in the total factor productivity literature. When input markets are imperfect, factor shares do not always fullly reflect input product elasticities. Since labor and capital markets are not likely to be perfect in Colombia, the estimated elasticities are used in order to calculate technical efficiency.

5 Technological Opportunities and FDI

In this section, the empirical results with respect to the diffusion of externalities from FDI are analized. 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.

5.1 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.[22]

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 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. The motivation is that all sectors connected through spillovers and linkages share a stochastic trend.

5.2 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.

[22] 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.

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.

The diffusion of externalities from FDI 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, 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.

5.3 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 rule out *intra*-industry spillovers but allow for *inter*-industry spillovers. 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 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. 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.[23] The following proposition captures the econometric implications of how physical and human capital accumulation per worker determine the relationship between average labor productivity and TFP.

Proposition 3 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.

Proof: See the Appendix.

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.

5.4 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 the former 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.[24]

[23] As derived in the Appendix, this observation leads to a definition of absorptive capacity as a weighted average of physical capital per worker and human capital per worker, where the weights are the shares of the respective inputs.

[24] The concept of causality used was introduced by Granger (1969) and further elaborated by Sims (1972).

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 1991; 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.[25] 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.[26] 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.

[25] A test of short-run causality would use $H_0 : \psi_{12}(L) = 0$ as the null hypothesis. See equation (21).

[26] 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.

5.5 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,

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

in which domestic TFP is decomposed in terms of a sectoral constant, FDI spillovers and a technological shock.[27] 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.[28] 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,

$$a_{ij}^F = \delta_{ij} \alpha_j^F + \sum_{l=1}^{n} \delta_{il} \gamma_{lj}^F = \frac{\partial k_i}{\partial I_{il}} \frac{\partial y_j}{\partial k_j} + \sum_{l=1}^{n} \frac{\partial k_i}{\partial I_{il}} \frac{\partial x_l}{\partial k_j^F} .$$ [29]

Hence, spillovers translate into growth if the sectors to which externalities diffuse provide inputs to other industries. In other words, forward linkages and spillovers are complements in the generation growth. Table 10 shows that 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 both forward and backward linkages. When MNCs import some intermediate inputs, crowding out of local upstream suppliers also occurs.

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[27] 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.

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

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

6 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 is needed. Recently, the availability of panel databases has made it possible to explore in more detail the extent of spillovers. By and large, the new evidence is focused on the rejection of *intra*-industry FDI spillovers. One study finds evidence of diffusion of generic knowledge, namely spillovers of exporting knowhow (Aitken, Hanson and Harrison, 1997). Although most recent findings seem at odds with the previous literature, both theoretical and empirical, they are in fact consistent with existing models and evidence. In particular, 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. 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 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 largely 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 recent 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.

In a normative context, the desirability of FDI as a market penetration strategy depends on the industrial organization in the host country. Also, the presence of MNC subsidiaries can impact the market structure of the domestic industry. On the one hand, the entry of foreign firms can have a predatory effect at the *intra*-industry level if inefficient producers are driven out of business. On the other hand, it could also provide a stimulus at the *inter*-industry level if there is an expansion in the demand for locally manufactured intermediate inputs. The predatory effect can improve long run efficiency only if there is a competitive fringe that disciplines the MNC subsidiary. As already discussed, the headquarters' strategy in choosing the optimal location will be to minimize the probability of market share loss subject to the availability of human capital. FDI can be a mechanism to seek monopolistic power while lowering production costs. If the costs of acquiring equipment and machinery embodying state-of-the-art technology are prohibitive or liquidity constraints on host country entrepreneurs are binding, the MNC subsidiary may emerge as a monopoly with limited incentives to introduce new techniques. In this case, competition is possible only if either FDI is unregulated or there is free international trade. Otherwise, there is no market discipline making it costly for the first mover or incumbent subsidiary to neglect productivity enhancing investments and engage in monopolistic practices.

Within the estimation framework sectors can be classified according to their growth properties: sectors that are part of the engine of growth; sectors that are not part of the engine of growth but are linked to it; and sectors that are isolated from the growth process. The leading sectors are catalysts for growth. Other sectors generate industrial development only indirectly. Meanwhile, the isolated sectors are unable to profit from linking with the engine of growth sectors. The impact of FDI depends on the characteristics of the sectors in which the multinational corporations concentrate. Inward foreign investment has the potential to be an engine of growth if it goes to leading sectors. If the inflows of investment go to sectors, which demand goods from leading sectors as inputs in capital accumulation, the presence of multinational corporations generates pecuniary externalities. Even if the foreign investment does not generate technological externalities, it can promote the sectors that constitute the engine of growth through upstream input demand. When FDI goes to leading industries, the operations of multinational corporations generate growth through *forward linkages*. In this case inward investment can enhance technological opportunities in other sectors. When investment is targeted to sectors that demand goods from leading sectors we have *backward linkages*, which stimulate the engine of growth. Finally, if FDI concentrates in sectors in the periphery of industrial development, it can be a hindrance to growth if it absorbs resources from other sectors causing *Dutch disease.*

In Colombian manufacturing, the industries that least benefit from FDI are food, basic metals and non-metallic minerals. The sectors that are able to benefit the most from FDI spillovers are paper and wood. The only sector that exhibits *intra*-industry spillovers is machinery and equipment. The FDI that generates the widest scope of technological opportunities to domestic manufacturers is concentrated in the chemicals and food sectors. While FDI may be not concentrated in the sectors with the most potential to provide widespread positive externalities, the presence of MNCs has generated neither a predatory influence on domestic competitors nor generalized Dutch disease. The findings complement the existing literature by showing that measurement of the diffusion of externalities from FDI requires a framework that accounts for sectoral interdependence among domestic and foreign producers. The *intra*-industry effect of FDI is part of the story about the impact on host-country manufacturing. With regard to spillovers, the greatest impact of MNCs is across rather than within the subsidiaries' own industries. The results show the prevalence of *inter*-industry externalities from FDI. Given the magnitude of current FDI inflows to less developed countries, this new evidence on the impact of MNC activities on host-country manufacturing is important.

In this paper, the parameters capturing the sectoral structure of technical knowledge spillovers from FDI have been estimated. Further research will attempt to decompose the impact of linkage externalities and competition. The main difficulty with measuring the extent of pecuniary externalities is that the available sectoral input-output tables encompass all manufacturers. However, since the technologies utilized by host country producers and by MNCs are different, these tables are inappropriate. Indeed, a stylized fact about MNCs is that their total factor productivity exceeds that of the host country competitive fringe. This is likely due to the fact that projects financed through FDI deploy more advanced technologies. To assess the impact of linkage externalities, input-output tables for each type of firm will be constructed. Finally, a decomposition of entry-exit dynamics among domestic enterprises is needed to measure the pro-competitive impact of FDI.

References

Aitken, B., G. Hanson and A. Harrison (1997), "Spillovers, Foreign Investment, and Export Behavior," *Journal of International Economics*, 43(1): 103-32.

Aitken, B., R. Lipsey and A. Harrison (1996), "Wages and Foreign Ownership: A Comparative Study of Mexico, Venezuela, and the United States," *Journal of International Economics*, 40(3): 345-71.

Aitken, B. and A. Harrison (1999), "Do Domestic Firms Benefit from Direct Foreign Investment? Evidence from Venezuela," *American Economic Review*; 89(3): 605-18.

Bardhan, P. (1982), "Imports, domestic production, and transnational vertical integration: a theoretical note," *Journal of Political Economy*, 90(5): 1020-1034.

Beveridge, S. and C. Nelson (1981). "A New Approach to Decomposition of Economic Time Series into Permanent and Transitory Components with Particular Attention to the Measurement of the Business Cycles." *Journal of Monetary Economics* 7:151-174.

Blomstrom, M., "Foreign investment and productive efficiency: The case of Mexico," *Journal of Industrial Economics*, 35(1): 97-110.

Blomstrom, M. and A. Kokko (1998), "Multinational corporations and spillovers," *Journal of Economic Surveys*; 12(3): 247-77.

Borensztein, E., J. De Gregorio and J-W. Lee (1998), "How Does Foreign Direct Investment Affect Economic Growth?", *Journal of International Economics* 45: 115-136.

Caves, R., *Multinational enterprise and economic analysis*, Cambridge University Press, 1982.

Clerides, S., S. Lach and J. Tybout (1998), "Is there learning by exporting? Micro evidence from Colombia, Mexico and Morocco," *Quarterly Journal of Economics*, 113(3), August 1998, pages 903-47.

Dunning, J. (1977) "Trade, location of economic activity and MNE: A search for an eclectic approach," in B. Ohlin, P.-O Hesselborn and P. Wijkman (eds.), *The International Allocation of Economic Activity*, London: Macmillan.

Engle, R. and C. Granger (1987). "Co-integration and Error Correction: Representation, Estimation and Testing." *Econometrica* 55:251-276.

Ethier, W. (1986), "The multinational firm," *Quarterly Journal of Economics*, 101(4): 805-834.

Globerman, S. (1975), "Technological diffusion in the Canadian tool and dye industry," *Review of Economics and Statistics*, 57(4): 428-444.

Griliches, Z. and J. Hausman (1986), “Errors in variables in panel data,” *Journal of Econometrics* 31(1): 93-118.

Griliches, Z. and V. Ringstad (1971), *Economies of scale and the form of the production function*, North Holland, Amsterdam.

Haddad, M. and A. Harrison (1993), “Are there positive spillovers from direct foreign investment? Evidence from panel data for Morocco,” *Journal of Development Economics*, 42(1): 51-74.

Harberger, A. (1969), “La tasa de retorno del capital en Colombia,” *Revista de Planeación y Desarrollo* 1(3):13-42.

Harrison, A. (1996). “Determinants and Effects of Foreign Direct Investment,” pp. 163-186 in Roberts, M. and J. Tybout (eds.), *Industrial Evolution in Developing Countries.* Oxford University Press.

Helpman, E. (1984), "Multinational corporations and trade structure," *Review of Economic Studies*, 92(3): 451-71.

Hopenhayn, H. (1992), “Entry, exit and firm dynamics in long-run equilibrium,” *Econometrica* 60(5): 1127-50.

Hulten, C. and F. Wykoff (1981), “The estimation of economic depreciation using vintage asset prices,” *Journal of Econometrics*, 15: 367-396.

Hirschman, A. (1977). “A Generalized Linkage Approach to Development, with Special Reference to Staples,” *Economic Development and Cultural Change* 25:67-98.

Jensen, R. (1982), “Adoption and diffusion of an innovation with uncertain profitability,” *Journal of Economic Theory*, 27(1): 182-193.

Johansen, S. (1991). “Estimation and Hypothesis Testing of Cointegration Vectors in Gaussian Vector Autoregressive Models.” *Econometrica*, 59:1551-1580.

Johansen, S. (198). “Statistical Análisis of Cointegration Vectors,” *Journal of Economics Dynamics and Control*, 12:231-24.

Jovanovic, B. (1982), “Selection and the evolution of industry,” *Econometrica* 50(3): 649-70.

Kaplinsky, R. (1995), “Technique and system:The spread of Japanese management techniques to developing countries,” *World Development*, 23(1): 57-71.

Kokko, A. (1994), “Technology, market characteristics, and spillovers,” *Journal of Development Economics*, 43(2): 279-293.

Kugler, M. and K. Neusser (1998), "Manufacturing growth and financial development: Evidence from OECD countries," *Review of Economics and Statistics*, 80(4): 638-46.

Mansfield, E. and A. Romeo (1980), "Technology transfer to overseas subsidiaries by US-based firms," *Quarterly Journal of Economics*, 95(4): 737-50.

Markusen, J. and A. Venables (1999), "Foreign Direct Investment as a Catalyst for Industrial Development," *European Economic Review*; 43(2): 335-56.

Markusen, J. and A. Venables (1998), "Multinational Firms and the New Trade Theory," *Journal of International Economics*; 46(2): 183-203.

Neusser, K. (1997). "Sectoral Growth with Marshallian Externalities." Mimeo, University of Bern.

Ng, S. and P. Perron (1995). "Unit Root Tests in ARMA Models with Data Dependent Methods for the Selection of the Trunction Lag." *Journal of the American Statistical Association* 90:268-291.

Pakes, A. and R. Ericson (1995), "Markov-perfect industry dynamics: A framework for empirical work," *Review of Economic Studies* 62:53-82.

Rivera-Batiz, F. and L. Rivera-Batiz (1990), "The effects of direct foreign direct investment in the presence of increasing returns due to specialization," *Journal of Economic Development* 34(2): 287-307.

Roberts, M. and J. Tybout (1997), "The Decision to Export in Colombia: An Empirical Model of Entry with Sunk Costs," *American Economic Review*, 87(4): 545-64.

Roberts, M. and J. Tybout, eds. (1996), *Industrial Evolution in Developing Countries.* Oxford University Press.

Rodriguez-Clare, A. (1996), "Multinationals, linkages, and economic development," *American Economic Review*, 86(4): 852-73.

Romeo, A. (1975), "Inter-industry and interfirm differences in the rate of diffusion of an innovation," *Review of Economics and Statistics*, 57(3): 311-319.

Romer, P. (1994), "New goods, old theory and the welfare costs of trade restrictions," *Journal of Development Economics*, 43(1): 5-38.

________ (1993), "Idea gaps and Object Gaps in Economic Development," *Journal of Monetary Economics,* 32(3): 543-573.

Tybout, J. (1992), "Making noisy data sing: Estimating production technologies in developing countries," *Journal of Econometrics* 53:25-44.

Varian, H. (1995), "Entry and cost reduction," *Japan and the World Economy*, 7(4): 399-410.

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 largest source of financing is FDI. 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

	Sectoral Capital Stock Financed through FDI							
Domestic Sectoral TFP	FBT	TEX	WOD	PAP	CHE	NMM	MTL	MEM
FBT	**2.44**	8.38	16.17**	23.41**	13.92*	10.67	9.40	12.59*
	(3)	(4)	(2)	(2)	(1)	(3)	(2)	(1)
TEX	6.42	**8.41**	13.90*	12.73*	14.06*	8.41	11.10*	7.07
	(2)	(3)	(2)	(3)	(1)	(2)	(4)	(3)
WOD	13.58*	18.92**	**7.80**	19.32**	7.80	13.99*	18.38**	9.35
	(1)	(4)	(4)	(3)	(2)	(1)	(3)	(3)
PAP	12.52*	11.95*	16.39**	**7.03**	16.56**	16.04**	8.92	12.33*
	(3)	(3)	(4)	(1)	(2)	(2)	(1)	(2)
CHE	12.68*	15.74*	16.07**	13.79*	**11.69**	7.45	20.13**	12.38*
	(2)	(1)	(3)	(4)	(3)	(4)	(1)	(4)
NMM	18.43**	5.27	14.08*	9.42	6.11	**5.02**	11.68*	13.13*
	(4)	(2)	(3)	(2)	(4)	(1)	(3)	(1)
MTL	15.24*	17.49**	9.74	8.25	12.64*	8.02	**5.77**	8.34
	(3)	(4)	(1)	(2)	(3)	(2)	(3)	(2)
MEM	19.04**	11.95*	18.69**	9.35	13.07*	19.23**	8.55	**14.34***
	(2)	(2)	(4)	(3)	(1)	(3)	(4)	(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 (1995). 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 (1995). 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 – The 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.

Appendix A – Proofs of Propositions

Proof of Proposition 1 Writing the capital stock vector whose components are determined by (14) in logarithmic form, the following expression follows,

$$k_{t+1} = c_k + [d + \delta(\alpha + \gamma)]k_t + \ln\eta_{t+1} + \delta \ln \xi_t \quad ,$$

and, $k_{t+1} = c_k + Ak_t + \varepsilon_{t+1}$, where c_k is a constant vector determined by the technology and preference primitives, the matrix in the equation is appropriately defined as $A \equiv d + \delta(\alpha + \gamma)$ and the error term vector as $\varepsilon_t \equiv \ln\eta_t + \delta \ln \xi_{t-1}$. Then, (15) obtains by differencing.

❑

Proof of Proposition 2 First, the following assumptions are made: (i) The initial values $\{\Lambda_{-k+1}, \ldots, \Lambda_0\}$ are considered to be fixed constants, and (ii) the roots of the characteristic polynomial are strictly outside the unit circle or equal to one; i.e. $|I_2 - \Pi(z)z| = 0 \Rightarrow |z| > 1$ or $z = 1$.

These are consistent with the reduced form (19) of the model derived above and satisfy the Granger Representation Theorem, which allows to write down the Beveridge-Nelson decomposition of the process $\{X_t\}$ as,

$$\Lambda_t = \Lambda_0 + C\kappa t + C\sum_{\tau=1}^{t} u_\tau + \zeta_t \quad ,$$

where $\{\zeta_t\}$ is a mean zero stationary process constructed from $\{u_t\}$, whose first n elements are represented in (22) and,

$$C = \beta_\perp \left[\alpha'_\perp (\Gamma(1) - I\ )\beta_\perp\right]^{-1} \alpha'_\perp \ ,$$

which is exactly the sum of the coefficient matrices in (21), the Wold representation of $\{\Delta\Lambda_t\}$, where $\perp$ denotes the orthogonal complement of the space generated by the column vectors of the corresponding matrix, and $\Pi = \Pi(1) - I$. The vectors α and β are 2n dimensional and both different from zero such that $\Pi = \alpha\beta'$. If $\alpha'_\perp (\Psi(1) - I\ )\beta_\perp$ is nonsingular, the process $\{\Delta\Lambda_t\}$ is stationary (Johansen 1991, p. 1559).

❑

Proof of Proposition 3 The production function in equation (1) can be written as,

$$Y_{it} = F(K_{it}, H_{it}, X_{it}, \xi_{it}) = \xi_{it} E_i K_{it}^{\alpha_i} (\overline{H}_{it} L_{it})^{1-\alpha_i} X_{it} \ ,$$

where $\overline{H}$ is human capital per worker and L is the number of workers.

Also, let $Z_{it} \equiv \xi_{it} E_i X_{it}$ be the state of technology. Hence, the impact of a change in the state of technology on average labor productivity may be written as,

$$\frac{\partial (Y_{it} / L_{it})}{\partial Z_{it}} = (K_{it} / L_{it})^{\alpha_i} (\overline{H}_{it})^{1-\alpha_i} \qquad \text{(A1).}$$

Analogously to equation (22), $z_t = \ln(Z_{1t}, ..., Z_{nt})'$ can be expressed as,

$$z_t = y_t - \alpha k_t - (1-\alpha)(\overline{h} + l) \; ,$$

using lowercase letterds for logarithmic vectors.

Now, labor productivity in logarithmic form is derived from the production function as,

$$\lambda_t \equiv y_t - l = z_t + \alpha(k_t - l) + (1-\alpha)\overline{h} \qquad \text{(A2).}$$

Let the vectoral logarithmic expression of (A1) be given by,

$$v_t \equiv \ln\left(\frac{\partial (Y_{1t} / L_{1t})}{\partial Z_{1t}}, ..., \frac{\partial (Y_{nt} / L_{nt})}{\partial Z_{nt}} \right),$$

and from (A1) and (A2),

$$v_t = \alpha(k_t - l) + (1-\alpha)\overline{h} = \lambda_t - z_t \, .$$

Hence, { v_t } is stationary if the logarithms of labor productivity { λ_t } and TFP { z_t } are cointegrated with cointegration vector (1, -1)'.

❑

Appendix B – The Algebraic Properties of Balanced Growth

The structure of the model satisfies the Perron-Froebenius Theorem from which the results below are derived (Berman and Plemmons, 1979, pp. 26-33). A is a non-negative matrix. Its spectral properties are such that the nonnegative octant of $\Re^n$ is left invariable. In particular, implies that A and its spectral radius $\rho(A)$ has the following properties:

<u>Property 1:</u> A is non-negative. I.e, $a_{ij} \geq 0, \forall i, j \in \{1, \ldots, n\}$, and $A \neq 0$. Then $\rho(A)$ is an Eigen value and a non-negative Eigen vector, $x \geq 0$, associated with $\rho(A)$ exists.

<u>Property 2:</u> A can be reduced to block triangular form by reorganizing the sectors:

$$A = \begin{pmatrix} A_{11} & 0 & \dots & \dots & 0 \\ . & A_{22} & 0 & \dots & 0 \\ . & . & . & 0 & . \\ . & . & . & . & . \\ A_{m1} & A_{m2} & . & . & A_{mm} \end{pmatrix},$$

where each block A_{ii} is square and irreducible.

Property 3: The sum or rows and columns of A, r_i y c_i respectively, satisfy the following conditions:

$$\min_i \; r_i \leq \rho(A) \leq \max_i \; r_i$$
$$\min_i \; c_i \leq \rho(A) \leq \max_i \; c_i$$

Equilibrium growth is only possible if $\rho(A) \geq 1$ given that $\{\varepsilon_t\}$ is a stationary process. Excluding the possibility of explosive Eigen values, $\rho(A)$ =1 is the only case compatible with balanced growth. The only equilibrium is one with balanced growth if both explosive and stagnating paths are ruled out. The following condition guarantees homogeneity of degree one with respect to the reproducible factor.

Assumption 1: $\rho(A)$ =1.

From Property 3, we know that this assumption imposes bounds on the strength of the externality. If there were no interindustry externalities (i.e., $\gamma = 0$ or $\gamma = I$), the sum of rows and columns respectively would be:

$$r_i = d_i + \sum_{j=1}^{n} \delta_{ij}\alpha_j \quad \text{and} \quad c_i = d_i + \sum_{j=1}^{n} \delta_{ji}\alpha_j \, .$$

As $\alpha_i \leq 1$, Property 3 can be satisfied when $\rho(A)$ =1 if $\alpha_i = 1$, for some i. But if $\alpha_i < 1, \forall i,$ the assumption implies the existence of externalities ($\gamma > 0$). The externality cannot be so strong that either $r_i > 1$ or $c_i > 1$ thus violating Property 3. To insure that there is convergence to a balanced growth path, a further assumption is needed.

Assumption 2: The sum of diagonal elements of the each component of the block is positive. For each block A_{kk} an element exists a_{ii} such that,

$$a_{ii} = d_i + \delta_{ii}\alpha_i + \sum_{j=1}^{n} \delta_{ij}\gamma_{ji} > 0 \, .$$

This inequality is violated if simultaneously there is total depreciation ($d_i = 0$); the good is not needed for its own production ($\delta_{ii} = 0$), and for each sector j, and either the good either does not generate externalities ($\gamma_{ji} = 0$) or is not necessary for capital accumulation ($\delta_{ij} = 0$). The condition in this assumption must be satisfied only for one element of A_{kk} and is therefore minimal. Assumptions 1 and 2 together imply that $\rho(A)$ =1 is the only Eigen value on the unit circle. Thus, we exclude possible solutions with periodic endogenous cycles.

Lemma 1: Under assumptions 1 and 2, if λ is an Eigen value with $|\lambda| = 1$, then,

$$\lambda = \rho(A) = 1.$$

The unit Eigen value induces unit roots in the process{ k_t } and therefore { Δk_t } is stationary if the largest block of the Jordan canonical form of A corresponding to the Eigen value $\rho(A) = 1$ is one dimensional.

Lemma 2: There exists a non-singular matrix *P* such that the Jordan canonical form of P can be written as, $\begin{pmatrix} I_m & 0 \\ 0 & J \end{pmatrix} = P^{-1}AP$. There exists also a matrix *C, (n x n)*, with the following characteristics,

(1) *C* is non-negative,
(2) *C* is of rank *m*,
(3) *b'C = 0 = Ca*,
(4) The columns (rows) of C are right (left) Eigen vectors of A asociated with the value $\rho(A) = 1$,
(5) *C* is idempotent, so that *C' C = C.*

The matrix $(I_n - A)$ in the representation { Δk_t} is nonsingular with rank *n – m* and with one last assumption the industrial structure can be linked to the growth pattern.

Assumption 3: The rank of $(I_n - A)$ is the same as the rank of $(I_n - A)^2$.

Under assumptions 1, 2, y 3, there are $e \leq m$ diagonal blocks with unit Eigen values. The sectors corresponding to such blocks drive growth. There are *e* sectors that constitute the engine of growth. The nature of economic growth is determined by the structure of the matrix *C*. In particular, a necessary condition for the jth sector to expand in equilibrium is that the jth row of the matrix is positive. Let $\{x^{(1)}, \ldots, x^{(o)}\}$ be the set of Eigen vectors of $\rho(A)$. The kth element of $\{x^{(1)}, \ldots, x^{(o)}\}$ is strictly greater than zero if and only if sector *k* has access to the engine of growth sector *j*.