Who are the world leaders in innovation? Exploring the changing role of firms in emerging economies

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Abstract: Recent literature shows that differences in structural characteristics at country level are important determinants of the innovative capacities and growth performance of different countries. Based on firm-level data collected from a survey, this study identifies who are the world leaders, followers, and marginalised firms in a sample of nine countries and a selection of industries in terms of firms' characteristics, the characteristics of the region where they are located, as well as the firm strategies to engage in global innovation networks. Our results, based on a small sample, show that some firms from emerging economies are among the exclusive group of world leaders and some firms from developed economies are among world followers and marginalised. Without attempting to generalise our results, the findings confirm the changing role of some firms in emerging economies from followers to world leaders in innovation.

Keywords: technology clubs; technological capabilities; region tier; global innovation networks; GINs; Europe; China; Brazil; India; South Africa.

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1 Introduction

In the last years there has been an increasing number of industry and firm-based cases suggesting that some firms from emerging economies are starting to upgrade capabilities and move up the value chain, from competing in costs to competing in knowledge and innovation (Altenburg et al., 2008; Pietrobelli and Rabellotti, 2009). A prime example in the information and communication technologies (ICT) is the embedded software cluster in Bangalore, India (Chaminade and Vang, 2008), and in the area of biotechnology the production of enzymes in India (Haakonsson and Ujjual, 2011). This new role of firms from emerging countries is changing the dynamics of production and innovation at a global scale). However, there has not yet been any systematic analysis of the main differences between three main groups of firms, world leaders, followers and marginalised in terms of innovation.

Hitherto, almost all evidence is based on the analysis of whole countries (Castellacci and Archibugi, 2008; Filippetti and Peyrache, 2011; Stöllinger, 2013; Kemeny, 2010; Fagerberg et al., 2007) or on one particular industry or region (Schmitz, 2007; Cusmano et al., 2010), while there are very few systematic comparative analysis of firms from different industries across the globe (Barnard and Chaminade, 2011).

What these macro level studies miss is the regional and industrial diversity. Regional disparities in terms of innovation are overwhelmingly high in most of the emerging economies and particularly in India and China. So, while the evidence at macro-economic level suggests that the level of technological capabilities and innovative performance of the emerging economies like China, India, Brazil and South Africa is still low, the disparity in terms of capabilities in firms, regions and industries may suggest that while the whole country may not be a world leader in terms of innovation, some firms in certain regions may be part of world level innovators.

Based on firm-level data collected during 2009–2010, this paper aims at identifying the micro, meso, and global characteristics of firms in three groups – world leaders, followers, and marginalised in innovation, in a sample of firms in four developed countries and five emerging or transition economies along three different industries, ICT, automotive, and agro-processing. The three industries have different technological capabilities, and respond to different dynamics regarding their innovation processes and scope of global innovation networks (GINs). This paper aims to address the following questions:

1 Can we find world leaders, followers and marginalised firms in innovation in developed and emerging economies and what are their main characteristics?

2 Can the micro and meso characteristics explain different patterns of GINs and innovation performance?

The remaining of the paper is structured as follows. In Section 2, we introduce the changing role of emerging economies in GINs and discuss the role of micro and meso determinants to access to GINs. In Section 3, we introduce the data set, the main variables and methods of analysis. Section 4 presents the main results, followed by conclusions in Section 5.

2 Theoretical framework

2.1 The changing role of technology clubs in innovation worldwide

Over the last two decades the literature on catching up has been dominated either by macroeconomists using country indicators and composites (Fagerberg et al., 2007; Castellacci and Archibugi, 2008; Castellacci, 2008; Kemeny, 2010) to monitor the accumulation of technological capabilities in different countries around the world and study the characteristics of technology clubs, or by development economists focusing on lead firms in global value chains, and upgrading in these value chains (Cusmano et al., 2010; Schmitz, 2007; Giuliani et al., 2005), often with a focus on particular industries.

At macroeconomic level, the empirical evidence suggests than none of the emerging economies are in the most advanced groups in terms of technological capabilities or innovation (Castellacci and Archibugi, 2008). Using composite indicators based on R&D expenditure, publications, patents, enrolment in tertiary education and communication infrastructure, Filippetti and Peryache (2011) show that most emerging economies –India, Brazil and South Africa – are still in the unbalanced technological catch-up group, while very few are in a balanced technological catch-up path – China, for example. While their advancement in terms of communication infrastructure, and knowledge and skills is impressive, they still show very poor levels of business R&D and patents. Stöllinger (2013) using also indicators on R&D expenditures, literacy rate and average schooling years portrays similar results, with most emerging economies like China, South Africa and Brazil in the imitation club, and India in the stagnation club due to the low literacy rate. Kemeny (2010) using an indicator that captures the country's technology level based on the goods it exports, concludes that the technological annual upgrading of China and India has not been up to the global standards and remain almost in the same club as in 1972, with China actually experimenting a 'quality downgrading' among the consistently exported goods. In a similar vein, Castellacci and Archibugi (2008) using indicators for technological infrastructure, human skills, and creation and diffusion of codified knowledge, argue that although China has cached-up technologically between 1990 and 2000, it is still in the marginalised group, characterised by low infrastructures and skills, and low innovation. What all these studies highlight is that China, Brazil and to some extent South Africa are better positioned than India, both in terms of technological capabilities as in terms of output,[1] but also that all emerging economies are still far from the most advanced economies in terms of innovation.

What these macro level studies miss is the regional and industrial diversity. Regional disparities in terms of innovation are overwhelmingly high in most of the emerging economies and particularly in India and China. In a recent study, Crescenzi et al. (2012) using regional data on patent intensity, share of R&D in GDP, and other indicators to capture structural features of innovation in a region, show that the innovation dynamics of Chinese and Indian regions differ substantially. While both countries show an increasing polarisation of innovation activities in certain knowledge hubs, the regional innovation dynamics in both countries is rather different. In China, the polarisation is driven by pure agglomeration economies and in fact has negative effects in terms of knowledge spillovers. In India, on the other hand, the innovative activities tend to concentrate in regions with good socio-economic infrastructures and high investment in science and technology (S&T) (at least in comparison with the rest of the country), and tend to generate positive knowledge spillovers. Regarding regional disparities in innovation capacity in China, Li (2009) shows that most of the differences in regional innovation performance are due to the business R&D expenditures, with some regions in China performing above the average like Beijing (Zhou and Xin, 2003), and some well below the average.

There are also significant differences in terms of the industry and the role that firms in emerging economies may play in global value chains or GINs in different industries (Aslesen et al., 2011). Borrás and Haakonsson (2011) and Haakonsson and Ujjual (2011), for example, document the upgrading trajectory of South African firms in the agro-food processing industry, and the prominent role that some firms play in the innovation network of world-leading Danish firms. Similarly, Cusmano et al. (2010) using a sectoral innovation system approach show that the new world producers have significantly upgraded in the wine producing industry globally by systematically investing in technological sophistication, standardisation but also by introducing marketing innovations. Altenburg et al. (2008) bring examples of the changing role of Brazilian firms in the auto global value chain, Chinese firms in the electronic global value chain and Indian firms in the software industry. The software industry in India is indeed one of the most documented cases when discussing technological upgrading and catching up by emerging economies (Altenburg et al., 2008; Chaminade and Vang, 2008; Parthasarathy and Aoyama, 2006). Not only Bangalore is considered to be the Silicon Valley of Asia (Saxenian, 2001, 2002) but also certain domestically owned firms like Wipro,[2] Infosys,[3] or TCS[4] are considered to be world leaders in the ITC industry (Parthasarathy and Aoyama, 2006).

So, while the evidence at macro-economic level suggests that the level of technological capabilities and innovative performance of the emerging economies like China, India, Brazil and South Africa is still low, the disparity in terms of capabilities in firms, regions and industries may suggest that while the whole country may not be a world leader in terms of innovation some firms in certain regions may be part of world level innovators. In addition, firms in these regions might be also shifting the competition and collaboration, both across and within national boundaries (Archibugi et al., 1999; Archibugi and Iammarino, 1999), while the engagement on GINs can support the upgrading of the level of innovation in emerging economies.

2.2 Modes of innovation and degrees of novelty

One of the challenges of scholars studying the technological capabilities of countries and their innovative performance is how to measure those capabilities and performance. Due to the limited availability of comparable indicators across the globe, most studies – like the ones cited in the previous section – end up using publications, R&D expenditure or education indicators to capture the innovative efforts, and patents to capture the innovative outputs. The later is particularly problematic for two reasons. First, patents are an intermediate output. They reflect the result of an invention but not necessarily a new product or process that has been launched in the market. Many patents never end up in new products. Second, not all industries have results that are patentable, so patents are a good indicator only for certain industries, and patent regimes differ across countries. New software development is an often cited example of an innovation which is not patentable in many countries. As a result, low patenting activity may reflect low innovation performance, but it may also reflect a specialisation in industries whose innovation is not patentable or a specialisation in types of innovations that are not patentable – for example, marketing innovations (Cusmano et al., 2010).

While it is almost impossible to find better indicators of innovation output at aggregated level, firm-level data can provide information on both the type of innovation as well as the degree of novelty. One of the most accepted definitions of innovation is that contained in the Oslo manual (OECD, 1992, 1997, 2005). The OECD distinguishes between technology and non-technology innovations. Technology innovations are related to new products (goods and services), and new processes (new or significantly improved methods of manufacturing and producing. Non-technology innovations are related to new or significantly improved logistics, distribution or delivery methods, and new or significantly improved supporting activities. Additionally, the OECD proposes to distinguish between three degrees of novelty of innovation, from new to the firm, to an intermediate level that is new to the market or industry and to new to the world as the highest possible degree of novelty. An innovation is new to the world if the firm has introduced a new or significantly improved good or service onto the global market before competitors. It is new to the market or industry if the firm is the first in that specific market or industry to have implemented it. It is new to the firm if the innovation was already available from its competitors in its market. These are the definitions of modes and degree of novelty of innovation that are used in this paper.

It has been generally argued that the proportion of firms introducing innovations that are new to the firm versus new to the world varies significantly between developed and developing countries. Also it has been argued that modes of innovation might also vary between developed and developing countries. Whilst firms headquartered in the North are implementing most of the new to the world product innovations, the product innovation in the South is often behind the technological frontier. It is mainly imitative innovation, therefore more related to the acquisition of technology developed somewhere else and adapted to the local needs than to the development of new products (Bell, 2009; Bell and Pavitt, 1993; Kim, 1997; Hobday, 1995) thus process innovation, and non-technological innovation are more important in developing countries. The OECD broad definition of innovation has an advantage over previous definitions, as it is able to capture innovations that are not strictly technological innovations which could be extremely important for the performance of firms in developing countries – like marketing or organisational innovations.

Lall (1992) and Bell (2009) have expressed the importance of increasing the developing countries' scientific and technological capabilities for creating new knowledge, and shaping the technologies they use which is critical for innovation and catching up. This premise is based on the discussion that developing countries are not only adopters of technology, but also adopt and are able to improve technologies and innovate. The Sussex Manifesto (Bell, 2009) emphasises that all countries possess indigenous knowledge, which provides an important base for catching up. In this regard we discuss some of the most important determinants for innovation in the next section, we focus on the role of firms' technological capabilities and the importance of the region from a regional innovation systems perspective as determinants to engage on GINs.

2.3 Determinants of innovation performance

Firm level characteristics – firm level characteristics are important determinants for innovation performance. Firm level characteristics can be grouped in structural – such as firm size, ownership and industry – and behavioural characteristics – such as R&D, innovation performance and openness strategies (Laursen and Salter, 2004). These characteristics have been considered as important determinants of innovation performance at firm level.

Firms' expenditure in R&D and innovation activities, the number of employees engaged in R&D and innovation, and the firm's openness strategy – have long been considered as determinants of firms' technological competences and innovative performance (Alcácer and Chung, 2003; Chudnovsky et al., 2008; Escribano et al., 2009; Giuliani, 2003; Ivarsson and Göran, 2005; Marin and Bell, 2006; Vera-Cruz and Dutrénit, 2005). Investments in R&D as well as in training are positively associated with the ability to generate innovations, as well as the capacity of the firm to absorb innovation developed somewhere else (Cohen and Levinthal, 1999).

Modularisation of production and to some extent innovation activities have played a key role to enable firms in developing regions to adopt standardised knowledge and technology, and facilitate the design and knowledge intensive activities along the value chain and to perform different activities in different locations that contribute to a particular product or service (Ernst, 2003; UNIDO, 2004). But, the firm needs to have the ability to manage and integrate these geographically dispersed sources of knowledge (Zander, 1999), and sometimes this ability to coordinate is linked to firm size and ownership. Some authors (Vonortas, 1997) find that size is related to the propensity to engage in R&D activities and cooperate in research. Others (Kleinknecht and Van Reijnen, 1992) find positive evidence only in the relationship between private firms and research organisations but not with regards to research collaboration with other agents. Firms' ownership has also been linked to the propensity to engage in innovation activities and in collaborative research where most of the empirical work points out that firms with foreign ownership have a higher propensity to engage in innovation activities (Crespi and Zuñiga, 2012).

Firms collaborate with external organisations to share and build new knowledge, thus we can argue that the engagement on global networks is central for firms' technological capabilities. Archibugi and Mitchie (1995) indicate that firms and other organisations may engage in innovation activities globally in different ways (modes), according to their main purpose and strategy. Firms may be willing to exploit internationally the technology produced on a national basis (global exploitation), develop a new innovation through global technological collaborations (global collaboration), or by locating R&D subsidiaries in other countries to take advantage of the host-country or host-region competences (global generation). These three modes of engaging in GINs[5] reflect two broader strategies, namely knowledge exploiting and knowledge seeking, which in turn are related to the level of firms' technological capabilities. At the same time, both, the exploitation and seeking strategies have a positive impact in the innovative performance of firms.

Regional context – the structure and dynamism of regions influence the innovation possibilities of firms located there at least in two ways (Chaminade and Vang, 2008; Giuliani, 2005). The institutional framework and the dynamics in terms of networks among agents and knowledge flows are important determinants for absorptive capacity, and the innovative potential that exist in a region (Malberg and Maskell, 2006; Asheim and Gertler, 2005; Cooke, 2001; Saxenian, 1994). Regions with strong systems of innovation may facilitate collaboration and generation of new knowledge, fostering innovation within that region both in developed (Asheim et al., 2007) and emerging regions (Chaminade, 2011a). Furthermore, as regions differ in terms of institutional endowment and innovation dynamics, some regions are more attractive for the location of R&D and other innovation related activities, acting as magnets for the location of firms in specific sectors, creating a virtual circle for innovation. Furthermore, recent evidence suggests that the institutional thickness of a region in a particular industry, rather than the country is directly related to the propensity of the firms to engage in GINs (Chaminade, 2011b; Tödtling et al., 2011). Chaminade and Plechero (2015) argue that firms need regular access to knowledge produced outside the organisation, and if that knowledge is not available within regional boundaries, firms would identify and access that knowledge by engaging in GINs. Based on this discussion, the engagement in GIN does not only depend on firms' technological capabilities and strategy, but also on the regional set-up. According to the discussion on regional systems of innovation (RSI), they can be thick or thin based on the institutional set-up, the dynamics in terms of networks among agents, knowledge flows, and the innovative potential that exist in a region (Asheim and Isaksen, 2002). Therefore, we expect the thickness of a RSI to impact firms' innovation performance and engagement in GINs.

3 Methodology

3.1 The data

This paper is based on a survey that was conducted across nine countries – Brazil, India, China, South Africa, Norway, Sweden, Germany, Estonia and Denmark; and three sectors – automotive, ICT and agro-industry, in the framework of the INGINEUS project. The survey for each country focused on either ICT, automotive or agro-industry.[6] ICT firms dominated the sample. This was in part due to the size of the Indian and Chinese markets, but also due to the nature of the agro and auto industries, which tend to be more concentrated. A detailed methodology report (European Commission, 2009a) summarises the main challenges encountered in this first attempt at gathering internationally comparable innovation data not confined to developed countries. Due to the novelty of the dataset and the potential sample selection and non-response biases involved, any analysis using it must be considered exploratory and findings interpreted first and foremost as indicative of patterns and relationships in need of further quantitative as well as qualitative investigation.

The selection of firms was based on existing datasets, i.e., statistics Sweden or the German commercial database Hoppenstedt. In emerging economies there was the need to combine existing databases to have more complete and up-to-date information, i.e., in Brazil the database of the automotive union SINDIPECAS, the official Annual Registry of Social Information (RAIS), and information from large automotive firms about their suppliers were used to compile a sample frame.[7] All databases were filtered to ensure that firms with five or more employees were contacted.

The information gathering also took place in a variety of ways. In countries with a culture of participating in surveys – like the Scandinavian countries, firms received a link to the questionnaire and answered it online. In the middle-income countries, data gathering was done by telephone or through face-to-face interviews. Table 1 indicates that 1,215 responses were collected in total and the response rate varied across countries. Answering the survey was not mandatory and there might be a bias in the response rate towards firms that either are more active innovators or firms that establish more global networks, thus the sample may not be completely representative of the firms population in terms of size, ownership, innovation performance, and organisation forms which might influence the results of the analysis.

Table 1 Distribution of countries, ownership and sector

Countries	*Standalone*	*Subsidiaries*	*Headquarters*	*ICT*	*Auto*	*Agro*	*Total*
Brazil	23	19	2	243	69	80	
China	97	58	66	17			
Estonia	13	4	0	324			
India	167	106	50				
South Africa	49	14	0				
Total emerging economies	349	201	118	584 (5.34%)	69 (25.9%)	80 (16.9%)	737 (6.32%)
Denmark	34	7	1	181	53	49	
Germany	29	10	4	171	24		
Norway	112	8	7				
Sweden	169	20	5				
Total high-income countries	344	45	17	352 (11.05%)	77 (6.18%)	49 (23.2%)	478 (10.59%)
Total	693	246	135	936	146	133	1,215

Notes: Number of responses and response rates in brackets.
Missing observations in the ownership of companies across different countries.

Source: Based on Barnard and Chaminade (2011)

Despite the limitations of the sample, we deem it adequate for the type of research questions investigated in this paper. We did not attempt to investigate the extent of the phenomenon but if there were new to the world innovators in emerging economies and, if so, what were the micro and meso characteristics that could explain this innovative behaviour.

The survey captures information about structural characteristics of the firm, such as size, industry, specific activities, and the main functions performed by the firm; and behavioural characteristics regarding innovation, such as input and output measures of innovation activities, including different forms of technological and non-technological innovation and degree of novelty. Additionally, the survey provides information on the strategies to access international markets in terms of innovation. Further information was gathered to generate an original variable that indicates the regional thickness in terms of innovation systems for that particular industry and region.

More than half of the firms in the sample are standalone companies (681), about 250 are subsidiaries of a multinational company, and 133 are headquarters of MNC. About 46% of the firms have less than 50 employees, 30% have between 50 and 250, and the rest have more than 250 employees. Only 100 companies have more than 1,000 employees. In terms of innovation, 49% of firms engage in innovation activities and 25% offshore production or innovation activities.

3.2 Indicators

We combine three techniques to identify the groups of world leaders, followers and marginalised in innovation, and their main characteristics. First, we select a set of indicators related to firms' structural and behavioural characteristics, regional set-up and extent of GINs to perform a factor analysis to extract a smaller number of factors. These factors will provide sufficient information to perform a cluster analysis that helps us to identify different groups of firms regarding their innovation performance. A third step in our methodology consists on running a multinomial logit model to assess the validity of our group classification. The following variables are considered for the analysis:

Firms' structural characteristics – type of firm (MNC, subsidiary or standalone company), firm size, and industry have been found to be important determinants for innovation performance. Regarding the type of firm, different works (Blomström and Kokko, 2003; Girma and Görg, 2005) claim that foreign direct investment brings positive benefits associated to higher knowledge, thus we argue that foreign ownership has a positive effect on firms' innovation intensity. We include a question that identifies if the firm is a standalone company, a subsidiary of a MNC, or the headquarters of a MNC. Type of firm is represented by a categorical variable that equals one when the firm is a standalone, two when is a subsidiary, and three for the headquarters. Several scholars have claimed the importance of firm size for innovation activities (Cohen and Levin, 1989; Benavente, 2006), larger firms are more prone to benefit from economies of scale related to production and R&D; they also benefit from a larger pool of human resources. We asked firms to indicate the number of full time equivalents breaking down the options by firm size categories, 10 to 49 employees, 50 to 249 employees, 250 to 999 employees, and more than 1,000 employees. We include firm size as a categorical variable that goes from one to five, indicating the number of employees (*size*).

Firms' behavioural characteristics regarding innovation – R&D activities, full time employees performing R&D, and innovation output have been important variables to identify firms innovation intensity. There is a consensus that indicates that firms investing more on R&D activities have higher innovation rates and also higher levels of productivity (Crépon et al., 1998; Crespi and Zuñiga, 2012). We asked in the questionnaire if the firms had significant R&D activity. We use a dummy variable that equals one if the firm performs R&D activities. Innovation output actually indicates the number of innovations that a firm has developed in certain period of time. Past innovation output is also a predictor of future innovation performance. We asked firms if they experienced innovation during the period of 2006–2008 asking to differentiate between type and level of innovation. For type of innovation firms had to identify four forms of innovation: product, service, process and support. We considered three degrees of novelty: new to the world, new to the industry and new to the firm. We built a categorical variable capturing the degree of novelty for the different types of innovation (*InnovLevel*).

Strategies of GINs.[8] Forms of engaging in international or global networks can also represent important determinants of innovation activity (Fitjar and Rodríguez-Pose, 2013; Laursen and Salter, 2006). We asked firms to identify their largest markets and the regions of these markets (exploiting strategy). We also asked firms if they offshore production or innovation activities. And finally we asked with whom they collaborated actively in the development of their most important innovation in the previous three years and where the partners were located. For global exploitation of innovation we rely on a five dummy variable that indicates if the firms' markets are global. For global collaboration of innovation we used a dummy variable that indicates if the firm has collaborated with partners abroad. For global generation of innovation we used a dummy variable that equals one when the firm offshore production or innovation activities, the survey did not collect information to identify where did the firm offshore production or innovation.

In terms of the *region*, several studies that focus on the analysis of GINs have discussed the importance of the regional characteristics as attractors of global networks (Chaminade and De Fuentes, 2012), but also have discussed that if regions do not have the right mix of organisations with high quality to establish networks, probably those firms with higher absorptive capacities will be attracted to engage in global networks (Chaminade and De Fuentes, 2012; Chaminade and Plechero, 2015; Laursen et al., 2011).

Following the previous work by Chaminade and Plechero (2015), we have categorised regions thickness in region tier 1, region tier 2 and region tier 3. This characterisation is based on the industry dynamism, but also on the regional thickness of a particular region for a particular sector. To define the three Tiers we combined quantitative (when available) and qualitative information about the innovation dynamics of the regional system of innovation (RSI) and their institutional thickness. The European Regional Innovation Scoreboard 2009 (European Commission, 2009b), which classifies European regions according to different indicators of regional innovation performance, was used as a proxy for evaluating the degree of innovation dynamics of some of the regions. To capture the organisational structure of the RSI we used the number of firms in a particular sector and region, number of employees, and in some cases the volume of exports by industry compared to the average of the country when that information was available. This latter information was used as a general proxy for assessing the organisational infrastructure of the region, and together with the innovation dynamic indicators are the only pseudo-quantifiable measure we can consider. Qualitative information was also collected through literature review, cluster reports and consultation with country experts involved directly in the INGINEUS project. Basically, regions with the highest regional innovation dynamics, highest concentration of educational facilities, firms and employment in the specific industry and region, with frequent interactions and a strong identity in that particular industry and region were considered as tier 1. Regions with an average number of firms and employment in that industry respect to the country, with some specialised supporting institutions and with less strong linkages, culture and shared norms were classified as tier 2. Those regions that have not or little specialisation in that particular industry, and/or with a weaker institutional setting or weaker innovation dynamics compared to other regions in that country were classified as tier 3. The final classification of the tiers for each region was checked once again with industry experts in each country. Table 2 indicates the number of firms by country included in each regional tier.

Table 2 Distribution of firms by country in regional tiers

Country	*Number of firms tier 1*	*Number of firms tier 2*	*Number of firms tier 3*
Brazil	18	50	1
China	147	50	46
Denmark	10	37	0
Estonia	14	3	0
Germany	22	20	10
India	50	235	30
Norway	105	58	13
South Africa	27	27	20
Sweden	75	33	87
Total	468	513	207

Source: Authors based on information contained in INGINEUS data (2008)

From our sample, we have complete information to analyse 944 firms, 78% of the total from the original database. Table 3 presents the descriptive statistics for the variables used for the factor analysis.

Table 3 Variables included for the analysis

Variables	*Description*	*Obs.*	*Mean*	*St. dev.*	*Min*	*Max*
	Structural characteristics					
Type	Categorical: 1 = standalone; 2 = subsidiary; 3 = headquarter	1,074	1.480	0.708	1	3
Size	Categorical: 1 < 10; 2 = 10–49; 3 = 50–249; 4 = 250–999; 5 > 1,000	1,061	2.767	1.153	1	5
	Innovation intensity and output					
R&D activities	Dummy: 1 if the firm has significant R&D activity; 0 otherwise	1,134	0.529	0.499	0	1
Innovation level	Categorical: 0 = none; 1 = firm level; 2 = industry level; 3 = world level	1,215	1.581	1.151	0	3

Table 3 Variables included for the analysis (continued)

Variables	*Description*	*Obs.*	*Mean*	*St. dev.*	*Min*	*Max*
	Global innovation networks					
Global exploitation	Dummy: 1 if the firm's markets are global in scope; 0 otherwise	1,080	0.301	0.459	0	1
Global links	Dummy: 1 if the firm establishes links with external organisations at a global level; 0 otherwise	1,215	0.658	0.474	0	1
Offshoring	Dummy: 1 if the firm offshores production/innovation activities; 0 otherwise	1,036	0.297	0.457	0	1
	Regional tier					
Region tier	Categorical: 1 = first tier; 2 = second tier; 3 = third tier	1,188	1.780	0.721	1	3

4 Empirical analysis

4.1 Factor analysis

We used eight indicators to identify the characteristics of innovation among the firms in our sample. We identified those indicators based on previous studies that focus on the analysis of collaboration to foster innovation. Structural factors related to firm size and type of firm, behavioural factors related to innovation decisions (De Fuentes and Dutrenit, 2012; Laursen et al., 2011), and the extent of global networks for exploitation, collaboration, and generation (Barnard and Chaminade, 2011; Chaminade and Plechero, 2015). Regarding the characteristics of global networks they indicate that a firm with more global networks will be able to have higher rates of exploitation, but also will be able to access more diverse sources of knowledge. In this regard with the data available we are able to identify the level of global integration and the extent of this global integration per firm.

The variables that we used for the factor analysis indicate firm's structural factors, behavioural factors related to innovation, the nature and extent of global integration, and the thickness of the region where the firm is located, indicated by the region tier variable.

We performed a factor analysis to reduce the number of variables by grouping them in the right association. Tables 4 and 5 indicate the results of the factor analysis using the method of maximum likelihood. We generated three main factors, which explain the 100% of the variance in the sample.

Factor 1 is mostly related to firm behavioural characteristics regarding innovation. This factor loads high in the variables related to firms behavioural characteristics for innovation. The factor analysis illustrates that the variables that indicate if the firm performs R&D activities, and the variable that indicates the level of innovation are closely related in factor 1. This we can suggest that factor 1 is a broad measure of behavioural factors regarding innovation. Factor loads for performing R&D activities are 0.66 and for innovation level is 0.59. Factor 1 account for 41% of the variance.

Factor 2 includes the variables that indicate firm's structural characteristics regarding the type of firm and firm size. Factor loads for type of firm are 0.50 and for firm size is 0.63. Offshoring of production and innovation is also correlated to factor 2. Factor loads for this variable are 0.38. Factor 2 accounts for 37% of the variance, and 78% of the cumulative variance.

Factor 3 includes the variables that indicate global exploitation and the regional tier where the firm is located. Factor loads for global exploitation are 0.53 and for region tier are 0.31. Factor 3 accounts for 21% of the variance, and 100% of the cumulative variance.

Table 4 Rotated factor loadings (pattern matrix) and unique variances

Variable	*Factor 1*	*Factor 2*	*Factor 3*	*Uniqueness*
Type	0.195	*0.505*	0.024	0.706
Size	0.136	*0.633*	0.142	0.560
R&D activities	*0.662*	0.176	0.086	0.523
Innovation level	*0.592*	0.105	0.052	0.636
Global links	0.255	0.195	0.213	0.852
Offshoring	0.269	0.385	0.286	0.698
Global exploitation	0.167	0.243	*0.530*	0.632
Region tier	–0.200	–0.104	*0.317*	0.849
Variance	1.051	0.954	0.540	
Difference	0.097	0.414		
Proportion	0.413	0.375	0.212	
Cumulative	0.413	0.788	1.000	
Log likelihood:	–4.900			
Schwarz's BIC	153.918			
(Akaike's) AIC	51.800			
$chi^2(28) = 843.59$ Prob > $chi^2 = 0.000$				
$chi^2(7) = 9.74$ Prob > $chi^2 = 0.203$				
Number of obs: 956				
Retained factors: 3				
Number of params: 21				

Notes: Factor analysis/correlation. Method: maximum likelihood. Rotation: orthogonal varimax.

Source: Authors based on information contained in INGINEUS data (2008)

Table 5 Factor rotation matrix

	Factor 1	*Factor 2*	*Factor 3*
Factor 1	0.691	0.640	0.336
Factor 2	–0.716	0.537	0.446
Factor 3	0.105	–0.549	0.829

Notes: Factor analysis/correlation. Method: maximum likelihood. Rotation: orthogonal varimax.

Source: Authors based on information contained in INGINEUS data (2008)

Table 6 Group (cluster) membership

Cluster	*Frequency*
1 (Marginalised firms)	300
2 (World followers)	417
3 (World leaders)	227

Source: Authors based on INGINEUS data (2008)

Table 7 Cluster characteristics

	Cluster 1 marginalised	*Cluster 2 followers*	*Cluster 3 leaders*	*Total firms*
Agro	42	25	12	79
ICT	225	357	194	776
Auto	33	32	21	86
A standalone company	247	273	75	595
A subsidiary of a MNC	44	8	98	220
Headquarters of a MNC	9	66	54	129
Fewer than 10 FTE	64	51	2	117
10 to 49 FTE	122	168	34	324
50 to 249 FTE	75	120	73	268
250 to 999 FTE	33	59	59	151
1,000 or more FTE	6	19	59	84
R&D activities	60	277	199	536
No innovation	86	30	10	126
Firm level innovation	119	112	34	265
Industry level innovation	45	126	63	234
World level innovation	50	149	120	319
External linkages	196	316	217	729
Collaboration country	159	277	168	604
Collaboration regional	114	176	139	429
Collaboration global	90	172	187	449
Domestic market	141	271	29	441
Regional market	92	80	5	177
Global market	58	60	192	310
Offshoring	29	94	168	291
Region tier 1	1	346	26	373
Region tier 2	155	71	158	384
Region tier 3	144		43	187
Brazil	13	8	5	26
China	39	144	34	217
Denmark	21	3	6	30
Estonia	2	12	11	14
Germany	6	20	144	37
India	76	60	9	280
Norway	32	69	6	110
South Africa	22	25	12	53
Sweden	89	76		177
Total firms	300	417	227	944

Source: Authors based on INGINEUS data (2008)

4.2 Cluster analysis

To identify the group membership of the firms in our sample, we used a technique of cluster analysis by K-means, which groups each observation according to the most similar characteristics to other observations. Cluster analysis by K-means performs non-hierarchical k-means, grouping cases based on their proximity to a multidimensional centroid. Thus, this technique groups the firms with more similar characteristics. We used the three factors obtained from the factor analysis to build clusters of firms regarding their structural characteristics, behavioural characteristics regarding innovation, extend of global networks, and regional thickness. We input the three factors to run a cluster analysis by k-means. This section presents the results of this cluster analysis that divides the firms into three main categories that indicate their innovation intensity.

We identified three main groups of firms in our sample with particular characteristics. Cluster 1 contains 300 firms, cluster 2 contains 417 firms, and cluster 3 contains 227 firms. The three clusters differ in terms of the degree of innovation novelty, from no innovation to world level innovation, thus we label the different groups in marginalised firms (cluster 1), world followers (cluster 2) and world leaders (cluster 3). Table 6 presents the distribution of firms in each group (cluster), and Table 7 presents the main characteristics for each cluster along the different dimensions analysed.

4.2.1 Marginalised firms (cluster 1)

We find most of the non-innovative firms in cluster one, 31% of the firms in our sample. We have labelled them Marginalised firms – as they are falling behind in terms of performance of innovations. Firms in this cluster are incremental innovators; most of the firms in this cluster report firm level innovations, only a very small number of firms show industry or world level innovations. These results can be related to the low level of R&D activities that report firms in this cluster.

Typically, a firm in this cluster will be a small standalone company located in a tier 2 or tier 3 region. An important percentage of firms from the automotive sector in Brazil (50%), agroindustry sector in Denmark (70%) and South Africa (42%), and from the ICT in Sweden (50%) fall into this category.

Most of the firms in this cluster have a clear domestic (47%) or regional (31%) orientation in terms of their markets. A small number of firms export to global markets (19%). In terms of collaboration, most of the firms in this cluster collaborate at country (53%) or regional (38%) level. However, about half of the firms in this cluster establish external linkages with different agents. Regarding offshoring, this is the group of firms that offshore less production and innovation activities (10%). These results suggest that firms in this cluster follow exploitation and knowledge seeking strategies at domestic and regional levels, which suggest that they have not developed the sufficient capabilities in order to exploit their technologies at a global level or identify and establish collaborations with global partners.

Surprisingly, we found a large percent of these firms located in Sweden, and 70% of the sampled firms in Denmark belong to this cluster. Also, an important percent of firms from developing countries fall into this category, i.e., 50% of the firms in Brazil.

4.2.2 World followers (cluster 2)

Firms in cluster 2 are identified as world followers in innovation, about 44% of the firms in our dataset belong to this group. This cluster has the second largest percentage of firms (35%) that have introduced new to the world innovations, also a high percentage of firms (30%) have introduced industry level innovations. A typical firm in this cluster is either a small and medium size standalone firm or a company headquarter. Geographically, they are located mainly in tier 1 (346) and tier 2 (71) regions, those are thicker regions in terms of the institutional set-up, and RSI. Interestingly enough, none of these firms are located in tier 3 regions.

An important percentage of firms from the ICT sector in China (66%), Norway (63%), Sweden (43%), and Estonia (86%); from the automotive sector in Germany (54%); and from the agroindustry sector in South Africa (47%) fall into this category.

Even though a large percentage of those firms establish global networks for collaboration (41%), we can observe stronger collaboration networks within the same country (66%) or region (42%). Regarding market exploitation, we observe that a higher percentage of firms in this cluster have mainly a domestic market (65%). We also observe that a small percentage of firms in this cluster have offshoring of production/innovation (23%). However, firms in these regions tend to establish formal or informal linkages with other organisations external to the firm (76%). As suggested by other authors (Barnard and Chaminade, 2011) there seems to be a trade off between innovation and internationalisation. The more innovative the firm is, the more local and regional its networks are, and results from this analysis confirm this same pattern. Additionally, the high percentage of local and regional networks can be explained for the location of firms in tier 1 and tier 2 regions with an important infrastructure set-up, these results confirm those by Chaminade and Plechero (2015).

4.2.3 World leaders (cluster 3)

About 24% of the firms in our sample belong to this group which includes the largest proportion of new to the world innovators. A typical firm in this cluster would be a medium or large size subsidiary or a standalone company. The majority of firms in this cluster are located in tier 2 (158) regions. A very high number of firms within this cluster perform R&D activities (87%), and almost the totality of firms would have performed innovations at different levels (95%).

An important percentage of firms from the ICT sector are located in India (51%), and from the Automotive sector in Germany (29%).

Firms in this cluster are specialised on international markets; as they exploit their technologies in global markets, collaborate in global networks and offshore production and innovation activities. Firms establish global collaboration networks (82%), but also collaboration networks at regional (61%) and country level (74%). Regarding exploitation of innovation, most of the firms in this cluster exploit their technologies in global markets (85%), while domestic and regional markets are not as present as global markets. It is important to note that this cluster has the highest percent of firms that offshore production and innovation activities (74%). These results suggest that firms in this cluster are highly internationalised, and the strategy of generation and collaboration networks is broad, benefiting from global knowledge, but also from country and regional networks, which might contribute to their innovative performance.

The location in tier 2 regions might explain the high rate of global collaboration of firms in this cluster. But our results also suggest that firms in this cluster have reached certain level of absorptive capabilities to identify and establish networks with global agents.

4.3 Regression analysis

We perform an econometric regression to identify the most important components for each of the clusters analysed and to test the robustness of the results presented in the previous section. We run a multinomial regression model, this method estimates the strength of the association between the independent variables and dependent variables. Thus, the results express the fit of the cluster model. The econometric model is estimated as follows.

$$clus_i = x_i b,\ j_{i1}, \ldots j_{in} + e_i$$

Where the dependent variable is the classification of groups (clusters). This is a categorical variable that takes the values of

1 for marginalised

2 for world followers

3 for world leaders.

The set of independent variables expressed as x_i are those factors identified in the factor analysis. We run two econometric models, the first one considers the factors generated during the factor analysis, factor 1 (behavioural), factor 2 (structural), and factor 3 (global exploitation and region tier), these are continuous variables. The second model accounts for the specific variables that were entered in the factor analysis model. These variables indicate firm type, firm size, performance of R&D activities, innovation level, external links, offshoring of production and innovation activities, global exploitation and the region tier where the firm is located.

The multinomial logit model produces n – 1 estimates in terms of the dependent variable. In this case, the model estimated two binary models, one for world followers (cluster two) and world leaders (cluster three). These results are relative of the reference cluster, in this case the Marginalised (cluster one). The multinomial regression model only outputs the results for two estimates. We tried by selecting the different clusters as reference clusters, and the results are not affected, we choose to keep the marginalised cluster as reference. The results of the model are presented in Table 8.

Table 8 Results of the multinomial logistic regression

Variables	*Model 1*		*Model 2*	
	Cluster 2 (followers)	*Cluster 3 (leaders)*	*Cluster 2 (followers)*	*Cluster 3 (leaders)*
F1 (firm behavioural characteristics)	2.880***	4.132***		
	0.224	0.378		
F2 (firm structural characteristics)	1.722***	4.916***		
	0.239	0.441		
F3 (firm's geographical spread)	–3.758***	3.469***		
	0.326	0.572		
Type			5.780***	10.23***
			1.163	1.926
Size			2.955***	10.39***
			0.77	1.9
R&D activities			19.78***	27.57***
			3.394	4.898
Innovation level			6.776***	6.922***
			1.213	1.23
Offshoring			3.330**	19.35***
			1.563	3.511
Global exploitation			–23.68	19.83***
			1.682	3.627
Region tier			–51.36	–10.55***
			1.682	2.022
Constant	0.883***	–2.558***	62.45	–68.65***
LR $chi^2(6)$	1327.93		1944.47	
Prob > chi^2	0		0	
Log likelihood	–344.16064		–35.889489	
Pseudo R^2	0.6586		0.9644	
Observations	944		944	

Notes: Standard errors in parentheses.
***p < 0.01, **p < 0.05, *p < 0.1.

The results from the multinomial logistic regression indicate that the three factors are significant to the clusters analysed. In particular the behavioural factor (factor 1) and the structural factor (factor 2) correlate in a positive way to world followers and world leaders. These results suggest that larger firms have a higher likelihood to be classified as world leaders or followers in terms of innovation, confirming the findings of previous similar studies (Crespi and Zuñiga, 2012). Also firms that perform R&D activities or that have innovation outputs in the past are more prone to be classified as world leaders or world followers in terms of innovation, confirming the results by Crespi and Zuñiga (2012).

Regarding geographical spread of innovation activities, our results indicate that the world followers do not engage as much in GINs, while the world leaders engage more in GINs. Looking at the results in model two to identify the specificities of GIN and its effects on the clusters, we identify that world followers and world leaders offshore production and innovation activities at different levels, but the differences arise in terms of exploitation of innovations, world followers (cluster two) do not export globally as much as the world leaders (cluster 3). Another important difference that contributes to the discussion made by Barnard and Chaminade (2012) and Chaminade and Plechero (2015), indicates that the regional context matters for the establishment of GINs, as firms in region tier 1 tend to establish less global networks. While firms located in region tier 2 and region tier 3 might establish more GINs following a global strategy for knowledge seeking and knowledge exploiting, as suggested by Chaminade and Plechero (2015).

5 Conclusions

The main aim of his paper was to investigate if there are world leaders, followers and marginalised firms in terms of innovation worldwide, and contribute to the discussion of technology clubs trying to assess that firm's characteristics, regional thickness, and the extent of GINs matter for classification.

Our initial hypothesis was that firms located in developed countries were grouped in clusters with world level innovations and more domestic and regional networks; while firms located in developing countries tend to be grouped in clusters that present firm or industry level innovations and more international networks to compensate for lower domestic capabilities.

Our results suggest that the type of country *per se* is not a determinant of innovative performance, or of a specific mode of international spread of innovation activities. We argue that different factors are important determinants of innovation performance, such as firms' structural characteristics, firms' behavioural characteristics, the region in which the firm is located, but also the mode of GINs that firms engage with. Clearly, world leaders and followers are mainly located in thicker regions, such as region tier 1 and region tier 2, and the marginalised group of firms is mainly located in tier 3 and some in tier 2 regions. This result contributes to the findings by Barnard and Chaminade (2011), Chaminade and Vang (2008), and Saxenian (1994) as we argue that regions with stronger infrastructure and linkages among agents (tier 1) are important determinants for innovative firms, but also for the mode of globalisation of innovation (Chaminade and Plechero, 2015). Firms in cluster one (marginalised) show lower levels of innovation and are mainly located in tier 3 regions, collaborate more with regional and local partners, which suggest that tier 3 regions are not thick enough in terms of the organisational infrastructure, and linkages that support innovation in firms. This also affects the exploiting strategy, as firms located to cluster 1 focus more on local markets than on global markets. These results suggest that firms that belong in cluster one do not have high levels of absorptive capacities to identify and establish networks with global partners. This argument requires further work to identify the level of absorptive capacities in firms that belong to cluster 1 located mainly in tier 3 regions. Policy implications here are two-fold, on the one hand it is necessary to foster firms' absorptive capacities as a first step to increase innovation performance and to promote collaboration with global partners. On the other hand, it is necessary to promote effective measures to foster regions, the organisations within those regions and linkages between organisations.

Firms that are world leaders and world followers located in tier 1 and tier 2 regions engage more in global innovation activities. In particular, the world leaders use extensively global exploitation strategies and global seeking strategies. Engaging in this type of GINs seems to play an important role in the innovation performance at firm level. Thus, we can argue that group (cluster) membership depends on a complex interaction between firm's characteristics, regional thickness and the strategy and ability to engage in GINs. In particular, we observe that global exploitation and sourcing strategies seem to matter for higher levels of innovation output.

From our sample we can argue that the most dynamic sector in terms of innovation intensity and globalisation of innovation is ICT. The specific characteristics of this sector play an important role to foster firm's technological capabilities in emerging economies and to link global activities among firms. The global activities among firms and actors in this specific sector have established a specific dynamism that foster technological capabilities at firms in developing countries and increases the innovation performance. In this sense, our results confirm the findings by the development literature in terms of upgrading value chains in emerging economies by accessing global networks (Giuliani et al., 2005; UNIDO, 2004). However, firm and sector characteristics play an important role for each specific dimension of globalisation of innovation.

As any exploratory analysis using novel, dedicated survey data, ours is characterised by important limitations. The most important ones relate to the sampling procedure and low response rate achieved in some of the countries and sectors. A second limitation is the cross-sectional nature of the data, which does not allow us to capture changes over time on the innovation performance of the firms considered leaders, followers or marginalised.

Unfortunately, there is little reason to expect that quantitative innovation data of sufficient quality and geographical coverage will be available in the near future. The value of our study is therefore linked to the exploratory purpose that it serves, as providing some first evidence of the role of firms located both in developed countries and in emerging economies as innovators worldwide.

Further research will need to deepen the analysis of particular characteristics of firms in each country located in each cluster, in order to better identify if globalisation of innovation is driven not only by MNC from developed countries, but also by standalone companies located either in developed countries or emerging economies.

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Notes

1 A conclusion also shared by Altenburg et al. (2008).

2 http://www.wipro.com.

3 http://www.infosys.com.

4 http://www.tcs.com.

5 GINs are defined in this paper as a "Globally organized web of complex interactions between firms and non-firm organizations engaged in knowledge production related to and resulting in innovation" (Borrás et al., 2009).

6 Sweden had both auto and ICT surveys.

7 See http://www.ingineus.eu/UserFiles/INGINEUS_D2.2_MethodologyReport(1).pdf (accessed 1 December 2011) for more detail about the data gathering process.

8 In this paper, we do not make a distinction between global and international. Both terms are used to refer to partners abroad.