Global Innovation Networks and Interactions Between Firms and Universities: evidences for Minas Gerais' automotive sector

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Abstract

The literature on Global Innovation Networks has contributed to identify changes in the activities of multinational corporations. However it does not fully explore the role played by university-firm interactions. This paper fills this gap using the INGINEUS survey to explore nature universities-firms interactions, and the relevance of factors such as type of enterprise, internationalisation, innovative effort, source of knowledge. The results showed distinctive patterns of innovation associated with different types of enterprise and university-firm interactions.

Keywords: university-firm interaction, global innovation networks, national systems of innovation, multiple correspondence analysis.

Resumo

A literatura sobre Redes Globais de Inovação tem contribuído para identificar mudanças no comportamento inovativo das corporações multinacionais. Contudo, tais estudos ainda não exploraram de forma plena o papel das interações universidade-empresa, nos âmbitos nacional e internacional, neste processo. Este artigo tenta contribuir para este aspecto utilizando dados provenientes do projeto INGINEUS com vistas a explorar a natureza das interações universidade-empresa, dentro e fora do país, e a relevância para este processo de fatores como tipo de firma, processos de internacionalização, esforços inovativos e fontes de conhecimento.

Palavras Chave: interação universidade-empresa, redes globais de inovação, sistemas nacionais de inovação, análise de correspondência múltipla.

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1. Introduction

The emergence of Global Innovation Networks (GINs) holds out the promise of technological upgrading, competence building and economic catch up for developing countries. Potential interaction with universities and public research institutes in a region or country is a key factor influencing the strategies of MNCs, both in relation to the education and training of a pool of highly skilled knowledge workers, scientists and engineers, or in relation to meeting R&D needs in the form of university-industry linkages. Global networks based on offshoring and outsourcing of research, development and innovation activities of Northern MNCs to Southern firms, universities and public research institutes offer the opportunity for technological spillovers, access to knowledge assets and learning that can strengthen Southern institutions and national systems of innovation.

A related phenomenon is firms from developed countries investing in advanced economies. These companies build external knowledge networks in order to overcome the constraints of immature innovation systems, using the resulting global knowledge flows to strengthen local capabilities. The emergence of GINs, of a new geography of knowledge, thus holds out the promise of subverting traditional global knowledge hierarchies. As Ernst and Hart (2007) note, the global changes 'evoke optimism, even utopian visions' for sharing in economic growth.

The research literature suggests that this promise may be realised in emerging economies like China and India – at least, in specific sectors such as ICT and electronics, and in specific regions of these countries. These countries have two major attractions for Northern MNCs – very large markets, and large pools of qualified engineers and scientists, the result of targeted government policy and investment in education and training. MNCs have offshored knowledge activities by establishing local innovation centres in countries such as China and India, contributing to form the hub of global innovation networks, including outsourcing to local universities in the host country.

These GINs are characterised by knowledge intensive forms of interaction between firms and universities, such as collaborative and contract research and customised training. Chinese universities, for instance, are increasingly found in the top ranks of the higher education league tables, one indication that global knowledge hierarchies are beginning to shift.

The research literature points to the possibility of such a subversion of pre-existing global hierarchies (Ernst 2009; Ernst and Naughton, 2008). However, at the same time, there is evidence that such global changes are uneven unevenly distributed (Ernst and Hart, 2007). Hence, there are evidences that the extent to which hierarchies matter may have been underestimated in the current literature on GINs.

A focus on interactions between firms and universities can usefully highlight the ways in which global knowledge flows are of benefit to learning and capability building in local innovation systems. Previous studies - whether in the developed world (Klevorick et al, 1995) or in developing countries (Lee, 2009; Kruss, 2009; Dutrénit, 2010) - have been able to capture only part of the broad picture. Research on global innovation networks (GINs) provokes students of interaction to advance towards a real global perspective. Indeed, as international connections are more widespread and more active than is typically assumed or explicitly stated, this global view is a better starting point for a study of interaction, or even a necessary starting point, given the global nature of science and technology.

A thorough review of the literature reveals two strands of studies on innovation. The first, focused on interactions (Klevorick et al, 1995; Nelson, 1993), and second, the more recent literature on GINs (Ernst, 2006; The Economist Intelligence Unit, 2007). However, these strands share a common problem: each has a blind spot in relation to the core focus of the other strand. The literature on interaction does not consider the international dimension in any depth, and the GINs literature does not integrate the university dimension adequately.

Only recently, an attempt to address the common weakness through a combination of the two approaches, searching for interactions between firms and universities globally can be found in Albuquerque et al, 2011. The study proposes a tentative taxonomy of interaction between firms and universities in a global context by adding a global dimension to the first approach and universities to the second. As a result, the taxonomy reinforces the role played by the level of maturity of NISs as well as of MNCs strategies in the emergence and development of GINs.

In spite of the increasing recognition of the importance of GINs and, within the networks, the key role played by universities and research institutes, empirical evidence beyond case studies is still elusive. The INGINEUS Project offered a singular opportunity to researchers of interaction between firms and universities to broaden their horizon and understand their subject in a global context. The project included the design of an original survey which included a multitude of questions designed to shed light on various aspects of GINs emergence and development.

The INGINEUS survey was conducted in nine countries amongst developed and developing ones. It was focused in three economic sectors with different technological allocation, agroprocessing, ICT and automotive. In the developing countries, that were also the largest analyzed, the survey was performed at the regional level. Thus in Brazil this survey focused the automotive sector firms located in the state of Minas Gerais, where is concentrated a representative part of the Brazilian automotive industry.

The objective of this paper is to use INGINEUS survey to explore nature of interaction between universities and firms, and whether the role of universities in global innovation networks is related to other factors such as type of enterprise, degree of internationalisation, innovative effort, source of knowledge, country, and three sectors with varying degrees of technological intensity. In doing so, the paper will contribute to the relevant literature primarily by searching for evidence of a relationship between NIS maturity, MNCs strategies and collaboration with universities and research institutions. This paper also aims to identify the position of Brazil, and of Minas Gerais' automotive sector, with regard to the university-industry interactions in comparison to the other countries and sectors analyzed.

To accomplish this task, the paper applies the Multiple Correspondence Analysis Method on the survey dataset. The technique transforms qualitative information available in a table in an instrumental chart, in order to enable the analysis of a large amount of data simultaneously.

The paper is divided in four sections apart from this introduction. Section two presents a review of the literature on GINs and on firm-university interactions. The objective is twofold. First, to reveal a theoretical void represented by the lack of attention to university-firm interaction in a global context. Secondly, by presenting a recent contribution, the section aims at reinforcing the importance of the nature of university-firm interactions as both cause and consequence of the level of maturity of NSI, which together with MNCs types and their strategies is at the core of GIN formation. Section three brings a description of the original dataset built by the INGINEUS project. The dataset consists of a focused survey applied to nine developed

and developing countries that contains a set of variables which will allow us to test for the country and sector differences innovative effort and levels of internationalisation which are associated with different types of collaboration with universities (foreign and local) as well as with types of firms, local, MNCs subsidiaries and local MNCs. The section also briefly introduces the Multiple Correspondence Analysis method, which enables the simultaneous analysis of various firm characteristics and variables drawn from the dataset. Section four brings the results from the Multiple Correspondence Analysis for the full sample as well as for each of the sectors covered by the survey. The section also brings a discussion of the results. Section six brings concluding remarks.

2. Interactions with universities and GINs

There is a void between two strands of the innovation literature concerning the interaction with universities and the formation of GINs. Each strand takes into account the significance of universities and multinational corporations (MNC), but fails to properly investigate the two together. The first investigative line, led amongst others by Klevorick et al (1995) and Cohen et al (2002), focuses on the interactions between universities and firms. Within this strand, knowledge flows of MNCs have been investigated (Narin et al 1997), but in general this literature tends to investigate interactions within the boundaries of a single country.

In the second strand of the literature, universities are seen as an important factor for the emergence of GINs. However, the nature of their role has received vey limited attention. Ernst (2006) and *The Economist Intelligence Unit* (2007) focused on the emergence of GINs, stressing the role of the talent pool available in developing countries as one key driver of emerging GINs. The taxonomy of GIN types proposed Ernst (2009) reveals the relative minor role given the universities. Out of the five types of GINs, only in one, related to Asian firms that build their own global networks, is there specific mention of universities. In the two most frequent types of GIN, intrafirm and interfirm networks, direct and indirect links with universities are only implicit, given that the author draws from previous formulations by Dunning (1995) and Kummerle (1997).

This section evaluates how each strand of the literature on innovation deals with the issue that is not at its core – how the literature on firm interaction with universities deals with the globalization of R&D, and how the literature on GINs deals with the role of universities.

2.1 References to Universities in the literature on GINs

There is a largely implicit relationship assumed between GINs and universities and research institutes, which the literature on GINs points to. A central study carried out by *The Economist Intelligence Unit* (2007). In this study, over 300 respondents identified universities and educational establishments as the most important collaborative partners, ahead of customers, suppliers, alliance partners and even joint ventures.

Further evidence of the importance of the globalization of industry-science relationships can be found in OECD (2008b). The report, aimed at evaluating the use of external sources of technology, shows the various ways in which firms search for and identify new external sources of innovation, particularly from universities and research institutes. Kummerle (1997) identifies foreign universities as frequent targets for “home base augmenting” foreign R&D.

Gompers and Lerner (2001) show that this trend in accompanied by novel financial arrangements. According to the authors, corporate venture capital is often used to foster joint ventures and collaboration with universities in order to access new ideas for innovation in the face of declining internal R&D.

Another key study from UNCTAD (2005), focuses on strategic alliances as an indication of the increasing internationalization of R&D. Collaboration between MNCs subsidiaries and local universities are reported in China (Microsoft Asia), Thailand (Seagate Technology), Morocco (STMicroeletronics) and Brazil (Motorola, HP, Compaq, Novartis, Roche). In the case of China, the report notes that R&D offshoring is explained by the abundance of supply of high-level skills, universities which are motivated to pursue funding from firms, and the IPR agreements with universities. Asian-based GINs are also found to search for foreign contacts, inter alia, with leading universities and research institutes based in the USA and Europe. This is the case of China's Huawei (Ernst& Naughton, 2008) and Taiwan's TSCM (Ernst, 2009).

What is evident in this literature is an emphasis in the significance of universities and public research institutes in the formation of different types of GIN, but in a very specific perspective. The focus lies on firm strategy at the expense of a in-depth investigation of the nature of interaction or the role of universities in national systems of innovation.

2.2 References to International Networks in the Literature on Interaction

Ernst (2002) highlighted the change towards decentralization of R&D in the last decades, criticizing the literature on the national system of innovation for neglect of the international dimension. This is a very strong criticism. The international perspective is part of the elaboration of on the literature national systems of innovation (NSIs). Early studies emphasize the relative slower trend towards the globalization of technology, vis-à-vis finance and production (Cantwell, 1995; Patel, 1995).

Further investigation of the evolutionary literature also reveals, at least implicitly, the relevance of the international dimension. A key subject of evolutionary studies – catch up processes – stress the importance of international links and access to foreign knowledge. After all, science is international by definition (Zitt et al, 2004).

Every successful catch up process involves flows of foreign technology and scientific knowledge. Each country that emerged to technological leadership devised designed novel ways to access and use knowledge available elsewhere: Germany from UK; US from Germany; Japan from Germany, England and US; Korea from with Japan and US. In these processes, students were sent abroad, engineers hired to run new firms or start new faculties. These are some of various strategies to absorb knowledge from abroad (Nelson, 1993).

Other important studies have shown that changes in the international scenario impact the fate of NSIs. This is the case of the post-war USA, as well as the European and Japanese catch up suggests (Nelson and Wright, 1992). Studies of international alliances and cooperation also have shown how connections between different NSIs are established (Hagedoorn, 2002; Ostry and Nelson, 1995). The importance of scientific infrastructure to the attraction of foreign firms has been shown by Pavitt (1991).

Another study by Patel (1995) focused on the levels of and changes in foreign R&D of American MNCs. The study shows that the most internationalized firms were not high-tech, nor typically associated with global mandates. Patel argued that the firms with higher R&D intensity were internationalizing technological activity to a lesser extent, because production and R&D were required to be in close proximity to one

another. Patel's research is a useful identification of changes over time. Since 1995, as Ernst has argued, there has been a sharp rise of internationalization of high-tech sectors.

2.3. A framework of global interaction and the changing

In spite of the lack of attention on the nature of university-industry interaction, the existing literature suggests that GINs have two main drivers. First, are the multi-national corporations (MNCs) and their growing capabilities, technological and locational diversity, as they move across the world selecting locations and distributing productive and innovative labour. Second, the formation and growing complexity of national systems of innovation, especially in the developing world, is a process that goes far beyond the push of production and R&D towards new regions and sectors. One important engine of this process is the internationalization of science. The formation of national systems of innovation (NSIs) involves political forces that shape states and their autonomy, capabilities and public resources to generate and support their public institutions.

Therefore, there are two movements reshaping and reorganizing the international division of labour – both MNCs and national systems of innovation. This reshaping of the international division of labour, in turn, affects the internal decisions of MNCs and the actions of their subsidiaries, pushing further changes in the international division of innovative labour. The combination of these two drivers leads to a complex picture, where the nature of NSIs matters for the formation of global innovation networks, their main characteristics and the nature and scope of the international hierarchies established.

In order to bring these insights and fill the void in the literature, Albuquerque et al (2011) have proposed a tentative framework of global interactions between firms and universities that provides synthesis between the literature on GINs (Ernst, 2006; UNCTAD 2005; Dunning and Lundan, 2009) and the literature on interactions between firms and universities (Klevorick, et al., 1995; Nelson, 1993). The framework yields four main types of interaction, with variations depending on their home-base location. More complex are bound to types emerge over time, as NISs become more mature and MNCs strategies become more complex, and multiple types co-exist in any one period in a specific country.

The first type is characterised by local firms interacting with local and/or foreign universities. This type of interaction doesn't involve cross-border transfer of knowledge, but could represent the first step for a firm to become transnational. That is, it allows for an initial accumulation of knowledge and capabilities that supports a transition, since there is a deep correlation between transnationality and R&D-intensity (Caves, 1996).

The second type of interaction involves MNCs subsidiaries interacting with home country universities. This would be the typical relationship reported in the literature on internationalization of R&D. MNCs have connections with their home country universities, but the host countries either do not have R&D activities or the R&D activities are completely centralized at the MNC headquarters.

The third type of interactions in market may the emergence of local universities. In this type MNCs interacting both with home country and host country universities and research institutes. This would be the more recent pattern of interaction, which the literature identifies as a typical global innovation network. It suggests a broader division of innovative labour within the MNC, with the possibility of a subsidiary assuming contacts and creating new contracts with universities in the host country. The nature of this relationship will depend on the nature of the subsidiary's role within the MNC.

Hence, links may be established to enable limited adaptive activities or more advanced projects, which would involve joint R&D with local universities, sometimes in connection with foreign universities as well. The hierarchy and the decision-making about the specific roles of home-country and host countries R&D departments may vary deeply.

The fourth type of interaction characterises an international consortia between firms and universities. This involves the same actors, but they might be created and coordinated by the academic side of the interaction. Intergovernmental cooperation and international institutions, such as the World Health Organization could trigger this kind of interaction. They could be "mission-oriented" and necessarily non-hierarchical. They also could be a characteristic of a global innovation system.

The elaboration of these four main types attempts to summarize the full range of interactions, but they certainly do not cover all possibilities. Many real world cases would be mixed cases. However, taken independently, each type signalises varying degrees of maturity of NISs as well as different levels of complexity of MNCs innovative strategies. Hence, this framework provides a means of analysing existing cases of interaction, to evaluate the extent to which they involve global knowledge transfer and strengthening of national systems of innovation, and hence, contribute to reproduce or subvert global hierarchies.

The importance of firm-university collaboration both at the national and international levels has been extensively registered in the literature going as far back a Prager and Omenn (1980). More recently, a new wave of country studies can be found, particularly in developing economies. Evidence of universities supporting R&D of various types in the USA can be also found in the multi-sectoral analysis of Mansfield and Lee (1996). Interaction within national boundaries that may involve MNCs subsidiaries can be found in Suzigan et al (2011), Lee et al, (2009) and Kruss (2009).

OECD (2008b) research on Japanese TNCs and their networks with universities in China, India, Japan, and the US illustrates a different set of possible connections between MNCs headquarters, MNCs subsidiaries (including in the USA) and universities. Ernst's (2009) also brings a case of a MNC based in a developing country interacting with universities from advanced countries. Likewise, Azevedo (2009), Dantas and Bell (2009, 2011) analyse Petrobras, a large Brazilian state owned company wich collaborates with 70 universities and research centers abroad.

The role of universities as search mechanisms for local economies can be found in Evenson and Golling (2003). The diversity of forms of interactions between universities and firms may be further illustrated by the Chinese experience: as Eun and Lee (2010) has shown, academic-run enterprises and university-run enterprises are specific forms of relationship. Eun et al (2006) suggest that these modes of interaction are specific for a context of universities with stronger capabilities than firms. Financial conditions matter here, since universities have access to state and to township and village resources that may fund new firms that they create - but they do not spin-off. This Chinese specificity, as Eun and Lee (2010) explains, has historical roots that can be traced back to 1949, the foundation of PRC. Futher localised evidence is shown in the case of Lenovo, one of the Asian GINs studied by Ernst (2009), was created as university-run enterprise, showing how a firm spun-off from a local university. The variety of cases also shows that over time the roles of universities become more diverse (teaching in new areas, research in various directions, following diverse motivations, demands for advice for public policy and public health) - or what Eun et al (2006) call the universities capabilities development.

In spite of the multitude of case and country studies, cross-country evidence of university-industry interaction is scant, particularly when the emergence of international networks is considered. The next sessions present an exercise aimed at filling this gap using a custom multi-country dataset built as part of the INGINEUS project.

3. Data and Methodology

3.1 The INGINEUS Survey

The INGINEUS project sought to evaluate the extent to which innovation takes place in global networks which spread out through both developed and developing countries. A key component of the project was the development of a new dataset based on a customised survey questionnaire aimed at creating indicators which allowed the comparison industries across regions. In doing so, the dataset allowed a better understanding of how different levels of development of national systems provide support for distinct levels of firm internationalisation, which includes to role played by university industry interactions. [5]

The survey was conducted by research groups from nine countries, including Norway, Sweden, Germany, Estonia and Denmark in the developed world, and Brazil, India, China, South Africa in the developing world. By design, each country was assigned a single sector (ICT, automotive or agroprocessing), chosen based on its importance both at their national and regional contexts. In addition, the sectoral choices were based on the notion that the process of outsourcing knowledge-intensive activities as well as the emergence of knowledge creating activities outside the EU could be spreading from more advanced to more traditional sectors of developing economies.

Finally, in order to enable the identification of distinct realities, each sector was covered by at least a developed and a developing country. Agroprocessing was included in South Africa and Denmark, automotive in Brazil, Germany and a small sample from Sweden, and ICT was the subject in India, China, Sweden, Norway and Estonia.

Whereas in developed countries the surveys were national, in developing countries the surveys were regional due to both the countries geographical size and populational spread. In Brazil, the survey was restricted to the State of Minas Gerais, in which a representative share of the automotive sector is located. In China two regions were targeted, Beijing and Shenzen. In India, dense IT clusters were targeted in the cities of Bangalore, Delhi, Mumbai, Pune, Trivandrum, Hyderabad and Kochi. Besides the role of these countries the data can show the role of these specific sub national regions in the GIN's context. For example, the survey data provides information about the interactions between Minas Gerais automotive sector firms and local and foreign universities. The same information can be gotten for the regions surveyed in South Africa and China.Following a lengthy process to ensure sectoral compatibility (ISIC/NACE codes) and coverage across datasets, 1215 responses were obtained, most of which in the ICT sector. Table 1 below shows the country and sectoral breakdown of the responses.

Table 1: INGINEUS survey results breakdown

Countries	ICT	Auto	Agro
Brazil		69	
China	243		

[5] Complete information of the INGINEUS survey design and full set of results, see (2011a, 2011b).

Estonia	17		
Denmark			49
Germany		53	
India	324		
Norway	181		
South Africa			84
Sweden	171	24	
Total sector	936	146	133

Source: INGINEUS (2011)

The survey questionnaire consisted of 14 questions, many of each with multiple sub questions, which can be found in Table 2 below. Apart from the country in which the firm is based, question were selected to differentiate R&D intensity, internationalisation (measured by the offshoring of production or R&D), different types of interaction with local and foreign universities and research institutes, type of enterprise (local, subsidiary of a MNC, and headquarter of a MNC), and source of technology.

Table 2: Questions, variables and country codes used in the MCA

Question	Variable	Options
Country		1. Germany 2. China, 3. South Africa, 4. Sweden, 5. Denmark, 6. Brazil, 7. Norway 8. Estonia, 9. Sweden-Auto
3.3: Do you have significant R&D activity?	R&D	1.No 3. Yes
9.1: Regarding internationalisation, does your firm offshore (or has your firm offshored) production or any R&D activities?	Internationalization	1.No 3. Yes
8. Has your enterprise developed formal/informal linkages (e.g. research relationships) with the following kinds of foreign organisations?	Informal Interaction with Foreign Universities and Research Centers	1.No 3. Yes
	Formal Interaction with Foreign Universities and Research Centers	1.No 3. Yes
7. Regarding the development of the most important innovation of your firm in the last 3 years: who did you actively collaborate with and in which geographical location?	Interaction with Local Universities and Research Centers	1. No 2. Yes
	Interaction with Foreign Universities and Research Centers	1. No 2. Yes
2. Are You?	Type of Enterprise	1. A standalone Company 2. A subsidiary of a MNC 3. The Headquarters of a MNC
5. Which is the most important source of technology for your enterprise?	Main source of Technology.	1. We produce most technological inputs in-house 2. We buy most of our inputs from other branches of our own MNC 3. We buy most of our technological inputs from non-MNC firms 4. We buy most of our inputs from MNCs with which we are not formally connected 5. We buy most of our inputs from public-sector organizations, e.g. research institutes, universities etc.

Source: INGINEUS (2011)

3.2 Multiple Correspondence Analysis Method The objective of the exercise presented here is to evaluate the association between different types of collaboration between universities and firms, and other key characteristics of the respondent firms. The number of observations enables the search of patterns of association between the selected variables which can define distinct profiles related to each selected variable and characteristic, with special attention to the variable “country”.

To carry out the study, the Multiple Correspondence Analysis method was used. The technique is a multivariate statistical method which enables the test for the

existence of association between two or more categorical variables. Given the characteristics of the INGINEUS survey, the method is used as an alternative of exploratory data analysis. One of the key features of the Multiple Correspondence Analysis method is its geometrical approach, which leads to the creation of bi-demensional charts in which all the analytical categories created by the selected variables can be analysed. Hence, the technique transforms qualitative information available in a table in an instrumental chart, in order to make the analysis of data easier The display of categories related to observed variables on a correspondence graph allows us to evaluate their association in order to group the sample's observations into distinct profiles (Greenacre, 2005).

The analysis of these observations, described by a set of variables and their categories, will occur by reducing the dimensionality of the system so that information can be systematized in a plane (Greenacre, 1994). The graphical analysis of the association between variables is done through the representation in the space of dimensions that reflect their behaviour. The number of dimensions evaluated increases with the number of variables considered in the analysis. This makes the association of a large set of variables unfeasible to be observed. The Multiple Correspondence Analysis allows reducing the dimensions required for graphical display of a set of variables, eliminating such limitation. Thus, the method generates a smaller number of dimensions (usually two) that summarize the information present in the set of chosen variables.The method starts from an indicative matrix based on the data set that has the same number of rows as observations and the same number of columns as the categories of all variables observed. Based on this data, the main coordinates related to the rows and columns of the matrix wherein the data originates are calculated for each category of the variables. The coordinates will be obtained from linear combinations of original variables. These combinations are responsible for the synthesis of all information from the variable set into a fewer set of dimensions that can be displayed in a chart.

The criterion for comparison between any two categories, **j** and **k**, for the set of variables observed, is given by the chi-square distance between the points that represent the rows and columns of the indicative matrix, defined by $d2_{\mathbf{j,k}} = n[(n_{\mathbf{j}} - n_{\mathbf{j,k}} / n_{\mathbf{j,k}}) + (n_{\mathbf{k}} - n_{\mathbf{j,k}} / n_{\mathbf{j}}n_{\mathbf{k}})]$, being $n_{\mathbf{j,k}}$ a gross frequency of those individuals that have both categories **j** and **k**. The term $n_{\mathbf{j}}$ represents the gross frequency of individuals that have only category **j** and $n_{\mathbf{k}}$ represents the gross frequency of individuals that have only category **k** . The outcomes are coordinates of each category, which are displayed in a correspondence chart that shows the new dimensions created for the analysis, considering its association as defined by the chi-square distance between them. The proximity between the categories of the analyzed variables in the correspondence chart will determine the association between them. This association is used for the identification of profiles in which sample elements fit. The proximity of variables, or lack thereof, is used as a parameter to define profiles in which it is possible to fit the elements of the sample (Greenacre, 2005).

In spite of being relatively novel in economics, it is possible to find examples of this type of application for innovation studies. Tether e Tajar (2008), for instance, uses the same technique to identify different patterns of innovation in Europe based on a survey.

The exercise of the Multiple Correspondence Analysis used in this article was based on data drawn from the results of the survey conducted by the INGINEUS project, given 1215 observations, referring to the nine participating countries and the three sectors (agro, auto and ICT). Each country of the sample is associated with a specific sector, as mentioned above, except for Sweden that presents observations for

the automotive and ICT sectors. That is why Sweden will be discriminated in the following analysis according to these sectors (Sweden Auto and Sweden ICT).

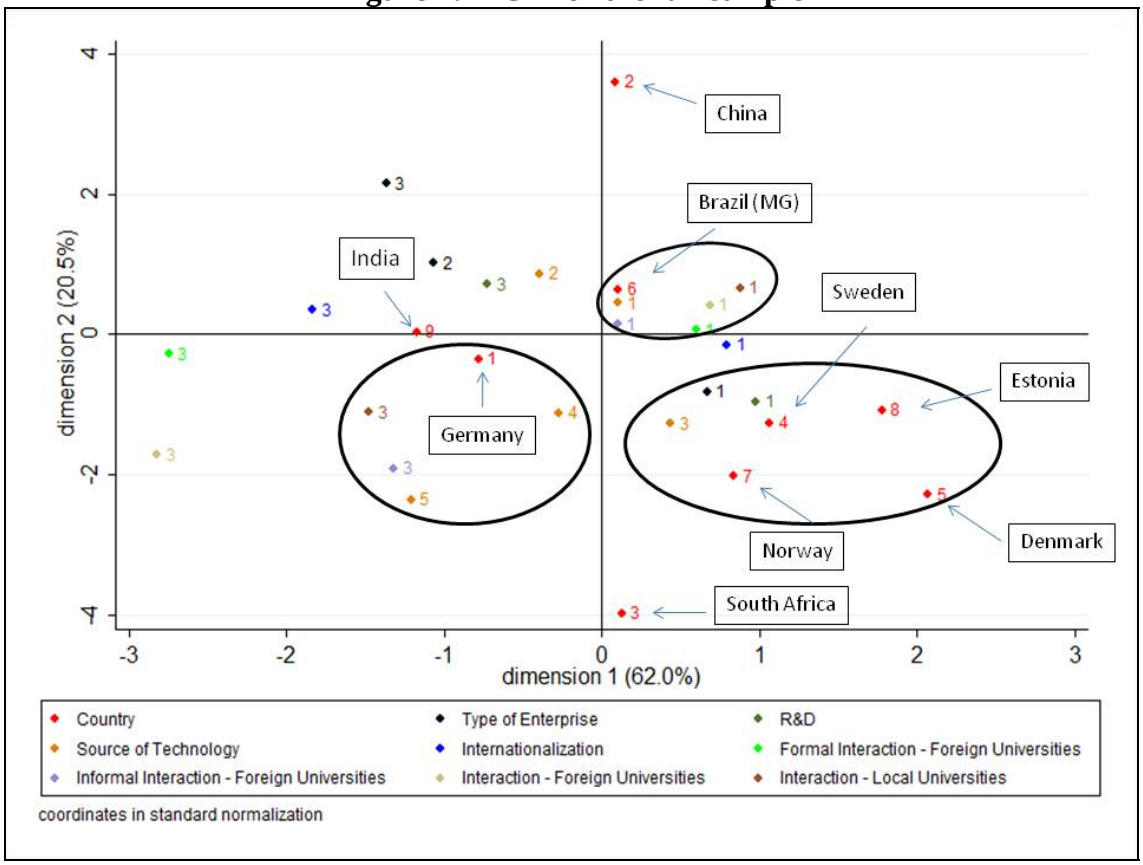
4. Results and Discussion

This section brings the results from the multiple correspondence analysis, which have been divided in two sets. The first represents the results for the full sample. In this exercise the objective is to test for the emergence of patterns in spite of the sectoral division of the survey. One caveat of this set of the results is the bias introduced by the ICT sector, which holds a significant higher number of observations in the dataset.

To circumvent this problem as well as to provide a clear analysis of the international insertion of the Minas Gerais' automotive sector, the second set of results is composed strictly for data regarding this sector. Through the MCA method it is done a comparison involving data from automotive sectors in Sweden, Germany and Brazil (Minas Gerais).

4.1 Full sample The first sets of results for the full sample can be found in Figure 1 below. It depicts a correspondence chart obtained from the MCA for all nine countries and sectors. Each axis represents a new dimension that summarizes the information of the set of variables, enabling their display in a simple bi-dimensional plane. Each variable is receives a distinct colour and number that represents one of the possible answers shown in Table 2. For instance, each bright red dot, numbered from (1) to (9), represent a country in the sample. Likewise, each black dot represents a type of enterprise, which can be either: (1) a standalone company; (2) a subsidiary of a MNC; (3) the headquarters of a MNC.

Figure 1: MCA for the full sample



In Figure 1, a profile is defined by a set of variables clustered together in one of the graphs quadrants. In most cases the profiles can be identified and interpreted given

that a group of variables is clustered near a country variable. For ease of exhibition each country has been labelled and each one of the profiles has been clearly circled.

The disposition of categories in Figure 1 allows us to define four different profiles, one in each of the chart's quadrants. The first profile (Profile 1) obtained, located in the first quadrant, is characterised by a pattern of low innovative effort (no local or offshored R&D), lack of interactions with local and foreign universities. The country more closely associated with firms that more frequently gave these answers together is Brazil. This result can be interpreted as a sign of relative weakness of the Brazilian NSI in which links between firms and universities are not well established. Another feature of this profile is related to the source of the technology used by firms. Firms within this profile tend to use technological inputs produced in-house, showing the association between the relative weakness of linkages with other universities is found alongside the relative lack of interactions with other actors within the NIS and even abroad.

In the same quadrant is possible to identity also the presence of China. However, the category that indicates this country in the chart is located in the extreme top of the quadrant and very close to the vertical axis. Given this position and the set of indicators chosen, it is not possible to associate this country to the other profiles obtained with the analysis. What can be said is that China displays a pattern that is completely different from the profiles arise from the MCA exercise.

In the third quadrant of the Figure 2 there is another clearly distinguishable profile. In this quadrant one can find characteristics that usually associated with more advanced NSIs. In Profile 2, it can be observed that the variable that indicate the existence significant R&D activities are close to the ones that indicate both formal and informal interaction with local and universities. The country more closely associated with this pattern of responses is Germany, depicted by the bright red dot labelled (1).

Two other key aspects of this profile are worth noting. The first is related to the source of technology used by firms. Firms within this profile also declared to purchase most of their technological inputs from MNCs with which they have no formal connections – i.e. MNCs which are not art of the firms production network – or from public-sector organizations, e.g., research institutes and universities. In addition, the profile is closer, albeit the distance indicates that this type of answer is not very frequent, to interactions (formal and informal) with foreign universities. The second aspect is associated with the type of enterprise. This profile is characterised by the dominance of firms which are either a headquarter or a subsidiary of a MNC over standalone companies, which are answers represented by the back dots numbered (2) and (3) ain the forth quadrant.

The disposition of variables in the third quadrant defines a profile of strong interactions between universities and research institutes and companies. These features are associated with a country with advanced NSIs, Germany. The combined analysis of Profiles 1 and 2 provides a key evidence for the association between significant R&D activities, procurement of technology from MNCs and from universities and research institutions, and formal and informal with URIs. In other words, different types of collaboration, technology procurement and firm type give rise to complex forms of GINs. What is more, the level of complexity increases as linkages with universities, local and foreign, become more frequent.

In the second quadrant of the correspondence chart it is possible to notice a profile formed by Norway, Sweden and Estonia. In addition to these, Denmark could also be included in the profile. Profile 3 is marked by a significant presence of local companies, no significant R&D, and the purchase of knowledge from other non-MNCs

as the main source of technology for the company. It is important to note that this result does not mean the absence of significant R&D being conduced by the respondent firms of these countries. It indicated that non-innovative companies are more frequent in the survey.

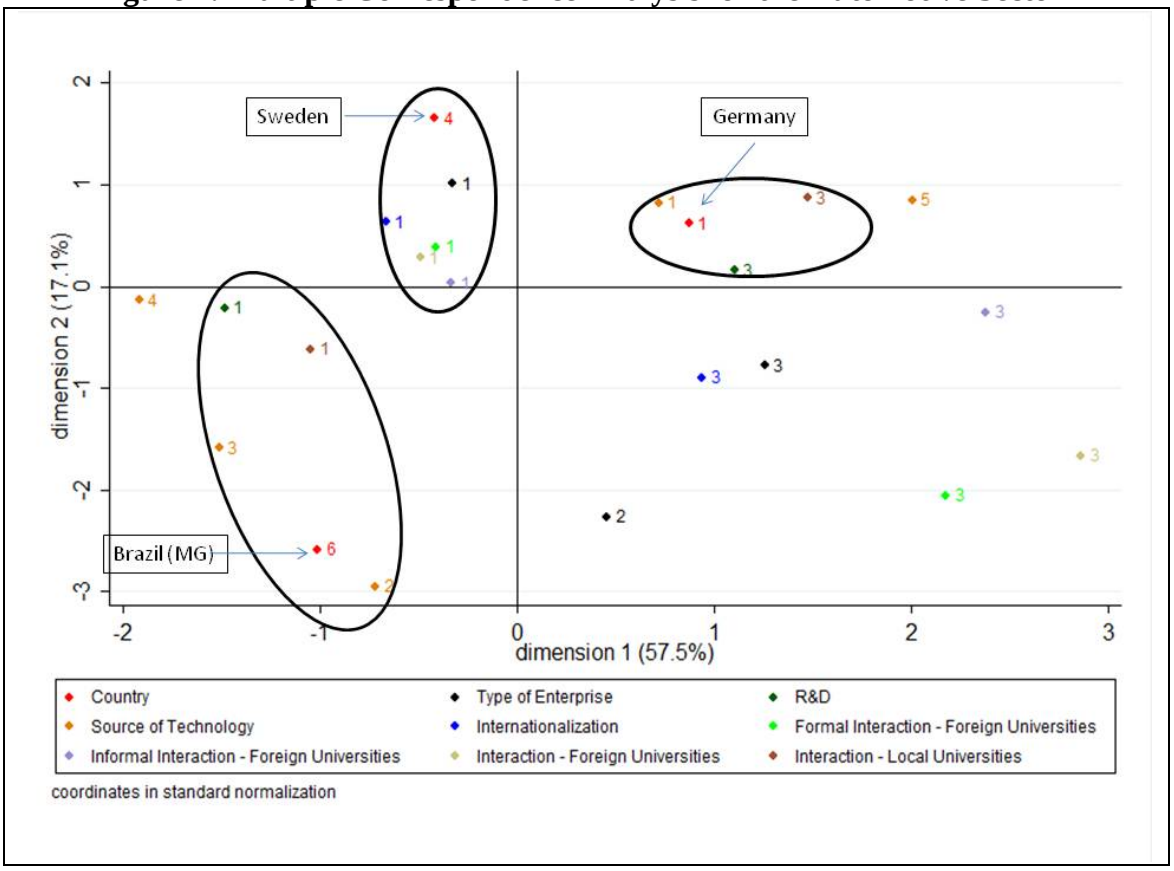
Still in the second quadrant, it is possible to identify the presence of South Africa, however it is positioned in the bottom of the quadrant and so near of the vertical axis of the correspondence chart. Like occurs with China, the position of this country in the chart shows the absence of a clear association between the variables chosen, indicating that the no single profile dominates the firms from this country.

In opposition to the cases above, in the fourth quadrant there is a set of variables that are closer to India. This profile might be characterized by the existence of headquarters and subsidiaries of MNCs, by the existence of significant R&D, and by the acquisition of technology from another branches of the same MNC that the company is associated. These are also companies which have declared to offshore production as well as R&D activities. All of these variables refer to large-scale companies. The position of India, which is only marginally in this country, indicates that a more complex situation may arise from the sectoral analysis. The distance also suggests that the largest firms may be associated with a country-independent profile.

4.2 Automotive Sector

The results for the automotive sector include Germany, Brazil, and Sweden. The sample for this exercise consisted of 146 observations. The correspondence Figure 2 below shows a clear distribution of the countries across the plane.

Figure 2: Multiple Correspondence Analysis for the Automotive Sector



The categories of the variable 'country' are clearly spread across the chart's quadrants, generating a profile marked by the presence of Germany; in the first quadrant, a profile

marked by the presence of Brazil, in the third, and a profile for Sweden, in the fourth quadrant. The second quadrant of the correspondence chart shows the association of a set of variables regardless of the variable 'country', i.e. which are frequently found together in different countries but are not the majority in the country in which they are located.

The first profile that can be assessed, whose main characteristic is the association with Germany provides the categories of the variables that indicate characteristics of a more mature NSI. It is possible to see in the first quadrant of Figure 2 the presence of interactions between companies and local universities. The variable "main source of technology" indicates that universities and research institutes as the main sources of knowledge as well as the company itself. These variables suggest that the companies located in Germany are capable of producing their technological inputs as wells as procure them from URIs.

The second profile observable is identified by the presence of Brazil. The profile is marked by the absence of interactions between firms and URIs. According the chart, firms acquire technological inputs from other branches of the MNC and from local companies. The purchase of technology from other MNCs is a feature that is also in the fourth quadrant of the chart.

In the fourth quadrant of Figure 2 there is a profile that all the variables are located almost near to the positive part of the vertical axis. This profile is identified by the presence of Sweden. The presence of the variable that indicates the occurrence of local firms (neither MNCs headquarters nor subsidiaries) and the lack of internationalization of R&D activities and production, suggest a pattern of companies of a smaller scale companies and a small international reach. The remaining variables indicate the lack of interactions with universities.

As previously mentioned, there a profile that is not associated with any specific country, in which it is possible to identify the positive categories for formal and informal interaction with universities and research institutes abroad and internationalization of R&D activities and production. It is also observed in the quadrant that defines this profile the categories that indicate the type of company as headquarters and subsidiary of MNCs. The presence of these categories classifies this profile by the presence of global companies that have formal and informal relationships with foreign URIs, and that have performed processes of internationalization of their R&D activities and production. It is clear that the variable 'country' is not an important variable to differentiate this profile of the others that have been obtained, as it does not integrate it into any of their categories.

5. Conclusions

The paper contributed to the literature on the emergence of GIN and to that of university-firm interactions by exploring INGINEUS' original survey. The use of Multiple Correspondence Analysis Method allowed us to identify clearly distinctive profiles for both the full dataset and the sector-specific samples, showing different country-specific patterns of association between the surveys variables.

The analysis for the full sample showed very distinctive patterns for countries with different levels of development, which are associated with NISs' of varying levels of maturity. The profile associated with Germany showed a pattern of significant R&D activities, simultaneously with formal and informal interaction with local and universities. Firms in this profile also declared purchase most of their technological inputs from MNCs with which they have no formal connections and from public sector organizations, e.g., research institutes and universities. Another profile, associated with

Brazil, was marked by weak innovative, lack of interactions with local and foreign universities, and procurement of technological inputs in-house. These profiles, taken together, show a close association between level of development of NIS, university-industry interactions and innovative effort.

The results showed that Norway, Sweden and Estonia formed a profile that suggests and intermediate level of NIS development. This profile was marked by a significant presence of local companies, no significant R&D, and the purchase of knowledge from other non-MNCs as the main source of technology for the company.

At this stage, the results for India, South Africa and China were not clear. The picture for some of these countries became clearer with the sector specific analysis. South Africa, for instance, appeared in a intermediate level in the exercise for the agroprocessing sector. In the ICT sector showed India in a profiled characterised by interactions between firms and universities and purchase of technology from another MNCs. In the case of China, however, the technique did not prove to be useful and firms from that country did not show a singular pattern that could form a profile.

The sectoral analyses also broadly confirmed trends found for the full sample for the automotive sector. Germany, when it comes to the university-company interaction, has shown results agreeing with what had been expected for more advanced innovation systems, whereas Brazil have shown some deficit in this matter. The European country stands as the one with the highest tendency of interaction in its automotive sector opposed to Brazil that is not associated with the variables that indicate the companies' relationships with the university system, whether on the inside or the outside. The companies surveyed in Brazil, all of them located in Minas Gerais state, are characterized for their dependence of technology developed abroad or purchased from other enterprises. It is also perceived that there is not an internal tendency related to the establishment of information flows between these enterprises and local or foreign universities. So it is possible to conclude that Minas Gerais' automotive sector still has not incorporated some important aspects to establish the necessary networks to engage in a GIN.

The exercise carried out in this paper opens the question as to why some forms of interactions with local and foreign universities can be found in some countries and not on others. The MCA analysis suggests that there is a case to be made regarding the influence of the level of development of NISs. Only two countries from the INGINUES survey, Germany and India, were in profiles that are, at the same time, innovative, connected with other partners, and show a degree of internationalisation. The first country has a notoriously well-developed NSI, the second a very large pool of qualified work for the ICT sector.

It is worth noting that all the results and interpretations can be only taken for this specific sample of companies in their respective sectors and countries. Even with a relatively high number of respondents, the survey is in not, with exception of Sweden, representative of the country sector. In addition, even though the multiple correspondence analysis provides a very effective means of interpreting a large number of answers at the same time, it also imparts a degree of bias when countries enter the sample as variables. Given that the number of firms from each country shows a high degree of variation, the position of each profile may be influenced by the high number of respondents in a particular country, even though the clustering of variables remains the same.

Regardless of this limitations, the exercise provided evidence for the importance of university-industry interactions and MNCs strategies in the context of the emergence of global innovation networks. The broad strokes of the picture painted by the profiles

can be further refined by case studies and larger surveys, both in terms of sample size and in terms of number of countries. Another fruitful avenue of research is the combined analysis the INGINEUS survey, CIS surveys and patent data.

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