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International knowledge spillovers and productivity: A study of the manufacturing industry in Mexico

Flujo internacional de conocimientos y productividad: un estudio de la industria manufacturera en México

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Abstract

The aim of this paper is to examine the degree of impact of technological externalities, associated with international trade and foreign direct investment (*FDI*), on productivity, and the role of technological capabilities in the process of dissemination of knowledge. Tested empirically the contribution of the international flow of knowledge on Total Factor Productivity (*TPF*) of manufacturing in Mexico for the period 1999-2012, using a panel autoregressive distributive lag (ARDL) model. The main findings are: i) the presence of gains in productivity via international trade, however the magnitude of these coefficients is small; ii) technological externalities are more relevant in sectors with high technological capacity; iii) the FDI has a marginal and inconclusive on the performance of productivity contribution.

JEL Codes: O30, O31, O47.
Keywords: Technological Externalities; Technological Capabilities; Productivity.

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Resumen

El objetivo de este trabajo es examinar el grado de incidencia de las externalidades tecnológicas, asociadas con el comercio y la Inversión Extranjera Directa (*IED*), sobre la productividad, así como el papel de las capacidades tecnológicas en el proceso de difusión de conocimientos. Con este fin, se prueba empíricamente, mediante un modelo panel autorregresivo con rezagos distribuidos (*ARDL*), la contribución del flujo de conocimientos internacional sobre la Productividad Total de Factores (PTF) de la industria manufacturera de México para el periodo 1999-2012. Los resultados principales indican: i) la presencia de ganancias en productividad vía el comercio internacional, sin embargo, la magnitud de estos coeficientes es pequeña; ii) las externalidades tecnológicas son más relevantes en los sectores de alta intensidad tecnológica; iii) la ejerce una contribución marginal y poco concluyente sobre el desempeño de la productividad.

Códigos JEL: O30, O31, O47.
Palabras Clave: Externalidades Tecnológicas; Capacidades Tecnológicas; Productividad.

Introduction

During the 1980s Mexico began the transition to a development strategy driven by economic openness. The underlying argument of this structural change—driven by the new global consensus on growth and development (IMF, 1997; OECD, 1998)—was that it would allow the economy to be more responsive to external shocks, encourage competition, boost competitiveness, promote technology transfer, improve the efficiency of the productive plant, and achieve sustained growth rates.

However, it is paradoxical that, after the implementation of extensive reforms to the economic system (commercial and financial deregulation), having macroeconomic stability and a vertiginous expansion of international trade, the rate of product growth retains a meagre dynamic. It is also clear that, despite the strengthening of the manufacturing sector (especially that of export), this has not been sufficient to sustain the growth of the economy as a whole.

Indeed, the specialization of the manufacturing industry in assembly/maquila segments and the heavy weight of imported production inputs seem to represent a cardinal restriction, first, of the achievement of gains in productivity and, second, of industrial competitiveness, in contrast to the dynamism of subsectors such as automotive or computer equipment.

Typically, the literature recognizes that a significant part of the technological progress of semi-industrialized countries is the result of the absorption and adaptation of foreign technology. However, exposure to the global technological frontier is not sufficient to ensure dynamic gains, since dispositions such as institutional development or the deepening of the financial system appear as fundamental determinants to optimize the process of acquisition, use, absorption, adaptation, and improvement of existing technology (Aghion and Howitt, 2009; World Bank, 2008; Fagerberg and Srholec, 2007; Lall, 1992; Grossman and Helpman, 1991, Ch. 5).

Naturally, this study seeks to know the extent and importance of the contribution of foreign technology capital—through trade or *FDI*—to the productivity performance of the manufacturing sector of Mexico, as well as the impact that the development of local technological capabilities has on the process of international diffusion of knowledge.

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The purpose is to obtain consistent evidence that allows a line of reflection to be drawn around the dynamic effects—magnitude and direction—that economic openness generates on industrial productivity and, therefore, on the rate of product growth, through the phenomenon of technological externalities. The aim is also to study the role of the formation of local technological capabilities in the diffusion of knowledge.

From this perspective, two generic assumptions are tested: first, that productivity gains are significant with a greater degree of economic openness; thus, the increase in trade intensity with industrialized countries (north-south model) stimulates the process of technology diffusion on and, therefore, productivity growth; second, that exposure to the global technological frontier does not generate an automatic virtuous circle, since disincorporation and appropriation of the international flow of knowledge, associated with trade and *FDI*, will be conditioned by the development of local technological capabilities.

The contribution of this study lies in the simultaneous analysis, at the industrial level, of international trade (exports and imports) and of *FDI* as channels of technology spillover, in addition to incorporating an industrial technology differentiation indicator to measure the role of innovation in the process of knowledge diffusion.

The work is organized as follows. In the first section, some stylized facts about the economic, commercial, and investment dynamics in Mexico are presented, outlining a preliminary causal relationship between productive specialization, competitiveness, and productivity. In the second section, a review of the state of the art is done with the purpose of knowing the main results and methodologies used in the study of the dynamic effects of economic openness. In the third and fourth sections, the theoretical and empirical discussion is established, respectively, on the process of knowledge diffusion, with the objective of examining the degree of incidence of technological externalities on the growth rate of productivity, as well as the role of technological capabilities in this process.

Mexico: general trend in economic activity, trade, and investment

The economic instability experienced in 1976 and 1982 promoted a wide debate on the continuity of the Substitution Industrialization Model (SIM) and, with it, the execution of intense commercial reforms and financial deregulation. The objective of these structural changes would be to ensure proper macroeconomic functioning, reduce the vulnerability of exports to external shocks, encourage competition and efficiency in the production plant, promote technology transfer, place the export manufacturing sector at the core of development, and achieve sustained economic growth rates (Puyana and Romero, 2009; IMF, 1997; OECD, 1998).

In a general balance, this new development strategy has generated mixed results. In macroeconomic matters, although the effects have been reasonable—since it was possible to contain the fiscal deficit and the inflation rate, as well as the amount and cost of the debt—the growth of the product has been moderate, flanked by a systematic contraction of the productivity and a deep delay of the development of the capabilities of decoding and technological creation. Indeed, the consolidation stage of the "Outward Growth Model" (*OGM*), marked by the entry into force of the North American Free Trade Agreement (*NAFTA*), allowed the Mexican economy to have a successful insertion into the international market, based on the rapid expansion of exports and the inflow of *FDI*; however; it also meant the substantial increase of imports due to the high content of inputs from foreign countries in the production of exports (see Table 1).

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Table 1
Mexico: Macroeconomic dynamic, external sector, and innovation

Variable	1994-2000	2000-2005	2005-2010	2010-2015	1994-2015
GDP/1	3.2	1.6	1.9	2.9	2.4
GDP per capita/1	1.4	0.3	0.4	1.4	0.9
TFP/1	-0.3	-0.7	-0.7	0.1	-0.3
FDI/1	7.1	4.7	-0.9	3.2	3.6
Export/1	11.7	2.8	3.2	6.7	6.4
Import/1	12.5	4.3	3.9	6.1	7.0
Inflation /1	21.6	4.9	4.4	3.6	9.0
Fiscal Balance/2	-4.2	-2.4	-2.2	-3.9	-3.3
Debt/2	44.2	41.8	40.5	46.1	43.5
R&D Expenses /2	0.3	0.4	0.5	0.5	0.4
Triadic Patents	9.9	15.9	18.7	16.9	15.2
Researchers/3	0.7	1.0	1.1	0.9	0.9

Own elaboration with data from the World Bank, INEGI, OECD, and IMF
1/ Average annual growth rate; 2/ Indicator as a proportion of GDP; 3/ Total researcher per 1000 personnel employed.

At the industrial level, the results are equally characteristic. Between 1990 and 2015 the manufacturing added value (*AV*) contracted to an average annual rate of 2.5%, while its participation in the national total decreased 3.0% to 18.8% during 2015; a figure that highlights the contribution of low technological intensity activities and the lax linkage capacity of the more dynamic industries. In the matter of efficiency[1], the manufacturing sector presents evidence of particular contrasts, because even if labor productivity (*LP*) grew during this period to an average annual growth of 1.7%, the total factor productivity (*TFP*) contracted to an average annual rate of 0.5%. Undoubtedly, the evolution of these indicators constitutes a relevant explanation to the slow growth of the Mexican economy, since the variation of these indicators synthesizes the correlation between increased efficiency (movement over the production frontier) and technological change (displacement of the production frontier).

In this context there are two relevant contrasts. On the one hand, there is the unfolding of productivity in the automotive industry, which while appearing consistent with the development of exports, the inflows of *FDI*, research and development expenses (*R&D*) , and the fixed capital formation (*FCF*) of the subsector, it is clearly incompatible with the strengthening of the intra- and inter-sectoral value chains. On the other hand, the antipode trend in the productivity of subsectors such as food or chemicals, especially when the characteristics of capital formation (physical and technological) and of *FDI* flows are observed (see Table 2).

[1] While efficiency and productivity are directly linked, conceptually they are different. Efficiency is defined as the relationship between the observed values of outputs and inputs versus relative optimal values. Thus, productive efficiency is achieved if, given a set of inputs and a technological level, the process is capable of generating the maximum possible output. Meanwhile, productivity is defined as the quotient between some measure of the volume of the output and some measure of the volume of the set of inputs used in production. In this context, changes in productivity are associated with increased efficiency, movement over the production frontier, and technological change, and displacement of the production frontier (Hernández, 2007).

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Table 2
Manufacturing Sector: Production, Investment, and Trade
(by economic sector, period 1990-2015)

Industry	AV1/	GFCF1/	FDI1/	R&D1/	EA2/	EM2/	X1/	M1/	PL3/	TFP3/
Manufacturing Sector	100.0	100.0	100.0	100.0	11.5	46.8	100.0	100.0	1.8	-0.5
Low Technology										
Food, beverages, and tobacco industry	27.3	10.8	27.4	12.5	13.1	42.0	3.9	4.6	1.6	-0.2
Textile, clothes, and leather products	6.1	1.8	3.0	4.4	3.5	39.6	4.6	4.4	0.9	-1.2
Wood, wood products, paper, and printing industry	4.0	2.4	2.2	2.1	15.9	43.3	0.9	2.7	2.6	-0.4
Oil refining products	3.8	3.8	0.3	1.2	30.7	51.9	1.6	5.6	1.3	-0.6
Other manufacturing industries	3.8	3.7	2.7	1.2	9.0	43.8	4.7	2.3	0.4	-1.4
Intermediate Technology										
Rubber and plastic industry	2.9	4.6	3.9	3.9	9.1	55.2	2.1	5.5	0.5	-1.3
Non-metallic mineral products industry	5.6	2.1	1.9	3.1	15.2	26.6	1.4	1.0	0.9	-1.2
Common metals industry	5.7	3.1	5.9	6.7	19.3	47.5	4.7	5.1	1.7	-1.9
Metalworking industry	3.2	3.2	2.2	8.3	13.0	45.2	2.6	4.6	1.4	-0.5
High Technology										
Chemical industry	12.0	9.0	10.9	22.7	28.8	50.0	4.7	10.7	1.3	-1.1
Machinery and equipment industry	3.5	8.5	3.3	4.1	7.7	69.5	6.5	10.7	3.0	-1.0
Computer equipment, communication, and measurement industry	5.2	19.6	10.2	2.7	8.3	62.9	24.6	21.5	0.8	-0.6
Electrical equipment industry	3.2	5.2	5.7	6.6	7.9	62.4	10.8	8.6	1.0	-0.7
Automotive industry	13.8	22.3	20.3	20.3	7.1	63.1	26.9	12.7	3.7	0.2

Source: own elaboration with data from the INEGI and STAN (OECD)
AV (Gross Added Value); GFCF (Gross Fixed Capital Formation); FDI (Foreign Direct Investment); R&D (Research and Development Expenses); EA (Employees with a high level of education); EM (Employees with a medium level of education); X (Exports); M (Imports); LP (Labor Productivity); TFP (Total Factor Productivity).
1/ Participation in the entire sector; 2/ Participation of the entire personnel employed in the subsector; 3/ Average annual growth rate. NOTE: The FDI Flow corresponds to the 1999-2015 period, while the expenses in R&D correspond to the 1995-2012 period.

Another aspect of the manufacturing sector is linked to its rapid rise and penetration within the commercial structure of the Mexican economy, becoming the pillar of international trade. Between 1990 and 2015, manufacturing exports and imports grew at an average annual rate of 8.5% and 9.1%, respectively, driven mainly by the dynamics of the automotive, computer and electronics, electrical equipment, machinery and equipment, chemical substances industries, etc.

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This trend is consistent with the inflows of *FDI* which, during the same period, recorded an average annual expansion of 3.2% and a mean participation of 49.3% on the total investment received by the Mexican economy, with the intensely technological subsectors being the main receptors.

Given these numbers, it is incompatible, first, that export manufacturing does not appear as a driving element of the national productive apparatus, despite the leverage in activities of high technological intensity; second, that the depth of inflows of *FDI* does not seem to create effective production gains, particularly when acknowledging that the greater presence of transnational corporations (*TNCs*) is an important mechanism for the access to the technological frontier; third, that the production processes of the dynamic subsectors are based on labor with medium and low education levels (middle school and high school), which on average exceeds 64% of the total personnel employed (see Table 2).

It is true that the performance of the manufacturing sector lies in a small group of industries that, by their characteristics, generate a compressed degree of local productive integration, either due to the high level of technological sophistication of some subsectors or to the low technological profile of other more traditional industries. In this context, the consolidation of a model based on the intermediate phases of global value chains (assembly manufacture) disrupts the dynamic gains associated to trade and *FDI*, among other aspects, because the development of new technologies or the accumulation of human capital does not represent the engine of industrial competitiveness. Similarly, in the extent that the corporate strategies[2] of *TNCs* are focused on natural resources exploitation activities or the installation of export platforms (characterized by their small contribution in added value), the impact on industrial productivity will be limited and pecuniary.

Diffusion of knowledge and productivity: a brief review of the literature

Empirical results in literature usually confirm the presence of dynamic effects associated to international trade and *FDI*, although these gains in productivity are only consistent in studies at a national level, as the evidence is less conclusive—concerning nature and magnitude—when operationalization evokes a greater disaggregation of the observation unit (industry or corporation), confirming that technology diffusion does not create an automatic virtuous circle (Ubeda and Pérez, 2017; Liang, 2017; Ali *et al*., 2016; Belitz and Mölders, 2016; Bournakis *et al*., 2015; Newman *et al*., 2015; Amann and Virmani, 2014; Hafner, 2014; Liao *et al*., 2012; Schift and Wang, 2010; Coe *et al*., 2009).

In a study for China, Liang (2017) analyzes the incidence and effectiveness of absorption capacity, geographical location, and industrial linkages (horizontal and vertical inter-industrial complementarity) in the process of technology diffusion through *FDI*, using data from 20,000 companies for the 1998-2005 period. In his results he finds evidence of technology spillovers between foreign suppliers and local companies (reverse linkage); however, his estimates do not reveal the presence of gains in productivity as consequence of the relation between foreign clients and local suppliers (horizontal spillover effects). In this circuit, he finds that the local technology capital improves the learning process and technology diffusion of Chinese companies.

[2] The literature identifies four investment corporate strategies of transnational corporations (ECLAC, 2007): (i) the search for natural resources, (2) the search for local markets (access to new markets), (3) the search for export platforms (supported by reduced production costs and economies of scale), and (4) the search for technological or strategic assets (linked to R&D activities).

Ubeda and Pérez (2017) empirically contrast the dynamic effects of *FDI* on *TFP*, in addition to incorporating absorption capacity, geographical distance, import penetration, market concentration, size, and age of companies as control variables in the system. Their estimates, based on data from 2,722 companies in the manufacturing sector of Spain during the 1993-2006 period, confirm the presence of gains in productivity caused by *FDI*, which are determined by the absorption capacity of local companies and geographical proximity. They also indicate a null impact of the age of the company and the degree of industrial concentration on *TFP*, as well as a negative association with the size of the company. With these results, they conclude that a limited formation of absorption capacities does not only cause losses in productivity, but also has collusion and displacement effects, with institutions being a fundamental condition for arbitration.

Through a dynamic panel model, Ali *et al*. (2016) empirically test the effect of technological effort (local and foreign) on *TFP*, in addition to the incidence of human capital and the technological gap. In their estimates, based on information from 20 countries between 1995 and 2010, they found evidence of a positive impact of domestic technology capital and the indicators of technology spillovers towards productivity, as well as a complementary effect between imports and *FDI* . Furthermore, they find that human capital (adjusted by patents and publications in scientific journals) is a determining factor of the international knowledge diffusion process, although the estimates do not show a deepening of the diffusion process as consequence of the greater technological gap.

In another study among countries, Belitz and Mölders (2016) evaluate the possible gains in productivity derived from import activity, flows of capital, and international cooperation (patents) in a sample of 77 countries during the 1990-2008 period. Their results suggest the presence of technology spillover effects on *TFP*, through intensive imports of goods in *R&D* and the greater presence of *FDI*; however, their estimates revealed that the contribution of international cooperation in *R&D* is only significant among advanced economies, which implies that externalities through this channel require a certain threshold of local technological development. In terms of local technology capital, the evidence was ambiguous.

Supported by a model of Panel-Corrected Standard Errors, Bournakis *et al*. (2015) empirically analyze the impact of capital stock (physical and human), intellectual property protection system (patents), and foreign knowledge (weighted by imports and *FDI*) on labor productivity, in 16 industrial aggregations from 14 OECD countries during the 1987-2007 period. Their estimates reveal the presence of intercountry technology spillovers, which are determined by the formation of local absorption capacities and the quality of institutional protection. They also find that technological externalities are more important in technology-intensive industries, confirming that the consolidation of an innovative profile is a conditional factor in the process of technology diffusion.

With enterprise-level estimates, Newman *et al*. (2015) analyze if the greater flow of *FDI* generates productivity gains through the supply chain (intra-sector and inter-sector) in the manufacturing sector of Vietnam, in addition to incorporating the degree of industrial concentration and international trade as control variables. Their sample includes data from 4,248 companies, added to 23 industrial subsectors during the 2009-2012 period. In their estimates they find evidence of indirect spillovers from foreign-owned companies into the maquiladora (assembly) sectors of final products, as well as direct spillover effects linked to domestic input

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suppliers. However, their results reveal a negative impact of transnational corporation (input suppliers) on the productivity of local industry.

Amann and Virmani (2014) study the contribution of domestic and foreign technology capital (weighted by received and issued *FDI*) on the evolution of *TFP*, in addition to the impact of human capital and patents in a sample of 34 countries from the OECD during the 1990-2010 period. In their estimates, they find technology spillover effects of *FDI* on productivity, specifically through north-south investment flows (*FDI* received). They also find a positive relation between the human capital indicator and the *TFP*. However, their regressions do not show a statistically significant relationship between patents and productivity. With these results, they conclude that the ability of a country to adapt and develop technology is a catalyst for productivity gains and hence for the process of technology diffusion.

Supported by an Autoregressive Distributed Lag Model (*ARDL*), Hafner (2014) empirically evaluates the impact of domestic and foreign technology capital (weighed by patents, trade, and *FDI*), as well as local physical and human capital, on the dynamics of labor productivity. Their estimates, based on data from Spain, Greece, Ireland, Mexico, and Portugal during the 1981-2008 period, reveal the presence of differentiated technology spillover effects. They find evidence in Greece and Ireland of productivity gains only through international trade, while in Spain these happen through trade and *FDI*. In Portugal there is the presence of externalities only through patents, while the results for Mexico did not show evidence of technology spillover effects. In general, there is a positive relationship between local expenditure on *R&D*, human capital, and productivity. With this, the crucial role of the local technological effort on the technology diffusion process is proven.

In turn Ang and Madsen (2013), through a dynamic panel, analyze the importance of local knowledge and six indicators of technology spillover (via imports, exports, *FDI*, patents, geographical proximity, and expenditure on *R&D* of the OECD) on *TFP*, in addition to including human capital, financial development, trade openness, and population structure as control variables. In their estimates, run with data from 6 Asian countries (China, India, Japan, South Korea, Singapore, and Taiwan) during the 1955-2006 period, they find a cointegration relationship between the TFP, the local stock of knowledge, and the indicators of technology spillover, although the most relevant diffusion mechanisms are imports and foreign *R&D* expenses. They also find a positive effect of trade openness and human capital on the growth of *TFP*. In light of these results, they conclude that both domestic technological effort and externalities are two propellers of Asian economic development.

Using a stochastic frontier analysis at the company level, Liao *et al.* (2012) study the inter- and intra-industrial impacts of the international knowledge diffusion process on the manufacturing sector of China during the 1998-2001 period. To this end, they specify a production function determined by labor, physical capital, local knowledge, exports, *FDI*, and foreign technology capital. In their results, they find evidence of inter- and intra-industrial technology spillovers in foreign *R&D*, in addition to dynamic gains associated with the flow of *FDI* ; however, their estimates reveal negative spillover effects through exports. Furthermore, they expose that the magnitude and incidence of technology spillovers, specifically the intra-industrial ones, are determined by the build-up of human capital and *R&D* expenses.

In a work for Latin America[3], Schiff and Wang (2010) measure the importance of foreign technology capital (through trade), education, and governance (accountability,

[3] Bolivia, Chile, Colombia, Ecuador, Guatemala, Mexico, Panama, Trinidad and Tobago, and Venezuela.

political instability and violence, government effectiveness, regulatory burden, rule of law, and corruption) on *TFP*. Their estimates collect data from 16 industrial aggregates of the manufacturing sector (6 intensive in *R&D* and 10 with low intensity in *R&D*) for the 1976-1998 period. According to their results, they find a positive effect of foreign technology capital, through imports, on productivity, although gains in productivity are more significant in the intensive industries in *R&D*. They also find that the indicators in education and governance generate an increase of *TFP* and promote the emergence of externalities, thus creating a virtuous cycle in economic growth.

Through a dynamic panel model, Coe *et al*. (2009) examine the contribution of human and technology capital (domestic and foreign), as well as the effect of "institutional" development on *TFP* growth, in a sample of 24 countries from the OECD for the 1971-2004 period. Their estimates reveal a positive impact of both technology capital—domestic and foreign (with and without weighting by imports)—and human capital on productivity. Their results also show that a greater level of protection of ownership rights, the simplicity of doing business and, a proper legal system enhance the international technology diffusion and appropriation process, concluding that institutional differences represent a determining factor in productivity and in the level of technology spillover incidence.

With industrial-level data, Bitzer and Kerekes (2008) empirically analyze whether international trade and *FDI* (issued and received) are determining mechanism in the international technology diffusion process. The sample includes data from 10 manufacturing sectors in 17 countries of the OECD during the 1973-2000 period. In their estimates they observe a positive technology capital effect (domestic and foreign) on the product. They observe that in this process imports and *FDI* inflows are two relevant channels of technology spillover, especially in potentially innovative countries, while there is no evidence of externalities linked to the issued *FDI*.

For their part, Falvey *et al*. (2007) examine the impact of investment, level of education, openness, economic gap, and technological externalities on the growth rate of the *GDP* per capita, in a sample of 57 developing economies during the 1975-1999 period. In their results, they find that technology spillovers, through trade, constitute a significant source of growth in developing countries; furthermore, they find that economies with greater absorption capacity (high level of education) significantly improve the effects of technology spillovers, while the size of the technological gap, as well as trade with industrialized economies, enhances the emergence of gains in productivity.

For their part, Xu and Chiang (2005) study the effect of human capital, the technological gap, and international knowledge (through trade and foreign patents) on *TFP* in 48 countries during the 1980-2000 period. Their results reveal that the local technological effort and the import of capital goods (externalities) represent two significant sources of *TFP* in developed countries. Furthermore, they find that low-income countries benefit most from the effects of patent related spillovers, while in middle-income economies productivity gains come from both trade and patents. Empirical evidence also suggests that institutional development and human capital are two determinants of technology diffusion, particularly among middle- and low-income countries.

Indeed, the literature on technological diffusion, in addition to analyzing the gains in productivity linked to trade or *FDI*, pay special attention to the role of other determining factors of the knowledge spillover process, such as the development of technological capabilities,

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geographic distance, or institutions; however, most of these studies partially examine the different transmission channels, a condition that could subject the results to overestimation (underestimation) biases due to the omission of relevant variables and, with it, the proper interpretation of the empirical evidence.

Innovation rate, externalities, and productivity: theoretical elements

In the field of the theory of economic growth two broad approaches are distinguished: one of supply, where the variations of the growth rate of the product are conditioned in the long-term to the factors of production; another of demand, based on the Keynesian tradition, in which the expansion of the product and employment is determined by the dynamics of the aggregate demand. The first differentiates between immediate causes and fundamental sources, which leads the discussion from the accumulation of capital (human and physical) or *R&D* expenses to those variables that impact the capacity of economies to accumulate factors and produce knowledge, such as international trade, institutions, or the financial sector (Snowdon and Vane, 2006). The second, on the other hand, emphasizes the restrictions to growth imposed by effective internal demand and balance of payments (Thirlwall, 2003).

Naturally, the purpose of this work does not reside in the detailed description of the characteristics of theoretical models or to exhaustively list them, but in distinguishing the mechanisms and conditions that optimize the presence of gains in productivity, derived from trade and investment flows, from the context of endogenous growth models (*EGM*).

Accumulation of knowledge as a driver for growth

At the core of the endogenous growth theory, two analysis approaches are found (Kosempel, 2003): 1) models based on the accumulation of human capital (Arrow, 1962; Romer, 1986; Lucas, 1988) and 2) models based on the accumulation of knowledge (Romer, 1990; Grossman and Helpman, 1991, Ch. 5).

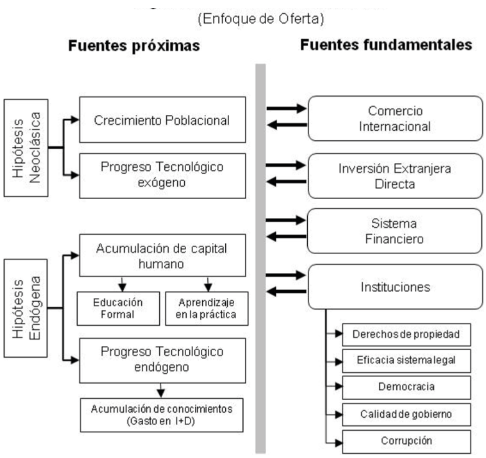

Figure 1. Theory of growth
Source: own elaboration based on Snowdon and Vane, 2006

The underlying argument in both families is that both human capital and *R&D* expenses are the immediate sources of growth, as they directly contribute to the evolution of technological progress. Indeed, the presence of externalities constitutes the fundamental hypothesis, since it allows replacing the neoclassical assumptions of perfect competition, constant returns to scale, and decreasing marginal returns on factors with those of imperfect competition, increasing returns to scale, and increasing marginal returns on factors; a position that leads to distancing and controversy over the convergence predictions of the traditional approach (Aghion and Howitt, 2009; Snowdon and Vane, 2006; Klenow and Rodríguez-Claire, 2004; Grossman and Helpman, 1991).

Within the framework of idea-based models, the evolution of technological progress is formalized in production as a result of deliberate actions, which translate to a continuous process of technological innovation; with the company being the main agent responsible for increasing productivity and, therefore, for the possibilities of product growth at the aggregate level, not only because they allocate resources to the activities in *R&D*, but also due to the effect of imitation and technological incorporation (Grosman and Helpman, 1991, Ch. 9).

Taking this discussion into account, this work takes foothold on the growth driven by the industrial innovation by Grosman and Helpman (1991 Ch. 5) and the addendum by Coe and Helpman (1995). Hence, a production function is assumed as follows:

$$Y = AL_Y^{\eta}K^{\beta}D^{1-\beta-\eta} \tag{1}$$

Where Y is the production of the final good, K is the collection of plants and equipment, L_Y is the total work directly employed in the production of the final good, A is a constant, and D is the set of differentiated intermediate inputs, defining the latter as:

$$D = n^{\frac{1}{\sigma-1}}L_D \tag{2}$$

With L_D being the amount of work employed in the manufacture of intermediate inputs, n is the amount of available inputs (determined by technological effort), and σ is the elasticity of substitution[4]. In this manner, replacing (2) in (1), the corresponding productivity function is obtained:

$$\frac{Y}{K^{\beta}L^{1-\beta}} = An^{\frac{1-\beta-\eta}{\sigma-1}} \tag{3}$$

The fundamental assumption of equation (3) is that multifactorial productivity depends on the accumulation of technology capital, therefore, the differences in the accumulated *R&D* expenses could explain the differences of the *TFP*[5].

In this line, it can be deduced that, at equilibrium, the rate of innovation is determined by the availability of resources (L), the productivity of work in *R&D* (α), market incentives (p), and the power of monopoly (v), as described in equation (4):

[4] The available amount of inputs is expanded in the form $n = \int_{-\infty}^{T} \dot{n}_t \, dt = a\int_{-\infty}^{T} r_t \, dt$, where $\dot{n}$ is the flow of new products, a is a constant, and r is the expense in *R&D*. Furthermore, a constant elasticity of substitution is assumed, $\sigma = 1/(1-\alpha)$, where Alpha is a positive constant that characterizes the different preferences for variety.

[5] When intermediate inputs are vertically differentiated, the efficiency of an input depends on the number of times it has been improved (different qualities); therefore, improved inputs are more productive. Thus, if economic agents invest in *R&D* activities to improve the quality of intermediate inputs, then the average productivity of all inputs will depend on the cumulative expenditure in *R&D*.

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$$g_n = (1 - \nu)\frac{L}{a}\nu\rho \qquad (4)$$

At the same time, the evolution of the product in the long-term (g_Y) and of the collection of aggregate capital (g_K) is conditioned to the dynamic of the innovation rate, while the investment rate $(\frac{K}{Y})$ is determined by product progression in the following manner:

$$g_Y = g_K = \frac{\eta(1-\alpha)}{(1-\beta)\alpha}g_n \qquad (5a) \qquad \frac{\dot{K}}{Y} = \frac{\beta g_Y}{\rho + g_Y} \qquad (5b)$$

Therefore, those economies with sustained innovation rates experience quick product and investment rate growth (Grosman and Helpman, 1991, Ch. 5).

On the other hand, the endogenous approach gives international trade an explicit role in the process of knowledge diffusion, as it[6]: a) facilitates the access to the technological frontier, b) allows the reallocation of resources from less productive sectors to more dynamic ones, c) reduces the costs associated to the development of new products, and d) brings about a rapid introduction of new technologies and varieties of inputs to production processes (Grosman and Helpman, 1991, Ch. 5).

From this perspective, Coe and Helpman (1995) analyze the effect of foreign technology capital, through imports, on the performance of productivity. To this end, they present an extension of equation (3) as follows:

$$lnPTF = \theta_i^d lnS_i^d + \theta_i^f m_i lnS_i^f \qquad (6)$$

According to the equation above, countries will improve their level of productivity not only as consequence of domestic technological effort $(\theta_i^d lnS_i^d)$, but also as a result of foreign technology capital $(\theta_i^f m_i lnS_i^f)$; thus, the greater the trade with countries in the technological frontier, the greater the gains in productivity.

It is necessary to note that although imports represent an important entry channel to the technological frontier of the world, it is an indirect and partial access; first, because the receiving economic agents do not have, as such, the engineering of the foreign technological effort (codified knowledge), only the result or manufacture of said process, limiting with it the effective understanding of technological innovation patterns; and second, because the exclusion of exports produces biases in the analysis of the dynamic gains derived from international trade, particularly if one considers that the export activity involves: a) learning processes linked to contact with world-class competitors and clients, b) increased use of available resources and economies of scale, c) access to larger markets, and d) intersectoral externalities.

In the same manner, the elimination of capital flows significantly constricts the assumptions concerning the study of international knowledge diffusion. Literature confers a crucial role to *FDI*, since the participation of transnational companies (partial or total) in the receiving

[6] However, greater exposure to global competition could also entail a process of industrial reconversion and self-selection, disarticulation of production chains, productive specialization towards less dynamic sectors (final stages of value chains), or market segmentation (Aghion and Howitt, 2009; Grossman and Helpman, 1991).

industries implies direct transfer of first-generation technologies or the presence of technological externalities[7] associated with their typical characteristics[8] (Keller, 2009; Romo, 2004).

Based on the above, this work presents an extended version of the model by Coe and Helpman (1995):

$$lnPTF_i = \theta_{0i} + \theta_{1i}^{d} lnS_i^d + \theta_{2i}^{f} x_i lnS_i^f + \theta_{3i}^{f} m_i lnS_i^f + \theta_{4i}^{f} ied_i lnS_i^f \quad (7)$$

Where S^d and S^f represent the collection of domestic and foreign technology capital, respectively; *x, m*, and *ied* represent the weighted indices (transmission channels) of exports, imports, and *FDI*, respectively; while θ_i^d and θ_i^f capture the elasticities of the *TFP* with regard to the domestic and foreign technological effort.

Despite the possible virtuous circle caused by the presence of technology spillovers, this process is limited, among other aspects, by: i) the development level of the technological capabilities of local companies and ii) the corporate strategy of *TNCs*. Therefore, if international trade or *FDI* represent an open channel for the use of foreign innovation (exposure to the technological frontier of the world), it is not enough to guarantee the appearance of productivity gains, given that learning and technological disengagement will be subject to the local formation of human resources, the development of innovation capabilities, and the deepening of technological linkage (Fagerberg, and Srholec, 2007; Lall, 1992). Thus, equation (7) is reparametrized as:

$$lnPTF_i = \theta_{0i} + \theta_{1i}^{d} lnS_i^d + \sum_{j=2}^{4} \theta_{ji}^{f} \vartheta_i + \sum_{j=5}^{7} \theta_{ji}^{f} \varphi_i \quad (8)$$

Where ϑ_i contains the variables that capture the gains in productivity in the manufacturing sector through trade and *FDI*, while φ_{it} captures the impact of the international flow of knowledge on the performance of the *TFP* of high technological intensity industries. This will allow examining the incidence of local technological capabilities in the technological diffusion process.

Empirical analysis: the case of the manufacturing industry in Mexico

Econometric specification

For empirical purposes, an autoregressive distributed lag model (*ARDL)* is used following the proposal by Pesaran *et al*. (1999). This is estimated through the Pooled Mean Group (*PMG*). Thus, the stochastic specification of equation (8) is defined as:

[7] These occur when local firms can benefit from the technological effort of transnational corporations without having to pay for it in a market transaction, due to their limited capacity to internalize the total value of the benefits generated by their technological progress. In other words, the presence of technology spillovers occurs when the cost of the knowledge obtained by local companies, as a result of the operation of *TNCs* , is lower to the original cost of the inventing agent. These can be grouped into four effects: i) linkage, when the local companies, in their interaction with *TNCs*, experience changes as consequence of quality requirements, delivery times, or technical and design specifications imposed by foreign companies; ii) demonstrative, which are present when local companies have more information on the costs and benefits of the adoption of new technologies as consequence of the successful introduction of new production techniques or organizational practices of the *TNCs*; iii) collaborative, which appear when domestic companies, through contractual agreements, limit technologies or the organizational ways of *TNCs* (horizontal linkages); iv) training, the mobility of the labor force in the *TNCs* towards the group of domestic companies (Romo, 2004).

[8] Among other aspects, economies of scale, high capital investment requirements, access to large distribution networks, intensive advertising, best management practices, or the availability of advanced technology stand out; their profile may produce indirect effects on the economic structure and industrial performance of the host economies.

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$$ln\tau_{it} = \sum_{j=1}^{p} \phi_{ij} ln\tau_{it-j} + \sum_{j=0}^{q} \theta'_{ij} H_{it-j} + \mu_i + \epsilon_{it} \quad (9)$$

In this expression, τ represents the total factor productivity; *H* is a vector of *kx*1 explicative variables (technological externalities indicators); ϕ_{ij} and θ'_{ij} are column vectors that contain the coefficients of the lagged dependent variable and of the explicative variables; while μ_i and ε_{it} comprise the specific effects of each group and the error term of the model.

It is important to note that if the variables of the system are integrated in the same order *I*(*d*) and there is a cointegration relation between them, the error term follows an *I*(0) process. Therefore, the long-term relation must incorporate an error correction equation, the objective of which will be to introduce the short-term dynamic of the variables, influenced by the deviation with respect to the balance path, to the long-term behavior.

Consequently, specification (9) must be re-written as an error correction equation:

$$\Delta ln\tau_{it} = \alpha_i ln\tau_{it-1} + \beta_i' H_{it} + \sum_{j=1}^{p-1} \phi_{ij}^{*} \Delta ln\tau_{it-j} + \sum_{j=0}^{q-1} \theta_{ij}^{'*} \Delta H_{it-j} + \mu_{it} + \epsilon_{it} \quad (10)$$

Where τ represents the Total Factor Productivity; *H* is a column vector of *kx*1 independent variables (gains in productivity through exports, $x_i lnS_i^f$, imports, $m_i lnS_i^f$, and foreign direct investment, $ied_i lnS_i^f$; effects of technology spillovers, $x_i lnS_i^f * dct$, imports, $m_i lnS_i^f * dct$, and capital flows $ied_i lnS_i^f * dct$); α_i is the adjustment speed coefficient towards equilibrium; β_i' groups the long-term parameters and vectors ϕ_{ij} and θ'_{ij} groups the short-term estimators; μ_{it} and ε_{it} capture the fixed effects and the error term, respectively; indices *i* and *t* compute, respectively, the transversal unit (industry) and time.

It is expected that the coefficients associated to the externalities for exports and imports will be positive (β_2; $\beta_3 > 0$), which would indicate that the greater the intensity in trade with innovative countries (technological frontier), the greater the effect of technology spillovers on the evolution of productivity (North-South model). Similarly, if the coefficient associated to gains in productivity through *FDI* is positive ($\beta_4 > 0$), it validates the assumption that a greater presence of transnational companies in the industry leads to a significant increase of industrial productivity.

On the other hand, if $\beta_5 > \beta_2$, $\beta_6 > \beta_3$ y $\beta_7 > \beta_4$, then it can be deduced that the effects of international technology spillover are more relevant to the extent that those in the industries maintain a continuous process of innovation, linkage, and accumulation of human resources, industries of high technological intensity. It is important to note that the empirical evaluation of equation (10) only refers to the impact of foreign technology capital, since there are no consistent elements to construct an indicator of domestic technology capital.

An advantage of the *PMG* estimator, with respect to other methodologies in dynamic panel models, is that it allows taking into consideration the specific heterogeneity of each economic subsector, which concedes that the short-term parameters, as well as the variance of errors and the adjustment speed, are heterogenous among the groups, while the long-term slope coefficients are assumed as being homogenous among the transversal observation units. Furthermore, the estimator may produce efficient and consistent parameters even in small samples, controlling them through self-relation and heteroscedasticity (see Blackburne and Frank, 2007; Pesaran *et al*., 1999)[9].

Definition of variables: Externalities and formation of technological capabilities

To measure the technological externalities linked to imports, *ExM*, the following indicator is assumed following the proposal by Coe and Helpman (1995):

$$ExM_{it} = \sum_{j=1}^{n} b_{ij} m_{it} SID_{jt}^{EU} \tag{11a}$$

In this expression, b_{ij} represents the imports of industry *i* from industry *j* in the United States (composition effect)[10], while m_{it} captures the trade intensity[11] of industry *i* in period *t*. With SID_{jt} being the technological effort of industry *j* in the United States in period *t*.

Regarding the gains in productivity linked to export activity *ExX*, a weighted index is used:

$$ExX_{it} = x_{it} SID_{it}^{EU} \tag{11b}$$

Where x_{ij} represents the intensity[12] effect of the flow of exports of industry *i* during period *t*, while SID_{jt} measures the technological effort of industry *j* in the United states during period *t*. By construction, it is assumed that domestic industries maintain a continuous learning process as a result of contact with world-class customers, who establish quality standards and concrete production algorithms, which they transfer through technological cooperation or joint training.

Comparatively, technology spillovers linked to foreign direct investment, *ExIED*, are approximated as follows:

$$ExIED_{it} = \frac{SIED_{it}}{K_{ct}} SID_{it}^{EU} \tag{11c}$$

In the above equation, $SIED_{it}$ represents the collection of *FDI* received by industry *i* in period *t*, while K_{ct} and SID_{it}^{EU} are the collection of fixed capital of the local manufacturing sector and the technology capital of industry *i* of the manufacturing sector of the United States during period *t*. The underlying assumption in (11b) and (11c) is the presence of a spillover effect vis-à-vis the receiving industry, *i*, and the issuing industry, *i* (e.g., productivity gains received by the automotive industry in the receiving country from the automotive industry of the issuing country).

Foreign direct investment and foreign technology capital assets are approximated using the perpetual inventory method. The former represents the collection of the investment received by subsector *i* from abroad in period *t*, while the latter is the accumulated *R&D* expenses of

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[9] In contrast to the generalized moments method (GMM), which in the case of samples with small N and large T produces notable biases, since as the number of endogenous variables increases the number of instruments increases significantly, particularly when the length of T increases, creating an excessive load in the estimation (overidentification of the model) and loss of robustness of the variance-covariance matrix.

[10] It is obtained as the share of imports of intermediate inputs-capital of industry *i* from industry *j*, in total imports of industry *i* during the period *t*, $b_{ij} = \frac{M_{ijt}}{\Sigma M_{it}}$. Empirically, the import ratio is estimated from the 2003, 2008, and 2012 symmetric import matrix.

[11] It is the quotient between the imports and the production of industry *i* in time *t*. $m_{it} = \frac{M_{it}}{PBT_{it}}$

[12] Obtained as the quotient between the exports and the production of industry *i* in time *t*. $x_{it} = \frac{X_{it}}{PBT_{it}}$

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industry *i* in the United States in period *t*. To capture the productivity gains of the dynamic subsectors, 3 interactive indices are approximated, which result from weighting the technology spillover variables by a technological intensity indicator (dichotomous variable that takes a value of 1 when the subsector is high and medium-high technology and of 0 when the subsector is medium-low and low technology), taking into account the industrial classification according to technological intensity of the OECD.

Results analysis

The study gathers information from 14 industrial aggregations of the manufacturing sector of Mexico (SCIAN 2007) for the 1999-2012 period. The data correspond to annual series, obtained from the INEGI and the Structural Analysis Database of the OECD, imports (*M*), exports (*X*), foreign direct investment (*FDI*), gross production (*PBT*), gross fixed capital formation (*GFCF*), and total factor productivity (*TFP*). Information is also collected on the research and development expenses (*R&D*) of industry *i* in period *t* of the manufacturing sector of the United States.

The empirical contrast starts with the analysis of the seasonality properties of the variables included in the system, using the unit root tests for Im-Pesaran-Shin, Fisher-Dickey Fuller Augmented, and Fisher-Phillips-Perron panel data. The results suggest that the variables are stochastic stationary processes, *I*(0), in first differences. Once the stochastic properties were determined, potential long-term equilibrium relationships were identified in each specification, using Westerlund's co-integration algorithm[13] (2007), see Tables A.1 and A.2.

The empirical results reveal the presence of mixed technology spillover effects on the productivity performance of the manufacturing sector of Mexico, see Table (3).

First, although empirical evidence confirms a positive net impact (0.15%) of the technological externalities associated with export activity, these are only positive within the high-intensity technology subsectors (0.22%), since in traditional industries the impact is negative (0.07%). In general terms, the results are consistent with the hypothesis that the expansion of the export sector, particularly dynamic subsectors, generates an increase in industrial efficiency and productivity, since the contact of domestic companies with world-class clients, exposure to the technological frontier, and the competitive pressure of international markets induce local companies to maintain a continuous process of innovation (productivity-learning-productivity). In this context, the fact that export externalities are more important in technology-intensive subsectors highlights the relevance of developing absorption, innovation, and technology linkage capabilities in the process of knowledge diffusion.

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[13] The selection of the optimal number of lags, for the co-integration test, was made by means of the Akaike information criterion (AIC). The Kernel bandwidth was set as: $4(T/100)^{2/9}$. The robust probability was obtained by means of a bootstrap procedure using 350 iterations, additionally the calculation includes a constant and a trend.

Table 3
Productivity and technology diffusion
Long-term equation (1999-2012)

Variable	i	ii	iii	iv	v	vi	vii
Constante	1.5849 [0.000]*	1.4397 [0.000]*	1.5641 [0.001]*	1.6173 [0.000]*	0.9879 [0.006]*	1.2783 [0.000]*	1.8453 [0.000]*
ExX	-0.0699 [0.000]*	0.0630 [0.024]*	-0.0006 [0.945]	-	-0.0643 [0.075]**	-	-
ExM	0.0784 [0.000]*	-0.0062 [0.873]	-	0.0190 [0.109]	-	0.0653 [0.000]*	-
ExIED	0.0890 [0.000]*	-	0.0984 [0.000]*	0.1009 [0.000]*	-	-	0.0955 [0.000]*
*ExX * dct*	0.2209 [0.000]*	0.0590 [0.093]**	0.0534 [0.010]*	-	0.1855 [0.000]*	-	-
*ExM * dct*	-0.1916 [0.000]*	-0.0439 [0.263]	-	0.0967 [0.001]*	-	-0.0615 [0.057]**	-
*ExIED * dct*	-0.1292 [0.000]*	-	-0.0836 [0.000]*	-0.1857 [0.000]*	-	-	-0.1101 [0.000]*
PTF_{-1}	-0.3638 [0.000]*	-0.3345 [0.000]*	-0.3730 [0.001]*	-0.3829 [0.000]*	-0.2322 [0.007]*	-0.2871 [0.000]*	-0.4196 [0.000]*

Source: own elaboration
Estimates based on Pooled Mean Group approach for panel.
*Significant at 5% **Significant at 10% P-value between brackets

Second, the estimates reveal a negative net effect of the externalities through imports on the productivity of the sector (-0.11%), contrary to what was expected. According to the results, productivity gains are only consistent among the group of low-intensity technological subsectors (0.08%), while importing activity generates a negative impact on the *TFP* of high-technological-intensity industries (0.19%). The empirical evidence seems to confirm the presence of technology spillovers of the pecuniary type, more than of the technological type, which would imply that local companies obtain benefits when the price of the technology—not available in the domestic market—is lower than the opportunity cost to develop it domestically, but only in the sense of the results of the manufacture of the imported inputs. On the other hand, the growing participation of imports in export production and the transition of the exporting manufacturing sector towards assembly activities (intermediate phases of the value chain) has generated, among other aspects: greater competition for imports, consolidation of a sector with low added value, inadequate formation of technological capacities, gradual disarticulation of productive chains, and the concentration of profits in large firms, among others.

Third, empirical evidence shows a negative net effect (0.04%) of the externalities, through *FDI*, on productivity. The greater presence of transnational corporations seems to project only productivity gains among low-intensity technological industries (0.09%), while the effect is negative in the more dynamic subsectors (0.13%). These results seem reasonable when considering that the emergence of technology spillovers through *FDI* can take more than one period, given the transition time between the effective entry of the *FDI* and the moment in which transnational companies reach their equilibrium size (system adjustment and production costs).

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In short, this indicates that the presence of transnational corporations does not automatically create a greater flow of knowledge and increased efficiency in the host industry.

Additionally, restricted specifications of the general model were estimated, columns (*ii*)-(*vi*), in which explanatory variables were omitted in a combined manner in order to test the consistency and robustness of the empirical results. The econometric evidence confirms the sense of the effects found in the general model; however, when excluding the variable of externalities via exports, the regressions indicate the presence of gains in productivity through the import activity of the dynamic industries. This probably implies that part of the variability of technology spillovers by imports could be being captured by the externalities associated with exports.

Conclusion

In this work, the contribution of foreign technology capital—through international trade and *FDI*—on the development of the productivity of the manufacturing sector in Mexico during the 1999-2012 period has been quantified. This was done through the phenomenon of technological externalities. The estimations obtained revealed that exports constitute a significant channel in the process of diffusion of knowledge, albeit under certain nuances, given that although the productivity gains are more relevant in the subsectors of high technological intensity, the positive net effect is marginal (in magnitude), which would indicate that said benefits are insufficient to constitute a driving factor for the manufacturing sector as a whole.

On the other hand, the results showed a positive impact of import externalities only in the segment of low-intensity technological industries, a condition that seems to confirm the occurrence of monetary rather than technology spillovers, in addition to revealing the limitations associated with the process of reconversion of production processes (specialization in segments with low contribution of added value), which leads to greater competition for imports and the gradual disarticulation of production chains.

Regarding the dynamic effects associated to *FDI*, the results show a marginal and inconclusive contribution to productivity performance. In this context, the productivity gains derived from the increased presence of transnational companies are not an instantaneous process, since the transition time between the effective entry of *FDI* and the time when the company reaches its equilibrium size (adjustment of systems and production costs) may take more than one period.

Furthermore, the evidence obtained suggests that the formation of local technological capabilities constitutes a determining factor in the process of knowledge diffusion, since the estimates showed that productivity gains are more important in those industries with a higher degree of technological development than in the subsectors located in traditional manufacturing. Consequently, the greater the degree of development of local capabilities for decoding, innovation, and technological linkage, the greater the presence of technology spillovers.

Finally, partial evidence was found supporting the hypothesis that strengthening trades with industrialized economies improves the learning process and the accumulation of externality-generating factors of the receiving semi-industrialized countries (North-South model), since estimates show the presence of productivity gains within the manufacturing sector of Mexico as a result of technological progress in the United States.

However, it is up to future research to integrate more robust indicators on the measurement of technological capabilities at the industrial level, as well as to extend the analysis of technological externalities from the inter-sectoral perspective, at the intra- and inter-country levels.

References

Ali, M., Cantner, U., and Roy, I. (2016). "Knowledge spillovers through FDI and trade: the moderating role of quality adjusted human capital". *Journal of Evolutionary Economics*, vol. 26, Pp. 837-868. https://doi.org/10.1007/s00191-016-0462-8

Amann, E., and Virmani, S. (2014). Foreign direct investment and reverse technology spillovers: The effect on total factor productivity. OECD *Journal: Economic Studies*, vol. 2014. https://doi.org/10.1787/eco_studies-2014-5jxx56vcxn0n

Ang, J., and Madsen, J., (2013). "International R&D spillovers and productivity trends In the asian miracle economies". *Economic Inquiry*, vol. 51(2), Pp. 1523-1541. https://doi.org/10.1111/j.1465-7295.2012.00488.x

Aghion P. and Howitt (2009). *The Economics of Growth*. Cambridge. MA: MIT Press.

Arriaga, R. & Landa, H. (2016). "Competitividad del Sector Externo Mexicano: Un análisis de la Condición Marshall-Lerner". *Revista Mexicana de Economía y Finanzas*, vol. 11(1), Pp. 79-101. https://doi.org/10.21919/remef.v11i1.78

Arrow, K. (1962). "The economics implications of learning by doing". *The Review of Economic Studies*, vol. 29 (3), Pp. 155-173.

Belitz, H. and Mölders, F. (2016). "International knowledge spillovers through high-tech imports and R&D of foreign-owned firms". *The Journal of International Trade & Economic Development*, vol. 25 (4), pp 590-613. https://doi.org/10.1080/09638199.2015.1106575

Bitzer, J. and Kerekes, M. (2008). "Does foreign direct investment transfer technology across borders? New evidence". *Economics Letters*, vol. 100(3), pp. 355-358. https://doi.org/10.1016/j.econlet.2008.02.029

Blackburne, E., and Frank, M. (2007) "Estimation of nonstationary heterogeneous panels". *The Stata Journal*, vol, 7 (2), 197-208.

Bournakis, I., Christopoulos, D. and Mallick, S. (2015). *Knowlegde Spillovers, absorptive capacity and growth: An industry-level Analysis for OECD countries*. FIW Working Paper No 147.

CEPAL (2007). *La inversión extranjera directa en América Latina y el Caribe*. Informe Anual

Coe, D., Helpman, E. and Hoffmaister, A. (2009). "International R&D spillovers and institutions". *European Economic Review*, vol. 53 (7), Pp. 723-741. https://doi.org/10.3386/w14069

Coe, D. & Helpman, E. (1995). "Internacional R&D spillovers". *European Economic Review*. Vol. 39(5), Pp. 859-887.

Dominguez, V. L. & Brown, G. F. (2004). *Inversión Extranjera Directa y capacidades tecnológicas*. LC/MEX/L.600, Documentos de Proyectos, Estudios e Investigaciones CEPAL

Fagerberg, J. and Srholec, M. (2007). "National innovation system, capabilities and economic development". *Research Policy*, vol. 37(9), 1417–1435.

Falvey, R.; Foster, N. and Greenaway, D. (2007). "Relative backwardness, absorptive capacity and knowledge spillovers". *Economics Letters*, vol. 97(3), 230-234. https://doi.org/10.1016/j.econlet.2007.03.015

FMI (1997). *World Economic Outlook*. International Monetary Fund Publishing.

Gerschewski, S. (2013). Do Local Firms Benefit from Foreign Direct Investment? An Analysis of Spillover Effects in Developing Countries. *Asian Social Science, Canadian Center of Science and Education*, vol. 9(4), 67-76. https://doi.org/10.5539/ass.v9n4p67

Grossman, G. M. and Helpman, E. (1991). *Innovation and Growth in the Global Economy*. Cambridge, MA: MIT Press.

Hafner, K. A. (2014). Technology spillover effects and economic integration: evidence from integrating EU countries. *Applied Economics*, vol. 46(25), 3021-3036. https://doi.org/10.1080/00036846.2014.920479

Hernandez, E. (2007). “La productividad multifactorial: concepto, medición y significado”. *Economía: Teoría y Practica, Nueva Época*, num. 26, Pp. 31-68. https://doi.org/10.24275/etypuam/ne/262007/hernandez

Im, K. S., Pesaran, M. H. and Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of Econometrics*, vol. 115(1), 53-74.https://doi.org/10.1016/s0304-4076(03)00092-7

Keller, W. (2009). *International trade, foreign direct investment, and technology spillovers*. Working Paper No. 15442, National Bureau of Economic Research. https://doi.org/10.3386/w15442

Klenow, P. and Rodríguez-Claire, A. (2004). *Externalities and growth*. Handbook of Economic Growth, vol. 1(A), pp. 817-861 https://doi.org/10.3386/w11009

Kosempel, S. (2003). “A theory of development and long run growth”. *Journal of Development Economics*, vol. 75, 201-220. https://doi.org/10.1016/j.jdeveco.2003.08.004

Lall, S. (1992). “Technological capabilities and industrialization”. *World Development*, vol. 20(2), 165-186. https://doi.org/10.1016/0305-750x(92)90097-f

Landa, H. (2010). *Crecimiento económico y apertura económica en México: el rol de las externalidades y las capacidades tecnológicas*, Tesis Doctoral, Estudios Sociales, Universidad Autónoma Metropolitana.

Liang, F. (2017). “Does foreign direct investment improve the productivity of domestic firms? Technology spillovers, industry linkages, and firm capabilities”. *Research Policy*, vol. 46 (1), 138-159. https://doi.org/10.1016/j.respol.2016.08.007

Liao, H., Liu, X., & Wang, C. (2012). “Knowledge spillovers, absorptive capacity and total factor productivity in China’s manufacturing firms”. *International Review of Applied Economics*, vol. 26(4), 533-547. https://doi.org/10.1080/02692171.2011.619970

Lucas, R.E., Jr. (1988). On the mechanics of economic development. *Journal of Monetary Economics*, vol. 22, pp.3-42.

Newman, C., Rand, J., Talbot, T., and Tarp, F. (2015). “Technology transfers, foreign investment and productivity spillovers”. *European Economic Review*, vol. 76, Pp. 168-187.

OECD (1998). Open Markets Matter: The Benefits of Trade and Investment Liberalisation. OECD Publishing, Paris.

Pesaran, M. & Smith, R. (1995). Estimating long-run relationship from dynamic heterogeneous panels. *Journal of Econometrics*, 68 (1), pp. 79-113 https://doi.org/10.1016/0304-4076(94)01644-f

Pesaran, H., Shin, Y. & Smith, R. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, vol. 94(446), pp. 621-634. https://doi.org/10.1080/01621459.1999.10474156

Puyana, A. & Romero, J. (2009). *México: De la crisis de la deuda al estancamiento económico*. El Colegio de México.

Rodrik, D. (2003). *Growth strategies*. Working Paper No. 10050, National Bureau of Economic Research.

Romer, P. (1986). Increasing returns and long-run growth. *The Journal of Political Economy*, vol. 94(5), 1002-1037. https://doi.org/10.1086/261420

Romer, P. (1990). Endogenous Technological change. *The Journal of Political Economy*, vol. 98(5), 71-102 https://doi.org/10.3386/w3210

Romo, M. D. (2004). Derramas tecnológicas de la inversión extranjera en la industria Mexicana. *Comercio Exterior*, vol. 53(3), 230-243.

Schiff, M. and Wang, Y. (2010). *North-south trade-related technology diffusion: virtuous growth cycles in Latin America*. Paper No. 4943, Institute for the Study of Labor Discussion. https://doi.org/10.2139/ssrn.1333627

Snowdon, B. and Vane, H. (2006). *Modern Macroeconomics: Its Origins, Development and Current State*. USA, Edit. Edward Elgar Publishing, Inc.

Thirlwall, A. (2003). *La naturaleza del crecimiento: un enfoque alternativo para comprender el funcionamiento de las naciones*, México, Fondo de la Cultura Económica.

Ubeda, F., and Pérez, F. (2017). “Absorptive Capacity and Geographical Distance Two Mediating Factors of FDI Spillovers: a Threshold Regression Analysis for Spanish Firms”. *Journal of Industry, Competition and Trade*, vol. 17 (1), 1-28. https://doi.org/10.1007/s10842-016-0226-z

Westerlund, J. (2007). Testing for Error Correction in Panel Data. *Oxford Bulletin of Economics and Statistics*, vol. 69(6), 709-748. https://doi.org/10.1111/j.1468-0084.2007.00477.x

World Bank (2008). *Global economic prospects: Technology diffusion in the developing World*. World Bank Press.

Xu, B. and Chiang, E. (2005). “Trade, patents and international technology diffusion”. *Journal Trade and Economic Development*, vol. 14(1), 115-135. https://doi.org/10.1080/0963819042000333270

Annex

Table A.1 Integration order
Panel Unit Root Test

Variable	Im, Pesaran, Shin [1]		Fisher-ADF [2]		Fisher-Phillips-Perron		I(d)
	Without trend	With trend	Without trend	With trend	Without trend	With trend	
lnptf	-0.6225 [0.2668]	-3.4317 [0.0003]	22.4736 [0.7589]	28.7833 [0.4236]	122.6277 [0.0000]	99.2134 [0.0000]	I(1)
lnExX	1.0139 [0.8447]	0.2660 [0.6049]	21.8433 [0.7885]	46.1140 [0.0170]	20.1391 [0.8593]	14.8782 [0.9797]	I(1)
lnExM	-1.1415 [0.1268]	-3.9546 [0.0000]	7.8294 [0.9999]	71.9343 [0.0000]	10.8219 [0.9985]	28.6609 [0.4299]	I(1)
lnExIED	-1.2330 [0.1080]	-1.0779 [0.1405]	9.6838 [0.9995]	15.4949 [0.9727]	19.6500 [0.8769]	22.8591 [0.7401]	I(1)
Δlnptf	-10.9432 [0.0000]	-8.3684 [0.0000]	41.5339 [0.0479]	109.1735 [0.0000]	274.8751 [0.0000]	120.2716 [0.0000]	I(0)
ΔlnExX	-4.4002 [0.0000]	-4.7054 [0.0000]	175.7633 [0.0000]	246.6821 [0.0000]	100.3145 [0.0000]	62.1294 [0.0002]	I(0)
ΔlnExM	-10.0897 [0.0000]	-6.9704 [0.0000]	90.1139 [0.0000]	129.6855 [0.0000]	66.7987 [0.0001]	40.6094 [0.0583]	I(0)
ΔlnExIED	-6.9446 [0.0000]	-6.7989 [0.0000]	72.4648 [0.0000]	55.7521 [0.0014]	187.0412 [0.0000]	157.5367 [0.0000]	I(0)

Source: own elaboration
1/ Ho: All panels contain unit roots and H1: Some panels are stationary. The table reports the statistical value W_t-bar.
2/ Ho: All panels contain unit roots and H1: At least one panel is stationary. P-value between parentheses.

Table A.2 Panel cointegration contrast
Westerlund Test (2007).

Model (i)

Statistic	Value	Z-value	Robust p-value
G_t	-2.505	0.854	0.000
G_a	-5.144	4.835	0.000
P_t	-5.135	4.337	0.500
P_a	-3.895	4.064	0.000

Model (ii)

Statistic	Value	Z-value	Robust p-value
G_t	-2.503	0.115	0.500
G_a	-1.933	5.971	0.000
P_t	-6.752	2.004	0.500
P_a	-1.679	4.876	0.000

Model (iii)

Statistic	Value	Z-value	Robust p-value
G_t	-4.296	-7.864	0.000
G_a	-2.417	5.724	0.000
P_t	-14.731	-6.841	0.000
P_a	-2.103	4.641	0.000

Model (iv)

Statistic	Value	Z-value	Robust p-value
G_t	-2.846	-1.415	0.260
G_a	-2.437	5.714	0.050
P_t	-6.155	-2.665	0.430
P_a	-2.835	4.236	0.040

http://dx.doi.org/10.22201/fca.24488410e.2018.2174

Model (v)			
Statistic	Value	Z-value	Robust p-value
G_t	-4.240	-8.628	0.000
G_a	-5.947	3.337	0.000
P_t	-14.506	-7.548	0.000
P_a	-4.861	2.484	0.000

Model (vi)			
Statistic	Value	Z-value	Robust p-value
G_t	-3.149	-3.602	0.000
G_a	-5.469	3.600	0.000
P_t	-9.039	-1.298	0.097
P_a	-3.690	3.199	0.000

Model (vi)			
Statistic	Value	Z-value	Robust p-value
G_t	-3.247	-4.053	0.000
G_a	-5.780	3.429	0.000
P_t	-11.321	-3.907	0.000
P_a	-5.925	1.835	0.000

Source: own elaboration.
Bootstrapping critical values under H0. Calculating Westerlund ECM panel cointegration tests.
Results for H0: no cointegration, with 14 series and 2 covariates

Table A.3 TFP estimates - Technological externalities

Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): indust	Number of obs =	182
Time Variable (t): t	Number of groups =	14
	Obs per group: min =	13
	avg =	13.0
	max =	13
	Log Likelihood =	572.8465

D.lnptf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ec						
lnexx	-.0698889	.0103522	-6.75	0.000	-.0901788	-.049599
lnexm	.0784477	.0112798	6.95	0.000	.0563398	.1005556
lnexied	.0890281	.0040115	22.19	0.000	.0811658	.0968905
lnexxdct6	.2209091	.0272876	8.10	0.000	.1674264	.2743919
lnexmdct6	-.1916324	.0256943	-7.46	0.000	-.2419922	-.1412726
lnexieddct6	-.1291754	.0127783	-10.11	0.000	-.1542203	-.1041304
SR						
ec	-.3638288	.0867079	-4.20	0.000	-.5337732	-.1938845
lnexx						
D1.	.0962617	.0368984	2.61	0.009	.0239422	.1685812
lnexm						
D1.	-.0633825	.030805	-2.06	0.040	-.1237592	-.0030057
lnexied						
D1.	-.0643002	.0258251	-2.49	0.013	-.1149164	-.013684
_cons	1.584922	.3681623	4.30	0.000	.8633373	2.306507

Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): indust	Number of obs =	182
Time Variable (t): t	Number of groups =	14
	Obs per group: min =	13
	avg =	13.0
	max =	13
	Log Likelihood =	511.96

D.lnptf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ec						
lnexx	.0630128	.0279091	2.26	0.024	.0083119	.1177137
lnexm	-.0061732	.0299356	-0.21	0.837	-.0648458	.0524994
lnexxdct6	.0589819	.0351349	1.68	0.093	-.0098812	.127845
lnexmdct6	-.0439471	.0392995	-1.12	0.263	-.1209727	.0330784
SR						
ec	-.3344634	.0771539	-4.34	0.000	-.4856823	-.1832446
lnexx						
D1.	.0547542	.024466	2.24	0.025	.0068018	.1027067
lnexm						
D1.	-.0389074	.0303353	-1.28	0.200	-.0983635	.0205487
_cons	1.439708	.3352149	4.29	0.000	.782699	2.096717

```
Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): indust                 Number of obs      =       182
Time Variable (t): t                       Number of groups   =        14
                                           Obs per group: min =        13
                                                          avg =      13.0
                                                          max =        13

                                           Log Likelihood     =   541.092
```

D.lnptf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ec						
lnexx	-.0006205	.0089279	-0.07	0.945	-.0181188	.0168778
lnexied	.0983608	.0062478	15.74	0.000	.0861153	.1106063
lnexxdct6	.0534107	.0208399	2.56	0.010	.0125652	.0942562
lnexieddct6	-.0836094	.0104209	-8.02	0.000	-.1040339	-.0631848
SR						
ec	-.3730233	.1087789	-3.43	0.001	-.5862261	-.1598205
lnexx						
D1.	.0583854	.024211	2.41	0.016	.0109326	.1058381
lnexied						
D1.	-.0665689	.0248397	-2.68	0.007	-.1152538	-.0178839
_cons	1.5641	.4542658	3.44	0.001	.6737558	2.454445

```
Pooled Mean Group Regression
(Estimate results saved as pmg)

Panel Variable (i): indust                 Number of obs      =       182
Time Variable (t): t                       Number of groups   =        14
                                           Obs per group: min =        13
                                                          avg =      13.0
                                                          max =        13

                                           Log Likelihood     =  529.9306
```

D.lnptf	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
ec						
lnexm	.0189521	.0118252	1.60	0.109	-.0042248	.042129
lnexied	.1008607	.0064435	15.65	0.000	.0882316	.1134898
lnexmdct6	.0967129	.0294097	3.29	0.001	.039071	.1543548
lnexieddct6	-.1856636	.0159069	-11.67	0.000	-.2168406	-.1544866
SR						
ec	-.3829003	.1080487	-3.54	0.000	-.5946719	-.1711288
lnexm						
D1.	.023502	.0186223	1.26	0.207	-.012997	.0600009
lnexied						
D1.	-.0177012	.0190503	-0.93	0.353	-.0550392	.0196368
_cons	1.617257	.4395339	3.68	0.000	.7557863	2.478728

Source: own elaboration.