Internal Barriers to Innovation and University-Industry Cooperation among Technology-based SMEs in Brazil

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Abstract

This paper associates internal barriers to innovation and the propensity of technology-based SMEs to cooperate with universities and research institutes (URIs) in Brazil. We analyse empirically three types of internal company barriers - financial, knowledge, and organisational. The data source is the latest edition of the Brazilian Innovation Survey (PINTEC 2014). We analyse the full sample of companies as well as the subsamples of high-tech manufacturing companies and knowledge-intensive business sectors (KIBS). Financial obstacles are shown to be strongly related to the propensity of KIBS to collaborate with URIs. Knowledge obstacles are related to the propensity of high-tech manufacturing SMEs to collaborate with URIs. No association is found for organisational obstacles. While URIs have other very important roles in the techno-economic system, their perceived contribution to alleviating internal innovation barriers (especially organisational barriers) for technology-based SMEs in an emerging economy may be less prominent than policy decision-makers may expect.
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Keywords: technology-based SMEs; university-industry cooperation; internal barriers; innovation survey; Brazil
1. Introduction

More than ever before, the dictum ‘no firm is an island’ (Tidd, Bessant, and Pavitt, 2005) rings true nowadays in the innovation realm. Openness and cooperation for innovation have quickly become imperative for many businesses across high-tech sectors. While this is not an entirely new phenomenon, (Vonortas, 1997; Avellar and Kupfer, 2011), it has certainly intensified more recently as transactions and interactions became easier and more widespread due to the diffusion of information and communication technologies, the growing cost and complexity of innovation activities, and the advancement of globalization and liberal political reforms worldwide, among others (Powell and Grodal, 2005).

In this context, various countries have developed strong interest in supporting cooperation mechanisms to enhance the innovative performance of firms. If until the end of the century the vast majority of firms involved in cooperation agreements were from developed countries (Hagedoorn, 2002; Vonortas and Zirulia, 2015), this is rapidly changing. Developing countries and emerging economies have particularly been promoting university-industry cooperation (Freitas, Marques, and Silva, 2013; Albuquerque et al., 2015; Moraes Silva, Furtado, and Vonortas, 2017).

Linking the knowledge generated in universities and the flow of well-trained graduates to the productive structure of the economy is understood as a prerequisite for technological and economic development (Mowery and Sampat, 2005; Freitas, Marques, and Silva, 2013). University-industry interaction has also been seen as a good channel for the creation of technology-based small and medium-sized enterprises (SMEs) which rely heavily on external sources to innovate (Tidd, Bessant, and Pavitt, 2005; Caetano and Amaral, 2011; Protogerou, Caloghirou, and Vonortas, 2017).

Our study addresses the association of internal barriers to innovation as perceived by technology-based SMEs with the propensity of these firms to cooperate with universities and
research institutes (URIs) in Brazil. Innovation requires overcoming obstacles inherent to change and can expose company difficulties with handling internal and external factors (Madrid-Guijarro, Garcia, and Van Auken, 2009). As the main factors determining the success or failure of innovation activities within SMEs are the internal ones (Hoffman et al., 1998), we assess to which extent they seek the cooperative ventures with URIs in order to alleviate such constraints.

While the bulk of the extant literature has focused on the analysis of obstacles to university-industry cooperation (e.g., López-Martínez et al., 1994; Valentín, 2000; Hall, Link, and Scott, 2001; Bruneel, D’Este, and Salter, 2010), in this paper we study the role played by internal barriers to innovation on the propensity of technology-based SMEs to resort to university-industry partnerships, following the steps of more recent studies (e.g., Antonioli, Marzucchi, and Savona, 2017; Kanama and Nishikawa, 2017). Specifically, we examine the relationship between firm perception of internal barriers to innovation and the company’s engagement in cooperation with URIs (presumably to mitigate some of the effects).

The empirical investigation is based on recently released data (December 2016) from the latest edition of the Brazilian Innovation Survey (PINTEC 2014), carried out by the Brazilian Institute of Geography and Statistics (IBGE). We use PINTEC microdata which can be accessed onsite following an elaborate application process designed to ensure the anonymity of responding organisations.¹ We study the association between the engagement of technology-based SMEs in cooperative ventures with URIs and these firms’ perception of three groups of internal barriers to innovation: financial, knowledge and organisational barriers. We appraise this association for the full sample of technology-based SMEs in PINTEC and also separately

¹ Following international practice, IBGE only publishes aggregate data to guarantee the secrecy of firm strategic information. In order to use PINTEC’s microdata, the formal access procedure involves the submission of a formal request to access the data onsite. Therefore, we do not own the database employed herein, and cannot make it available.
for the subsamples of high-tech manufacturing companies and knowledge-intensive business services (KIBS).

Results show that financial and knowledge obstacles are associated with cooperation with URIs when considering the full sample of technology-based SMEs. In the subsample of high-tech manufacturing companies, knowledge obstacles appear statistically significant in explaining collaboration with URIs. In the subsample of KIBS, the financial obstacles appear strongly statistically significant in explaining collaboration with URIs. No statistically significant association was found for organisational obstacles.

The rest of the paper is organised as follows. Section 2 provides the theoretical background and research hypotheses, discussing the relationship between technology-based SMEs and external knowledge exploration, especially via university-industry cooperation, as an alternative to overcome internal barriers to innovation usually faced by these companies, such as those linked to finance, knowledge and organisational structure. Section 3 presents our research design and methodology; it also explains the data. Section 4 discusses the empirical results. Finally, Section 5 provides final remarks and policy implications.

2. Theoretical background and hypotheses

2.1 Small companies and innovations

Since the pioneering work by Schumpeter (1942), several authors within the Innovation Studies have built upon the importance of company size in the innovation development, which was later named the Schumpeterian Hypothesis.\(^2\) The reasoning is straightforward: the larger the company, the higher its internal resources and capacity to explore, on the one hand, economies

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\(^2\) Even though the hypothesis on the positive association between firm size and innovative performance has become widely known as the Schumpeterian Hypothesis, there is actually another hypothesis based on Schumpeter’s work that is considered under the same umbrella, which sustains a positive relationship between innovation and monopoly power (Kamien and Schwartz, 1982). Therefore, we can talk in terms of ‘Schumpeterian Hypotheses’, in plural, although one of them is clearly more acknowledged.
of scale in research (larger research departments interaction, better ability to exploit specialised equipment, deeper division of labour among researchers) and, on the other, economies of scope in research (name recognition to move easily into new markets, multiproduct approach to deal with diversity) (Kamien and Schwartz, 1982; Vonortas, 2009a).

However, after several decades of empirical study the validation of the Schumpeterian Hypothesis remains inconclusive, as the findings point out that, although research and development (R&D) activities increase monotonically with firm size, the number of innovations tends to increase less than proportionally while the share of R&D effort dedicated to more incremental and process innovation expands (Cohen, 2010). A new branch of the literature emerged in the 1990s to explain such inconsistencies proposing that smaller firms (small and medium-sized enterprises – SMEs) are more capable of innovating than their larger counterparts, especially when it comes to more radical innovations (Acs and Audretsch, 1990; Christensen, 1997; Baumol, 2002).

Within this new branch, the work by Christensen (1997) provided one of the most powerful explanations for this situation. It argued that leading, and usually large, companies fail when confronted with disruptive innovations precisely because they are good at working with their mainstream users and incumbent technologies, and then are not able to see the potential of new and typically small markets stemming from cutting-edge technologies. Conversely, smaller companies characteristically possess a range of advantages to tackle the issue of innovations, such as agility, flexibility, openness and fast decision-making (Hoffman et al., 1998).

Nevertheless, small firms differ widely. They account for more than 90% of the business companies in most economies, ranging from mom-and-pop shops to cleaning services to manufacturing firms to information technology and biotechnology start-ups. In this paper we are concerned with a very specific type of SME based on new technologies, which represents a
tiny subset of such companies. The companies we are concerned with are typically established by highly qualified personnel, require large amount of capital and are characterised by higher technical and market risk (Tidd, Bessant, and Pavitt, 2005).

The literature has called these companies ‘Technology-based SMEs’, which have attracted increasing attention over the last few years as scholars from advanced economies realised the capacity of these firms to reshape the technology and market landscapes (Haeussler, Patzelt, and Zahra, 2012), even though within less developed countries it has remained a somehow underrepresented topic of research (Pinho, Côrtes, and Fernandes, 2002; Fernandes, Côrtes, and Pinho, 2004; Moraes, Lima, and Lobosco, 2011). This paper intends to expand the knowledge about technology-based SMEs in a developing context, exploring the nature of such companies in the contemporary Brazilian economy.

2.2 Technology-based SMEs and external knowledge exploration

There currently is a huge literature on inter-organisational collaboration for innovation involving firms, universities, research institutes, private consultancies, public laboratories, among others, stressing the relevance of these relationships to improve information diffusion, resource sharing, access to specialised assets, and inter-organisational learning (Powell and Grodal, 2005; Vanhaverbeke, 2006). The need to move away from the idea that innovation stems only (or mostly) from the internal capacities of atomistic economic agents competing for profits in impersonal markets was imperative after the explosion of inter-firm cooperation in the past decades and the growing empirical evidence pointing out the importance of networks of collaboration to the innovation process (Vonortas, 2009b).

One of the most significant turning points in the literature certainly came from the work by Chesbrough (2003) on the Open Innovation approach, which could basically be understood as the antithesis of the traditional vertical integration model, or ‘closed innovation’, according
to which in-house R&D would be the primary driver to internally developed innovations. The Open Innovation approach understands the R&D as an open system operating in an environment in which useful knowledge is widely distributed (Chesbrough, 2003). As the ‘closed innovation’ approach has been challenged since the 1980s by trends like the increasing costs and complexity of R&D, the shortening of technology life-cycles, the presence of knowledgeable suppliers and clients, it became clear that companies stuck at this outdated paradigm would likely overlook the various business opportunities from the large pool of external knowledge (Vanhaverbeke, 2006).

The new paradigm postulating the Open Innovation approach arose precisely to fill this gap. However, the intention of this approach is not to deny the importance of firms’ internal resources, especially the intramural R&D efforts. In fact, since the seminal paper by Cohen and Levinthal (1989) on the dual role of R&D in generating new information at the same time that enhances firms’ absorptive capacity to explore external knowledge, the relevance of the internal capacities of companies has become indisputable, even in an environment of increasing expansion and distribution of the pool of external knowledge. Actually, the problem would be more related to the conservative nature of learning at organisations, which by mechanisms of self-reinforcement would result in specialization that can be harmful in environments of constant change (Levinthal, 1996). This implies the risk of a ‘competence trap’ for companies locked in a highly specialised technological path, then losing the ability to appraise external opportunities.

The solution to avoid the ‘competence trap’ is provided by the strategy of developing multiple knowledge bases. March (1991) proposed in a very eloquent paper that companies must find an appropriate balance in their innovation search strategies between knowledge exploitation of their current competencies and knowledge exploration of new opportunities with the aim to achieve successful product development. Such notion is in tune with the idea of
complementary routines associated with successful innovation management under discontinuous conditions, which tend to be related to highly flexible behaviour, tolerance for ambiguity, emphasis on fast learning, characteristics often found in small entrepreneurial firms capable of managing innovation in ‘ambidextrous’ fashion (Tidd, Bessant, and Pavitt, 2005).

Indeed, there are some evidence pointing out that entrepreneurial SMEs might be more likely to have diverse and extensive linkages with a variety of external sources of innovation, which have proved to be fundamental in order to companies obtain necessary resources to develop innovative products and then increase their survival chance (Powell and Grodal, 2005). Freeman and Soete (1997) noticed in their typology of innovation strategies that even though the offensive strategy is usually grounded on a key role for in-house R&D efforts, there is an exception to this generalization constituted by the small entrepreneurial firms founded in order to explore an innovation partial or totally developed outside their boundaries, especially in the case of technology intensive innovations. These companies are usually involved in the so-called strategic alliances (or knowledge-intensive partnerships) which are collaborative arrangements focusing primarily on the generation, exchange, adaptation and exploration of technical advances, and typically comprise URIs when R&D is the focus (Rothaermel and Deeds, 2006; Vonortas and Zirulia, 2015).

Actually, URIs have played a distinctive role in the development of technology-based SMEs. Acs, Audretsch, and Feldman (1994) found that, while large firms are more responsive to intramural R&D than small ones, smaller firms are more responsive to university research than their larger counterparts. The founders of technology-based SMEs usually have an academic background or even are current or former employees from universities, so that the university researchers themselves may be more willing to work with a small young company which they know the owners rather than faceless multinational corporations (Storey and Tether, 1998). Besides, studies pointed out that the presence of URIs in a region favours an enabling
environment for the creation of new innovative companies (Fernandes, Côrtes, and Pinho, 2004). In fact, it was found in Brazil that technology-based SMEs predominantly cooperate with URIs (more than 50%) instead of other more traditional partners among incumbent companies, such as suppliers (less than 10%) and customers (less than 20%) (Côrtes et al., 2005).

2.3 Internal barriers within technology-based SMEs

The big versatility and ability of technology-based SMEs to explore external knowledge does come with a price. On the one hand, these companies tend to be less prone to suffer from the ‘Not Invented Here’ (NIH) syndrome, which typically involves the decision of firms to mistrust and not incorporate external knowledge as it does not align with their perception of the technology and industry (Katz and Allen, 1982); on the other, the intense openness to external knowledge reveals what are the main weaknesses of such companies: their internal resources deficiencies (Hoffman et al., 1998; Tidd, Bessant, and Pavitt, 2005). In fact, sometimes the close links between SMEs and universities imply a lower in-house R&D expenditure needed (Veugelers and Cassiman, 1999), suggesting a substitution of internal capabilities by external ones.

Put another way, the ‘Achilles’ heel’ of technology-based SMEs is their huge limitations in terms of financial, knowledge and organisational internal resources. In this context, the engagement in cooperative ventures with universities, research institutes and the national science and technology infrastructure in general could alleviate the burden of the internal barriers as it expands the firms’ knowledge sources and intensifies the generation of new marketable technologies (Pinho, Côrtes, and Fernandes, 2002; Kim and Vonortas, 2014a). All in all, cooperative agreements and network strategies are critical elements to determine the survival and prosperity of technology-based SMEs facing internal constraints.
The more traditional theoretical perspective on cooperative ventures for innovation has associated incentives to cooperate with learning and knowledge benefits to companies (Mowery and Sampat, 2005), but hardly ever with minimizing or alleviating their barriers. The literature on obstacles to innovation, in its turn, has mostly neglected the impact of obstacles in changing companies’ strategy as an indirect effect, focusing more on the direct effect of obstacles on firms’ innovation activities and performance (Pellegrino and Savona, 2017). Following the lead of very recent researches (e.g., Antonioli, Marzucchi, and Savona, 2017; Kanama and Nishikawa, 2017), the question that we put forth in this paper is whether the perception of internal barriers to innovation by technology-based SMEs in Brazil foster cooperative ventures with URIs to alleviate such barriers. In order to tackle this issue, we have formulated the following research hypotheses based on three recurrent internal barriers as identified in the literature:

Firstly, we consider financial obstacles. In fact, most studies on innovation barriers until recently had focused on financial constraints impact on companies’ innovative behaviour based on the seminal works by Nelson (1959) and Arrow (1962) on the (semi) public-good nature of knowledge engendering underinvestment in innovation (Hall, 2008). Regarding cooperation incentives, the literature has pointed out that external partnerships help to share costs and risks involved in the innovation process (Hagedoorn, Link, and Vonortas, 2000; Caloghirou, Tsakanikas, and Vonortas, 2001; Eom and Lee, 2010). In addition, it is widely acknowledged that problems associated with financing investments in new (and usually costly) technology are most apparent for small firms and start-ups lacking the appropriate internal funding (Álvarez and Crespi, 2015). There is also a growing literature paying attention to risk management practices among SMEs and small entrepreneurial companies (Street and Cameron, 2007; Verbano and Venturini, 2013; Kim and Vonortas, 2014b). Therefore, we hypothesise:
**H1** – Technology-based SMEs are more prone to cooperate with URIs when facing financial barriers;

Secondly, recent literature has stressed the importance of knowledge obstacles to innovation as well (D’Este et al., 2012; Pellegrino and Savona, 2017). Galia and Legros (2004) highlight that information on markets and technology is fundamental to the process of matching technology possibilities to market opportunities in the innovation development, while D’Este, Rentocchini, and Vega-Jurado (2014) stress that the breath of firms’ skill base is important for innovation particularly within newly established companies and SMEs. In terms of external knowledge sourcing, the decision to collaborate with other actors of the innovation system is usually related to the need to handle internal knowledge and skills shortages as the partnerships might both provide access to crucial knowledge and lead to upgrade of skills (Caloghirou, Ioannides, and Vonortas, 2003; Barge-Gil, 2010; Antonioli, Marzucchi, and Savona, 2017). Thus, we arrive at our second hypothesis:

**H2** – Technology-based SMEs are more prone to cooperate with URIs when facing knowledge barriers;

Finally, another internal barrier that must be considered is the organisational one. Organisational and technological innovations are currently seen as intertwined, or even complementary (Lam, 2005; Ballot et al., 2015). In fact, the internal dimension of the organisation and the way it structures and operates its innovation management cannot be ignored to understand the innovation barriers faced by firms (Nagano, Stefanovitz, and Vick, 2014), especially when analysing firms with widely acknowledged managerial deficiencies
such as SMEs (Martin and Staines, 1994; Ruiz-Jiménez and Fuentes-Fuentes, 2016). When it comes to technology-based SMEs, many of these companies tend to seek the high quality prestigious facilities (laboratories, technology transfer offices, etc.) that URIs may provide through contracts of partnership, or even through the incubation or installation in Science Parks managed by universities, which can provide a broad network and managerial services for these firms (Storey and Tether, 1998). Such collaborations might then be relevant to overcome organisational barriers. Hence, we arrive at our third hypothesis:

**H3** – Technology-based SMEs are more prone to cooperate with URIs when facing organisational barriers.

3. **Research design and methodology**

3.1 **Data**

Our main data source is the last edition of the Brazilian Innovation Survey (PINTEC 2014), released in late 2016, which was first designed by IBGE in the early 2000s to provide a broad understanding of the innovation and R&D activities in the Brazilian economy and to support the actions and planning of the public and private actors (Moraes Silva and Furtado, 2017). In contrast to earlier editions, the current survey covers not only manufacturing sectors and technological innovations, but in tune with the latest edition of the OECD’s Oslo Manual (OECD, 2005) it also covers selected service sectors (notably KIBS) and non-technological innovations (organisational and marketing ones) (IBGE, 2016).

PINTEC 2014 comprises companies that have: i. active status in the Central Business Register held by IBGE; ii. main economic activity in extractive industry, manufacturing industry, electricity and gas, telecommunications, information technology services, architecture and engineering services, R&D services, data processing and web hosting, or editing, printing
and music recording; iii. headquarters in Brazil; iv. 10 or more employees; v. business entity registration. The survey has two time references: i. most qualitative variables refer to the period 2012-2014; ii. quantitative variables and a few qualitative ones refer to 2014.

The survey’s sample design departs from the assumption that innovation is a rare phenomenon, so the sampling procedures need to ensure its representativeness. Therefore, PINTEC 2014 employed a stratified disproportional sampling procedure in which large companies (more than 500 employees in manufacturing and more than 100 employees in services) were automatically included in the sample while the others were sampled according to their probability of being innovative (more likely innovative companies as identified in a screening process using government databases had higher weight in the sample selection). The final sample reached 17,171 firms, whose results were expanded to a universe of 132,529 firms by means of the Horvitz-Thompson estimator. Table 1 presents the aggregate sectoral distribution of companies surveyed.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extractive and manufacturing industries</td>
<td>14,387</td>
</tr>
<tr>
<td>Electricity and gas</td>
<td>96</td>
</tr>
<tr>
<td>Selected services</td>
<td>2,688</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>17,171</strong></td>
</tr>
</tbody>
</table>

Source: IBGE 2016.

PINTEC 2014 covers a wide spectrum of themes, from innovation activities and funding to cooperation partnerships and obstacles to innovation, among others. Figure 1 summarises the sixteen sections of the survey’s questionnaire and their directional flow. While a filter mechanism directs non-innovative companies (without ongoing or abandoned projects) to answer a more limited set of sections than innovative ones, both innovators and non-innovators
answer the sections on problems and obstacles to innovation, organisational and marketing innovations, and biotechnology and nanotechnology diffusion.

3.2 Empirical strategy

In order to study technology-based SMEs, our empirical strategy involves the circumscription of the PINTEC’s sample into a reduced subsample with the characteristics of interest to our research. There is no consensual definition of technology-based SMEs in the literature, but some scholars have shown that focusing on SMEs operating in technologically intensive sectors can render good results (Storey and Tether, 1998; Haeussler, Patzelt, and Zahra, 2012). Besides, previous studies have found high concentration of technology-based SMEs on technologically advanced sectors in Brazil (Pinho, Côrtes, and Fernandes, 2002; Fernandes, Côrtes, and Pinho, 2004). Therefore, we narrow down the observations from our data source to companies having
between 10 and 249 employees (the widespread definition of SMEs in Brazil) which belong to the manufacturing and service sectors most technologically intensive (High and Medium-high levels as classified by the OECD, and the so-called KIBS surveyed by PINTEC 2014). Table 2 presents the sectors comprehended by our study.

<table>
<thead>
<tr>
<th>Code</th>
<th>Sectors</th>
<th>Technological intensity</th>
</tr>
</thead>
<tbody>
<tr>
<td>C-20</td>
<td>Manufacture of chemicals and chemical products</td>
<td>Medium-high</td>
</tr>
<tr>
<td>C-21</td>
<td>Manufacture of basic pharmaceutical products and pharmaceutical preparations</td>
<td>High</td>
</tr>
<tr>
<td>C-26</td>
<td>Manufacture of computer, electronic and optical products</td>
<td>High</td>
</tr>
<tr>
<td>C-27</td>
<td>Manufacture of electrical equipment</td>
<td>Medium-high</td>
</tr>
<tr>
<td>C-28</td>
<td>Manufacture of machinery and equipment</td>
<td>Medium-high</td>
</tr>
<tr>
<td>C-29</td>
<td>Manufacture of motor vehicles, trailers and semi-trailers</td>
<td>Medium-high</td>
</tr>
<tr>
<td>C-30</td>
<td>Manufacture of other transport equipment</td>
<td>Medium-high</td>
</tr>
<tr>
<td>C-325</td>
<td>Manufacture of medical and dental instruments and supplies and optical articles</td>
<td>Medium-high</td>
</tr>
<tr>
<td>J-58</td>
<td>Press and publishing activities</td>
<td>KIBS</td>
</tr>
<tr>
<td>J-592</td>
<td>Sound recording and music publishing activities</td>
<td>KIBS</td>
</tr>
<tr>
<td>J-61</td>
<td>Telecommunications</td>
<td>KIBS</td>
</tr>
<tr>
<td>J-62</td>
<td>Computer programming, consultancy and related activities</td>
<td>KIBS</td>
</tr>
<tr>
<td>J-631</td>
<td>Data processing, web hosting and related activities</td>
<td>KIBS</td>
</tr>
<tr>
<td>M-71</td>
<td>Architectural and engineering activities, technical testing and analysis</td>
<td>KIBS</td>
</tr>
<tr>
<td>M-72</td>
<td>Scientific research and development</td>
<td>KIBS</td>
</tr>
</tbody>
</table>

We unfortunately lose two important information with our definition of technology-based SMEs, both related to PINTEC’s database limitations. First, we do not have data on microenterprises (companies with less than 10 employees), although this type of company may have a significant impact when we talk about knowledge-intensive activities (Baumann and Kritikos, 2016). Second, we do not have data on companies’ age, although young firms are often associated with innovativeness when it comes to technology-intensive sectors (Protogerou, Caloghirou, and Vonortas, 2017). However, we believe that such limitations do not substantially restrain our results.
Methodologically, we employ econometric analysis to assess the effects of three groups of internal barriers (Financial, Knowledge and Organisational)\(^3\) on the propensity of technology-based SMEs to cooperate with URIs in Brazil. We ran probit models with the following specification:

\[
\text{Prob}(Y = 1 \mid x) = \int_{-\infty}^{x'} \phi(t) dt = \Phi(x' \beta).
\]

The set of parameters \(\beta\) reflects the impact of changes in \(x\) on the probability of \(Y = 1\), while the function \(\Phi(t)\) is a commonly used notation for the standard normal distribution (Greene, 2011). Probit models are adequate to handling dichotomous dependent variables, as the predicted probabilities are limited between 0 and 1. Our dependent variable is precisely a dichotomous (dummy) one, indicating whether companies have or not engaged in cooperative arrangements for innovation with universities and research institutes in Brazil between 2012-2014 (COOPURI).

The independent variables represent a set of internal barriers grouped into three variables: **Financial Obstacles (FINOBS)** comprehending excessive economic risk (RISK), high cost to innovate (COST) and lack of adequate funding sources (FUND); **Knowledge Obstacles (KNOBS)** comprehending lack of qualified personnel (STAFF), lack of information on technology (INFOTECH) and lack of information on markets (INFOMKT); **Organisational Obstacles (ORGOBS)** comprehending organisational rigidities (RIGID), innovation centralised in another company from the group (CTGRP) and difficulty to comply with standards, norms and regulations (STAND). All the specific internal barriers’ variables are also dummies and indicate whether the company has assigned high importance to such barrier. In

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\(^3\) We have employed just a thematic grouping of the various internal barriers. As robustness check, we also ran multiple correspondence analysis to verify whether there would be different/more ‘natural’ obstacle groups. The analysis did not produce any significant result.
the case of the aggregate independent variables (FINOBS, KNOBS and ORGOBS), they basically indicate whether the company has assigned high importance to at least one of the internal barriers comprised in the group.

We also include a set of controls to account for other factors that likely impact on firms’ propensity to cooperate with URIs, reducing potential omitted variable bias. First, a dummy variable indicating high expenditure (above the sample average) on intramural R&D (HRD) accounting for the companies’ absorptive capacity (Laursen and Salter, 2004). Second, a dummy variable indicating the introduction of product or process innovation at country or world level (INNO) accounting for the firms’ innovativeness (Kim and Vonortas, 2014a). Third, a dummy variable indicating whether the company is part of a corporate group (GRP) accounting for group affiliation (Tether, 2002). Fourth, a dummy variable indicating the use of informal methods of intellectual property protection (IMP) accounting for the firms’ appropriability (Eom and Lee, 2010). Fifth, a dummy variable indicating use of public funding to R&D and innovation projects in cooperation with URIs (GOV) accounting for public support (Negassi, 2004). Finally, we also introduced dummy variables for each macro-region of the country (South, Southeast, North, Northeast and Central-West) accounting for regional particularities (Ponds, van Oot, and Frenken, 2007). Hence, we have the following specification for our models:

$$\text{COOPURI}_i = \alpha + \beta_1 \text{OBS}_i + \beta_2 \text{X}_i + \varepsilon_i$$

As we said before, COOPURI denotes our dependent variable; OBST is a vector of the independent variables grouping the different internal barriers as perceived by companies (FINOBS, KNOBS and ORGOBS); X is a vector of appropriate control variables; and $\varepsilon$ is the
error term. In addition to the coefficients, we report the marginal effects of the probit models as well. Table 3 presents a list with the variables definition.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
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<tbody>
<tr>
<td>COOPURI</td>
<td>Cooperation partnership with universities or research institutes</td>
</tr>
<tr>
<td>FINOBS</td>
<td>Assignment of high importance to at least one financial obstacle to innovation (excessive economic risk, high cost to innovate, lack of adequate funding sources)</td>
</tr>
<tr>
<td>KNOBS</td>
<td>Assignment of high importance to at least one knowledge obstacle to innovation (lack of qualified personnel, lack of information on technology, lack of information on markets)</td>
</tr>
<tr>
<td>ORGOBS</td>
<td>Assignment of high importance to at least one organisational obstacle to innovation</td>
</tr>
<tr>
<td></td>
<td>(organisational rigidities, innovation centralised in another company from the group, difficulty to comply with standards, norms and regulations)</td>
</tr>
<tr>
<td>HRD</td>
<td>High expenditure on intramural R&amp;D in 2014</td>
</tr>
<tr>
<td>INNO</td>
<td>Introduction of product or process innovation at the country or world level</td>
</tr>
<tr>
<td>GRP</td>
<td>Affiliation to a national or international corporate group</td>
</tr>
<tr>
<td>IMP</td>
<td>Use of at least one informal method of intellectual property protection (product design complexity, industrial secrecy, lead time over competitors, among others)</td>
</tr>
<tr>
<td>GOV</td>
<td>Use of public funding for R&amp;D and innovation projects in cooperation with universities or research institutes</td>
</tr>
</tbody>
</table>

* All variables are dummies and defined over the reference period 2012-2014, unless when specified differently.

In addition to running the models for the whole sample of technology-based SMEs, we also run them for two subsamples differentiating between manufacturing and service firms as these are expected to be significantly different (Gallouj and Savona, 2009). From our perspective, it is crucial to undertake an assessment of the internal barriers in the propensity of technology-based SMEs to cooperate with URIs differentiating between high-tech manufacturing companies and KIBS in Brazil, which could render some interesting results to characterise these unlike sectors.

4. Results and discussion

4.1 Descriptive statistics
A first look at descriptive statistics helps understanding the nature of the data in the study. As shown in Table 4, we work with a fairly balanced sectoral distribution of firms (about 2,000 firms belonging to manufacturing high-tech sectors and 1,700 belonging to KIBS) and a slightly less balanced size distribution (the number of medium-sized companies in the sample is about 50% larger than the number of small companies). The total sample is made of 3,736 firms.

<table>
<thead>
<tr>
<th>Size/Sector</th>
<th>High-tech</th>
<th>KIBS</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small (10-49 employees)</td>
<td>733</td>
<td>746</td>
<td>1,479</td>
</tr>
<tr>
<td>Medium (50-249 employees)</td>
<td>1,312</td>
<td>945</td>
<td>2,257</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>2,045</strong></td>
<td><strong>1,691</strong></td>
<td><strong>3,736</strong></td>
</tr>
</tbody>
</table>

Company response distribution in terms of assigned importance to the obstacles addressed in this study is shown in Table 5. The Table presents the number firms according to size strata and sector groups assigning high importance to the aggregates of internal barriers. It can be observed that financial obstacles receive the highest mention across all firm sizes and sectors. Financial obstacles are followed by knowledge obstacles, while organizational obstacles come in third place. Medium-sized firms and manufacturing high-tech firms seem to report higher importance across all types of obstacles – however, it should be noted that they make up a big part of the sample: the intersection of these two groups (1,312 firms) comprises more than one third of the total sample.

<table>
<thead>
<tr>
<th>Obstacles to innovation</th>
<th>Size</th>
<th>Sector</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small firms</td>
<td>Medium firms</td>
</tr>
<tr>
<td>Financial obstacles</td>
<td>460</td>
<td>743</td>
</tr>
<tr>
<td>Knowledge obstacles</td>
<td>223</td>
<td>294</td>
</tr>
<tr>
<td>Organisational obstacles</td>
<td>179</td>
<td>266</td>
</tr>
</tbody>
</table>
Table 6 shows the distribution of firm responses relating to the control variables. There is once more high concentration in the group of medium-sized and manufacturing high-tech companies, which could again stem from the greater representativeness of these companies in the sample. Interestingly, comparing the data from Tables 5 and 6, the very same group of companies (medium-sized high-tech manufacturing) more intensively reporting internal obstacles to innovation is also the one more engaged in innovation-related activities. This seems consistent with recent literature pointing out that companies need to pursue innovation in order to face barriers (D’Este et al., 2012). The most frequently mentioned factor is the use of informal methods of intellectual property protection (complexity of product design, industrial secrecy, time lead over competitors, etc.), while the least mentioned factor is government support to university-industry cooperation.

<table>
<thead>
<tr>
<th>Control variables</th>
<th>Small firms</th>
<th>Medium firms</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High-tech</td>
<td>KIBS</td>
</tr>
<tr>
<td>High R&amp;D</td>
<td>35</td>
<td>55</td>
</tr>
<tr>
<td>Innovativeness</td>
<td>89</td>
<td>69</td>
</tr>
<tr>
<td>Informal IP</td>
<td>131</td>
<td>95</td>
</tr>
<tr>
<td>Government support</td>
<td>9</td>
<td>6</td>
</tr>
<tr>
<td>Group affiliation</td>
<td>53</td>
<td>75</td>
</tr>
</tbody>
</table>

Finally, Table 7 contains the descriptive statistics on means, standard deviations and correlations between the explanatory and control variables. It displays low values of both means and standard deviations. The correlation matrix indicates no correlation higher than 50% and, thus, no concern for multicollinearity.
4.2 Estimation results

Table 8 presents the estimation results for all three samples: full sample (Model 1), high-tech manufacturing subsample (Model 2), and KIBS subsample (Model 3).

Table 7 - Descriptive statistics (means and standard deviations) and correlation matrix of explanatory and control variables ($n = 3,736$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean</th>
<th>S.D.</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. FINOBS</td>
<td>0.322</td>
<td>0.467</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. KNOBS</td>
<td>0.138</td>
<td>0.345</td>
<td>0.404</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. ORGOBS</td>
<td>0.119</td>
<td>0.323</td>
<td>0.371</td>
<td>0.371</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. HRD</td>
<td>0.149</td>
<td>0.356</td>
<td>0.145</td>
<td>0.093</td>
<td>0.068</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. INNO</td>
<td>0.165</td>
<td>0.371</td>
<td>0.141</td>
<td>0.094</td>
<td>0.081</td>
<td>0.389</td>
<td>1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. IMP</td>
<td>0.238</td>
<td>0.426</td>
<td>0.184</td>
<td>0.147</td>
<td>0.108</td>
<td>0.339</td>
<td>0.401</td>
<td>1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. GOV</td>
<td>0.016</td>
<td>0.125</td>
<td>0.048</td>
<td>0.004</td>
<td>0.038</td>
<td>0.209</td>
<td>0.114</td>
<td>0.133</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>8. GRP</td>
<td>0.147</td>
<td>0.354</td>
<td>-0.031</td>
<td>-0.028</td>
<td>0.033</td>
<td>0.097</td>
<td>0.079</td>
<td>0.054</td>
<td>0.019</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 8 - Probit regression results

<table>
<thead>
<tr>
<th>Variables</th>
<th>Full sample (model 1)</th>
<th>High-tech (model 2)</th>
<th>KIBS (model 3)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Coefficients</td>
<td>Marginal effects</td>
<td>Coefficients</td>
</tr>
<tr>
<td>FINOBS</td>
<td>0.183** (0.0824)</td>
<td>0.0179** (0.00808)</td>
<td>0.0860 (0.111)</td>
</tr>
<tr>
<td>KNOBS</td>
<td>0.177* (0.0983)</td>
<td>0.0174* (0.00962)</td>
<td>0.248* (0.131)</td>
</tr>
<tr>
<td>ORGOBS</td>
<td>0.0254 (0.105)</td>
<td>0.00248 (0.0103)</td>
<td>0.0352 (0.136)</td>
</tr>
<tr>
<td>GOV</td>
<td>1.359*** (0.180)</td>
<td>0.133*** (0.0175)</td>
<td>1.160*** (0.228)</td>
</tr>
<tr>
<td>INNO</td>
<td>0.350*** (0.0861)</td>
<td>0.0342*** (0.00844)</td>
<td>0.324*** (0.111)</td>
</tr>
<tr>
<td>HRD</td>
<td>0.713*** (0.0838)</td>
<td>0.0698*** (0.00838)</td>
<td>0.877*** (0.109)</td>
</tr>
<tr>
<td>GRP</td>
<td>0.231** (0.0926)</td>
<td>0.0226** (0.00908)</td>
<td>0.389*** (0.120)</td>
</tr>
<tr>
<td>IMP</td>
<td>0.457*** (0.0804)</td>
<td>0.0447*** (0.00795)</td>
<td>0.466*** (0.107)</td>
</tr>
</tbody>
</table>
In Model 1 (full sample) ‘Financial Obstacles’ (FINOBS) and ‘Knowledge Obstacles’ (KNOBS) are positively and significantly associated with the tendency of technology-intensive SMEs to cooperate with URIs. Interestingly, the FINOBS coefficient seems to reflect the strongly statistically significance of financial obstacles in KIBS (Model 2). Whereas the KNOBS coefficient seems to reflect the relatively weak statistical significance of knowledge obstacles in high-tech manufacturing companies (Model 3). By and large, the control variables had the expected positive and significant coefficients on almost all three models.

The estimation results reported above lead to the following observations:

1. Financial obstacles appear strongly linked to university-industry cooperation in the cases of the full sample of technology-based SMEs and the subsample of knowledge-based business services SMEs. While the literature has identified cooperative ventures as an important coping strategy to share costs, risks and reduce the financial burden between partners, and given that the financial barriers are key to SMEs, cooperation with universities appears in our analysis positively linked only to business services when the sample of technology-based SMEs is disaggregated by sector. Thus, hypothesis 1 is only partially confirmed.

2. Knowledge obstacles appear weakly linked to university-industry cooperation in the cases of the full sample of technology-based SMEs and the subsample of high-tech manufacturing SMEs. While the literature has identified the relevance of cooperative arrangements to explore external knowledge and cope with internal knowledge shortages, the presumed knowledge transfer here is preconditioned upon a minimum level of internal absorptive
capacity in terms of skills and knowledge base. Technology-based SMEs are naturally expected to have such capacity, which could explain why knowledge barriers are only weakly linked to collaboration with universities. Besides, when the full sample is disaggregated by sector, knowledge obstacles appear associate only to high-tech manufacturing SMEs, wherefore Hypothesis 2 is only partially confirmed.

3. Organisational obstacles did not produce statistically significant results. Hypothesis 3 is not confirmed. On the one hand, this might be due to the fact that organisational barriers are simply not alleviated by the cooperation with URIs as these organisations themselves are not well-organised and motivated for market innovation; on the other, this might stem from the organisational flexibility of technology-based SMEs preventing them of suffering from organisational constraints (the less mentioned group of barriers in our sample), which would make pointless the need to resort to university-industry cooperation to alleviate this rare problem among such companies.

4. The control variables appeared highly statistically significant in their association to URI cooperation for technology-based SMEs across the different sectoral groups. Elements such as company innovativeness, R&D expenditure, group affiliation, public support, and use of intellectual property protection instruments were strongly associated to company propensity to engage in cooperative ventures with URIs.

5. **Final remarks and policy implications**

This paper appraised the relationship between internal firm barriers to innovation and the propensity of technology-based SMEs to engage in university-industry cooperation. Our analysis was motivated by argument in recent literature that companies change their strategy in response to their perception of innovation obstacles, and that cooperative ventures with URIs as well as other companies may provide an alternative (Antonioli, Marzucchi, and Savona,
Relying on microdata from the sixth edition of the Brazilian Innovation Survey (PINTEC 2014), we empirically investigated this idea in the context of an emerging economy. In the case of the full sample of technology-based SMEs the perception of financial and knowledge obstacles was found to be positively associated with the probability of firms engaging in cooperative ventures with URIs. Regarding financial barriers, collaborating with URIs and thus accessing public funds more easily can certainly be a strong incentive for SMEs. Access to expensive, modern technological infrastructure of well-funded research groups in URIs can provide yet another strong incentive. Regarding knowledge barriers, external knowledge exploration is evidently one of the tenets for university-industry cooperation: the knowledge produced by URIs is usually of a more fundamental nature than what industry does – to the extent it is useful for business purposes, industry will try to establish channels for collaboration and learning.

However, there is differentiation among the subsamples. In the case of high-tech manufacturing companies, only knowledge obstacles are associated with cooperative ventures with URIs (in a statistically significant manner). As these companies are probably more engaged in science-based activities than the ones operating in services, the need to resort to university-industry collaborations in order to access basic research and specialised equipment might be bigger. In the case of KIBS, the financial obstacles are strongly associated with cooperation with URIs. For such companies, sharing research costs and accessing public funding appear to be the primary incentives for collaboration. Organisational obstacles did not provide any statistically significant result, raising questions on the capacity of university-industry cooperation to mitigate internal organisational constraints whenever they appear.

The above, of course, should not be taken to imply that industry cooperation with URIs is not important. What it says is that such cooperation is not perceived by knowledge-intensive SMEs to be of critical importance in alleviating innovation obstacles. This, in fact, should not
be surprising – it corroborates survey results that have repeatedly shown SMEs rating collaboration with universities quite low in their strategic outlook. The reason is simple: URIs are not typically geared up to short- and medium-term innovation, the typical timeframe of technology-intensive SMEs, short of funds. While universities and research institutes have other very important roles in our techno-economic systems – as, for instance, is indicated by the strong association with high innovativeness and R&D expenditure in our empirical investigation – their perceived contribution in alleviating innovation obstacles for technology-based SMEs in a developing economy may not be among their top contributions.

From the policy perspective, these findings suggest that creating public incentives to technology-based SMEs cooperate with URIs is not the best strategy to help these companies to overcome internal barriers to innovation. In fact, what the obtained results showed was that such cooperative ventures are very unlikely to mitigate internal barriers, especially knowledge and organisational ones. One possible exception refers to financial obstacles among technology-based SMEs operating in KIBS. In this case, the university-industry cooperation was significantly associated to financial constraints, although the marginal effect of the relationship was fairly low (about 3%). Anyway, since the predominant barriers among technology-based SMEs in Brazil are of financial nature, the public policy should focus efforts in tackling this issue, not necessarily via university-industry cooperation, but mostly through specific business lines of credit and venture capital addressed to these firms.

Future work should try to correct some of the limitations of this analysis. First, cross-sectional models cannot control for unobserved and time-invariant heterogeneity across firms. One possible way of overcoming this limitation would be to run panel models using more than one editions of PINTEC. The challenge here is the changes in terms of variables and scope of PINTEC over time. Second, PINTEC data do not include important information such as company age, manager profile, team culture, patents, and micro-enterprises. Third, the analysis
should be replicated with similar data in other emerging economies in order to be able to compare across countries and start addressing the impact of systemic factors on the relationships examined herein.

References


Vonortas, N. (2009a). “Scale and scope in research”. In: Dalanghe; Muldur; Soete (Eds.), *European Science and Technology Policy*. Cheltenham: Edward Elgar Publishing.
