BRAZILIAN INNOVATION TAX POLICY AND INTERNATIONAL INVESTMENT: EVIDENCE FROM UNITED STATES ENTERPRISES AND INTERNATIONAL PATENT APPLICATIONS

Daniel Gama e Colombo[*]

Abstract

In the last decades, multinational enterprises (MNEs) have increased their internationalization levels of innovation activities, directing more resources to research and development (R&D) out of their home countries. Brazil has benefited from such changes and has received increasing investment from MNEs. In 2005, the federal government approved new tax incentives (Law 11,195/05) to foster business innovation in the country by reducing the tax cost of R&D projects. This paper presents the first quantitative assessment on whether these tax breaks have attracted 'footloose R&D', diverting international investment from other economies. After a literature review on locational factors for R&D attraction and an analysis of the Brazilian case, an econometric model is presented, using data on R&D investment by U.S. MNEs and priority patent applications. No evidence that Brazilian tax incentives have attracted international R&D from alternative host countries is found. This result is in accordance with previous research suggesting R&D performed in Brazil by MNEs is mainly adaptive and support-oriented and, for this reason, tax incentives are not of primary importance as an attraction factor. It also suggests that claims that international fiscal competition lead to a zero-sum game may be unfounded in the Brazilian case.

Keywords: Innovation. International investment. Tax incentives.

Resumo

Nas últimas décadas conglomerados multinacionais (MNEs) aumentaram o nível de internacionalização de suas atividades de inovação, direcionando mais recursos de pesquisa e desenvolvimento (P&D) para localidades fora de seu país de origem. O Brasil beneficiou-se dessa mudança, e recebeu valores crescentes de investimentos de firmas estrangeiras. Em 2005 o governo federal aprovou um pacote de incentivos fiscais (Lei 11.196/05) para fomentar a inovação empresarial no país reduzindo o custo fiscal de projetos de P&D. Este artigo apresenta uma análise quantitativa original que investiga se essa redução tributária foi capaz de atrair recursos de P&D em detrimento de economias concorrentes. Após uma revisão da literatura sobre fatores locacionais de atração de P&D e uma análise do caso brasileiro, propõe-se um modelo econométrico utilizando dados de investimentos em P&D de MNEs norte-americanas e de pedidos prioritários de patentes. Não é identificada evidência de que os incentivos fiscais brasileiros tenham atraído P&D de destinos alternativos. Esse resultado encontra-se de acordo com pesquisas anteriores que sugerem que o P&D realizado no Brasil por MNEs é primordialmente de natureza adaptativa e voltada ao suporte das atividades locais, e que, por esse motivo, incentivos tributários não são de primeira importância na atração de investimentos. As conclusões do estudo refutam para o caso brasileiro o argumento de que competição fiscal entre países pode levar a um jogo de soma-zero.

Palavras-Chave: Incentivo Fiscal. Inovação. Investimento Internacional.

Área: 6 (Políticas Públicas e regulação); item 6.2 (Políticas de Ciência, Tecnologia e Inovação)

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[*] Aluno do Programa de Doutorado em Economia do Desenvolvimento na Faculdade de Economia, Administração e Contabilidade da Universidade de São Paulo (FEA/USP).

1 Introduction

Industrial investment in innovation has changed substantially in the last decades. Although a large portion of funding is still in the hands of multinational enterprises (MNEs) from developed countries (UNCTAD, 2005b; OECD, 2008), the potential for offshore research has reshaped the strategy of these groups. Resources and projects are divided among several geographic areas either to exploit local competitive advantages or to support production and sales. So far Brazil has received a small share of these funds, but it has recently experienced an increasing inflow of international research and development (R&D) investment.[1]

As innovation generates positive externalities and knowledge spillovers, governments have tried to develop and implement policies to increase and attract these investments. In this policy context, the use of tax incentives as a tool to foster innovation has particularly increased in the last decades. They tend to be more "market-friendly" than direct subsidies since the decision on the projects to be implemented remains within the firm (Hall & Van Reenen, 2000). However, this strategy has been criticized as 'beggar-thy-neighbor' schemes at the international level, as MNEs relocate their R&D investments to take advantage of local tax breaks. According to this argument, investment increases in one country are majorly the result of reduction in others (Knoll, Baumann & Riedel, 2014; Bloom & Griffith, 2001; OECD, 2013). This suggests fiscal incentives may constitute a zero-sum game, not raising global R&D levels while fostering competition between governments with a negative impact on public budget.

In 2005, the Brazilian federal government enacted Law 11,196/05, consolidating and expanding tax incentives to companies willing to invest in scientific and technological development in the country. Up to date the impact of these incentives on R&D investments by MNEs in Brazil has not been properly evaluated by quantitative studies. The objective of this paper is to present a first investigation on the topic. Based on a review of the relevant literature and data on R&D internalization and its drivers, an econometric model is presented to test whether there is evidence that tax breaks granted by Brazilian authorities have diverted investment from other sources, attracting 'footloose R&D' (as defined by Bloom & Griffith, 2001). Two distinct sets of panel data are used for estimation: R&D investment of United States (U.S.) MNEs abroad; and priority patent applications in which at least one of the inventors is from a country different from at least one of the applicants.

The paper is structured as follows: the second section discusses R&D internationalization as a global trend, presenting the theoretical framework and relevant literature, identifying its main drivers and analyzing the role of tax policy in this context. The third section is dedicated to the Brazilian case, presenting data on international investment in the country and analyzing the innovation tax policy introduced by the government. The fourth section presents the econometric analysis, describing the empirical model and its results. The fifth and last section concludes the study by discussing the findings and its policy implications.

2 International Investment in Innovation

2.1 Current trends.

R&D was one of the last activities of the value chain to be internationalized by multinational groups after distribution, sales and production (OECD, 2011). Although exceptional examples do exist, the main trend until the 1980s was centralization of technology development in the parent company`s domestic facilities. The main explanation for this is the vital importance of technology for business, along with its tacit nature, economies of scale for laboratory equipment and research, difficulty of knowledge transfer and the risk of information leaks (OECD, 2008).

Starting in the 1990s, international competition drove MNEs to decentralize their research efforts to other countries. At a slow but growing pace, part of these activities was outsourced to foreign affiliates or subcontracted to specialized firms abroad. Studies identified a group of "centrifugal forces" that counterbalance R&D centralization: support for production and adaptation of products to foreign markets;

[1] See data presented in section 3.1.

development or customization of technology for natural resource extraction; technology seeking the capture of spillovers; access to low cost or highly skilled personnel; and proximity to customers or partners (Thomson, 2009; OECD, 2008).

In spite of these drivers, the majority of MNEs' R&D is still performed in the home country (OECD, 2014). Internationalization is growing, but it is still far behind other value adding activities. The UNCTAD`s World Investment Prospects Survey informed that, in 2016, only 43% of the respondent MNEs planned to spend more than one-fifth of their R&D budget abroad. In comparison, for the same lower limit, the percentage of respondents rises to 68% when it refers to asset internationalization, 70% for investment and 88% for sales (UNCTAD, 2014).

MNEs offshoring R&D are mostly from a few countries, with a high predominance of parent companies from the U.S., United Kingdom, Japan, Germany and France (UNCTAD, 2005b). The level of internationalization also varies with geography: Western European groups presented higher levels of R&D offshoring in 2005, while Japanese and South Korean enterprises had higher expectations of internationalizing such activities in the future (UNCTAD, 2005b). As per sectorial differences, the chemical and pharmaceutical industries are the ones that most internationalized their innovation efforts (UNCTAD, 2005a and 2005b). Pharmaceuticals is also indicated as the leading industry for R&D internationalization by a more recent report of the European Commission (EC, 2012).

The largest part of internationalized R&D is directed to developed countries (OECD, 2008). According to the aforementioned European Commission Report, "the linkage between the U.S. and the E.U. is the single most important bilateral relationship in the internationalization of business R&D" (EC, 2012, p. 28). The relevance of emerging countries in this field is still limited.

Nonetheless, all revised studies and reports were unanimous in stating that emerging countries are becoming relevant players in this field, attracting a growing share of resources. However, as this is a recent trend, and one which requires a minimum level of qualified labor and infrastructure, only a few developing countries are truly attractive and receive a significant portion of investments. In 2005, the World Investment Report (UNCTAD, 2005b) limited this group to five nations: China, Singapore, Brazil, Mexico and Korea.

It is relevant to discuss not only the extent but also the nature of R&D performed in these countries. This is a difficult question to address due to the lack of available data. In OECD (2011), it was argued that a large proportion refers to non-core development such as product design, software development and high-tech manufacturing, although there are cases where MNEs installed research-focused facilities in developing economies. In the same sense, UNCTAD (2005b) stated that "in developing countries, while most R&D has traditionally been of an adaptive nature, recent trends suggest that more sophisticated activities are also expanding" (UNCTAD, 2005b, p. 138).

A last recent development is that developing countries are not only attracting foreign capital, but their MNEs are starting to internationalize R&D. This new trend is led mostly by Chinese multinationals, followed by a small number of Indian, Korean and Brazilian groups (UNCTAD, 2005b). OECD (2008) stated that the motives of these companies are slightly different from developed countries' MNEs, as they are more interested in complying with requirements to enter foreign markets and obtaining new technologies and skills.

2.2 Types of international R&D and drivers of investment location.

Considering the portrayed scenario of rising internationalization, the purpose of this subsection is to review the literature and relevant data on country features and factors influencing MNEs' decisions on the location of their R&D facilities or the destination for their resources. The pioneer works on the subject date from the 1960s and 1970s and include Dunning (1958), Brash (1966), Safarian (1966) and the U.S. Tariff Commission (1973). One particular influential framework was proposed by Dunning (1988, 1994 and 1998) and used (with minor changes) in Thomson (2009), UNCTAD (2005b), OECD (2008) and EC (2012). The author argued that firms engage in different types of R&D abroad when they intend to acquire competitive advantages "which are best exploited internationally from a foreign location" (Dunning, 1994, p. 75).

There are four main categories of technological innovation undertaken by MNEs in other countries. The first is the adaptation of products, materials or processes to the local market. The second is research on basic materials (mainly natural resources or immobile inputs) or products, due to the constant need for testing and interaction with the customer. In some cases, these two types are considered jointly under the label of adaptive or asset-exploiting R&D (EC, 2012; Thompson, 2009). The third type is rationalized research or "innovative R&D" (UNCTAD, 2005b), turning the local site into a technology exporter for other labs in the R&D network. Finally, MNEs may establish "monitoring posts" in specific places with the purpose of keeping track of the latest technological developments and benefit from knowledge spillovers.

The main type of R&D received by the majority of emerging economies is adaptive. This is regarded as the most common or 'traditional' form of R&D internationalization (UNCTAD, 2005b), and it is meant to adapt products to local regulations or consumer preferences, preparing them to be manufactured or sold in the local market. Internationalization drivers in this case are weak, and development should be limited, local and demand-oriented, not affecting core business technology or the innovation strategy of the group at the international level. As a consequence, the main variable for determining the R&D level should be market size or level of sales of the respective affiliate or local representative. In some cases, economies of scale may dictate that one facility works as a base for an entire region, so export levels might well be significant. On the supply-side, the availability of a minimally qualified workforce is also a relevant factor, although it should be more a requirement than an attraction force.

In more recent and limited cases, MNEs have identified competitive advantages in undertaking R&D not only for market exploitation, but also to supplement or expand technology development in the home country. Supply-side factors play a more pivotal role, and the critical one is the presence of a substantial pool of highly qualified scientists and engineers in specific areas. This directs this type of investment to developed economies, although South-East Asia has attracted a group of facilities, and there are special cases of innovative R&D in other countries, such as the automotive industry in Latin America (UNCTAD, 2005b) and, more recently, the case of pharmaceutical companies in Brazil (Dias, Teixeira, Queiroz & Galina, 2013). Presence in, and interaction with, universities is also a relevant feature, as it may boost innovation efforts. In addition, as the technology developed in these centers may have a strategic competitive advantage, an institutional framework protecting intellectual property rights is crucial.

The last type is a very specific case of R&D offshoring, mainly used by companies as monitoring outposts to access innovation externalities from clusters and regions with a concentration of innovative firms (Cantwell & Janne, 1999; Le Bas & Sierra, 2002; and, more recently, Jindra, Hassan & Cantner, 2016; and Siedschlaga, Smith, Turcu & Zhang, 2013). It is "mainly drawn to countries boasting world class clusters of technological and industrial activity" (UNCTAD, 2005b, p. 165), and, for this reason, it happens almost exclusively in developed economies. The attraction factor, in this case, is merely the presence of the cluster. The main examples are the Silicon Valley electronics/information technology and Boston pharmaceuticals industries.

Some factors seem to be applicable to all cases. The most important one is market size. In spite of carrying a more vital role in adaptive and non-central R&D, demand-orientation is usually mentioned as the most important investment attraction aspect regardless of the type of R&D (EC, 2012; OECD, 2011; Hall, 2011). Labor costs and wages, on the other hand, are not identified as determinant factors, although they may be influential in the case of innovative R&D in emerging countries (UNCTAD, 2005b; OECD, 2011).

Since the advance of international R&D in the 1990s, several empirical studies tried to identify and empirically test the strength of locational attraction factors. Such studies vary both in their methods, units of analysis, period, and regions studied. Results, as expected, are not unanimous, although patterns may be found that can provide important insights. Three surveys of this literature that cover different periods are EC (1998, focused on the European case), Hatem and Py (2008), and Hall (2011).

Methods applied to evaluate the relevance of country features were essentially surveys, econometrics modeling, data analysis and, to a minor degree, case studies (Mechin, 2006; Sapelak & Ricalde, 2008). Surveys are generally used for assessing future trends or gaining insights into the motive and rationale of the decision-making process of innovation strategies. Particularly influential research studies that followed this strategy are Edler, Meyer-Krahmer and Reger (2002), UNCTAD (2005a), and Thursby and Thursby (2006). Econometric models test if country features influence the innovation investment of international groups and other variables. The main relevant characteristics stressed in these studies are: market size or affiliates` sales levels, which was confirmed in nearly all studies reviewed (Hatem, 2009; Kumar, 2001; Cantwell & Piscitello, 2002; Jones & Teegen, 2003; Athukorala & Kohpaiboon, 2001), agglomeration economies (Hatem, 2009; Jindra et al., 2016; Siedschlag et al., 2013), knowledge externalities (Jindra et al., 2016), human capital (Siedschlag et al., 2013, Cantwell & Piscitello, 2002; Jones & Teegen, 2003) and R&D intensity in the region (Siedschlag et al., 2013, Shimizutani & Todo, 2008; Belderbos, Lykogianni & Veugellers, 2008; Athukorala & Kohpaiboon, 2001).

Data analysis studies and reports (OECD, 2008, 2011, 2014 and 2015; UNCTAD, 2005b; EC, 2012) rely mainly on country data, descriptive statistics and time series along with literature surveys, presenting a comprehensive and updated description of the situation and future trends for companies` investments policies. In general, findings in these empirical studies matched predictions of Dunning's (1988) theoretical framework. Relevant factors may rank differently, but the picture remains unchanged: with the exception of very developed clusters, demand is still the main attraction feature, although it plays a more significant role for emerging countries, in light of the nature of the majority of R&D activities developed therein. Institutional factors seem dependent on the nature of R&D – they are not mentioned as relevant for adaptive research, as technology generated in this case is not central to the group's business, and, therefore, intellectual property is not of primary importance.

2.3 Tax incentives and foreign R&D attraction - the 'footloose R&D' argument.

The analysis on the relevance of tax incentives as factors of attraction of international R&D may be deemed to be a recent development of and the intersection point between two important contemporary debates in economics: (a) the impact of these policies on private R&D; and (b) the main drivers of innovation investment location, as presented in section 2.2.

Empirical evidence provided by companies` surveys do not grant these incentives primary importance in the attraction of new investment (Thursby & Thursby, 2006). They seem to matter more in developed nations, but are still less relevant than several other factors, such as intellectual property protection, collaboration with universities and quality of R&D systems. Governments, nonetheless, have been using this instrument to attract innovation activities to their territories due to their positive externalities (Köhler, Laredo & Lamer, 2012).

Another point that has received considerable attention in empirical reports is the corporate strategy of reallocating money from one country to another to take advantage of fiscal benefits without raising global expenditure. This was called by Bloom and Griffith (2001) as 'footloose R&D', and the issue was discussed in OECD (2013). This report presented a quantitative model to analyze the effective value and impact of tax measures on the location of expenditure and knowledge-based capital. One of the findings was that international competition for R&D may lead to overall loss of tax revenues without the corresponding increase in innovation, calling therefore for international cooperation and consistency between national policies. In OECD (2014), the topic was once again highlighted, observing that individual tax alleviation policies can generate a zero-sum game at the international level, which may be considerably costly considering that around 90% of the total R&D worldwide is in MNEs` hands. Similar conclusions were reached by Köhler et al. (2012) and in the report of the French *Assemblée Nationale* (2010).

In the academic literature, however, this topic has not yet been extensively discussed (Thomson, 2009, described it as being "at a nascent stage"). Pioneer studies on the subject date from the 1990s (Hines Jr., 1993, 1994 and 1995). The most influential of the studies on this topic is Bloom and Griffith (2001), that developed the 'footloose R&D' argument. By analyzing a panel of countries, the authors found that business R&D in the United Kingdom was attracted to other countries by tax incentives. Wilson (2009) conducted a similar study focusing on the competition between U.S. states, concluding that "nearly all" R&D augmentation caused by tax reductions was caused by relocation between states. Considering European MNEs, Knoll et al. (2014) found that nearly 80% of the R&D increase caused by tax incentives in one country is due to relocation. Hines Jr. (1995) presented evidence that local R&D and imported technology are substitutes, and that MNEs respond to an increase in royalty tax rates by increasing local R&D. Finally, Dischinger and Riedel (2010) and McKenzie and Sershun (2010) also concluded that R&D tax incentives affected international flow of investment.

These results were challenged by a second group of studies that, in essence, followed the empirical literature of drivers of internationalization of R&D. Their main arguments are: (a) that once an adequate number of country features are added as controls, tax costs or incentives lose statistical significance, meaning that other factors are more relevant for location of innovation activities; and (b) that fierce international competition does not allow substantial relocation results to emerge or be sustainable, as tax incentives granted by one country are likely to be counterbalanced by similar provisions abroad (OECD, 2014; Köhler et al., 2011). Athukorala and Kohpaiboon (2006) defended the first point by running two groups of estimates: the first one with a full set of control variables that did not find significance for tax incentives; and a second reducing the number of controls that generated significant results similar to Hines Jr. (1995) and Bloom and Griffith (2001). Based on such analyzes, they argue that the specification used in such studies was actually biased by omitted variables. In the same sense, Thomson`s (2009) results were that "no evidence was found to support the hypothesis that tax incentives are effective in either inducing MNEs' affiliates to undertake additional R&D or to encourage additional international R&D contracts" (Thomson, 2009, p. 40).

The paper by Hines Jr. and Jaffe (2001) presented an alternative impact of tax incentives on international investment. Focusing exclusively on the firm`s dilemma of local versus foreign R&D, the study concluded that these two activities are actually complementary, and therefore a tax decrease in either country is more likely to increase the levels of innovation in both locations. Such result, however, was not discussed or even considered by later analyses.

The two most frequent indicators for innovation activities used in this literature are R&D expenditure by country or state (as a measure of input), and location of intellectual property application or ownership, which works as a proxy for innovation generated locally. The latter is challenged as a reliable indicator, on the basis that patent protection is heterogeneous among sectors and corporate tax planning may affect location selection (EC, 2014). Studies also differ on the measure of tax costs or incentives considered. While the majority use tax rates or values extracted directly from tax laws or regulations, a smaller group considers the abovementioned user cost of capital and the '*b-index'*.

The first conclusion taken from this literature review is that it remains an open debate that has not yet reached a level of consensus. Diversity of methods, data and variables lead to different conclusions and interpretations of the behavior of international groups when pursuing technological development worldwide.

A second relevant point is that these studies focused on developed countries, and there is little (if any) discussion on whether and to what extent their results apply to emerging economies. As mentioned previously, the type of R&D MNEs undertaken in each nation may differ drastically depending on the level of the wealth of the nation, and it is not obvious whether the attraction of fiscal measures would be stronger or weaker in either one.

3 Analysis of the Brazilian Case

3.1 Business innovation by MNEs in Brazil.

R&D offshoring forms part of the total foreign direct investment (FDI) made by international business groups in the country. From the time of the commercial liberalization and institutional reforms in the 1990s (along with a massive privatization program), Brazil became more appealing to international investors (Ruiz, 2015; Hiratuka, 2008) although serious challenges remained to be solved. Until 1994, international investment directed to the country was stagnant, growing substantially thereafter. The services sector has usually led the FDI entering the country, with an average of 50% of equity participation in the 2001-2014 period, followed by the industrial sector, with an average of 37% (BACEN, n.d.).[2]

The figures for the Brazilian innovation system, on the other hand, do not show a positive picture. Brazilian gross expenditure on science and technology in 2013 was around 1.7% of the country`s GDP, below the OECD average (around 2.4%) and far from some of its most innovative economies such as South Korea (4.15%), Israel (4.09%) and Japan (3.47%) – OECD (2016).

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[2] Excludes intercompany loans.

The challenge to increase the technological efforts of Brazilian industry involves the attraction of international capital. Although foreign companies represent only a small number of the total of industrial firms, their R&D spending is usually higher (Arbache, Goldstein & Marques, 2011; Costa, 2005; Queiroz, 2011). Figure 1 evidences such argument by presenting the average R&D and innovative activities expenditures of firms by origin of controlling capital, according to the 2011 edition of the Industrial Innovation Survey (PINTEC - IBGE, 2013). Although firms owned by nationals represent the great majority of the survey sample, it is clear that their innovation outlays are substantially smaller than those of firms controlled by foreign capital. For this reason, the identification of local factors that can attract foreign innovation funds is of great importance, along with the discussion of the role of public policies.

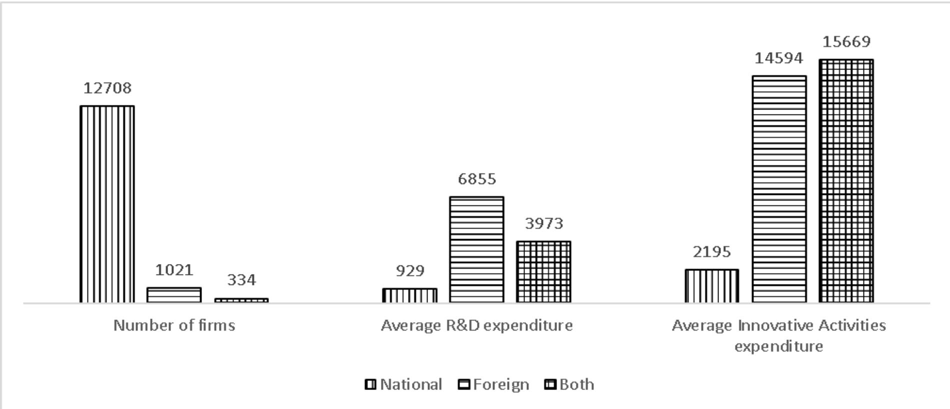

Figure 1. Number of firms, and average R&D and innovative activities expenditure by origin of controlling capital. Brazilian R$ 1,000.00. Source: IBGE (2013, confidential microdata).

Costa (2005) identified three stages of the development of innovation activities by international groups in Brazil. From the 1950s until the end of the 1980s, the country passed through the import substitution period. At this phase, nearly all technology was imported, and residual development was carried out for adaptive purposes only. From the 1990s, the increase in FDI and international competition brought new investment that led to technological upgrading and efficiency gains. However, it was only in the late 1990s that MNEs started to include Brazilian facilities and affiliates in their global R&D strategies.

As is the case in almost every developing country, Brazil attracts a small fraction of the total of international resources for R&D that leave MNEs` headquarters. In the case of U.S. MNEs, Brazilian affiliates receive an annual share of less than 4% of total R&D offshoring, as depicted in Figure 2. The time series is also informative in the sense that the situation has improved in the last decade. Following the FDI trend discussed previously, the share of U.S. R&D offshored to Brazil has risen from around 1% to more than 2.5%, reaching a top value of 3.5% in 2010. While total international R&D by U.S. groups grew on average around 5% during this period, investment directed to Brazil doubled that rate. Narrowing the focus to the manufacturing sector, investment in Brazil grew by more than 9%, bringing the share of funds to 3.3% of the total.

Ruiz (2015) reported that a great part of R&D directed to Brazil refers to transportation equipment, or more specifically, to flex-fuel technologies. Arruda, Barcellos and Tumelero (2014) identified ‘current or potential’ sectors in which the country has knowledge advantages that may attract foreign capital - agribusiness, information technology, energy, nanotechnology, biotechnology, chemicals, aeronautics, aerospace and defense.

With respect to the investing countries, Ruiz (2015) used patent data and concluded that, during 1980-2010, the major firms were from the U.S., Germany, Switzerland, Netherlands, France and Italy. This scenario is confirmed by the data displayed in Table 1, that details the location of foreign controlling capital reported by Brazilian firms in 2011 for the PINTEC survey (IBGE, 2013). Firms controlled by U.S. and European capital represent the great majority of the reporting firms, and they also account for the greatest part of expenditures in R&D and innovative activities.

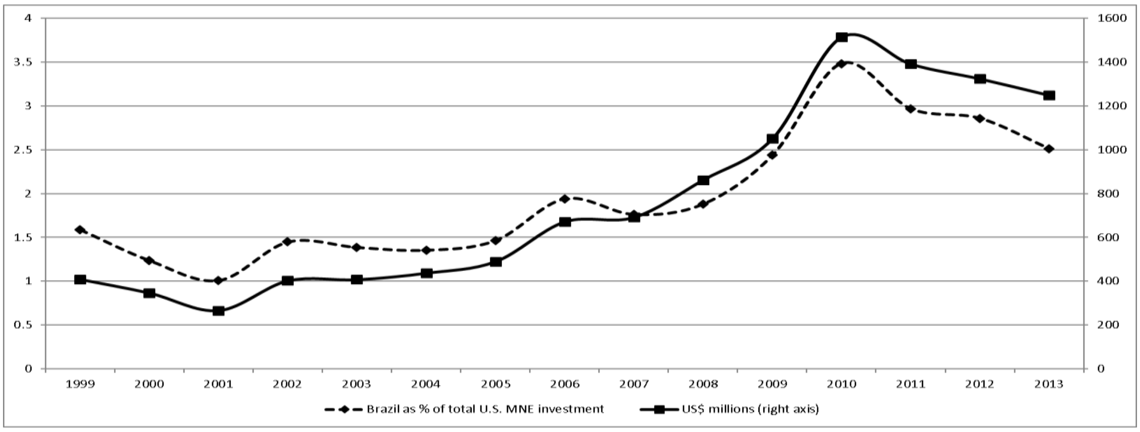

Figure 2. Total amount and share of R&D invested by U.S. MNEs in Brazil. Real 2014 values readjusted according to the CPI index. Source: U.S. B.E.A. (n.d.).

Table 1

Number of firms and total spending on R&D and innovative activities in 2011, by location of foreign controlling capital

Location of foreign controlling capital	Number of firms	Total spending (U.S. dollars)	
		R&D	Innovative Activities
Mercosur (other than Brazil)	60	61,694	118,390
U.S.	333	1,557,604	3,960,398
Canada and Mexico	38	191,609	468,626
Other American countries	36	25,677	47,662
Asia	133	228,485	919,769
Europe	740	2,372,774	5,206,816
Oceania or Africa	15	533	4,938

Not included firms controlled exclusively by Brazilian capital. Values in Brazilian *reais* converted to U.S. dollars according to the exchange rate applicable on Dec. 31st, 2011.
Source: IBGE (2013, confidential microdata).

The data presented in this section suggests that, in spite of being an important market for foreign firms, Brazil does not attract technology-intensive investment. This is in accordance with the conclusions of the literature for developing countries, as discussed in section 2.2. Nonetheless, attractiveness for innovation activities has increased and gained momentum, following a more general trend of FDI inflow.

3.2 Factors of attraction of international R&D.

To better understand the described scenario, the main drivers or factors of attraction of R&D investment in Brazil should be considered, including the challenges or barriers for further expansion. As an emerging economy with a non-developed innovation system, Brazil should attract more adaptive and support focused R&D, which makes market size and potential growth the most important assets to sustain and increase investment levels, leaving a secondary role for technological capabilities and other supply-side factors. Costa (2005) stressed the importance of market size, although she also identifies the relevance of investment trajectories, as companies with long-term local presence have more easily transitioned their technological developments up to the global strategic R&D level.

In the case of U.S. MNEs, the available data makes a compelling case for demand-pull factors, as affiliates sales and R&D expenditure are a case of almost perfect collinearity (0.96) for the 1999-2013 period (although the high correlation is not specific to the Brazilian case. The number is very similar - 0.98 - if all affiliates out of the U.S are considered). The R&D intensity of Brazilian affiliates grew slightly in the period (from 0.51% to 0.59%), but it is still smaller than the total for the entire group of host countries (0.81). This reinforces the previous argument that Brazil is receiving more resources but it still lags behind as an attractive location for international innovation (U.S. B.E.A., n.d.).

Relevant empirical literature that tried to track and measure attraction factors for international R&D in the country mainly comprised surveys of local affiliates' staff. Most of the studies found results consistent with the theoretical literature and the innovation investment scenario discussed previously, emphasizing the relevance of market size, minimum availability of research personnel and science and technology institutions. In a 2007 survey with 48 affiliates of foreign groups, respondents identified good opportunities to invest in R&D in Brazil. Although attraction factors were not ranked, the most relevant ones were: perspective of market growth, competitive costs and presence of high quality professionals, universities and research centers (Engenhar, 2007).

A similar study (described in Queiroz, 2011) also concluded that market size and workforce were the main factors attracting R&D projects to the country. The quality and educational level of human resources were described as adequate, but shortage of professionals was shown to be a factor hindering further investment.

The predominance of demand-side factors was better evidenced in Arbache et al. (2011). In a survey with more than 70 companies, the growth of both local and regional markets was ranked as the primary motivator for implementing R&D in Brazil. The presence of a qualified pool of researchers was also mentioned as an advantage, although its limited size was considered a challenge. The research also found out that for the majority of the affiliates (83%) R&D strictly followed headquarters` agenda, and that independent high-order R&D was conducted by less than half of the affiliates.

Similar results were found by Arruda et al. (2014). According to the study, a great number of multinationals that developed R&D in Brazil still focused on adaptation and product support. Such affiliates had to present a strong case to convince their parent companies to transfer substantial research to their facilities because of high costs and the bureaucratic requirements they faced. The study confirmed that the national and Latin American markets were usually the main factors of attraction, but other features such as geography and specific technological clusters were also important.

Finally, Galina, Camillo and Consoni (2011) presented conclusions that differed from the previous studies and the international literature. They surveyed 54 MNEs and found that, as the complexity of technological activities increased, the market size and demand-side factors actually gained importance, while qualified workforce, infrastructure and local science and technology systems became less relevant.

The above-mentioned studies converge in terms of challenges and negative features that hinder investment. High costs, taxes and excessive bureaucracy are relevant aspects taken into consideration by MNEs, affecting the competitiveness of the economy (Arruda et al., 2014; Galina et al., 2011, and Arbache et al., 2011). These studies also agree that the insufficient number of scientists, engineers and qualified personnel for conducting high level R&D still remains the most relevant restriction for increasing the complexity of innovation projects and introducing local laboratories and facilities into the global strategic innovation plans of these multinational groups.

3.3 Innovation tax policy and attraction of international R&D.

In the last decades, the debate on appropriate policies to foster entrepreneurial innovation has regained strength in Brazil. The challenge of creating a business environment that encourages R&D without protectionism but enhancing firms' international competitiveness has been the subject of great discussion among scholars and policy-makers. Evidences of this paradigm shift are the three major industrial policy plans issued by the federal government, along with a National Strategy for Science, Technology and Innovation in 2012 (MCTI, 2012).

In this new policy context, tax incentives are one of the strategies that have gained momentum. In 2005 the federal government enacted Law 11,196/05 (also known as "*Law of Goodness"*), which consolidated and expanded tax incentives to companies willing to invest in scientific and technological development. The objective was to reduce the cost of performing R&D activities within national territory, thus encouraging firms to increase their expenditure in innovation and generating knowledge spillovers and positive externalities. The structure of the benefits was similar to the practice in other countries, deducting expenditure from taxable income or reducing tax rates that are levied on R&D inputs and outputs.

The main objective of the policy was to reduce the tax cost of performing R&D in the country. Araujo (2010) estimated the magnitude of such change through the '*b-index*', used by OECD to measure the fiscal burden on innovation. Such estimate suggests that the policy approved in 2005 reduced the tax burden of R&D in Brazil, and that such benefits are consistently higher than the average of OECD, although it is similar to or even lower than some of its economies, such as Spain, France and Canada (Warda, 2013).

The law does not establish any requirement for capital ownership, and therefore does not distinguish between locally-owned companies and affiliates of multinational groups. Table 2 below presents the total number and percentage of potentially innovative firms present in the 2011 PINTEC survey (IBGE, 2013), indicating how many participated in the policy and dividing them by capital origin. Although local firms represent the majority of the sample, the percentage of those that obtained tax benefits is substantially lower than in the foreign-owned group.

Table 2

Distribution of potentially innovative companies in the PINTEC survey, according to origin of controlling capital and participation in the tax policy in 2011

Did the firm benefit from tax incentives in 2011	No. of firms - Controlling Capital Origin	
	Local	Foreign
Yes	322 (2.53%)	166 (16.26%)
No	12,386 (97.47%)	855 (83.74%)

Percentage of firms by participation in the policy in parentheses. Firms with both national and foreign controlling capital represented a very small share and were excluded. Source: IBGE (2013, confidential microdata).

These numbers suggest firms with international capital may be in a better position to benefit from the incentives provided by the Brazilian tax policy. They do not mean, however, that such companies or additional innovation funds were necessarily attracted to the country by the incentives. Galina, Camillo and Consoni (2011) reported that innovation policies did not rank as a primary factor for R&D attraction in their survey. Queiroz (2011) also concluded that such incentives are of secondary importance, and argued that, as more countries approve similar measures, they lose relevance as a decisive factor for new projects or funds. In Arbache et al. (2011), fiscal incentives again received low frequency of responses when MNEs were questioned about their motivation to perform R&D in Brazil.

The survey by Arruda et al. (2014) specifically referred to the incentives of Law 11,196/05. They reported that, from the MNEs` perspective, the tax policy is a positive and attractive feature of the local innovation system. However, the excessive bureaucracy and accounting requirements, along with the legal uncertainty (firms do not know beforehand whether the reported expenditure will be accepted by the authorities), reduces positive impacts.

The discussion presented along this section gives inconclusive results on the relevance of tax policy for attraction of funds for business technology. The country certainly improved its participation in the international map of innovation, as evidenced by the increasing share of resources directed to it. Qualitative evidence provided by the reviewed literature, however, suggests that Brazil still has problems in attracting R&D above the adaptive level. It is difficult to assess whether the observed increase in R&D inflow is an exclusive result of market factors, following the trend of FDI increase in the last two decades, or if policies designed to boost innovation expenditure are also a relevant explanatory factor. No quantitative studies that tried to test the impact of such policies in this type of investment were found. The empirical study described in the next section is a first attempt to fill this gap.

4 Empirical Analysis

This section presents the research to assess whether the Brazilian tax policy has had a measurable impact on the flow of international R&D investment directed to the country. Due to data availability, investigation is limited to whether the Brazilian policy was a relevant factor in attracting investment from other locations in a ‘beggar-thy-neighbor’ scheme, thus contributing to the entrance of ‘footloose R&D’ in the country.

Unlike other econometric studies discussed in section 2.3, the objective is not to test the relevance of tax policies in general, but only the one implemented in Brazil. The main motivations for this choice of research are the intrinsic features of tax incentives and the nature of their expected impacts. Part of the controversy and absence of consensus in the literature (section 2.3) can be explained by particularities of the different institutional frameworks and economic incentives of stakeholders present in each economic system. From this, one can expect that it would be difficult for such incentives to have a uniform impact in all cases. Country specific studies (such as this one) are then necessary to assess the effects of national policies, even if their conclusions cannot be generalized to other situations.

4.1 The data.

For this analysis, a group of different datasets on several countries were merged. They refer to (a) tax costs and incentives to R&D in different countries; (b) activities and innovation investment of U.S. MNEs` international affiliates, (c) priority patent applications from different patent offices worldwide, including the country of origin of their respective applicants and inventors; and (d) specific features of each nation, including market, institutional, and science and technology systems. The data were arranged in an unbalanced panel format, covering the period from 1999 to 2013. As the interest lies on the effects of Brazilian policy in other countries, data for Brazil were excluded from all regressions.

As a measure of tax costs and generosity of incentives, the '*1-(b-index)'* is used herein. This indicator is a transformed version of the '*b-index'* (Warda, 2001)[3] used in OECD studies, and it constitutes a more direct measure of tax generosity or "implied subsidy rate" (OECD, 2013). Index values used in this analysis were estimated by Warda (2013), Stewart, Warda and Atkinson (2012), OECD (2014),[4] and, for the Brazilian case, Araujo (2010).[5]

However, it is important to consider that if firms respond to tax benefits, they do so comparatively. Or, as suggested by Wilson (2009), both in-country and out-of-country tax costs are relevant. Therefore, a correct model specification should take into account not only Brazilian incentives, but the difference between the index for Brazil and for each other country is used as the variable of interest (variable '*tax_inc'*)[6].

In the case of U.S. MNEs, the study is limited to manufacturing groups with affiliates operating out of the U.S. and positive R&D expenditure abroad. The following data were extracted from the U.S. Bureau of Economic Analysis (B.E.A.) database on Activities of U.S. Affiliates of Foreign Multinational Enterprises (U.S. B.E.A., n.d.): R&D expenditure by manufacturing affiliates in each country per year, in million U.S. dollars, log-linearized (variable '$r\&d^{MNE}$'); total value of sales of the respective affiliates in each country per year, in million U.S. dollars, log-linearized (variable '*sales*'); and export rate of affiliates, or the percentage of total sales to elsewhere other than the host country (variable '*exp*').

Data on priority patent applications[7] were extracted from the European Patent Office Statistical Database (E.P.O., 2015). Following the approach developed and described in Thomson (2013) and de Rassenfosse et al. (2013), the information from the country of residence of applicants and inventors is used to obtain a proxy for R&D performed or contracted abroad[8]. Based on these guidelines, fractional patent

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[3] "The b-index is a measure of the level of pre-tax profit a "representative" company needs to generate to break even on a marginal, unitary outlay on R&D" (OECD, 2013a, p.1).

[4] Missing data was extrapolated linearly for short intervals with no significant change in the index.

[5] Contrary to the author's estimates, I only reflected the changes of Law 11,196/05 in 2006, the first year in which firms could benefit from the incentives.

[6] This specification is appropriate for it captures the relevance of the Brazilian policy controlling for the tax generosity adopted by each country, and it can be used in a panel dataset analysis along with fixed effects and time dummies as covariates.

[7] A priority application is the first filing aimed at protecting a particular patent. Pursuant to Article 4 of the Paris Convention for the Protection of Industrial Property, once an application has been submitted to any national patent office worldwide, the applicant has 12 months to apply for protection in any other country which is part of the convention, claiming priority over any applications filed after the original submission. De Rassenfosse et al. (2013) maintained that priority applications are a valid and important indicator of innovation because they eliminate the geographic bias and are the closest measure to the date of the invention.

[8] The basic idea of the indicator is to consider the applicant as the owner of the intellectual property and funding party of the innovation project. The inventor, on the other hand, is assumed to be the party that effectively carried out the research project, with resources provided by the applicant. Therefore, if the applicant is resident in one country and the inventor in another, it is assumed that the former has transferred resources and implementation of the project to the latter, regardless of whether a corporate or contract structure was used. As patent applications may have more than one applicant or inventor from different

application data were extracted and grouped according to the country of origin of applicants and inventors.[9] The cases where these two coincide represent around 90% of the sample for the year 2013; they were excluded, as this investigation focus exclusively on offshored R&D. Moreover, only patent applications were retrieved, excluding utility models and new designs. For the purposes of this analysis, only data for the 100 countries with the highest number of priority applications in 2013 were considered. As Brazil mainly receives innovation investment from a limited group of nations, origin of applicants was limited to six countries (U.S., Germany, China, France, United Kingdom and Netherlands) responsible for 80% to 90% of the yearly innovation investment directed to Brazil. Finally, patent application count was grouped by receiving country and log-linearized, thus reaching a proxy for global innovation offshoring (variable '*pat*').

Data on specific features of invested countries were gathered from different sources with the objective of controlling for factors that, according to the reviewed literature, may influence the decision of MNEs to invest in innovation there. These may be divided into three main groups. The first refers to data on the institutional and policy framework: the "legal system and property rights" index[10] of the Economic Freedom of the World annual reports (Gwartney, Lawson and Hall, 2015), that provides an indicator of the level of institutional development of each country (variable '*pr*'). The second group of country specific variables refers to the economic activity level or size of the economy: gross domestic product (GDP), in million U.S. dollars, log-linearized (nominal value - World Bank, n.d.; variable '*gdp*'); level of human capital, considered as number of researchers per 1,000 people in the work force (OECD, 2016; variable '*hc*'); and level of industrialization of the economy, measured as the industrial sector`s added value as a share of GDP (World Bank, n.d.; variable '*ind*'). Indicators on the technological development or innovation system of host nations are also considered: total R&D expenditure as a share of GDP per country (World Bank, n.d.; OECD, 2016; variable '$r\&d^c$'); exports of high technology goods as a share of the country`s GDP (World Bank, n.d.; variable '*ht_exp*'); and stock of patents filed by residents in each local patent office, log-linearized (WIPO, n.d.; '*patstock*')[11].

Descriptive statistics for all variables described in this section are presented in Table 3.

Table 3

Descriptive statistics of variables used in the empirical analysis

Variable	Obs	groups	T-bar[a]	Mean	Std. Dev.			Min	Max
					Overall	Between	within		
$r\&d^{MNE}$	643	50	12.86	4.28	2.56	2.38	0.69	-0.92	8.88
pat	749	50	14.98	4.96	2.04	2.01	0.47	0.00	8.73
$1\text{-}(b\text{-}index)_{it}$	418	37	11.3	0.15	0.12	0.11	0.06	-0.23	0.32
gdp	750	50	15	12.67	1.27	1.21	0.42	9.35	16.07
sales	750	50	15	9.39	1.63	1.56	0.51	4.6	12.55
exp	613	50	12.26	41.41	21.12	21.4	6.25	0.00	92.55
pr	739	50	14.78	6.62	1.66	1.61	0.42	1.88	9.62
hc	543	47	11.55	5.28	3.84	4.14	0.97	0.09	17.94
ind	716	49	14.61	31.75	9.57	9.42	2.34	6.97	66.76
$r\&d^c$	574	49	11.71	1.49	1.06	1.06	0.2	0.04	4.52
ht_exp	745	50	14.9	5.42	10.99	10.56	3.28	.00	84.4
patstock	750	50	15	9.4	2.42	2.39	0.49	3.06	14.97

[a] average number of years under observation.

countries, a "fractional counting methodology" (de Rassenfosse et al., 2013) is used, meaning each applicant is assigned with an equal share of each patent filing, and the same procedure is applied for inventors.

[9] MySQL Code used available upon request to the author.

[10] This index is comprised of the following items: judicial independence, impartial courts, protection of property rights, military interference in rule of law and politics, integrity of the legal system, legal enforcement of contracts, regulatory restrictions on the sale of real property, reliability of police and business costs of crime (Gwartney et al., 2015).

[11] This indicator is the result of the sum of all patent files deposited in each country by residents since 1980 up to each year in the dataset, with a depreciation rate of 15%.

4.2 Estimation strategy.

To assess the correlation of the Brazilian policy with R&D investments in other countries, two groups of estimates are presented herein. The first empirical analysis uses aggregate data from U.S. MNEs. It is assumed that parent companies, at the beginning of each period, analyze the sales performance of each international affiliate on the last period ($sales_{i,t-1}$), along with a series of economic, institutional and technological indicators of each country ($c_{i,t-1}$). Based on such analysis, they decide how much to invest in each international affiliate ($r\&d^{MNE}_{it}$).

They also study and compare tax incentives for locally performed R&D granted by each government in different locations, including the Brazilian tax policy in place each year. It is further assumed that companies know the rate of incentives applicable in each country when they make their decision, as such benefits are in general approved or announced by the government before companies can apply or benefit from them. For this reason, this variable is considered at the same time period as the dependent variable. This leads to the static investment equation (1), which captures the described process. All variables are described in section 4.1. (f_i) accounts for countries` fixed effects, (f_t) are time dummies that capture the possible influence of year effects, and (v_{it}) is the error term. All control variables (c_{it}) are included in the equation with one lagged period.

$$r\&d_{it}^{MNE} = \beta_0 + \beta_1[tax\_inc\,]_{it} + c_{i,t-1} + f_i + f_t + v_{it} \quad ;$$

$$c_{it} = \beta_2 sales_{it} + \beta_3 exp_{it} + \beta_4 pr_{it} + \beta_5 hc_{it} + \beta_6 ind_{it} + \beta_7 r\&\mathrm{d}_{it}^{C} + \beta_8 patstock_{it}. \qquad (1)$$

Wilson (2009) suggested adjustment costs may play a pivotal role in the definition of investments directed to each affiliate. This means parent companies take into consideration the value invested in previous years, in order to avoid discontinuing ongoing projects or in light of multi-year planning. To test such argument, a dynamic version of the above model is estimated, including the lagged value of the dependent variable as one of the controls.

$$r\&d_{it}^{MNE} = \beta_0 + \beta_1[tax\_inc\,]_{it} + c_{i,t-1} + \beta_9 r\&d_{i,t-1}^{MNE} + f_i + f_t + v_{it}. \qquad (2)$$

The second empirical analysis uses the fractional patent application indicator described above. The investment model is similar to the one represented by equations (1) and (2) above, with three necessary changes. First, the market size is measured by GDP level of each country per year, as there is no data on the value of sales of these companies' affiliates in each country, (data for U.S. MNEs reveal such variables are highly correlated). Similarly, data on export orientation is replaced by exports of high technology goods as a share of the country`s GDP (*ht_exp*). This should provide a measure of the export orientation of high technology industrial sectors of each nation.

Finally, the investment equation must take into account that patent filings are outputs of the innovation process, and not inputs as is the case in R&D expenditure. To deal with such feature, at time (*t-1)*, parent firms observe tax incentives for innovation in place in different countries, as well as last period (*t-2*) variables for potential demand (market size and export orientation), supply factors (human capital, knowledge stock, industry share of GDP and total country R&D expenditure) and institutional features (protection of property rights). Making the investment decision in (*t-1*), innovation projects take on average one period to mature and result in a priority patent filing. Therefore, the dependent variable should be considered in period (*t*).

This proposal is represented in equations (3) and (4) below for the static and dynamic models, respectively.

$$pat_{it} = \beta_0 + \beta_1[tax\_inc\,]_{i,t-1} + c_{i,t-2} + f_i + f_t + v_{it} \quad ;$$

$$c_{it} = \beta_2 GDP_{it} + \beta_3 ht\_exp_{it} + \beta_4 pr_{it} + \beta_5 hc_{it} + \beta_6 ind_{it} + \beta_7 r\&d_{it}^{C} + \beta_8 patstock_{it}. \qquad (3)$$

$$pat_{it} = \beta_0 + \beta_1[tax\_inc\,]_{i,t-1} + c_{i,t-2} + \beta_{10}pat_{i,t-1} + f_i + f_t + v_{it}. \quad (4)$$

Coefficients of the equations are estimated using a number of panel data parametric models. The existence of fixed effects is assessed through the Hausman test, and upon confirmation, fixed effects estimator is applied. For comparison purposes, results of the random effects model (Wooldridge, 2002) are also depicted. For the dynamic specifications, three classes of estimators are used: (a) the fixed effects; (b) Arelano-Bond difference-GMM (Arelano & Bond, 1991); and (c) bias-corrected least squares dummy variables estimator (LSDVC) (Bruno, 2005; Bun & Kiviet, 2003).[12]

4.3 Presentation of results.

Table 4 presents the estimated coefficients and other results for the U.S. MNEs' investment model, both for static and dynamic versions. The Hausman test suggests the presence of fixed effects, confirming the relevance of the country's time invariant features for investment decisions, and rendering the random effects estimator inconsistent.

Table 4

Results of the main U.S. MNE model. Dependent Variable: $r\&d_{it}^{MNE}$

Variables	Estimator				
	Random Effects	Fixed Effects	Fixed Effects	Arelano-Bond	LSDVC
$r\&d_{i,t-1}^{MNE}$			0.345***	0.484***	0.417***
			(0.095)	(0.143)	(0.117)
$1\text{-}(b\text{-}index)_{it}$	-0.524	-0.912	-1.137	-1.427	-1.084
	(0.462)	(0.592)	(0.694)	(0.926)	(1.222)
$sales_{i,t-1}$	1.048***	0.860***	0.576***	0.411***	0.542**
	(0.055)	(0.196)	(0.117)	(0.139)	(0.270)
$pr_{i,t-1}$	0.054	0.049	0.046	0.034	0.036
	(0.059)	(0.080)	(0.057)	(0.066)	(0.139)
$ind_{i,t-1}$	-0.010	0.028	0.050***	0.049**	0.048
	(0.011)	(0.017)	(0.013)	(0.018)	(0.062)
$patstock_{i,t-1}$	0.058	0.081	0.007	-0.046	-0.004
	(0.076)	(0.276)	(0.207)	(0.233)	(0.487)
$hc_{i,t-1}$	-0.031	0.037	0.041	0.029	0.038
	(0.045)	(0.057)	(0.055)	(0.067)	(0.090)
$r\&d^{c}_{i,t-1}$	0.734***	0.328	0.223	0.229	0.194
	(0.145)	(0.267)	(0.203)	(0.233)	(0.436)
$exp_{i,t-1}$	-0.001	0.004	-0.003	-0.003	-0.003
	(0.003)	(0.007)	(0.005)	(0.006)	(0.009)
Observations	241	241	218	218	218
R-squared	0.93	0.653	0.750		
Number of id	31	31	31	31	31
Country FE	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Hausman Test	$X^2 = 50.23$; $P> X^2 = 0.0002$				

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

The variable for the level of sales of the respective affiliate presents the strongest and most consistent result in all models. Estimation results suggest the elasticity of R&D investment to sales ranges

[12] Judson and Owen (1999) suggested LSDVC is more appropriate for unbalanced panels with small group numbers as in this case, outperforming other estimators as system GMM.

from 0.41 to 0.86, and the coefficient is significant at a 95% confidence level for all estimators. The lagged version of the dependent variable also influences the present outcome, and the positive coefficient is significant in all dynamic estimators applied.

The variable for Brazilian policy, on the other hand, did not reach a significant result in any of the estimations, suggesting the country incentives do not influence the decision of these enterprises on how much to invest in other countries. This result implies that the Brazilian policy is not successful in attracting 'footloose R&D', and the increase in the incentives rates does not divert resources from other destination options.

The majority of the other control variables presents a coefficient with the expected positive sign, but without statistical significance on the 95% confidence level.

Estimation results for the fractional patent application models are displayed in Table 5. In this case, the Hausman test did not confirm the presence of country fixed effects, so the random effects estimator can be considered consistent and efficient. The variable representing market size is again a chief explanatory factor. The GDP coefficient is positive and statistically significant in nearly all models at a 90% confidence level. The elasticity of innovation investment to GDP is estimated to range from 0.25 to 0.84.

Table 5

Results of the main fractional patent application model. Dependent Variable: pat_{it}

Variables	Estimator				
	Random Effects	Fixed Effects	Fixed Effects	Arelano-Bond	LSDVC
$pat_{i,t-1}$			0.583***	0.632***	0.687***
			(0.057)	(0.053)	(0.085)
$1\text{-}(b\text{-}index)_{i,t-1}$	0.180	0.143	0.204	0.126	0.195
	(0.183)	(0.164)	(0.165)	(0.238)	(0.215)
$gdp_{i,t-2}$	0.840***	0.819**	0.325*	0.290	0.251**
	(0.240)	(0.307)	(0.191)	(0.199)	(0.121)
$pr_{i,t-2}$	0.098	0.054	-0.020	-0.027	-0.029
	(0.063)	(0.059)	(0.043)	(0.044)	(0.036)
$ht\_exp_{i,t-2}$	0.004	-0.001	-0.003	-0.003	-0.003
	(0.005)	(0.007)	(0.003)	(0.003)	(0.005)
$ind_{i,t-2}$	0.006	0.017	0.007	0.006	0.007
	(0.012)	(0.019)	(0.010)	(0.012)	(0.010)
$rd\_gdp_{i,t-2}$	0.075	0.062	0.059	0.080	0.033
	(0.115)	(0.121)	(0.078)	(0.084)	(0.116)
$patstock_{i,t-2}$	0.131	-0.009	-0.042	-0.056	-0.024
	(0.191)	(0.299)	(0.131)	(0.128)	(0.093)
$hc_{i,t-2}$	0.032	0.044	0.017	0.007	0.015
	(0.027)	(0.027)	(0.017)	(0.016)	(0.032)
Observations	296	296	296	296	296
R-squared	0.7945	0.338	0.561		
Number of id	33	33	33	33	33
Country FE	Yes	Yes	Yes	Yes	Yes
Year dummy	Yes	Yes	Yes	Yes	Yes
Hausman Test	$X^2 = 24.83$; $P > X^2 = 0.0983$				

Standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Coefficient of the constant variable not presented.

The lagged version of the dependent variable is also positive and statistically significant in all models, confirming the influence of past decisions in the definition of current values.

Brazilian tax incentives again do not seem to be a relevant factor, as the respective variable did not achieve significance in any of the models. Other variables do not achieve statistical significance in most of the regressions, which seems to confirm the results of the previous model.

4.4 Robustness checks.

Two alternative versions of the main models are estimated to test robustness of the results[13]. The LSDVC dynamic models are estimated multiple times, gradually excluding each of the control variables, to check if results are sensitive to the models' specifications. Secondly, it may be the case that only a part of alternative host countries may be affected by the Brazilian tax policy. In particular, nations with a low volume of funds are less likely to perceive any impact since they probably are not strong competitors for 'footloose R&D' funds. Therefore, the main models are estimated taking resources directed to Brazil as a lower limit on the countries to be included in the regressions.

Confirming the main model's findings, in none of these cases is the coefficient related to the Brazilian policy or investments received by the country a statistically significant explanatory variable of the innovation resources directed by MNEs to other nations. Robustness checks also follow the main model's results in showing the relevance of market size and past investment, as coefficients of sales levels. GDP and lagged dependent variables are positive and have statistical significance in almost all tested specifications.

5 Discussion of the results and policy implications

Based on the quantitative study described in this section, the answer to the initial question is negative, i.e., no evidence was found suggesting that tax incentives established by the Brazilian government has attracted international 'footloose R&D' from alternative host countries. Results indicate that the Brazilian tax policy has no significant correlation with investments directed to other countries, thus leaving no empirical basis to maintain that MNEs took funds from alternative destinations to invest in innovation in Brazil because of the beneficial fiscal treatment. The fact that regressions using two distinct indicators of R&D investment (along with a group of robustness checks) point to the same direction substantially strengthen such conclusion.

Data discussed in section 2 indicate that cross-border innovation has been on the rise in the last decades as multinational groups have been internationalizing a greater part of their R&D activities. Additionally, the Brazilian market became more attractive and has gained importance in the international economy during this period. It is more likely that the increase in foreign innovation funds directed to Brazil is explained by these general trends rather than by corporate tax planning.

These findings provide interesting insights in light of the literature discussed throughout this paper; they are in accordance with the findings of surveys of Brazilian MNEs` affiliates that indicate tax incentives are not really of primary importance in attracting resources for R&D from parent companies (Galina et al., 2011; Queiroz, 2011; Arbache et al., 2011; Arruda et al., 2014). This is an important result as this is the first quantitative confirmation of such hypothesis.

Focusing on the economic literature on impact of innovation tax policies, this study does not provide support to the argument that these incentives work as 'beggar-thy-neighbor' schemes. It should be stressed that these results are case specific and not applicable to all countries. Loss of generality, however, is the cost to consider the conclusions fairly robust for the Brazilian case.

The positive signs and statistical significance of the coefficients of variables representing demand-side factors (total sales or GDP levels) of the host countries are also noteworthy. They confirm previous results that the majority of R&D is mainly attracted by the market potential. The consulted literature on internationalization of R&D takes these features as typical of adaptive or "market seeking" R&D (OECD, 2011; UNCTAD, 2005b; Dunning, 1994). This is still the dominant type of innovation transferred by multinational groups to affiliates or contractors in other countries. It is largely driven by market proximity, and its purpose is mainly production support and adaptation to local conditions, consumers' preferences or existing regulations.

Results of the dynamic models suggest that there are indeed considerable adjustment costs in international R&D funds, as suggested by Wilson (2009). Firms do not seem inclined to make radical changes in their investment policies in each country, smoothing such path to avoid discontinuances. It may

[13] Robustness checks results available upon request to the author.

also be the case that firms make multi-year plans to take advantage of economies of scale in research or which are necessary for the maturing of new technologies.

The main point of the study is that, in the case of Brazil, fiscal benefits do not seem to be the most appropriate policy tool for attracting 'footloose R&D' or for competing at the international level for innovation funds that are not specific to supporting local activities. This study provides solid grounds for maintaining that, up to this point, the reduction of tax costs was not a driver to pull investment from other sources towards facilities and affiliates in the country.

The literature suggests that, in the case of more central or technology-complex R&D, supply-side factors play a more relevant role than the availability of a highly qualified workforce, research infrastructure or technology clusters. Policies aiming to foster investment in these areas seem to be a more promising choice for making the country more attractive for this type of R&D. Such a conclusion is in accordance with previously mentioned surveys (Arruda et al., 2014; Galina et al., 2011, and Arbache et al., 2011) and the available data on the poor quality of the country's human capital, especially the pool of workforce specialized in engineering related areas (WEF, 2015).

The adaptive orientation of R&D performed in the country, as discussed in section 3.1, also suggests that measures to boost the local market seem to be the most straight-forward way to bring more innovation funds to local affiliates, although they may not change its main objective or nature. The positive and significant coefficients for sales levels and market size provide empirical support for this conclusion.

The fact that the fiscal policy did not attract "footloose" R&D does not mean that it is meaningless or without impact. As mentioned, recent studies for the Brazilian policy (following the conclusions of international research) identified the positive impact of these incentives, increasing the amount of R&D investment, although with different levels of elasticities (Shimada, Kannebley Jr. & De Negri, 2014; and Kannebley Jr. & Porto, 2012).

The results are also relevant from an international cooperation perspective. They suggest the worries expressed by the OECD (2013, 2014) that international competition should lead to a zero-sum game and overall reduction of revenues may be unfounded for the Brazilian case. This study is more aligned with the branch of literature that emphasizes macroeconomic and market size variables as attraction factors for international R&D (Thomson, 2009; Athukorala & Kohpaiboon, 2006). I conclude that claims for coordination rules at the international level (OECD, 2013) should be considered carefully, as they may inefficiently hinder countries in adopting tax incentives that increase their international R&D levels with no negative impact on the flow to other economies.

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