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U.S. R&D internationalization in less-developed countries: Determinants and insights from Brazil, China, and India

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Abstract

The growing U.S. R&D internationalization has historically been concentrated in developed countries. However, in the past few decades, the internationalization has moved toward less-developed countries (LDCs), particularly Brazil, China, and India. What location factors are making some LDCs more "inviting" for U.S. R&D offshore? To answer this first question, we constructed a panel data using secondary data from the U.S. Bureau of Economic Analysis regarding the R&D investment made by the majority-owned foreign affiliates of U.S. parent companies in 71 countries. We then applied a Heckman two-step correction for selection bias test. The results highlight some important differences between developed countries' and LDCs' attractiveness. Based on these initial results, we conducted a detailed analysis of the determinants of U.S. R&D investments in Brazil, China, and India, which revealed that China's determinants mostly match those found in more developed countries.

KEYWORDS

innovation, multinational companies, R&D captive offshore, R&D internationalization

JEL CLASSIFICATION

O32; O39; F63

1 | INTRODUCTION

Both economic literature and business literature have paid ample attention to the location factors that affect R&D internationalization. There are recent fruitful studies, for example, of R&D carried out internationally by subsidiaries from Italy (Cozza, Franco, & Perani, 2018), Japan (Suzuki, Belderbos, & Kwon, 2017), Spain (Tamayo & Huergo, 2017), and France (Jabbour & Zuniga 2016). The U.S. case is not different.

Indeed, numerous empirical studies carried out in recent decades reveal that the R&D intensity of U.S. affiliates in host countries is determined mainly by domestic market size, overall intramural R&D capability, and the cost involved in hiring R&D personnel in host countries (Athukorala & Kohpaiboon, 2010; Doh et al., 2005; Flores & Aguilera, 2007; Hegde & Hicks, 2008; Kumar, 1996, 2001). Moreover, other relevant factors, such as domestic business environment aspects, include the availability of technical personnel, nature of property right legislation, tax concessions, political stability, and the nature of the foreign trade regime (Athukorala & Kohpaiboon, 2010). Other relevant factors also include institutional and cultural aspects, such as political and legal systems, cultural similarities, and levels of trust (Flores & Aguilera, 2007).

From a different perspective, instead of focusing on the attracting factors from abroad, there are studies that target the internal repulsion factors that influence U.S. companies to perform R&D abroad, namely, the emerging shortage of highly skilled science and engineering talents in the United States (Lewin, Massini, & Peeters, 2009). In fact, this shortage drives U.S. companies abroad, especially to new hubs with large quantities of science, technology, engineering, and mathematics workers, chiefly in China and India (Branstetter, Glennon, & Jensen, 2019).

Although an abundant literature has empirically examined the factors that drive the location choice of U.S. R&D intensity abroad (Demirbag & Glaister, 2010; Siedschla et al., 2013), a limited number of studies have presented specific analyses regarding the specific context of LDCs, focusing on emerging markets such as Brazil, China, and India.

In short, this paper fills that gap, shedding some light on the indigenous features that make some LDCs more attractive than others for U.S. companies to develop R&D locally, complementing studies present in the literature that have conducted exploratory analysis of U.S. inward R&D-related foreign direct investment (FDI) in Asia and Latin America (Chiarini, 2017; Hiratuka, 2010).

Both Chiarini (2017) and Hiratuka (2010) have used the same secondary data we use here, which are available at the U.S. Bureau of Economic Analysis (BEA). However, we advance their studies by proposing econometric models that empirically demonstrate which location factors differentiate LDCs from developed countries for U.S. R&D abroad. Based on the models' results, we seek to advance our understanding of the determinants of U.S. R&D investments in LDCs through a detailed analysis of the specificities of Brazil, China, and India, whose investment growths were relatively more prominent than that of their peers. We show that China has attracted more U.S. R&D investments than the other two countries due to its efforts in strengthening its innovation system (IS). This matters because, according to the Neo-Schumpeterian hypothesis, development is determined by a country's ability to pass from imitation to innovation (Kim, 1997). Thus, besides corroborating that there are differences between the determinants of U.S. R&D offshore in developed countries and LDCs, we reveal in this study that the Chinese development trajectory is convergent with the idea of technological catching-up, a decisive element to help overcome its underdevelopment status.

The remainder of the paper is organized as follows. In section 2, we theorize that R&D is a key activity and it is performed at home (onshore) and abroad (offshore). We also discuss potential opportunities and challenges for LDCs from the internationalization of R&D. It is important to mention that by no means does this section cover all the literature available on corporate R&D efforts and their internationalization, as it goes beyond the scope of this paper and has already been discussed by other scholars.[1] Against this background, in section 3, we present the empirical methodology embracing a descriptive analysis of the database and the models. In section 4, we present the econometric results, and in section 5, we introduce an exploratory discussion of what makes Brazil, China, and India important LDC receivers of U.S. inward R&D-related FDI. Finally, in section 6, we address the main conclusions and policy recommendations.

2 | FRAMING CORPORATE INVESTMENT IN R&D: WHY TO INVEST ABROAD?

2.1 | Companies' Strategies in Locating Their R&D Activities

Companies' competitive advantages come from their accumulated capabilities to create, transfer, combine, assemble, integrate, and exploit knowledge assets. Knowledge assets help to build the company's capabilities, which in turn underpin its products and services that it offers to the markets (Teece, 2004). Consequently, performing R&D is a relevant activity, as not only does it generate new knowledge, but it also enhances the company's ability to assimilate and exploit existing knowledge—a firms' "absorptive capacity" (Cohen & Levinthal, 1989, 1990).

It is part of the companies' strategy to decide where to locate their R&D centers. For example, companies may decide either to perform R&D in-house or to outsource it to an R&D provider. They may decide to perform it in the home country (onshore) or in a foreign country (offshore). In this regard, it is possible to identify four compatible strategies (Figure 1):

(i) R&D performed in-house in the home country,
(ii) R&D outsourced to a provider in the home country (onshore outsourcing),
(iii) R&D performed in-house but under an affiliated foreign subsidiary (captive offshoring), and
(iv) R&D outsourced to an unaffiliated provider located in a foreign country (offshore outsourcing).

We can say that innovative efforts are a principal source of a company's ownership advantages (Dunning, 1980; Dunning & Lundan, 2008). In this way, the ownership advantages are dynamic: they seek to improve existing technologies and methods and to seek out new advantages. The learning

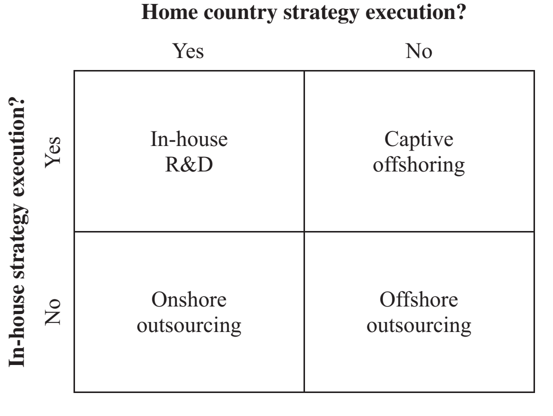

FIGURE 1 Companies' locational R&D strategies
Source: Authors' own.

process that leads to innovation is also an ownership advantage, and subsidiaries can enlarge their knowledge base from the global, local, or internal knowledge networks, which are contingent on the strategic choice made by the headquarters (Athreye, Batsakis, & Singh, 2016). Therefore, multinational companies (MNCs) that can organize a network (subsidiaries and parent companies) to incite knowledge creation and to exploit local resources can expand to different locations.

2.2 | R&D Internationalization and the Centrifugal Forces

A strong trend toward the internationalization of R&D began in the 1980s (Archibugi & Iammarino, 2002; Chesnais, 1994; Dunning, 1994; Filippetti, Frenz, & Ietto-Gillies, 2017). According to the literature, both captive offshore and offshore outsourcing have increased; nevertheless, empirical studies show that the former is still preferred to the latter (Albertoni & Elia, 2014).

The increasing offshore trend is driven in large measure by technology factors (Florida, 1997). Thus, companies perform R&D abroad to secure access to scientific and technical human capital (Florida, 1997)—even if they risk to having their R&D leaked to foreign competitors (Athukorala & Kohpaiboon, 2010)—to improve existing assets and to tap into knowledge around the globe (Dunning & Narula, 1995). Accordingly, this trend reflects the global character of knowledge asset creation and exploitation (Teece, 2004).

Innovation studies literature indicates that two centrifugal "forces" are capable of explaining the dispersion of R&D activities abroad. First, production processes and products need to be adapted to suit local conditions and regulations, that is, asset/competence-exploiting or home-base-exploiting R&D (Cantwell & Mudambi, 2005; Dunning & Narula, 1995; Kuemmerle, 1999). In fact, a large share of R&D investments from MNCs have been made on the adaptation/standardization to local demand conditions, especially in LDCs. Probably because of that, the expected market growth is a more important factor when deciding whether to conduct R&D investments in LDCs than in more developed countries (Thursby & Thursby, 2006).

Second, to benefit from localized technology spillovers in these locations, companies locate R&D facilities abroad, especially in prominent centers of excellence in specific technologies, to enable themselves to enrich their own R&D (Athukorala & Kohpaiboon, 2010), that is, asset/competence-augmenting or home-base-augmenting R&D (Dunning, 2009; Kuemmerle, 1999). This force is a determinant to R&D investments in developed countries, as revealed by the importance of factors such as access to scientists and engineers, both as employees and at universities, and intellectual property (IP) protection (Hall, 2011). It is more important that the MNCs can overcome lock-in traps,[2] and therefore, they perform research abroad to access available external knowledge (Levinthal & March, 1993), benefit from potential knowledge spillover opportunities (Feinberg & Gupta, 2004), and take advantage of qualified personnel (Lewin, Massini, & Peeters, 2009).

2.3 | LDCs and Inward R&D Investments

Many LDCs try to attract high value-added activities (e.g., R&D, engineering, and product design) from abroad; however, attracting FDI in R&D and trying to host innovative activities may require the participation of the most productive MNCs, which are likely to be larger in size (Tabrizy, 2017). This may have both positive and negative effects for LDCs, as presented in Table 1.

Indeed, many potential challenges and opportunities for host countries from the internationalization of R&D are discussed in the literature. The potential opportunities include the increase in overall

TABLE 1 Potential opportunities and challenges for national innovation systems that host international subsidiaries from the internationalization of R&D

Opportunities	Challenges and risks
Increase in aggregate R&D expenditure	Loss of control over domestic innovation capacity and commercialization
Knowledge diffusion to the host country	Less strategic research, fewer radical innovations, more adaptations
Demand for skilled personnel	Separation of R&D and production
Structural change and agglomeration effects	Competition with domestically owned firm for resources (crowding-out)

Source: Authors' own, adapted from Dachs (2014).

R&D expenditure in the host country, the diffusion of knowledge domestically, the increase in demand for skilled personnel, and the structural changes and agglomeration effects. Dachs (2014) thoroughly reviews these issues.

In terms of the challenges and risks, we can show, for example, that if MNCs acquire indigenous firms' research facilities, the host country loses the control of the technology, which had previously been locally produced and which may also reduce the levels of research done locally. As part of rationalization strategies, mergers and acquisitions may reduce R&D activities, so the remaining R&D becomes narrower in scope (or more focused) and its time horizon becomes shorter (UNCTAD, 2005). Therefore, there may be less strategic research, fewer radical innovations, and more adaptation. Empirical evidence shows that LDCs are chosen for low-value R&D (or adaptive R&D), that is, the adaptation of products and processes to local conditions and activities not related to knowledge creation. Therefore, MNCs may impose a new type of international division of labor in which advanced countries conduct high-value R&D activities whereas LDCs conduct low-value R&D activities, with the former adding more value to the global chains and the latter adding relatively less value, blocking the national system of innovation's access to the global knowledge network (Marin & Arza, 2009). Finally, we can cite that internationalization of R&D for host LDCs may cause crowding-out effect—that is, subsidiaries competing with domestically owned firms for local resources may crowd-out local indigenous firms.

3 | EMPIRICAL METHODOLOGY

3.1 | Data and Some Descriptive Analysis

Our analysis is focused on a national-level panel data with information about host countries. We compiled the dataset based on information available at the World Bank (WB),[3] the BEA, and the U.S. Patent and Trademark Office (USPTO). Table 2 presents the variables considered for the econometric models. Data regarding U.S. R&D captive offshoring and IS require a more detailed presentation; in sections 3.1.1 and 3.1.2 we make an effort to do so. However, it is worth mentioning that by IS, we refer to elements that interact in shaping innovation processes as well as elements that link innovation to economic performance (Lundvall, 2007). A narrow perspective links innovation to science activities, and this is the concept we apply in this paper. We shall return to this topic in section 3.1.2.

Before we proceed with explanations of the variables, we now present the reasons why we analyze the data on U.S. R&D captive offshore:

TABLE 2 Variables investigated

Variables	Units	Source
a. Dependent variable		
U.S. R&D captive offshore	USD[a]	BEA
b. Independent variables		
Lagged value of U.S. R&D captive offshore	USD[a]	BEA
GDP per capita[b]	USD[a]	WB
Population	Number of inhabitants	WB
Open trade[c]	% of GDP	WB
Innovation system		
1. R&D expenditure	% of GDP	WB
2. USPTO patents per capita	Per million inhabitants	USPTO
3. High-technology exports	% of manufactured exports	WB
4. ECI	–	Hausmann et al. (2013)
5. Scientific/technical journal articles per capita	Per million inhabitants	WB
c. Control variables		
Geographical distance[d]	km	https://www.distancefromto.net/
Dummy for economic cycles[e]	–	Authors' own

[a]Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB database.

[b]GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.

[c]Sum of exports of goods and services plus imports of goods and services as a proportion of GDP.

[d]Variable used in the first stage of the Heckman model.

[e]Economic cycles identified in 2000–2001 and 2009.

Source: Authors' own.

(i) U.S. companies invest the most in domestic activities to develop new technologies through R&D, significantly ahead of Japanese, German, French, and British companies (Chiarini, 2017);
(ii) U.S. private R&D abroad is continually increasing (Laurens et al., 2015); and
(iii) The expansionary trend of U.S. private R&D performed abroad through foreign affiliates provides a sound example of private R&D internationalization.

3.1.1 | Dependent variable: U.S. R&D investment abroad data

The departure point of the database is U.S. corporates' R&D captive offshore, which is the dependent variable. According to a BEA Survey, R&D is planned, creative work aimed at discovering new knowledge or developing new or significantly improved goods and services.[4] In our study, it is developed by majority-owned foreign affiliates of U.S. MNCs.

BEA provides historical series for outward direct investment, including R&D figures in millions of current U.S. dollars for many countries worldwide. We selected the data and then we deflated the time series using the GDP deflator (year-base 2010) available at the WB database.

Once the database regarding the U.S. corporates' R&D investment abroad was created, the first thing to note was its increase through time. Table 3 and Figure 2 show that more and more U.S. majority-owned affiliates abroad have been investing in R&D in other countries, corroborating our choice to analyze the case of U.S. companies.

It is also interesting to note that U.S. corporate R&D investment abroad fluctuates together with economic cycles. From 1997 to 2000, the average growth rate was 10.5% per year; however, with the bursting of the dot-com bubble in the late 1990s, U.S. corporate R&D investment abroad fell, with the rate in 2001–2004 reducing to 3.97% per year. In the following period (2005–2008), investment started to grow again, reaching 9.90% per year, when the economy recovered. However, with the 2008 financial crises, U.S. R&D investment abroad reduced drastically, with a negative growth rate of 3.61% (in 2009–2010). With economic recovery and expansion, U.S. corporate R&D investment abroad again increased to a 10.7% growth rate (2011–2014). This fluctuation suggests that R&D investment is procyclical, and it is sensitive to economic conditions (Archibugi & Michie, 1995). Therefore, in the next section, we control the models, with a dummy variable trying to capture the effects of economic cycles on R&D investments.

It is also interesting to note from Table 3 that most of U.S. R&D captive offshore is concentrated in high-income countries (with a proxy used for developed countries), and they respond to an average of 87% of total U.S. R&D investment abroad (in 2000–2016). Figure 3 shows the evolution trend of U.S. captive offshore both in developed countries and in LDCs.

When taking a long-term perspective to consider the LDCs, we can see that some of them seem to be increasingly attractive players in global R&D, whereas other middle- and low-income countries

TABLE 3 R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies (all industries), by region and by selected countries, millions of constant U.S. dollars, selected years

	2000	2005	2010	2015	2016
Europe	**15,843**	**20,674**	**23,902**	**35,594**	**34,463**
France	1,803	2,471	2,021	2,432	2,493
Germany	3,834	5,067	6,717	9,560	9,889
UK	5,060	5,943	5,788	6,734	6,561
Latin America	**816**	**925**	**2,553**	**2,598**	**2,157**
Brazil	311	445	1,389	964	875
Mexico	373	(D)	337	732	454
Asia and Pacific	**4,845**	**5,238**	**8,564**	**15,614**	**15,286**
China	623	734	1,535	3,732	3,852
India	(D)	360	1,716	3,457	3,695
Japan	2,006	1,888	1,812	2,730	3,083
Developed countries	**22,713**	**27,884**	**33,367**	**50,172**	**48,096**
LDCs	**2,467**	**2,091**	**4,331**	**10,989**	**10,816**
Total	25,182	30,402	39,887	61,161	58,915

Note: Absolute value is in millions of constant U.S. dollars. Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB. According to the BEA, D = suppressed to avoid disclosure of confidential information.
Source: Authors' own. Data sourced from BEA, Survey of U.S. Direct Investment Abroad (annual series) and complied by Science and Engineering Indicators.

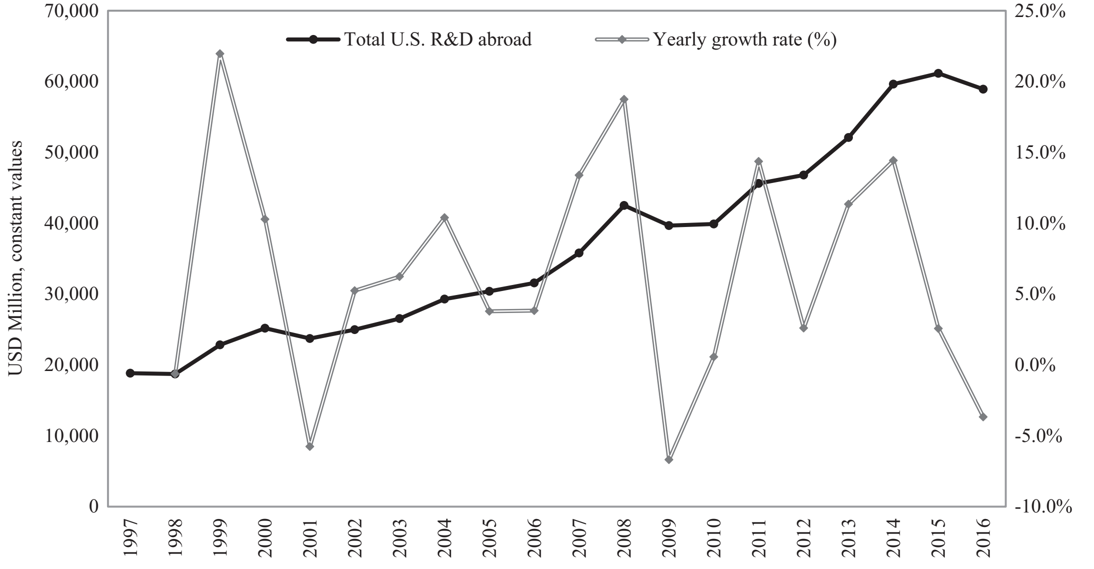

FIGURE 2 R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies and yearly growth rate
Source: Authors' own. Data sourced from BEA. Note: Absolute value is in millions of constant U.S. dollars. Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB.

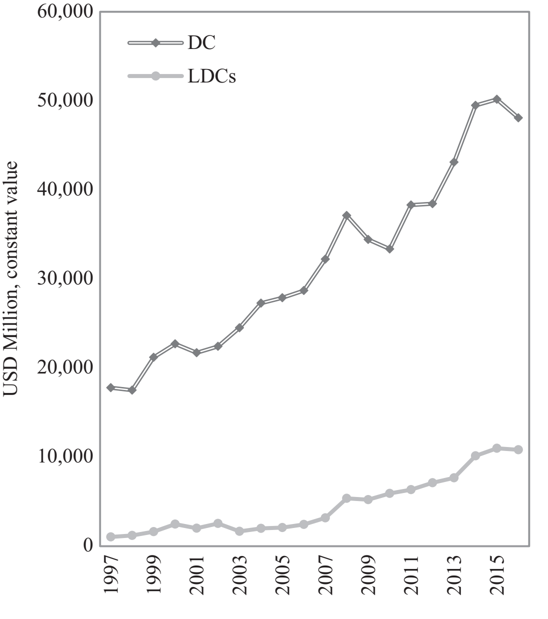

FIGURE 3 R&D performed abroad by majority-owned foreign affiliates of U.S. parent companies
Source: Authors' own. Data sourced from BEA. *Note:* Absolute value is in millions of constant U.S. dollars. Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB.

are still not part of the game. That is the case of China and India, especially from 2010 onward, when they start to be protagonists, whereas Brazil seems to have become less attractive since then, playing a secondary role (Figure 4).

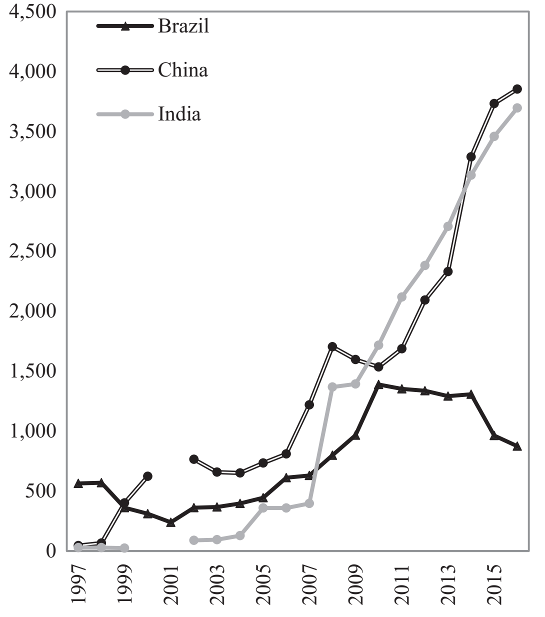

FIGURE 4 R&D performed in Brazil, China, and India by majority-owned foreign affiliates of U.S. parent companies
Source: Authors' own. Data sourced from BEA. *Note:* Absolute value is in millions of constant U.S. dollars. Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB.

3.1.2 | Independent variables

As presented in Table 2, we use different independent variables to explain the allocation of the U.S. inward R&D-related FDI.

Previous R&D investment
With this dimension, we expect to capture elements of path dependence (Antonelli & Colombelli, 2013; Narula, 2002), which explain the accumulation of technological knowledge in a given trajectory (Dosi, 1982).

Market consumption
Market consumption is measured by two variables: population (size) and income (consumption capacity), whose proxy is the GDP per capita. With these variables, we expect to capture the influence of the demand to attract U.S. inward R&D-related FDI. This expectation is based on the fact that much of MNCs' R&D investment in LDCs focuses on adapting to local demand conditions. As presented by Marin and Arza (2009), this can be especially relevant to countries with a large geographic dimension.

International openness
We propose that in internationally open economies, R&D inflow would tend to be higher, especially considering the global value chain perspective (Gereffi et al., 2001).

Innovation System
Another variable used in the model is the IS of the host countries. According to Lundvall (1992, p. 12), an IS "is constituted by elements and relationships which interact in the production, diffusion

and use of new, and economically useful, knowledge and … encompasses elements and relationships, either located within or rooted inside the borders of a nation state."

Many possible variables used in the literature characterize an IS, ranging from narrow to broad definitions (Lundvall et al., 2009). The previous literature focused on effort-related and performance-related indicators. The main indicators proposed are R&D expenditure, science and technology (S&T) expenditure,[5] human resources allocation in R&D, patent applications and scientific publications, among others (Lundvall et al., 2009). However, some IS elements and relationships that directly affect the national learning capacity are both informal and difficult to measure. For this reason, in a broad perspective, other indicators should be considered, such as those that analyze social institutions, communication and education infrastructure, and the type of relationship between actors (Lundvall et al., 2009).

We decided to treat the IS as the first factor obtained by the factor analysis technique for science, technology, and innovation variables.[6] Unfortunately, due to the lack of comparable data in a historical perspective for many countries, we opted to focus only on indicators from a narrow definition of IS. The ones selected are:

a. R&D investment,
b. Patents deposited at USPTO per million inhabitants,
c. High-technology exports,
d. Economic complexity index (ECI), and
e. Scientific/technical journal articles per million inhabitants.

The term "R&D investment" connotes the current and capital expenditures (both public and private) on creative work undertaken systematically to increase knowledge. R&D covers basic research, applied research, and experimental development. The variable "patents deposited at USPTO per million inhabitants" refers to the number of patent applications filed in the USPTO by country of origin and based on the residence of the first-named inventor.

The "high-technology exports" variable represents products with high R&D intensity, such as those in aerospace technology, computers, pharmaceuticals, scientific instruments, and electrical machinery.

The "economic complexity index" (ECI), according to Hausmann and colleagues (2013), is a scale that uses the theory of, and calculations for, economic complexity to rank countries according to their level of complexity. The indicator rigorously captures measures of ubiquity and diversity of the countries' exports, allowing the identification of patterns of specialization of countries in world trade. It ranks the diversification and complexity of a country's export basket.[7]

Finally, the variable "scientific/technical journal articles per million inhabitants" refers to the number of scientific and engineering (physics, biology, chemistry, mathematics, clinical medicine, biomedical research, engineering and technology, and earth and space sciences) articles published.

The first factor is able to explain 100.32% of total variance. Furthermore, each variable has the following correlation with the first factor: "R&D investment": 0.9583; "patents deposited at USPTO per million inhabitants": 0.8669; "high-technology exports": 0.3447; ECI: 0.7653; and "scientific/technical journal articles per million inhabitants": 0.7932 (Table 4).

3.1.3 | List of countries

Getting a temporal database for a large number of countries is not easy. There is non-negligible lack of information for many of them, which makes it quite hard to form balanced panel data. We made an

TABLE 4 Factor analysis/correlation

Factor	Eigen value	Difference	Proportion	Cumulative
Factor 1	3.00364	2.83769	1.0032	1.0032
Factor 2	0.16595	0.14887	0.0554	1.0586
Factor 3	0.01708	0.08182	0.0057	1.0643
Factor 4	−0.06474	0.06311	−0.0216	1.0427
Factor 5	−0.12785	–	−0.0427	1
Variables	**Factor 1**	**Factor 2**	**Factor 3**	**Uniqueness**
R&D investment	0.9583	−0.0670	−0.0064	0.0771
Patents deposited at USPTO per million inhabitants	0.8669	−0.2015	0.0733	0.2024
High-technology exports	0.3447	0.2370	0.0675	0.8204
ECI	0.7653	0.2505	−0.0208	0.3511
Scientific/technical journal articles per million inhabitants	0.7932	−0.0436	−0.0817	0.3623

Note: Method, principal factors; observations, 1,094; retained factors, 3/Rotation (un-rotated) / number of parameters, 10; LR test, independent versus saturated: $\chi^2(10) = 3698.63$; Prob>$\chi^2 = 0.0000$.
Source: Authors' own.

exhaustive effort to make databases compatible to include the largest number of countries possible. In total, we captured 71 countries (dispersed all over the world) that appear for at least 5 years in the sample (Table 5). Unfortunately, we were not able to consider more countries, because information was not available, and among those considered, there is still a significant amount of missing data, which means that we were obligated to deal with unbalanced panel data.[8] These are probably non-negligible limitations of the database and consequently of the model.

In the following list, we separated countries into developed countries versus LDCs. It is worth emphasizing that the group of LDCs was not stable throughout the period (1997–2015) once we used the level of income as a proxy for economic development. Therefore, some countries historically changed their income-level status, according to the World Bank methodology.[9] For example, Croatia was considered a high-income country only after 2008, so from 1997 to 2007 it was grouped as an LDC (middle- and low-income country). Other countries considered as high-income countries are South Korea (from 2001); Saudi Arabia (from 2004); Trinidad and Tobago (from 2006); Barbados (from 2006); Czech Republic (from 2006); Estonia (from 2006); Slovakia (from 2007); Hungary (from 2007); Latvia (from 2009); Poland (from 2009); Uruguay (from 2012); and Chile (from 2014). Other countries, such as Russia (in 2014 and 2015) and Argentina (in 2014 only), had the "high-income status" only for a short period. We follow this methodological rigor because the main aim of this work is to identify features of LDCs that have influenced U.S. R&D investment abroad. Consequently, the groups of LDCs vary yearly.

3.1.4 | Descriptive statistics

This short descriptive presentation of statistics, for dependent and independent variables, considers four periods of time (1997–2000, 2001–2005, 2006–2010, and 2011–2015), as depicted in Table 6

TABLE 5 List of the 71 countries used in the econometric models

Argentina	Czech Republic	Italy	Paraguay	Sri Lanka
Australia	Denmark	Japan	Peru	Sweden
Austria	Ecuador	Kazakhstan	Philippines	Switzerland
Azerbaijan	Egypt	Kuwait	Poland	Thailand
Belarus	Estonia	Latvia	Portugal	Trinidad and Tobago
Belgium	Finland	Lithuania	Romania	Tunisia
Bolivia	France	Malaysia	Russia	Turkey
Brazil	Georgia	Mexico	Saudi Arabia	Ukraine
Bulgaria	Germany	Moldova	Serbia	United Kingdom
Canada	Greece	Morocco	Singapore	Uruguay
Chile	Hungary	Netherlands	Slovak Republic	Venezuela
China	India	New Zealand	Slovenia	
Colombia	Iran	Norway	South Africa	
Costa Rica	Ireland	Pakistan	South Korea	
Croatia	Israel	Panama	Spain	

Source: Authors' own.

(the descriptive statistics and Pearson correlation matrix is in Table A1, Appendix A). We present the percentage of missed countries[10] as well to specify how unbalanced the panel data are.

U.S. R&D captive offshore has increased mainly in LDCs in recent years, reaching, in 2011–2015, 675% of its value in 1997–2000. This is followed by an increase in GDP per capita and population (our proxies for market consumption). However, there is no significant improvement in IS (factor increases from –0.62 to –0.61) and trade openness (75.05% to 77.67%).

For developed countries, we also see an expansion of US R&D investments, but reasonably more modest than those in LDCs, as we showed in the previous section. Finally, we notice an increase in GDP per capita, trade openness, and IS, besides a decrease in population.

3.2 | Modeling

With the data available, we use the Heckman two-step correction for selection bias (Heckman, 1979), as it is based on non-randomly selected samples from a U.S. R&D investment abroad database.[11] This procedure is used because the BEA dataset does not disclose all information (or present aggregate values for a group of countries) to warrant confidentiality. In all those cases, we consider a null value of investments, which is clearly not entirely true.

Following econometric specification, in the first step, we formulate a probit model for the probability of a country receiving U.S. R&D investment. For this step, all independent and control variables presented in Table 2 are considered.

In the second step, we correct the model for self-selection by incorporating a transformation of these predicted individual probabilities as an additional explanatory variable through the Inverse-Mills

TABLE 6 Descriptive statistics (average by periods)

	1997–2000		2001–2005		2006–2010		2011–2015	
Variables	**DCs**	**LDCs**	**DCs**	**LDCs**	**DCs**	**LDCs**	**DCs**	**LDCs**
Number of variables	77	130	112	164	149	155	159	148
Missing countries (% of total)	20.62	30.48	11.81	28.07	6.29	20.92	4.79	21.28
U.S. R&D captive offshore (USD in million)	938.81	29.41	1,029.21	38.56	1,044.55	137.35	1,291.83	227.90
GDP per capita (USD)	35,826.36	9,862.13	38,628.88	11,570.81	38,941.80	13,387.70	37,091.39	7,914.81
Population (millions)	28.20	88.70	27.90	80.90	23.70	118.00	24.30	106.00
Open trade (% of GDP)	86.39	75.05	89.05	81.09	101.22	80.63	105.65	77.67
IS (factor)	0.68	−0.62	0.91	−0.59	0.85	−0.55	0.88	−0.61

Source: Authors' own.

Ratio (IMR). The explanatory (independent + control) variables considered in this step are the same as in the first step, although we exclude the control variable "distance."

To reinforce analysis, we define three distinct models:

a. a complete model with all the 71 countries in the data base,
b. a model with only developed countries (high-income countries), and
c. a model with only LDCs (low- and middle-income countries).

This method is used considering the database as a panel data (1997–2015). The first stage (probit models for three distinct configurations) is presented in Appendix A (Table A2). The Hausman test was performed in the second stage of "model *a*" (complete model) to choose among fixed effects and random effects (Table A3, Appendix A). The results point out the preference for fixed effects, so all three econometric models were performed to that. Those models are presented in the following section.

4 | RESULTS

As presented in the previous section, we had two different specifications of our models. We use GDP per capita and population data in both logarithm values and in natural values. The two specifications seem to be robust—that is, GDP per capita and population in both logarithm and natural values do not drastically change the estimation results. In Table 7, we present the parameter estimates and the results for all the models, and subsequently, in the following subsections, we propose some possible interpretations.

4.1 | Previous R&D Investments

We find there is a positive relation between current R&D expenditure and previous year's R&D expenses for all the models presented in Table 7; however, it seems more important to developed countries compared to LDCs.

The positive relation may be derived from the rigidity of investment in innovative activities, because previous R&D investments define a sort of sunk cost whose maintenance of investment becomes necessary for the maintenance of established R&D activities.

That being said, one can propose that R&D is cumulative and complementary; that is, inventive activities are conditioned on knowledge levels already achieved by the companies. Therefore, the generation of new knowledge is built upon current and past knowledge (Malerba & Orsenigo, 1993; Nelson & Winter, 1982), and innovative success yields profits that can be invested again in R&D (Nelson and Winter, 1982), encouraging more R&D and innovation. According to Antonelli and Colombelli (2013, p. 31), the "generation of new knowledge at time *t* is possible only standing upon the shoulders of the technological knowledge that has been generated until that time." Therefore, R&D cumulativeness and complementarity may create a group of less-developed host countries where U.S. companies keep investing in R&D, promoting R&D centralization.

The previous finding corroborates other empirical studies presented in the literature. For example, Demirbag and Glaister (2010) show that MNCs' prior R&D activities in a specific country increase the likelihood of that country being selected by the MNCs for offshoring R&D projects.

TABLE 7 Parameter estimates and results

	Model 1	Model 2	Model 3
	Full Sample	**DC subsample**	**LDC subsample**
Lagged value of U.S. R&D captive offshoring (*t*–1)	0.673***	0.631***	0.582***
	21.54	14.50	10.57
Ln GDP per capita	0.772***	0.191*	2.025***
	4.23	1.75	4.95
Ln population	0.848**	0.690*	2.026***
	2.11	1.75	2.49
Open trade	0.00153	0.00192	−0.00207
	−1.10	−1.20	−0.68
IS	0.017*	0.258**	−0.164
	1.78	2.74	−0.99
Dummy for economic cycle 2000/2001	−0.0017	−0.0075	−0.0054
	−0.03	−0.13	−0.05
Dummy for economic cycle 2009	−0.126**	−0.145**	0.045
	−1.96	−2.21	0.32
IMR	−0.280***	−0.18*	0.109
	−2.98	−1.82	−0.53
Constant	−20.35***	−14.88**	−53.30***
	−3.05	−2.04	−3.41
N	621	383	238
F	229.13	99.12	98.38
Prob > *F*	0.00	0.00	0.00
R^2 between	0.895	0.873	0.664

Note: (*) $p<0.1$, (**) $p<0.05$, and (***) $p<0.01$.
Source: Authors' own.

4.2 | Market Consumption

Market features are measured by two aspects: population (size) and income (consumption capacity), whose proxy is GDP per capita. The GDP per capita was statistically significant in all three models, although only with p-value < 0.1 for *Model 2*. Thus, an analysis performed with more rigorous levels of statistical significance would point out that per capita income is a determinant of R&D attractiveness mainly for LDCs. This understanding is reinforced by the results of population size, as the coefficient for LDCs is higher than that for developed countries. This confirms the importance of demand, as presented in some empirical studies (Cantwell & Janne, 2000; Marin & Arza, 2009; Zedtwitz & Gassmann, 2002). This is an expected result, as local demands generate product adaptation needs. In this sense, cultural preferences, local infrastructure features, or even climatic conditions—that is, particularities of markets—are considered.

For example, in Brazil, it is well known that the automotive industry performs "tropicalization" (Consoni & Quadros, 2006), or the adaptation of products to local conditions. One example of this is that carmakers' subsidiaries in the country need to equip cars with specially developed damping systems due to road conditions.

4.3 | International Openness

In all the models presented in Table 7, characteristics of international openness are not relevant for U.S. corporate R&D captive offshore. This finding corroborates the empirical analysis presented by Kumar (2001) and Marin and Arza (2009). According to Kumar (2001, p. 169), "More restrictive trade regimes may attract more R&D investments than more open ones keeping other things same, especially in LDCs. A possible explanation for this outcome is that import barriers encourage MNE affiliates to undertake indigenization and hence product and process adaptations locally by making imported alternatives more expensive." By the same token, Lema, Rabellotti, and Sampath (2018) have shown that virtuous insertion of LDCs into global value chains occurs in a three-stage time dynamic and that the absence of technological policies can limit the evolution of the stages, limiting the achievement of R&D.

4.4 | Innovation System

The IS is relevant for U.S. corporate R&D internationalization only when the investment is made in developed countries.

The influence of the IS of a host country on the location decision of MNCs' R&D activities is also empirically presented in the literature, and various studies (Cassiolato & Soares, 2014; Demirbag & Glaister, 2010) show that the more developed the knowledge infrastructure and the larger the pool of experts for the R&D projects of a country, the greater the likelihood of that country being selected by an MNC for offshore R&D projects.

For LDCs, our model shows that U.S. companies are more attracted by their consumption market and that IS features seem to be unimportant. This could corroborate the thesis of knowledge-exploiting or home-base-exploiting R&D in LDCs (Dunning & Narula, 1995; Kuemmerle, 1999). In this regard, the average value for the "IS" variable in LDCs with positive values for U.S. R&D captive offshore is –0.53, and –0.69 for countries with null values. In developed countries, these values are 0.96 and –0.24, respectively.

4.5 | Controlling Variables

We use controlling variables for economic cycles for all the models presented. This is done once there are fluctuations in R&D investment during the period of analysis. As we can see in Figure 2, U.S. R&D investment abroad declined during periods of economic crisis (2000–2001 and 2009) mainly because of the investment reduction in developed countries, as those countries were the epicenter of the crisis (Lane, 2012). Therefore, we can expect that R&D expenditures are sensitive to economic cycles, as presented in the literature (Archibugi & Michie, 1995; François, Patrick, & Lloyd-Ellis, 2009).

Similarly, looking at Table 7, we can see that the dot-com crisis (2000–2001) was not statistically significant for any model. However, the 2009 financial crisis was statistically significant for *Model 1* (full sample) and *Model 2* (developed countries), negatively affecting U.S. R&D investment abroad. In other words, in those years, U.S. corporate R&D captive offshore in developed countries was negatively affected by economic cycles. This is expected, as returns to R&D investment are subject to uncertainty, and during drastic reductions of national income, companies do not expect to invest in risky and long-term activities.

In regard to *Model 3* (LDCs), crises were not statistically significant to explain U.S. corporate R&D investments abroad. The previous finding may suggest that U.S. R&D captive offshore in those countries is more resilient to the financial crisis than it is in developed countries. This may be because the R&D carried out in LDCs is the home-base-exploiting type. Therefore, those countries that did not immediately suffer the negative impacts of the crisis continued to receive R&D investment from the U.S. (especially Brazil, China, and India) to adapt production processes and products to suit local conditions and to take advantage of their market size.

We could also suggest that the strategy of U.S. companies in regard to their inventive activities is to reduce monetary inversions in countries where there is a higher stock of investments (developed countries), preserving the values in countries with a lower R&D structure (LDCs). The U.S. R&D captive offshore averages in developed and LDCs were, respectively, USD 1,041.73 million and USD 99.20 million during the entire period of analysis. During the economic downturns, the R&D investment decline in relation to the previous year was 7.3% for developed countries and 5.1% for LDCs in the first cycle (2000–2001), and 12.5% for the former and 2.0% for the latter in the second cycle (2009).

5 | U.S. R&D INVESTMENT IN BRAZIL, CHINA, AND INDIA

Brazil, China, and India are emblematic cases for understanding the evolution of U.S. R&D internationalization toward LDCs and the ability of LDCs to attract such investments. In some way, this triad of countries differs from other LDCs as they receive more R&D investments than their peers. In 2016, for instance, the three countries together received about USD 8,422 million, representing over 75% of other LDCs (Figure 5).

From the econometric model presented in the previous section, we could find that for LDCs, market consumption and R&D investment cumulativeness explain why majority-owned foreign affiliates of U.S. parent companies invest in R&D activities in those locations. However, even if features of the IS for LDCs were not statistically significant in the models, we believe that an investigation of this factor for Brazil, China, and India can reveal more about the location factors that are making them more inviting for U.S. R&D investment abroad.

In fact, when conducting a statistical test[12] to compare averages between Brazil, China, and India and other LDCs in regard to the IS, we find that there is a statistically significant difference, which allows us to conclude that the average of the IS is higher for Brazil, China, and India than that for other LDCs. However, if the Innovation System is different than LDCs' does not mean they are statistically the same as the IS of more developed countries. Looking at Table 8, we can also see that the average value of IS for Brazil, China, and India differs from that of developed countries.

Figure 6 illustrates the direction of the transformation of the Chinese IS, while that of Brazil and India is lagging behind. At the beginning of the series, we were certain to classify the Chinese IS as typical of an LDC, but this would seem a misconception toward the end of the period. This is not only a reflection of Chinese R&D investment patterns, which increased its R&D/GDP ratio from 0.89% to 2.06% (2000–2015) (Figure 7), but also the increase of its economic complexity (0.31–0.61), which resulted in an increase in high-tech exports (from 18.98% to 25.65%) (Table A4, Appendix A) to a much higher level than that of Brazil, India, and other LDCs.[13] Brazil registered a timid improvement

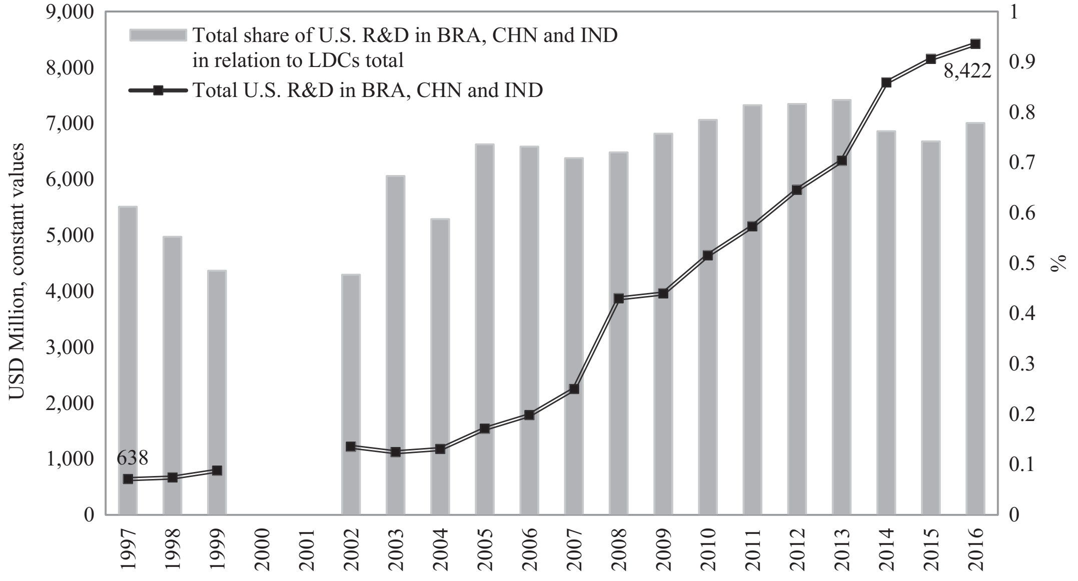

FIGURE 5 U.S. R&D performed in Brazil, China, and India by majority-owned foreign affiliates of U.S. parent companies, total value and share in relation to LDCs' total
Source: Authors' own. Data sourced from BEA. *Note:* Absolute value is in millions of constant U.S. dollars. Current U.S. dollars were deflated by GDP deflator (year-base 2010) available at the WB.

TABLE 8 Descriptive statistics and Z-test for comparison of averages

Descriptive Statistics	Average	SD
Brazil	−0.223	0.076
China	0.029	0.386
India	−0.051	0.044
LDCs	−0.617	0.326
Developed countries	0.740	0.963
Comparison	**Z-Test**	***P*-value**
LDCs versus Brazil	17.948	0.000
LDCs versus China	7.233	0.000
LDCs versus India	6.238	0.000
Brazil versus DCs	20.694	0.000
China versus DCs	7.225	0.000
India versus DCs	28.228	0.000

Note: $p < 0.01 = 2.33$.
Source: Authors' own.

trend, whereas India had no clear improvement at all, even though it is considered to have an emerging science and technology (S&T) and R&D ecosystems (Patra & Krishna, 2015).

Studies show that although China has been focusing central efforts on the promotion of S&T in its development agenda (Tang & Hussler, 2011), there is no effective industrial policy in Brazil that boosts the development of national technologies (Esteves & Feldmann, 2016); even the significant

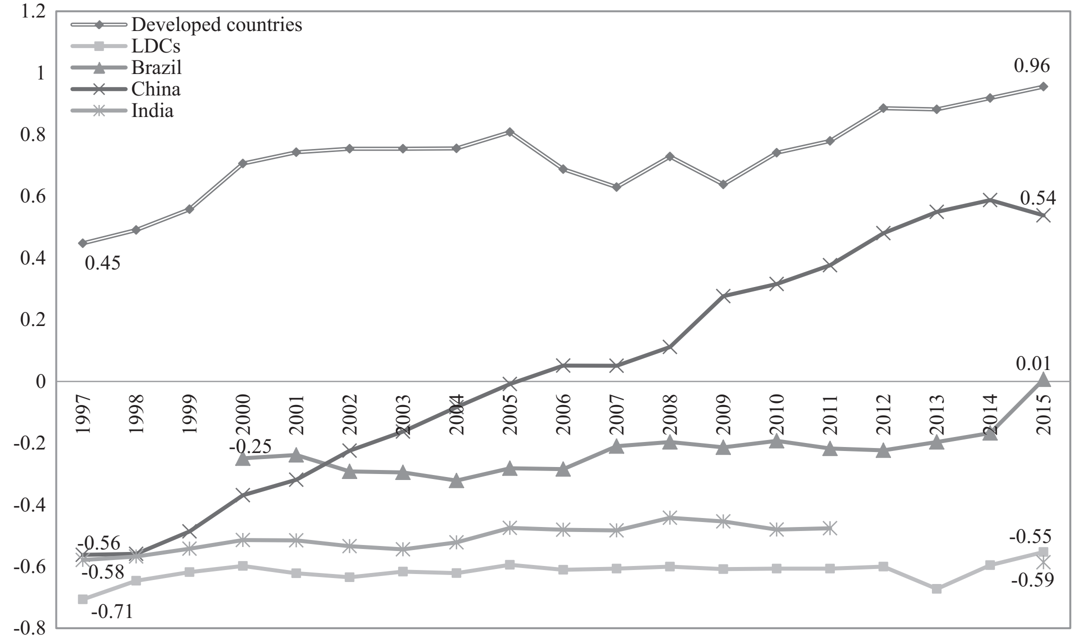

FIGURE 6 Evolution of the IS factor, China, Brazil, and India, 1997–2015
Source: Authors' own.

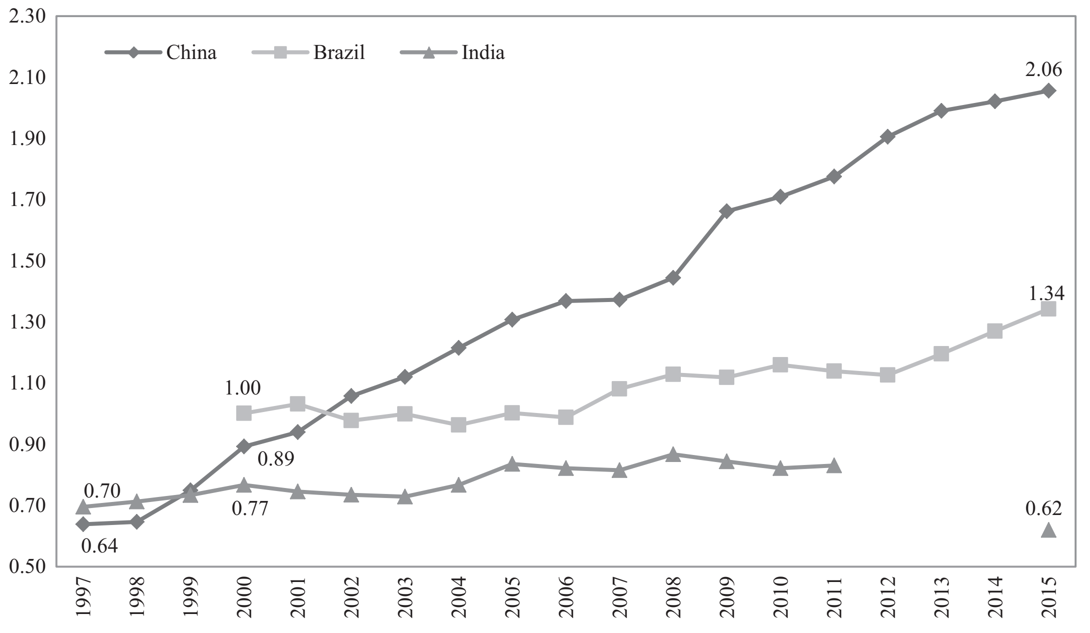

FIGURE 7 Evolution of the R&D (% of GDP), China, Brazil, and India, 1997–2015
Source: Authors' own.

efforts made in the past two decades were not sufficient to significantly increase the private R&D expenditure in the country (Reynolds, Schneider, & Zylberberg, 2019). The R&D/GDP ratio increase from 1% to 1.34% (Figure 7) was mostly accounted for by government expenditure, not private investment in innovative activities.

According to Tang and Hussler (2011), the Chinese IS has been benefiting from the attraction of new actors for innovation, from the institutional building to catalyze knowledge generation and from the promotion of interactions between indigenous actors of innovation. In the opposite direction is Brazil, where industrial policies do exist, but are still far from being a facilitator and promoter of innovation (Rapini, Chiarini, & Bittencourt, 2017). Therefore, an important difference between China and Brazil is that in China, industrial and S&T policies deliberately sought to absorb technology from the MNCs. In the Brazilian case, there was no such concern, and the structural reforms implemented in the country in the 1990s reduced technology efforts of both national corporations and MNCs (Katz, 2001). In other words, the Brazilian industrial policy reinforced the adaptive format of the R&D that had been previously carried out, whereas the Chinese made it possible to take advantage of opportunities (e.g., the ones presented in Table 1), via knowledge diffusion to the host country and demand for skilled personnel.

A key feature of R&D investment by MNCs in India is the sectorial concentration of about 50% of total investment in software and information technology (IT). The percentage rises to 80% including the aerospace, pharmaceutical, and automotive sectors. According to Mrinalini, Nath, and Sandhya (2013), even in the software and IT sector, India-based multinational R&D initiatives do not appear to be of major relevance to multinationals given their global scale.

The evolution of the IS and the absorption of U.S. R&D investments in Brazil, China, and India indicate that upgrading S&T infrastructures and institutions must be a continuous policy in LDCs and should include investments in aspects that could improve countries' capacities to absorb, generate, and manage technological change. In fact, recent empirical studies demonstrate that the countries that join the group of receivers of knowledge and innovation from FDI invest in such elements (Cassiolato & Soares, 2014; Filippetti, Frenz, & Ietto-Gillies, 2017).

Let us return to the question raised in the introduction of this paper: what makes Brazil, China and India important LDC receivers of U.S. inward R&D-related foreign direct investment? Our models have helped illuminate the important fact that these countries have already accumulated great amounts of U.S. R&D investment and have large consumer markets. However, as we see, they have relatively better IS in comparison to other LDCs, which is a significant factor in attracting foreign R&D investment from developed countries. This led to the conclusion that the IS of these countries may be paramount to the absorption of multinational R&D investments. It should be noted, however, that this hypothesis is more plausible in China, where the IS characteristics are clearly evolving to something close to what defines the IS of developed countries.

6 | CONCLUSIONS AND POLICY RECOMMENDATIONS

The literature shows that both the asset exploitation and asset augmentation strategies explain the dispersion of R&D activities abroad. In general, developed countries tend to receive more investments of the second type, and LDCs tend to receive more investments of the first type. According to our models, the two types of investment are related to the host countries':

(i) IS maturity,
(ii) R&D investment cumulativeness, and
(iii) market consumption.

The first two items are more related to the asset augmentation type of investment, whereas the last one is more related to the asset exploitation type. In fact, our study found that R&D investment cumulativeness and market consumption are important determinants to explain U.S. R&D internationalization toward LDCs, whereas international openness and the characteristics of their IS did not demonstrate statistical significance. Notwithstanding these facts, the quality of the IS is very important to attract R&D investment from developed countries. Based on these results and on the fact that each LDC may benefit differently depending on the type of R&D undertaken and on the particularities of their IS, our study of the elements related to the IS of Brazil, China, and India has shown why these countries are more inviting to the U.S. R&D investment. We found that the increased amount of U.S. R&D offshore in China has been accompanied by consistent improvements in China's IS.

In fact, if we consider that (1) R&D activities by MNCs have historically focused on developed countries; (2) that the quality of their Innovation System is a determinate element of this attraction; (3) that there is a recent evolution of U.S. R&D investment in favor of LDCs, especially China; (4) that the growing foreign R&D activities in China were accompanied by a substantial improvement of its IS; and (5) that the improvement of Innovation System is the fundamental step that needs to be taken to catch up with other countries, then we can expect that China is on the right path to be soon classified as a developed country (at least in terms of technological catch-up). If our reasoning is correct, the recent phenomenon of R&D dispersion in favor of LDCs will merit a re-reading of the topic regarding the ability of LDCs to attract FDI. Scholarship should give less weight to traditional variables such as those related to the economic sphere (potential internal markets) and emphasize more on the propensity of MNCs to multiply their knowledge hubs.

Finally, it is important to mention that attracting those investments alone will not solve LDCs' challenges to overcome underdevelopment per se. It may be important for technological catch-up, as positive effects are likely to result; however, it does not mean domestic companies in Brazil, China, and India will automatically benefit from MNCs' R&D activities performed in their territories. Domestic companies must enhance their absorptive capacity to benefit from external knowledge from MNCs, and governments should make efforts to improve their industrial and innovation policies in such a way as to incentivize the dissemination of MNCs' expertise locally (Archibugi & Pietrobelli, 2003; Filippetti, Frenz, & Ietto-Gillies, 2017; Lee, Szapiro, & Zhuqing, 2018) and to strengthen their IS.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available at the World Bank, the Bureau of Economic Analysis (U.S. Department of Commerce), and the U.S. Patent and Trademark Office. No restrictions apply to the availability of these data.

ENDNOTES

[1] See Dachs (2014) and for a systematic review of R&D internationalization, see Vrontis and Christofi (2019).

[2] According to technological change specialists, companies might become locked-in by inferior technologies within the confines of specific technological paradigms and also by institutional constraints (legislation, economic rules, and contracts) (Foxon 2002). Technological lock-in happens, for example, because of increasing returns to adoption, preventing the company from adopting other superior options (Arthur, 1989). Institutional lock-in can interact with and reinforce the drivers of technological lock-in (Foxon 2002).

[3] The WB database is a collection of data compiled from officially recognized international sources with indicators aggregated in the following areas: agriculture and rural development, aid effectiveness, climate change, economy and growth, education, energy and mining, environment, external debt, financial sector, gender, health, infrastructure, poverty, private sector, public sector, science and technology, social development, social protection and labor, trade, and urban development (https://data.worldbank.org/).

[4] This includes (1) activities aimed at acquiring new knowledge or understanding without specific immediate commercial application or use (basic research); (2) activities aimed at solving a specific problem or meeting a specific commercial objective (applied research); and (3) systematic use of research and practical experience to produce new or significantly improved goods, services, or processes (development). According to the BEA, R&D expenditure includes all costs incurred to support R&D (wages, salaries, and related costs; materials and supplies consumed; R&D depreciation; cost of software used in R&D activities; utilities, such as telephone, fax, electricity, water, and gas; travel costs and professional dues; property taxes and other taxes incurred on account of the R&D organization or the facilities they use; insurance expenses; maintenance and repair, including maintenance of buildings and grounds; company overhead including personnel, accounting, procurement and inventory, and salaries of research executives not on the payroll of the R&D organization) and does not include capital expenditures, expenditures for tests, and evaluations once a prototype becomes a production model, patent expenses, and income taxes and interest (BEA 2004).

[5] S&T expenditures = R&D expenditures + related scientific and technical Activities (RSTA) expenditures. The RSTA are those activities related to experimental research and development and that contribute to the generation, diffusion and application of scientific and technical knowledge. They cover various scientific and technological services, including: libraries, information and documentation centers, reference services; museums of science and/or technology, botanical or zoological gardens; topographic, geological and hydrological surveys and many others (OECD 2015).

[6] A composite innovation measure is important since variables regarding ST&I are highly correlated (which inevitably biases the coefficients, besides affecting their significance). The same strategy was used in different studies (Caliari and Chiarini 2016; Caliari and Rapini 2017; Caliari and Santos 2016)

[7] For a methodological presentation of ECI, please see Hausmann *et al*. (2013). Furthermore, ECI has been validated as a relevant economic measure by showing its ability to predict future economic growth (Hidalgo and Hausmann 2009), and explain international variations in income inequality (Hartmann et al. 2017).

[8] This should not be considered a crucial problem, since the reason for the lack of data of some observation i is not correlated with the idiosyncratic errors (Wooldridge 2008).

[9] In order to maintain the methodological rigor in our models, which will allow us to identify the characteristics of developing countries that influence the U.S. inward R&D-related FDI in developing countries, we have decided to either include or exclude countries in this groups over time, following the income classification proposed by the World Bank.

[10] A country is missed in the panel data for a given year if there is no information for some of its independent variables.

[11] In a preliminary study, we used a panel data econometric method for censored outcomes through the random-effect Tobit model with the same variables used here (Chiarini et al. 2018). The random-effect Tobit model was calculated using quadrature, which is an approximation whose accuracy depends partially on the number of integration points used. Then, we established a procedure to check the quadrature approximation, verifying whether the changes in the number of integration points affect the outcomes. We found essentially the same results as we present here.

[12] The Z-test for comparison of averages is given by: $Z = \frac{\overline{X_1} - \overline{X_2}}{\sqrt{s_1^2/n_1 + s_2^2/n_2}}$, where $\overline{X}$ is the average of each subsample, s is the standard-deviation, and n is the number of data.

[13]It is important to note that this Chinese movement could not be predicted in our econometric model for two reasons: (*i*) a dummy for China would not have statistical significance (too small an amount of information); and (*ii*) the statistic model is static, which makes it difficult to identify the Chinese dynamism.

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APPENDIX A

TABLE A1 Descriptive statistics and Pearson correlation matrix

Variables	Mean	*SD*	1	2	3	4	5	6
1. US R&D captive offshoring (USD millions)	483.48	1,164.14	1					
2. US R&D captive offshoring (*t*–1) (USD millions)	463.97	1,125.72	0.9879	1				
3. GDP per capita	19,485.88	19,197.11	0.4126	0.4137	1			
4. Population (millions)	65.5	204	0.1253	0.106	−0.1981	1		
5. Open trade (% of GDP)	85.0	50.7	−0.0665	−0.0717	0.1449	−0.2194	1	
6. Innovation (factor)	0.0	0.97	0.4943	0.491	0.7172	−0.0327	0.1538	1

Source: Authors' own.

TABLE A2 Econometric probit models

	Model 1	Model 2	Model 3
	Full sample	DC subsample	LDC subsample
Ln GDP per capita	1.968***	1.629*	2.129***
	4.30	1.88	3.23
Ln population	1.874***	3.968***	2.154***
	5.99	3.82	5.41
Open trade	0.007	−0.001	0.012
	1.12	−0.03	1.35
IS	1.328***	3.221***	−0.107
	2.60	2.71	−1.02
Distance	−0.001	0.001	−0.001
	−0.26	0.61	−0.5
Dummy for economic cycle 2000/2001	−0.249	−0.724	−0.077
	−0.88	−1.16	−0.23
Dummy for economic cycle 2009	0.593	0.090	0.845
	0.96	0.04	1.15
Constant	−49.481***	−80.102***	−57.351***
	−6.00	−3.26	−5.06
N	1094	497	597
Wald χ^2	77.50	24.33	36.63
Prob > χ^2	0.00	0.00	0.00
Log likelihood	−152.02	−36.06	−113.91

Note: (*) $p < 0.1$, (**) $p < 0.05$, and (***) $p < 0.01$.
Source: Authors' own.

TABLE A3 Hausman Test for Model "a" (full sample)

	Fixed effects (FE)	Random effects (RE)	Difference	sqrt(diag(V_FE-V_RE)) SE
US R&D captive off-shoring (t–1)	0.6732429	0.8994962	−0.2262533	0.0271934
Ln GDP per capita	0.7719897	0.0559463	0.7160434	0.1786259
Ln population	0.8476819	0.0862257	0.7614562	0.4001383
Open trade	0.0015290	0.0008492	0.0006798	0.0013465
Innovation	0.0166286	0.0658804	−0.0492518	0.0815529
Dummy for economic cycle 2000/2001	−0.0017029	−0.0541876	0.0524847	0.0159406
Dummy for economic cycle 2009	−0.1259768	−0.1792546	0.0532779	-
IMR	−0.2804590	−0.0857472	−0.1947118	0.0885158

Note: FE = consistent under Ho and Ha; obtained from xtreg; RE = inconsistent under Ha, efficient under Ho; obtained from xtreg; Test: Ho: difference in coefficients not systematic; χ^2 (8) = 81.87; Prob > χ^2 = 0.0000.
Source: Authors' own.

TABLE A4 Innovation system variables

Variable	1997	2000	2005	2010	2015
R&D investment					
Developed countries	1.65	1.82	1.83	1.83	1.94
LDCs	0.49	0.55	0.54	0.59	0.62
China	0.64	0.89	1.31	1.71	2.06
Brazil	.	1.00	1.00	1.16	1.34
India	0.70	0.77	0.84	0.82	0.62
Patents deposited at USPTO per million inhabitants					
Developed countries	98.63	148.06	174.62	199.43	234.59
LDCs	0.98	4.43	2.78	2.84	3.95
China	0.10	0.37	1.63	6.10	15.60
Brazil	0.80	1.25	1.57	2.86	4.11
India	0.14	0.42	1.28	3.08	6.08
High-technology exports					
Developed countries	17.98	20.47	17.45	13.96	14.84
LDCs	8.90	12.24	10.99	11.17	11.70
China	13.12	18.98	30.84	27.51	25.65
Brazil	7.54	18.73	12.84	11.22	12.31
India	6.54	6.26	5.80	7.18	7.52
ECI					
Developed countries	1.26	1.29	1.20	1.07	1.16
LDCs	0.11	0.15	0.14	0.03	0.09
China	0.33	0.31	0.47	0.77	0.61
Brazil	0.61	0.60	0.45	0.25	0.70
India	0.10	0.21	0.16	0.11	0.25
Scientific/technical journal articles per million inhabitants					
Developed countries	568.48	920.5	1,174.6	1,259.0	1,364.2
LDCs	48.56	103.0	165.2	173.6	224.1
China	9.90	37.5	126.4	236.9	299.9
Brazil	26.79	66.0	116.0	210.2	257.4
India	9.64	19.8	29.0	51.0	81.4

Source: Authors' own. Data sourced from the World Bank and from USPTO.