8 PRODUCTION *IN* INDIA TO INNOVATION *FROM* INDIA: THE EVOLUTION OF R&D OFF-SHORING IN THE INFORMATION AND COMMUNICATIONS TECHNOLOGY SERVICES INDUSTRY

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Abstract: As the economic dependence of advanced industrial economies on agriculture and manufacturing declines, scholars posit an international division of labor wherein advanced economies innovate to create a range of services, by drawing on high-skills and demanding users, while emerging economies undertake labor-intensive, and relatively low-wage and low-skill production. However, as the world's largest exporter of software services, India departs from this stylized model. While India's insertion into the international division of labor as a producer of custom software was driven by the availability of low-wage (even if high-skill) labor, this paper will describe the transition to being a part of global innovation networks. The paper draws on case-studies of four firms in India to illustrate how they are changing their position in the ICT industry to work more closely with customers in response to two forces: first, the growing importance of the organizational specificities of technology adoption among users and, second, the increasing emphasis placed on open/user-led innovation, especially at the "bottom of the pyramid". The case-studies will explore the changing organizational logic and structure of firms with the globalization of innovation, and the resulting knowledge flows as they become part of new networks.

Keywords: India, Global Production Networks, ICT, Software Services, User-led Innovation, Global Innovation Networks

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8.1 From manufacturing to services: a one-way street for innovation?

As the economic dependence on service grows at the expense of agriculture and manufacturing, especially in advanced industrial economies, Chesbrough (2011) argues that approaches to innovation must change. He suggests that treating every business as a service is the best way of dealing with the commoditization of products and the drift of production to low-wage locations (emerging economies). "The route to prosperity for advanced companies and advanced economies lies in services and rethinking business to innovate and build them." (p.2) Chesbrough calls on innovators to work with producers and suppliers and co-create with customers the range of services they seek.

Chesbrough's general argument about the importance of services is evident in Cusumano et al (2006) who extend the product-process life cycle model by proposing a service life-cycle model. In the service life-cycle model, firms differentiate themselves in markets characterized by product commoditization by seeking revenues from the sales of services, or products sold with services. This shift in the source of revenues for firms making products often demands capabilities, such as consulting or systems integration, which differ from traditional production activity. Cusumano (2008) applies this framework to the information and communications technology (ICT) industry and shows that services increasingly provide three important sources of revenue for software producers: through new customers, new delivery models and new revenue models.

Whereas Chesbrough posits a division of labor in which firms in advanced economies innovate by providing services, even as emerging economies undertake production, Cusumano does not specify any spatial division of labor in the shift toward services in the ICT industry. But, in the ICT industry, the spatial division of labor has departed from Chesbrough's model as the Indian case attests. The Indian software services industry grew every year from 1985-86 to 2008-09, from US$81 million in 1985-86 to US$58.7 billion, with more than three-fourths of those revenues coming from exports.[1] Along the way, India also became the world's largest exporter of software services.[2] As Section 3 describes, this growth happened as the industry in India integrated itself into global markets, initially by offering custom software development before moving to technology support and consulting. The early competitive advantage of the industry in India came from relatively low cost but skilled labor.[3] But the fortunes of the industry are no longer tied to low wages and India is increasingly a location for innovative activity.[4] This evolution of the ICT service industry in India raises the following question: how does entry into Global Production Networks (GPNs) on the basis of services evolve to a position in Global Innovation Networks (GINs)?

[1] www.nasscom.in.

[2] http://web.worldbank.org/WBSITE/EXTERNAL/NEWS/0,,contentMDK:22151486~menuPK:34463 ~pagePK:34370 ~piPK:34424~theSitePK:4607,00.html).

[3] One indicator of skills availability is the annual output of graduates with a Bachelor's degree in engineering. This outpur grew from 247 at the time of independence in 1947 to 237,000 in 2006 (Banerjee and Muley 2009:9). The figure for the US in 2006 was 104,200 (*ibid.*:31).

[4] By 2006-07, R&D services accounted for 15.7% of India's ICT service exports (www.nasscom.in). More broadly, India claimed half the R&D projects destined to Asia-Pacific in 2005 (IBM-BLI 2006). There is also a shift in perception: about 29 percent of respondents to a survey by the World Investment Report 2005 identified India as the third most attractive R&D location, after China and the US (UNCTAD, 2005).

8.2 Seeking an explanation for the Indian ICT services industry

The literature on the geography of innovation highlights the importance of understanding demand side forces instead of placing the burden of the explanation entirely on supply-side forces such as skilled labor. As Storper (2009) points out, innovation tends to agglomerate in specific "geographical contexts". Explanations for agglomeration include the drive to minimize the costs associated with non-routine transactions that characterize the development of new products and services (Scott, 1988), to gain access to the tacit knowledge (Gertler, 2003), and the networks of trust that are critical to such development (Saxenian, 1994). Akin to co-creation, a long-standing literature has emphasized producer-user interaction (Lundvall, 1988) and user-led innovation (von Hippel, 2005). Consequently, most inter-firm innovation takes place among domestic firms for products and services targeted at their own home markets (Håkansson, 1989). In the case of software, Egan (1997) shows how the US packaged software industry has drifted away from regions where the computer manufacturing industry is dominant to regions with a concentration of the leading firms in user industries.

To examine the role of demand in the transformation of the ICT industry in India, this essay will examine the changing division of labor of the ICT industry. Figure 1 shows how the technology architecture of contemporary ICTs can be understood as a series of horizontal layers. The lower the layer, its "world view" will more likely be limited as it is built on an intimate knowledge of hardware platforms such as computers or communication channels. Conversely, higher layers are less dependent on the hardware and more concerned with details native to the application because the lower layers give them that freedom. The architecture has two roles. It not only influences the technical attributes of a system, but also gives intellectual control by:

"….allowing us to substitute the complex with a set of interacting pieces, each one of

which is substantially simpler than the whole. The prudent partitioning of a whole into parts is what allows groups of people - often groups of people separated by organizational, geographical, and even temporal boundaries - to work cooperatively and productively together to solve a much larger problem than any of them would be capable of individually. It's "divide and conquer" followed by "mind your own business" - that is, each part can be built knowing very little about the other parts - resulting in "*e pluribus unum*." (Bachmann et al, 2000:1).

This layering will provide the framework to understand the activities of four firms with a presence in India - Infosys, Cisco, Nokia Siemens Networks (NSN), and Siemens. As Figure 1 shows, each of these firms occupies different layers. Sections 4 to 7 of this paper will describe how, despite their different product and service offerings, common to these firms is the effort to stretch their capabilities to reach the customer directly, thereby integrating India into GINs.

Figure 1: **ICT Architecture and the relative positions of firms**

Layer	Function	Infosys Existing capabilities	Infosys GIN strategy in India	Cisco Existing capabilities	Cisco GIN strategy in India	NSN Existing capabilities	NSN GIN strategy in India	Siemens Exisitng capabilities	Siemens GIN strategy in India
7 Customer									
6 Application	Domain specific services	Customised IT Solutions and Technology Services				OSS and BSS for service providers			
5 Development Tools and Middleware	Languages and methodologies to build applications							Solutions for energy, healthcare and transport sectors	
4 Database	Data retrieval and management		Co-creation and ecological integration using middleware frameworks such as cloud computing, mobility, and business analytics		Develop partnerships with domain specialists and Systems Integrators to enable total solutions based on IP based Services		Managed Services based in partnership with ISPs and Global Network		Products for the next 4 billion, based on designs developed in collaboration with the users from emerging markets
3 Connectivity and Network	Internet protocols and voice/data transfer								
2 Operating Systems	Hardware Software interface			Network hardware and operating systems		Telecommunications switching		Industrial automation and controls	
1 Equipment (Hardware)	Physical storage, computing and networking								

The effort to reach the customer will be explained as an outcome of two forces that India's technological capability and service industry has ridden on. The first is the changing approach to technological adoption. Following the invention of the microprocessor in 1972, the availability of increasingly more powerful and inexpensive hardware triggered the personal computer (PC), networking, and the internet revolutions in the 1970s, the 1980s and the 1990s respectively. While early adopters of these general purpose technologies had an opportunity to rework their business to gain competitive advantage, the increasing affordability and accessibility of technology made the deployment of ICTs just another aspect of doing business and a prerequisite to compete in the market (Carr, 2004). As ubiquitous technology made information availability less of an issue, what differentiated users was not the adoption of ICTs *per se* but the organizational means of adopting technology. This required the producers of ICTs to be more sensitive to user and customer needs, which typically vary by domain and geography. The paper will use the Infosys and Cisco cases to understand how they work in India to meet the needs of customers.

Second, with a demographic shift in advanced industrial economies and demand saturation, other markets, especially the estimated four billion consumers with the lowest incomes at the 'bottom-of-the-pyramid' (BoP), are becoming attractive (Prahalad, 2006). The BoP is a potentially vast and yet largely untapped market, as the majority owns few consumer products. But there are challenges when entering the unfamiliar operating conditions in this market as infrastructural inadequacies, socio-cultural diversity, and affordability, mean that existing metrics for 'lead' users do not work. Consequently, needs are hard to identify, and technological solutions difficult to conceive, for researchers in the affluent world. In this regard, India's size, a hard-to-match economic and social diversity which translates into diversity in the demand for products and services, and the availability of technical skills, make the country a unique location for research and development (R&D) as the NSN and Siemens cases will describe.

After explaining how and why production *from* India is giving way to innovation *in* India, the paper will close by reflecting on the Indian case. In particular, the concluding section will discuss the changing organizational logic and structure of firms with the globalization of innovation, and the shifting knowledge flows as they become part of new networks.

8.3 The entry of India into the GPNs of ICT services

Until the 1980s, the Indian ICT industry functioned within the confines of an autarkic, public-sector enterprise dominated, import-substitution led industrialization (ISI) model that was inimical to innovation. The highlight of the period was the Government of India (GoI) forcing IBM to shut its operations (Grieco 1984). Following IBM's departure, the initiatives by many of its former employees created a domestic software industry in the private sector (Subramanian 1992).

Meanwhile, an independent global software industry grew following IBM's decision in 1969 to sell software separately instead of bundling it with hardware (Campbell-Kelly, 2003). The decision was crucial as it gave customers the option of buying their software and hardware from different vendors since IBM, at that time, commanded two-thirds of the world's computer market. Subsequently, the technological revolutions since the 1970s led to a proliferation of computer usage, creating a huge demand for software. However, software production is craft-like and labor intensive, relying on trial and error to achieve its goals, and is plagued by uneven productivity and quality (Brooks 1995). The absence of any 'silver bullet' to overcome this 'software bottleneck', and the inability of software producers in advanced economies to deploy enough software professionals to work at relatively low wages, created opportunities for countries like India (Parthasarathy, 2000).

The demand for skilled labor coincided with a supportive policy environment in the 1980s. Two key initiatives were the Computer Policy of November 1984, and the Computer Software Export, Development and Training Policy of December 1986 (Subramanian, 1992). The 1984 policy gave the software industry various incentives and made software exports a priority. The 1986 policy aimed at increasing India’s share of world software production by giving the industry independence, with the government stepping in to only provide infrastructure and to play a promotional role. Overall, this policy was an explicit rejection of ISI and the ideology of self-reliance in the software sector.

Despite the initiatives, exporting in this phase typically involved little more than bodyshopping, or the practice of providing inexpensive on-site (i.e. at customer locations overseas) labor on an hourly basis, for low value-added programming services such as coding and testing. The drawback with this practice was an underutilization of the skills of well-trained professionals, many of whom tended to quit seeking technically more challenging and better paying jobs once sent overseas (Heeks, 1996). The high turnover only reinforced the tendency of Indian firms to compete on the basis of low costs rather than being able to fall back on a repository of technical and managerial expertise acquired from previous projects.

To overcome this problem, the GoI established the Software Technology Parks (STPs) in 1990 as export zones dedicated to the software industry, offering data communication facilities which firms that use to offer offshore services, i.e. service provision from India, instead of having to work at customer sites overseas.[5] In 1991, the year after the STPs were established, there was a major shift in economic policies, including devaluation of the Rupee, trade liberalization and duty rationalization, openness to foreign investment, and a new industrial policy that removed entry barriers for new firms, a process that is still underway.[6]

The shift to offshore services in a more liberal economic environment marked the beginning of a new relationship between the Indian software industry and global markets.[7] Reinforcing the policies initiatives since 1984 that facilitated the new relationship, was the serendipitous benefits conferred by the availability of a labor pool familiar with the operating system Unix. As Unix had a profound impact on almost every commercial operating system since it was first developed in 1969 (Salus, 1994), Indian programmers entered the 1990s in a position of special advantage (Udell, 1993).

It was against the backdrop of such conscious efforts and unforeseen benefits that STPs transformed the industry in the 1990s, and the share of offshore services in software exports increased from 5% in 1990 to 38.62% in 2000-2001 (Parthasarathy, 2010). Software factories emerged in India, with the infrastructure, technology, quality processes, productivity tools, and methodologies of the customer workplace. According to Arora and Asundi (1999), acquiring industry-accepted quality certification norms and an on-going commitment to quality, is a means to get bigger projects and

[5] For details of all the benefits offered by STPs, visit www.stpi.soft.net.

[6] For details of these policy changes, see Acharya (2002) and the essays in Oman (1996).

[7] According to NASSCOM (www.nasscom.in), the share of software in Indian exports grew from 1.9% in 1994-1995 to 24.6% in 2006-2007. Rising software exports also helped increase India’s share of world exports from 0.5% to 1.1% between 1985 and 2005. See http://indiabudget.nic.in/es2007-08/chapt2008/tab75.pdf.

more profitable turnkey contracts.[8] Obtaining turnkey contracts forces firms to develop substantial management skills, as they have to coordinate a wider range of tasks than just programming, and take responsibility for the overall project schedule, quality and productivity, in contrast to bodyshopping, which is little more than resume selling.

Not only did some Indian firms get better work at better rates, but they also began to move away from competing on hour-based productivity to intellectual property (IP) rights based productivity, by converting knowledge gained from custom projects in domains, such as banking or telecommunications, to a customizable generic product for customers with similar needs. Apart from the shift to offshore services by large Indian firms, the liberal economic climate of the 1990s also witnessed an influx of multinational corporations (MNCs), including IBM's return, to establish offshore development centers (ODCs). The ODCs capitalized on the communications infrastructure at the STPs and on Indian skills.

Despite the transformations in the Indian software services industry in the 1990s, the dominance of exports indicated that most firms addressed overseas markets and their ties were to customers and other firms in the main market. As a result, there was little interaction among firms locally, thereby limiting innovation. Confidentiality clauses in export contracts typically limited the ability of Indian firms to subcontract work locally. As for MNC ODCs, although many were developing new products and technologies for their parent bodies, they were often reluctant to share proprietary technologies and had almost no local ties.

The turn of the millennium, however, led to a qualitative transformation in the activities of firms in India. Facilitating this shift, ironically, was the global slump in demand for ICT products following over-investment in the 1990s.[9] Despite this slump the Indian software industry and exports continued to grow after 2001. Enabling the growth were the efforts by firms worldwide to control costs by outsourcing, not just software but everything from R&D services at one end of the skill spectrum to business processes such as voice-based customer support centers (call-centers) at the other (Srinivas and Jayashankar 2002). Another enabler was a deepening of the labor market. Following the global demand slump, NASSCOM estimates that approximately 35,000 professionals returned to India, mostly from the US (Singh 2003). Of the returnees, an estimated 10%-15% had been abroad for at least 10 years. How these factors led to the integration of firms in India into GINs is explored in the four case studies.

8.4 Infosys: from services to Infosys labs

Founded with US$250 in 1981 by seven people, Infosys grew to a US$4.8 billion firm in 2009-2010, employing 113,796 employees mostly offering custom software development, maintenance, re-engineering, IT infrastructure services and business process outsourcing.[10] But, since the 1990s, Infosys has faced the growth pressures of a software services firm that deployed labor intensive

[8] The norms include the as the ISO-9001/9000-3 standards prescribed by the International Standards Organization, and the Software Engineering Institute's five-level Capability Maturity Model (SEI-CMM), to codify quality procedures in the development process.
[9] For instance, in the US, spending on IT, after growing by 16% in 2000, fell by 6% in 2001 (*Economist* 2002) and, in aggregate terms, technology spending declined from nearly 5% of GDP in 2000 to about 4% by 2003 (*Economist* 2003).
[10] www.infosys.com.

processes in mature technologies and markets.[11] As client-server technologies gave way to internet technologies, customers began to ask, 'how do we leverage these technologies' instead of saying, 'this is what we were doing, help us doing this'. In other words, while technology was available to anybody, the critical issue was how best to exploit it. As a firm that is in the business of helping customers exploit technology, believing that "technology is not the only differentiator, but technology is the key differentiator", Infosys had to identify emerging technologies, select the ones with promise, and devise innovative applications of those technologies for customers. Thus, there was a need to prepare for customers and their context with the necessary IP i.e., instead of being a "reactive problem solver", the firm had to be a "proactive problem definer." It was such reasoning that led to Infosys Labs being established in 2000, to focus on market creation based on new technologies, instead of delivering products and services with existing technologies like other parts of Infosys. Infosys Labs aims to make itself an integral part of the service chain that firms depend to run more efficiently and to deploy new products and services.

There are three aspects to Infosys Labs' working with customers to help them reinvent themselves and stay competitive. One aspect is building 'tomorrow's enterprise', which is about the changes that organizations should make they decide on their strategies. The second aspect is operations, where Infosys Labs ensures the process efficiency of, say, Business Process Outsourcing organizations, by linking business goals, predictive models and day-to-day activities with real time data.[12] The third aspect is innovation to help clients develop offerings with their customers in mind. This is not merely

> "….about the clients deciding okay, these are the products I want to do, [or] in case of an IT organization, they might just decide, 'this is an IT system I want….and you help me with that,'….that's what was called development. But lots of R&D companies, when they decide on a new product and want to take it to the market,….say, 'I have decided to build this product, help me with that.' We call it product engineering."

The technological underpinnings of product engineering at SETLabs are cloud computing, mobility, and business analytics. These provide a horizontal foundation (middleware) on which diverse domains such as banking, insurance, retail, manufacturing, and healthcare, can erect their layers. For instance, mobile banking[13] solutions are built on top of the platform mConnect, which is a context-aware, real-time enterprise middleware that enables mobile services for websites and eCommerce platforms.[14] The idea is that customers from domains such as banking should not spend their resources looking at mobility; rather, they are better off devising ways to exploit mobility in their business. While Infosys Labs provides the technology foundation, it works with consultants from the industry business units of Infosys for domain expertise.

In its efforts to build "tomorrow's enterprises", Infosys Labs has increasingly relied on the concept of "co-creation", whose premise is that "innovation is no longer possible within the four walls" of any organization but lies at the intersection of disciplines, technologies, domains, markets, and

[11] Unless otherwise mentioned, this section draws from interviews with Subrahmanyam Goparaju, Vice President and Head, Infosys Labs and Manish Srivastava, Principal Architect, Microsoft Technologies, Infosys Labs, Bangalore 26 July 2010.

[12] http://www.infosys.com/investors/reports-filings/annual-report/annual/Documents/Infosys-AR-10.pdf

[13] http://www.infosys.com/finacle/solutions/solutions-mobile-bank-in-a-box.asp

[14] http://www.infosys.com/offerings/products-and-platforms/mconnect/pges/index.aspx

people. [15] As part of the co-creation process, Infosys Labs runs workshops with customers to identify problems of interest, and to seek out new initiatives and product ideas. In other words,

> "People actually see us as partners in innovations, more and more conversation are about innovations. How do I innovate, where can I innovate etc., etc.."

Although a majority of the 600 people with Infosys Labs are in India, in Bangalore, Hyderabad, and Pune, up to 25% of its staff is typically traveling to interact with clients on select projects that Infosys undertakes. The interaction is to understand the market and the issues that clients face, especially when doing something for the first time, and to identify possibilities for IP generation.

Co-creation is not merely a relationship between Infosys Labs and the client, because it is often difficult to meet all the needs of a customer. Thus, it is also about

> "…working with a lot of universities, research institutes and consortia to identify the right kind of problems of relevance to organization and society. We work with other technology partners, whether it is large platform players or small companies, [on] problems of relevance in the context of business….around exploiting ICT. We are participating in several research consortia. For instance, we are driving something called the Indo-UK Advanced Technology Center [IU-ATC], a consortium where BT is the lead industry partner of their side, we are the lead industry partner from this side, and then there are universities on both sides. This consortium is looking at next generation networks."[16]

Working in consortia helps address challenges. In engineering terms,

> "….you can actually solve a problem only by combining multiple technologies. There may be a core technology no doubt, but there will be a lot of enabling things. Innovative applications and innovatively combining those things is a place where we actually add a lot of value."

But what perhaps characterizes co-creation is a contextual relationship that has no template to *a priori* define the roles of partners. Instead, roles best suited to the effort have to decided upon only after all the partners have had a say. This is a radical departure from outsourcing where a customer could say

> "'if you don't want to do it….we will be giving it to somebody else.' You need those partners, in order to fulfill all his needs and in the ecosystem if somebody doesn't do well, it will have a larger impact on you also. Earlier, for example I needed to be able integrate all my applications internally with speed. Then it came to integrating applications across partners, again lot of them one to one and, in this process on company has been integrated with another company's process. [But] today we are talking about ecosystem integration. It should be dynamically possible….and we as a company should be prepared for this….It is the trend that we need to see at Infosys Labs. We should be building our capabilities so that our company can actually play in the change model. That's the end model."

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[15] http://www.infosys.com/innovation-co-creation/pages/index.aspx

[16] The IU-ATC brings together universities, industrial partners and SMEs in both countries. The initiative aims to establish Next Generation Networks, Systems and Services, which will put in place the support infrastructure to enable the Digital Economy of both countries, especially in domains such as education, entertainment and health. For details, see http://www.iu-atc.com/.

8.5 Cisco: globalization Center East

Cisco first came to India in 1995 to establish a representative office to provide data communications solutions to customers.[17] In 1999, the firm established a Global Engineering Development Center in Bangalore with an investment of US$20 million to develop and test Cisco IOS(R) software, network management software, application specific integrated circuits (ASICs), and other technologies like VOIP (voice over internet protocol).[18] This Center was in addition to the joint development centers established in partnership with Wipro Technologies and Infosys Technologies in Bangalore; HCL Technologies in Chennai, and Zensar Technologies in Pune. For Cisco, like most MNCs, India was, aside from being a market, a source of "engineering and talent" to develop its products:

> "But, over a period of time, the company realized the importance of moving into other parts of the world. The market of the future is going to be this part of the world. Realizing that the markets are going to grow, in China, Brazil, India and other emerging economies, it was important to then start looking into creating products, and services that were relevant to those markets. Also, Cisco had been present in all these countries so there was definitely a sense of where the differences and gaps were, and where the transitions were taking place. How we are going to respond to these opportunities? Then 4 years ago, we realized it was important to be in these markets, to understand what the markets needed, what the customers needed and what would work for them. So I would think much of the pressure for globalization came from the customer and market, more than anything else."

As the idea of a global Cisco evolved, CEO John Chambers announced an investment of US$1.1 billion in India over three years during a visit to India in October 2005.[19] Of this, US$750 million was for R&D, training, staffing and development; US$150 million was to provide leasing and financial solutions to customers and partners; US$100 million was venture capital directed at Indian start-ups; and US$100 million was for customer support operations including establishing spare parts depots and channel development. According to Chambers,

> "Cisco chose India as the location from which to expand its globalization vision because India has a highly skilled workforce, supportive government, innovative customers and world-class partners that already have global capabilities."[20]

Central to the "globalization vision" of Cisco is an effort to redefine itself as a provider of products and services of relevance to various markets by drawing on its strengths in networking technologies. Emblematic of this shift is the promotion of Smart+Connected Communities, a territorial concept that integrates various infrastructural and social functions:

> "The foundation for the city of the future will be the network and the information it carries, enabling the delivery of vital services from transportation utilities and security to entertainment, education, and healthcare. Everything will be connected, intelligent, and green: from office buildings and appliances to hospitals and schools. Citizens and businesses will

[17] Unless otherwise mentioned, this section draws on an interview with Susheela Venkataraman, Managing Director, Internet Business Solutions Group, Bangalore, 30 July 2010.
[18] http://newsroom.cisco.com/dlls/fspnisapi997f.html
[19] http://newsroom.cisco.com/dlls/global/asiapac/news/2005/pr_10-19b.html
[20] http://newsroom.cisco.com/dlls/global/asiapac/news/2006/pr_12-06c.html

enjoy unprecedented levels of collaboration, productivity, and economic growth without compromising the environment. Managing and operating such a smart, connected community will be efficient, coordinated, and secure."[21]

The provision of such services on an open-architecture platform requires partnerships with both domain experts and systems integrators to tie together customer needs.

Typical of such relationships is Cisco's alliance with Chennai-based Apollo Hospitals, Asia's largest health care provider, to deliver health care in rural Raichur district, Karnataka, with the Cisco HealthPresence™ Extended Reach technology. The technology uses high definition audio and video to facilitate end–to-end telemedicine and remote diagnostics.[22] Similarly, Cisco is working with Hindustan Construction Company which is developing Lavasa, a 12500 acre "live, work, play" city about a three hour drive from Mumbai.[23] A third partner, Wipro, will use Cisco's platform to design the infrastructure for telecom services for governance, and to provide solutions, such as integrated building management systems, physical security requirements and other on-demand services, for resident and visitors. These partnerships also travel internationally. A case in point is Cisco offering Telepresence, a technology that provides high-definition audio and video conferencing facilities, allowing participants to meet their colleagues, customers and business partners across a virtual table, to the Westin Tokyo and other hotels belonging to the Starwood Hotels and Resorts group.[24] This offering is made using the networks of Tata Communications.

The physical center of Cisco's expansion in India was a new US$50 million, million square foot campus in Bangalore to house 3000 employees.[25] The new facility was designated as Cisco Globalization Center East in December 2006 and serves as a "mirror site" to many headquarters functions including R&D, IT, sales and customer support, and finance. The 12.5 hour time difference between San Jose and India allowed the firm to be run 12 hours out of the US and 12 hours in India. In other words, Bangalore is no longer only a place for software development or engineering. It provides every other function as part of a global team, participating in global work. In the words of Chief Technology Officer Padmasree Warrier, "The Globalization Center in Bangalore is not a center for [the] India market, it is a center for global markets."[26]

Cisco East was established under Wim Elfrink, the firm's first Chief Globalization Officer. Elfrink has been based in India since 2007 and reports to John Chambers. In addition to his corporate role, Elfrink chaired the CII (Confederation of Indian Industry) Steering Committee on Intelligent Urbanization, which in May 2010 recommended a Framework for Sustainable Urbanization for India. A number of senior executives moved from San Jose with Elfrink and, while many have since returned, others have come to take their place reflecting the original intent of using Bangalore to offer an exposure to what doing business in new markets is about. In this regard, geography also played a role as India is about a five hour flight across a region covering a good portion of the firm's future market.

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21 http://www.cisco.com/web/strategy/docs/scc/09CS2326_SCC_BrochureForWest_r3_112409.pdf
22 http://newsroom.cisco.com/dlls/2010/prod_050710b.html?sid=BAC-JsSynd
23 http://newsroom.cisco.com/dlls/2010/prod_070710.html?sid=BAC-JsSynd The Lavasa project has become controversial following allegations that due procedure for land acquisition and environmental clearances were not followed. http://www.indianexpress.com/news/building-blocks-before-hill-city/725830/0 But this controversy will not affect the analysis of this essay.
24 http://newsroom.cisco.com/dlls/2011/prod_012811.html?sid=BAC-JsSynd
25 http://newsroom.cisco.com/dlls/global/asiapac/news/2005/pr_10-21.html
26 http://www.forbes.com/2010/01/26/forbes-india-padmasree-warrier-cto-cisco-tech-with-business.html

8.6 Nokia Siemens Networks (NSN): formally (un)acknowledged R&D in Bangalore

Siemens Network Services (SNS, which subsequently became NSN) originally came to India in the 1990s to take advantage of the low cost and the perception that software could be more easily developed in India than in other countries.[27] Yet, while Siemens has been associated with India since 1922, SNS was testing the waters since local engineers lacked domain knowledge in telecommunications. Further, as a strongly process oriented firm, it was uncertain about how to control software development that it was undertaking for the first time outside Europe. Thus,

> "for the first four to five years we focused mainly on Microsoft based software. In India we were not touching anything but pure software….which wouldn't harm our core business. It was mainly our Element Management Systems and Network Management Systems which are all software, which ran on Microsoft's technology. That's all - nothing more happened, a lot of people were brought in to work on software technologies."

During the dotcom bust, cost pressures and a hiring freeze led to questions about why low cost locations, instead of working on applications alone, could also not work on core technologies that contributed significantly to revenues. Since core technologies had, until then, not been designed and engineered outside Western Europe (in the case of SNS), it was considered risky. Nevertheless, many managers were willing to move of at least parts of technologies elsewhere because India not only had the technical skills, but there were also unique market demands.

Two examples illustrate this point. First, licenses for telecommunications service provision are offered on a state-by-state basis in contrast to the national licenses in European countries. Thus, a user moving from one state to another has to pay roaming charges, which requires certain billing procedures. Two, Indian service providers not only offer low cost services, but also low denominations recharges for prepaid accounts. However, the more the number of calls that can be made for a fixed amount, and the lower the denominations for which prepaid recharges are available, the greater the demands on the system requiring not just the customization of equipment designed elsewhere, but an ability to architect a product in a manner that the European operations could not do from a distance.

By 2003-04, SNS India demonstrated its capabilities sufficiently that global product management teams began to push innovation to India. India was not alone in this regard; China and Poland were also a part of the shift that was taking place in which Europe retained only product management, business management and some high level architecting. Project development for a global market meant that the process was no longer confined to one location. As a result, instead of being confined to managing teams of 15 to 30, managers in India had to manage teams of 250-300 some of whom were based locally, with the rest in different countries.

The ability to manage projects, and growing local demand, led to product and program management responsibilities. While project managers are treated as cost centers, a product manager is a business 'owner' who provides a vision for products and is responsible for the profitability of the business.

[27] Unless otherwise mentioned, this section draws on an interview with A Ravikiran, Head of Value Added Services, and Communication & Entertainment Solutions, Nokia Siemens Networks, Bangalore, 21 July 2010.

Product management requires a person who, with product architects and R&D capabilities, can translate the visions into a tangible product. Growing product development from 2005 led to growth in local R&D and an emphasis on developing IP. But getting employees to move beyond writing software to develop a product or being a technical expert was a challenge. Incentives were offered and they made

> “….a very big difference for us….lots of engineers were given bonuses and rewards….I mean getting an IPR was becoming a prestigious thing in the company so it was a culture shift and when that happened…. we have been….finding lot of IPR filing from this location.”

In addition, Siemens held workshops for employees to understand how an idea could become IP. The company also established an office for IP in Bangalore to help with the legal process. These initiatives led employees to think about ideas that might be valuable in India and elsewhere. After a couple of ideas made it to the market, and those championing them gained visibility, there was a sense that Bangalore as a location could “do it”.

Following Siemens’ decision to exit the telecommunications business, and the formation of NSN on 1 April 2007, the new firm was built largely with people from SNS since SNS tended to do most things in house. By contrast, Nokia, which provided the management for NSN, preferred to either work with partners. R&D was no exception to this rule. Thus, NSN has pursued a strategy that which has placed “….more importance on the business aspect and customer ….more on the development aspect but not on the R part”. One reason has been the difficulty of finding enough people with the right skills for emerging technologies:

> “….on certain key technologies we don’t get people here and if I wanted to do something on Wimax or TDLT or LTE I wouldn’t find anybody here. I have to train a lot of people on technology and then they start learning….. In China we are able to find a lot of them….It is a pretty big industry there, so China promotes these technologies and they want people….We are not promoting any of these. I mean India, in telecom, if you look around the industry even you don’t find anybody talking about LTE, hardly anybody talking about LTE even if you go to university. I will not find anybody talking to me about LTE but in China we do find that.”

To overcome this problem, NSN has started to partner universities such as the Indian Institute of Science in Bangalore and Anna University in Chennai. Despite these issues, the R&D group in Bangalore employs 2500, a number which will double if its local subcontractors are also taken into account.[28] Its size notwithstanding, the Bangalore R&D center is not a legal entity and finds no mention on the NSN website. The R&D center is an asset that is home to research groups of various product teams. Overseeing the center are four coordinators, reflecting the matrix structure of NSN.

The firm has however, been more accepting of the migration of product and business management to India, a market “where more things were happening in the last ten years than in any other country in telecom”. On one hand, India has the world’s second largest mobile subscriber base, which is growing.[29] On the other, the average monthly revenue per user in 2008 was only US$6.50, in comparison with the European average of US$36. Yet, if the operating margins of Indian telecom service providers compare favorably with those of their western counterparts, it is because of the innovative, low-cost “Indian model” of telecom service provision. The embodiment of this model is

[28] http://www.lightreading.com/document.asp?doc_id=203174&f_src=lightreading_node_2292.

[29] The rest of this paragraph is drawn from the Economist (2009) unless otherwise mentioned.

Bharti Telecom, to which NSN has been a provider of managed services.[30] In this arrangement, the service provider focuses only on promoting telecom services to the end customer, leaving the design, management, and maintenance of the network to vendors such as NSN who are paid on the basis of the traffic handled and performance and service indicators.

Since the managed services model was pioneered in India, the firm shifted its headquarters for global business services from Munich in Germany to Noida, in the National Capital Region in 2008.[31] Managed services now accounts for about half of NSN's revenues as the model has traveled beyond India.[32] Catering to global services is the Global Network Solutions Center (GNSC) in Chennai which offers solutions ranging from "business consulting and network design to network delivery and integration…. to enable full end-to-end solution capabilities in multi-technology and multi-vendor environments."[33] Besides Chennai, which is the hub for NSN's operations centers across the world, GNSCs can also be found in Noida and in Lisbon, Portugal, and two more are being established in Brazil and in Russia. At the end of 2010, NSN employed 15,000 in India (of the 60,000 employed worldwide) with a third of those focused on global functions. As the headquarters for global services, as home to two GNSCs, as the site for the largest share of its R&D employees, and with manufacturing facilities in Chennai and in Kolkata, "India is the most critical piece in the puzzle for NSN because we now have all the competence."

8.7 Siemens: Corporate Research Technologies India

Despite Siemens' long presence in India, the firm was relatively late in establishing research facilities in the country.[34] The decision to establish the Corporate Research Technologies India (CRTI) in Bangalore in 2004 was driven by a combination of reasons. Broadly, there was recognition of market saturation in affluent countries and that growth would be driven primarily by new markets in Asia. Commercial considerations, including the need to understand new customers and to find the technical skills to meet their needs, and a sense of corporate social responsibility, to contribute to the social upliftment of a relatively poor population, drove the desire to be close to these markets.

Given India's strengths in ICTs, CRTI focused on software engineering, distributed computing, and embedded systems, to reinforce "the structure of Siemens' Corporate Technologies as a network of competencies". Although this focus provided a starting point, the domains were a constraint. Not only did India have competencies that went beyond ICT services, but the firm had to look elsewhere to address local needs for which building global products alone would not suffice. In the area of health care, where Siemens is strong,

[30] For instance, NSN won a contract for US$900 million in 2007 to expand Bharti Airtel's GSM (Global System for Mobile Communications) network, and its fixed national long distance and international long-distance networks. In 2011, NSN won a contract for US$700 million to increase Bharti Airtel's rural coverage. http://www.pcworld.com/businesscenter/article/189090/indias_bharti_building_out_with_nokia_siemens_gear.html

[31] http://www.intology.com/business-finance/nokia-siemens-planning-to-shift-head-quarters-from-munich-to-india/

[32] For case studies of managed services in Brazil and the Czech Republic, see http://www.nokiasiemensnetworks.com/portfolio/services/managed-services

[33] http://www.nokiasiemensnetworks.com/portfolio/services/global-service-delivery

[34] Unless otherwise mentioned, this section draws on an interview with Mukul Saxena, Senior Vice President, Siemens Corporate Technology India, Bangalore, 27 July 2010, and many discussions with Zubin A. Varghese, Technology Leader-Sustainable Infrastructure Technologies, Siemens CRTI.

> "You cannot claim to be a leading social health care provider….in a country like India when the health care is targeted only to the top 200 million people. So if you really want to position yourself you need to understand….how we can add technologies which can impart or improve the health standards of….the next billion people in the country."

This led to rethinking about the focus areas and pursuing what was relevant from the perspective of the local market and to build the competencies in those areas. Following considerable representation and pitching to Corporate Technology at the board level, the 90 permanent employees of CRTI (which is one of 13 world wide Corporate Technology centers that employ 1900 in all) now work on SMART (simple, maintenance-free, affordable, reliable, and timely) innovations in the areas of infrastructure technologies (including health care and industrial applications), energy systems, embedded hardware and software technologies that address the triple bottom line of economic, social and environmental sustainability. Within these areas, CRTI has to work for internal and external customers to generate income. It also gets funds directly from the Board for projects of long term or local relevance for which technology cannot be adapted.[35]

An instance of developing products for other groups and locations is the low-cost camera system in the C-arm interventional fluoroscopic X-ray system, an imaging device which is manufactured at Siemens' factory in Goa. Currently, the image intensifier and the camera are sourced from Japan. Besides being expensive, it also has limitations in terms of the features and image quality. With its expertise in vision and embedded systems, CRTI redesigned the device to get better image resolution which, in turn, translates into lower exposure to x-rays. This innovation will cost the cost of the C-arm to a small fraction of the original price, and has consequently triggered interest in the German headquarters.

Developing products of local relevance, however, is a challenge because

> "There are two ways of addressing the local markets. You have this developed product and its okay, I de-feature the product and position it in the Indian markets. That will give you some kind of leverage, but only to a specific point, because….you have frozen the design….Many times, we need to….design products from ground zero, understanding the local requirements. In the process what comes out is very, I would say, innovative thinking, which goes into the product."

Acknowledging the value in not re-inventing the wheel, and in sourcing technology from relevant local stakeholders, CRTI has adopted an open innovation model in which it works closely with teams in academic institutions, NGOs and NPOs. Facilitating these relationships are fellowships, internship programs, grants and shared research programs which also open up hiring opportunities for the company. CRTI is moving away from the notion that the "lab is our world" to the idea that the "world is our lab".

Instances of this include the efforts to partner the Christian Medical College, Vellore, in community outreach programs where technologists accompany doctors and other medical personnel to the field as part of efforts to develop low-cost diagnostic and screening devices such as a low-cost fetus monitoring device that simplifies the diagnosis—and potentially accelerates the treatment—of problem pregnancies. Similarly, CTRI is working with ASHA (Accredited Social Health Activist)

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[35] While the figures for CRTI are not available, the sources of funding for Siemens Corporate Technology globally are: contract research for various sectors (about 57 percent), corporate financing (33 percent), and external funding (10 percent). http://www.siemens.com/innovation/en/about_fande/ corp_technology/ facts_figures.htm

who are the interface between rural communities and the public health system.[36] This partnership is meant to help track the health records of rural citizens who may move around for personal or professional reasons. To do this tracking CTRI is trying to automate the process by giving the ASHA worker mobile support systems, which is nothing but a laptop computer with a mobile that connects to a backend server with the database of the whole population. This represents less a technical challenge than a question of determining how best to insert Siemens' technological capabilities within India's rural healthcare system.

Despite the learning from the local markets, and the possibility of innovations traveling across borders, since cost is an issue even in developed economies,

> "….the country also has limitations….in terms of core fundamental research. I still don't see us coming out with the next generation materials which will enhance the efficiency of photovoltaics…. But India, I would say, will always continue to provide a very good way of doing the translation of technologies….[from]….developed economies, we need to bring a level of commercialization of technologies and in the process have an advantage which will be global….because the moment the volume starts kicking in, it will bring down the cost of technology.

8.8 Conclusions

India found a place in the international division of labor of the ICT services industry in the 1980s for many reasons. First, technological changes fuelled a demand for software while the labor intensive character of software development fuelled a demand for skilled labor. This search for locations that could provide the necessary labor opened a window of locational opportunity that India seized. India could seize this opportunity primarily because its education policies managed to create a large pool of skilled labor with the sought after Unix skills. The availability of this labor pool was reinforced by policy changes that encouraged the growth of the software industry. Initially, however, the integration into the GPNs of the world software industry meant little more than the pursuit of practices of labor arbitrage or bodyshopping.

In the 1990s, institutional initiatives in the form of STPs, which provided data communications infrastructure and financial incentives, encouraged the practice of offshore development. The economic policy changes since 1991, also made India a more attractive location for MNCs. The establishment of ODCs expanded the scale and scope of work. Not only did exports from India grow, but firms were also obtained larger projects which, in turn, were a means of obtaining more profitable turnkey contracts. Such contracts required firms to coordinate a wider range of tasks than just programming, and develop substantial management skills.

Despite the changed character of the Indian software services industry in the 1990s, and its changed role in GPNs, it primarily addressed global markets. The absence of local users hindered innovation. In other words, firms were producing *in* India, using factor inputs such as skilled but low-cost labor, infrastructure and other financial incentives. Besides Infosys, which evolved from practicing bodyshopping in the 1980s, Cisco and SNS came to India in the 1990s only to take advantage of the skills. The new millennium witnessed a change in the roles of firms as they began

[36] For more on ASHA, see http://www.mohfw.nic.in/NRHM/asha.htm#abt

to consider operating *from* India by building on technological and outsourcing capabilities. There were at least two forces driving this evolution that this paper highlights. First, there was the awareness among customers of the likely corrosion of any competitive advantage gained from deploying ICTs unless there was a unique organizational means of technology adoption.

Thus was established Infosys Labs, as it was no longer sufficient for Infosys to build quality software as a "reactive problem solver". Instead, the firm had to be a "proactive problem definer" to help customers build 'tomorrow's enterprise', akin to Carr's argument. Although Infosys Labs is not necessarily the source of middleware such as cloud computing, its role is to enhance combinatorial possibilities of such technologies by working with customers to help them develop innovative offerings for their clients. This effort at co-creation not only underscores the idea that innovation is increasingly to be found at the intersection of disciplines, technologies, domains, markets, and people, i.e., "innovation is no longer possible within the four walls" of any organization, but it also began to change the role of Infosys. From being just a provider of outsourced ICT services, with a specified role in a transaction, it was moving to become one of many partners in an ecosystem where there is a collective effort to define outcomes without any template for the roles of partners.

This changed role of Infosys had implications for changes at Cisco. As firms such as Infosys and Wipro, besides engineering Cisco products, evolved to become systems integrators, Cisco could globalize as a provider of products and services for various markets based on its strengths in networking technologies. Emblematic of this shift is the promotion of the Smart+Connected Communities, to integrate various infrastructural and social functions in communities. The provision of such services on an open-architecture platform requires partnerships with both domain experts and systems integrators to tie together customer needs.

The cases of NSN and Siemens reflect the cultivation of new markets with new customers, as these firms turned their attention to a hitherto neglected and underprivileged section of society. Ironically, what was often considered a drawback for India, became an asset. SNS (subsequently NSN) too came to India in the 1990s to take advantage of low costs. There was the perception that software could be more easily developed in India than in other countries despite limited domain knowledge. Even the subsequent move to push innovative activity to India was driven by cost considerations following the dotcom crash and the need to customize products for the Indian market. Nevertheless, this led to the development of product management skills and eventually to innovation. Although the formation of NSN reduced the emphasis on research, innovation came in the form of managed services as a new business model. This innovative model, which lowers costs for service providers, was demanded and made possible by a vast new market of poor subscribers in the world's second largest market for mobile telephony.

Reaching out to a new market was even more pronounced in the case of Siemens CRTI. Driven by a self-conscious desire to address new markets, from the vantage of commercial benefits and a sense of social responsibility, CRTI decided to develop SMART innovations for the socially underprivileged. To do that, however, CRTI had to go beyond merely lowering the cost of existing products as that would not lead to innovation that is responsive to local needs. In the process, CRTI decided to open up the innovation process by partnering with local NGOs and academic institutions and shift from the idea that the 'lab is our world' to the 'world is our lab'.

The effort to reach out to customers by firms had consequences for organizational structures and knowledge flows. Infosys Labs was established as a distinct organization within Infosys to help the firm become a "proactive problem definer". By actively participating in co-creation, Infosys Labs hopes that Infosys does not remain just an outsourcing organization at the receiving end of knowledge flows, but that it also becomes a producer and integrator in a knowledge ecosystem. For Cisco, integrating India into its GIN led to the establishment of the Cisco Globalization Center East in Bangalore to serve as a "mirror site" for various headquarters functions. Bangalore was no longer limited to undertaking software development or engineering, or a center for India. It was for all functions, as part of a global team, participating in global work for the global market. As Cisco became more global, and it began to partner with firms from other domains, executives from the US moved to Bangalore to gain exposure to what doing business in new markets (not just in India) was like.

With NSN, since the managed services model was pioneered in India and has since traveled across the world to account for half of NSN's revenues, the firm shifted its headquarters for global business services to India in 2008. Catering to global services is the GNSC in Chennai, the hub for NSN's operations centers across the world. Besides, as the site with the largest number of R&D employees, and with manufacturing facilities, India became "the most critical piece in the puzzle" for this firm of German and Finnish progeny. Essentially, for NSN, reaching out to the domestic customer meant taking charge of the entire telecommunication supply chain, from product development to providing technical and post R&D support, which was previously done from Europe. India therefore gradually moved from being just a R&D hub to a profit center before it became the business hub.

While CRTI was meant to add to Siemens' global network of competences, the range of competencies that the Bangalore laboratory chose to focus on widened after its establishment. This widening had organizational implications. For a highly process driven firm that undertakes most work in-house, seeking partners in the NGO world shows how the creation of IP and products for the BoP cannot be limited to the confines of a laboratory. Ideas drawn from the public domain, or the world at large, to the laboratory are critical. These flows between for-profit and formal, and not-for-profit (and sometimes informal) institutions is akin to the increasing burring of boundaries in software products as closed source code and open source code are increasingly "co-mingled" (Lerner and Schankerman, 2010).

The experience of firms in India shows that entry into GINs need neither be limited to advanced industrial economies nor does it have to be the preserve of those who make products. Market opportunities, derived either from the changing role of technology for users across the world, or the opportunities presented by the hitherto neglected BoP population locally, have induced firms to innovate with new organizational forms and channels of knowledge flows. This reworking of the social division of labor to explicitly address, for instance, the demands for product and services of a country with India's size and socio-economic diversity, also allowed exports to other parts of the world with similar needs. However, neither should the novelty of this innovation nor should its impact be exaggerated. It is not new to the extent that India's entry into GPNs of the ICT services industry was itself based on new spatial and organizational arrangements. The pursuit of bodyshopping in the 1980s, and the establishment of ODCs in the 1990s, allowed the evolution of technical and service delivery capabilities. These capabilities were a pre-requisite to the changes in the past decade. Finally, as firms have opined, India is as yet an unlikely location from which to expect a seminal technological breakthrough.

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9 GLOBAL INNOVATION NETWORKS, LOCAL SKILLED LABOUR MARKET OUTCOMES AND INNOVATION CAPABILITY: EVIDENCE FROM INDIA'S INFORMATION AND COMMUNICATION TECHNOLOGY SECTOR

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Abstract: Global Innovation Networks which are active in the developed world are fast gaining roots in the developing world as well. Literature argues that firms in the developing world would gain from GINs , by enhancing their ability to innovate, through interactive learning and capability building. This paper argues the generally held view that India has abundant supply of skilled manpower do not empirically hold, instead most of the high-tech sectors are confronted with skill scarcity. Using insights from the Dutch disease economics, and empirical evidence from India's IT sector, the study shows that in the context of skill scarcity the entry of MNCs results in a general increase in the wages of Skilled manpower. While the MNCs manage to address the high labour cost situation through various strategies, the local stand alone firms are adversely affected which in turn get reflected in their ability to be innovative.

Keywords: Global Innovation Network, Information and Communication Technology, India, Dutch disease Skilled Labour Market, R&D outsourcing

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9.1 Introduction

If the available evidence is any indication, Global Innovation Networks (GINs) which originated as a network confined to firms in developed countries to foster innovation appears to have become widespread with increasing participation from developing countries (UNCTAD 1995, Athukorala and Kohpaiboon, 2010, Ernst 2011). While the knowledge intensive industries are the leaders, other sectors are also catching up in the context of heightened competition under globalization wherein innovation holds the key to survival. In this bandwagon, India has not been left much behind. Similar to the global trends (Niosi 1999) in India also the emerging sectors like automobiles, pharmaceuticals and biotechnology are increasingly participating in GINs (TIFAC 2006). India's presence, however, has been most notable in the sphere of Information and Communication Technology (ICT) that accounted for almost 40 percent of the total Foreign Direct Investment in R&D (TIFAC 2006). Thus today there appears to be a shift in the strategy of ICT multinationals from considering India as a part of their Global Production Networks (GPNs) to Global Innovation Network. At the same time, ICT companies of Indian origin have also been increasingly globalizing their innovation activities (Joseph 2009).

Though there are a growing number of studies[1] on global innovation networks dealing with its determinants and outcome using ever new indicators, their focus, by and large, has been on the developed countries. Hence notwithstanding a few studies, (Athreye and Prevezer 2008; Qu et al 2009; Ernst 2011) our understanding on the implications for host developing countries on their participation in GINs remain at best rudimentary. In this context, the present study intends to explore the implications of India's increased participation in GINs by taking the case of India's ICT sector with a view to draw policy implications. Drawing insights from the Dutch disease economics and the underlying specific factors model, this paper analyses the plausible implications of increasing flow of FDI in R&D and consequent effect on the market for skilled labour in India. Further, the impact of this resource movement on domestic innovation capability building is analysed to highlight the plausible role that state policy could play in harnessing GINs as an instrument for promoting learning and innovation to be competitive in an era of globalization.

The reminder of the paper is organized as follows. Second section develops an analytical framework to address the issue at hand. Third section discusses the data sources and variables. The fourth section presents the empirical evidence against the backdrop of an evolutionary picture of India's ICT sector which provides the context in which GINs formation took place. The last section presents the concluding observations and draw implications for policy.

9.2 Analytical framework

The unprecedented growth in global innovation networks on the one hand and increasing participation of developing countries therein, on the other, have attracted significant scholarly attention given its importance in the innovation process and informed policy making in both the developed and developing countries. These studies have, indeed, broadened our understanding on the inducement mechanisms as well as the implications of GINs for countries and firms both in the North and the South. Drawing from the received wisdom, it is possible to locate a host of

[1] Readers are referred to the special issue of *Research Policy* (Internationalization of Industrial R&D, March 1999).

"centripetal forces[2]" which induce the firms to centralize the R&D activities in the head quarters and "centrifugal forces[3]" that work towards the dispersion of R&D activities across different locations beyond the home country. Attempts have also been made in terms of locating the push and pull factors.

The unprecedented increase in the pace at which GINs are being formed (UNCTAD 1995; Ernst 2011), however, suggests the presence of certain factors that reduced the uncertainty as well as the cost of coordination and transaction and thus undermined the power of centripetal forces. There are two important factors for this rebalancing and resultant increase in the mobility of knowledge as argued by Albuquerque et al (2011). First one relates to the improvement in the information communication infrastructure and its extensions around the world and second being the policies that liberalized trade and investment which helped firms to exploit the benefit of technological change. To this we may add the emergence of new locations that are perceived as capable of providing complimentary capabilities, especially human capital, at lower cost. For instance, it has been shown that by 2010 China would have more science and engineering doctorates than United States (Freeman 2005; National Science Board 2008).

While Globalization of R&D and formation of GINs appears to be benign and beneficial to firms in home country and host country, it could also be considered as a double edged sword both for the MNCs and the host developing country firms. As far as the MNCs are concerned in the current context of heightened competitive pressures they have many gains to be made from GINs. At the same time, there are pains associated with R&D outsourcing. From the developed country perspective, the situation is best summed up by Kaiser and Grimpe (2010) when they remarked, R&D outsourcing is certainly beneficial to innovation performance and it may increase their efficiency, reduce cost, or foster innovation by getting access to valuable resources not available internally. At the same time, it might lead to dilution of firms' resource base, deterioration of integrative capabilities and management attention.

With respect to the host developing countries one view considers that inward investments in R&D are generally beneficial to economic growth and welfare. This is because such investments provide technology and managerial skills which create positive spillover effects. These effects include technical support and assistance to local suppliers and customers, copying foreign R&D outcomes by local units. Thus viewed it might lead to strengthening of the innovation system in general and learning process in particular of the host countries by facilitating greater interaction between the foreign R&D units and other local agents involved in the production and innovation process. Knowledge frequently results from the search for new solutions that are based on the firm's existing knowledge base (Cohen and Levinthal, 1989; Nelson and Winter, 1982; Teece, 1986) and that the extent of such benefits derived depends on the firms' capabilities. On the other hand, it is also argued that GINs could turn out to be "poisoned chalice" (Ernst 2011). Local R&D activities

[2] The centripetal forces included the need to protect firm-specific technology to: avoid R&D leakage (Rugman, 1981); to mirror and retain home market advantages Steele (1975); due to the tacit nature of technological knowledge, need for closer coordination in decision making in the face of uncertainty of innovation Patel and Pavitt (1991); take advantage of scale economies in R&D high cost of co-ordination and control (Eg. Vernon, 1974)

[3] The centrifugal forces include demand oriented factors that emanate from the need to be nearer to the export market to : exploit regions' differential advantage in production and in R&D Cantwell (1995); supply side factors operating as centrifugal forces most important one appears to be the access to scientific and technological skill including scientific infrastructure that are available in the host countries at a more advantageous terms than in the home market (Ernst 2011).

undertaken by the foreign firms tend to tap into unique local R&D resources with little or no benefit to the host countries. Working on problems of little relevance to the local economy, they may represent nothing other than disguised brain drain diverting scarce technical resources from more useful purposes. In a similar way foreign acquisition of local technology base companies are often lamented as a mechanism by which production and exports of vital technologies are diverted from their country of origin (Dunning,1992).

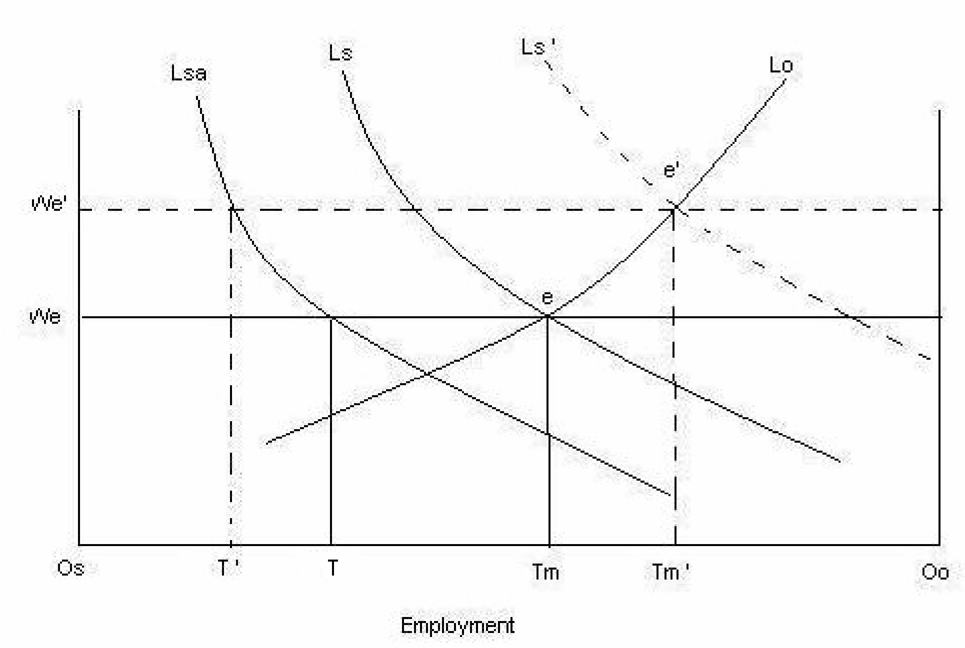
To the extent that the relative scarcity and deficit in scientific infrastructure and skilled manpower in the developing countries is higher than that in the developed countries, it is important to explore the implications of developing countries' participation in global innovation network with respect to innovation in general and technological capability building in particular. Here, the findings of a study by Athreye and Prevezer (2008) on possible consequences of R&D offshoring on domestic innovative capability and building domestic infrastructure are instructive. It is found that domestic patenting has been concentrated in sectors that are different from sectors of R&D off shoring. Also the location of R&D activities in India and China since 1995 seems to have not strengthened the science base of these countries as evident from publication data. Studies on Bangalore, where large scale R&D offshoring has taken place, have also mostly failed to find significant linkages between foreign firms and the local economy and the sort of inter-firm networks one would expect in the presence of traditional technology spillovers (Parthasarathy 2004). Another study on R&D offshoring and technology learning in ICT industry in China suggested that it has a positive effect on the intensity of R&D of host country firms. However, the magnitude of the impact depended on both the technological and geographical distance between the multinational and host country firms (Qu et al 2009).

The crucial issue is whether GINs, as they operate today, help strengthening the national innovation system in general and innovation capability building in particular. Implications of increased demand for skilled professionals on account of the participation in GINs and the resultant rise in wage levels and the consequent movement of skilled manpower from other sectors to innovative activities in ICT may be examined in terms of the "resource movement effect" in the literature on Dutch disease economics (Corden and Neary 1982). To begin with, it may be kept in mind that the resource movement effect is confined only to those sectors of the economy, which compete with the ICT sector for technically skilled manpower for innovative activities. For analytical purpose, the sectors that require the technically skilled manpower for innovative activities are divided into two broad sub-sectors; a) those engaged in the innovation in sectors other than ICT and b) those involved in Innovation in the ICT sector. The demand from the ICT sector may be divided into that from the ICT multinationals (both domestic and foreign) which are active nodes in global innovation networks and that from local stand alone firms which are either not or only weakly linked to the global innovation network, smaller in size and more oriented towards the local market.

Innovation in any sector, especially in service sectors, being a highly skilled labour intensive activity, greatly depends on the access to skilled manpower. Therefore the outcomes of changes in demand for and supply of skilled manpower in the skilled labour market get reflected in the innovative outcomes in the sectors concerned. Therefore, in what follows we shall begin with an analysis of the labour market outcomes. Following Corden and Neary (1982) the labour market implications on account of resource movement due to changes in demand for skilled labour in one of the sectors may be illustrated with the help of fig 1 which assumes full employment and other standard assumptions in the specific factors model (Jones 1965). In the figure, the length of the horizontal axis Os Oo is equal to the total supply of skilled labour available in the economy for the innovative (R&D) activities, which is fixed. The vertical axis indicates the wage for the skilled manpower. R&D employment in the ICT sector is measured from Os and that in sectors other than ICT (that compete for skilled manpower for R&D with ICT sector) is measured from Oo. The curves Lsa, Ls and Lo show the demand for R&D labour from stand alone firms in ICT, total R&D labour from ICT and the R&D labour demand from sectors other than ICT. The total demand for R&D manpower for the ICT sector is drawn as a horizontal sum of that from the stand alone firms and multinational (both foreign and local) firms.

In the figure the initial equilibrium is shown by the intersection of curve Ls and Lo at point e where the wage rate is We. At this point total R&D manpower available in the economy is allocated across different sectors as follows; OsT is the R&D employment in the stand alone companies, T TM by the multinational and Oo Tm by the sectors other than ICT. By assumption, this also indicates the initial innovation capability of each sector.

Figure 1: Effect of the GINs on the market for R&D manpower



Now we shall examine how the allocation of R&D manpower across different sectors, and therefore their innovation potential is affected by the entry of ICT sector into the GINs. Entry of MNCs results in an increase in the demand for R&D manpower by the multinational (shown by shift from Ls to Ls' in fig) leading to a new equilibrium at e'. This would cause a rise in the wage rate in that sector (We to We'). The higher wage rate naturally would attract the R&D manpower, which is mobile, to the MNCs from the stand alone firms and sectors other than ICT engaged in R&D which by assumption are competing for skilled manpower with the multinationals.

Given the higher wage rate offered by the Multinationals R&D manpower from the stand alone firms and sectors other than ICT move towards the Multinational firms. By assumption wage rate increases in all the sectors from We to We'. In the fig, R&D employment by the stand alone firms declines from Os T to OsT' and that of sectors other than ICT declines from OoTm to OoTm'. Needless to say R&D employment by the multinational increases from T Tm to T' Tm' indicating an increase in their R&D effort and innovation potential. Given the assumption of full employment, increased employment in R&D by the MNCs is possible only by drawing R&D manpower either from the stand alone companies or from the sectors other than ICT or both with a corresponding decline in their innovation potential.

In such context, the stand alone companies and other sectors will have the following choices; either they could pay the salaries on par with the multinational firms, or be satisfied with the second best by paying lower wages. Given the other pecuniary benefits associated with multinationals (like the prestige associated with working for MNC firms), stand alone firms in ICT and firms in sectors the other than ICT are unlikely to attract the best brains even by offering the wages offered by the MNCs. Under such conditions, these firms will be left with hardly any options but to be satisfied with the second best. Whatever be the strategy adopted, there could be adverse effect on the firms operating in sectors which require skilled manpower leading to a reduction in their employment which in turn, by assumption, leads to a reduction in their innovation potential. On the other hand, given the excess demand situation in the home market for the MNCs, the observed rise in wage rate is unlikely to have any adverse impact on the multinationals as the wage in India is still lower than that in their domestic economies. Similarly, there is unlikely to be any adverse effect on the export oriented domestic multinationals, at least in the short run, as they are still having comparative advantage on account of the fact that the domestic wage is still much lower than that of the world wage rate.

The situation however, could be eased by expanding the supply of skilled manpower, that is expanding the horizontal axis. This is an area where institutional interventions are called for. There could also be a spillover effect on account of increased interaction of foreign firms, with the local firms and the knowledge generating system in the country. The net outcome, in fact, is an empirical issue that needs further enquiries and beyond the scope of the present paper. In the next section we shall present available empirical evidence focusing on the ICT sector as a detailed exploration of the sectors other than software dealt within our model is beyond the scope of the present paper.

9.3 Data sources

The data utilized for this paper comes from two sources. One is the INGINEUS survey for Indian firms conducted by us during 2010 and the CMIE PROWESS database. The INGINEUS survey was designed to understand the nature, patterns and characteristics of Global Innovation Networks. The survey had a uniform questionnaire canvassed across 14 countries that included BICS and selected countries from EU. This paper has utilized the survey relating to firms in India. The firms were chosen from the NASSCOM Directory of ICT firms. The NASSCOM Directory is released every year and covers all areas of software production and related industries such as IT Enabled Services. The 2009-10 Directory provides the information of 1287 firms in different areas of IT industry.

Survey instrument was administered in eight cities/ IT clusters that together represented nearly 93 percent of all firms according to the NASSCOM directory. After attempting do an online survey which generated very poor response rate a survey team conducted face to face interviews in eight cities[4] during the period March 1st to April 30th, 2010 ending up with a sample of 325 completed

[4] Cities covered in the survey were Bangalore, Delhi/Noida/Gurgaon, Mumbai, Pune, Chennai, Trivandrum, Hyderabad and Kochi

surveys representing a favorable response rate of 24 percentage. There were 167 standalone firms, 106 MNCs of Indian origin and 50 subsidiaries of foreign firms.

We have depended on The PROWESS database of the Centre for Monitoring Indian Economy (CMIE) for most of the time series information. This is a firm level database of Indian firms across all industries which provides information on the real and financial variables of the firm. The data is collected from the annual balance sheets of the firms. While the firm coverage of Prowess is not complete, the firms covered under CMIE have a cumulative share of nearly 90 percent of the reported IT sales. We classified the firms on the basis of the following: Foreign MNCs are defined as firms that either report themselves as foreign firms or have a share of more than 10 percent of foreign equity ownership, which is the convention to identify as MNC. Indian MNCs are defined as those firms who have subsidiaries or have joint ownership of entities in other countries[5]. Domestic firms are those firms that have less than 10 percent foreign equity and have identified themselves as private Indian firms. The number of firms in the available data base varies year to year. For foreign subsidiaries the number of firms varied from 24 in 2000 to 48 in 2004, with the total number of observations being 440 for the period 2000 to 2009. For the Indian MNCs it carried between 90 and 110, and for stand alone firms it varied between 254 and 476. The total number of observations was 6392 for the period 2000 to 2009.

9.4 Empirical evidence

9.4.1 ICT sector in India: An evolutionary picture

During the last forty years, India's ICT sector which originated in the early 1970s has undergone major changes. These changes *inter alia* are manifested in the institutional arrangements, nature of activities undertaken, market orientation and role of different actors involved. In what follows, we shall discuss the evolution, rather succinctly, by focusing on only two important aspects[6] relevant for GINs to argue that state played a key role in the observed transition from one stage to another and that the state has a crucial role to play in the current phase wherein the sector is at the cross roads.

Onsite to offshore development

Indian firms made their presence in 1970s in ICT software and service exports mostly by providing services in the premise of the customers (often called onsite development). During the early years the focus had been on low value-added services pioneered by firms like Tata Consultancy Services (TCS) a part of Tata Group (Heeks 1996). Even at this stage, in contrast to the view that was held in few quarters (Arora et al 2001), the sectoral innovation system that evolved, mostly at the instance of the state, did play an important role in incentivizing software production and exports(Joseph 2002, Joseph 2008; Joseph 2009, Parthasarathi and Joseph 2002, Kumar and Joseph 2005 Balakrishnan 2006). In a period when very high tariff and non tariff barriers were the rule, duty free

[5] Indian MNCs are identifted from a database on Outward Foreign Direct Investment created by Dr. Jayaprakash Pradhan which identifies Indian MNC firms on the basis of acquisitions, mergers and equity participation in foreign firms. We acknowledge him for sharing this database.

[6] For a more detailed discussion on these aspects please refer Joseph (2007) and Joseph 2010)

import of computer systems without reference to indigenous angle clearance was permitted for software export. Moreover, in a period when there were a series of restrictions on Foreign Direct Investment (FDI), 100 per cent foreign owned companies were permitted to set up software export operations provided they located in the Santacruz Electronics Export Processing Zone (Parthsarathi and Joseph 2002).

It was, however, held that the generally practiced strategy of onsite development was inimical to the declared objective of maximizing export earnings for which the state encouraged the software sector (Government of India 1986). The strategy of onsite services involved inefficient utilization of manpower and substantial outflow of foreign exchange because the software personnel had to spent substantial time with the service receiving firms in the foreign countries (Sen 1995). Hence the net export earning has been only of the order of 50 per cent of the gross FOB value of total exports of software and services (Joseph and Harilal 2001). It also accentuated brain drain as the software personnel sent abroad for onsite work rarely returned home as they could easily find more attractive employment opportunities (Parthasarathy 2004). With a view to increase the net export earnings government has been systematically encouraging offshore development. An explicit software policy was announced in 1986 and software was identified as one of the key sectors in India's agenda for export promotion. The policy underlined the importance of an integrated development of software for the domestic and export markets (India, Department of Electronics, 1986) and came up with various measures to accomplish these objectives. A notable institutional intervention by the state that facilitated offshore development has been the establishment of Software Technology Parks (STP) to provide the necessary infrastructure including data communication facilities for software export[7]. As a result, of these initiatives the share of onsite services in total exports declined from about 90 per cent in the mid-1970s to 30 per cent by late 1990s. These initiatives which helped building domestic IT infrastructure are also likely to have influenced the decision of MNCs to invest in R&D centres in India.

From BPOs to KPOs: Increased technological competence

The comparative advantage of Indian firms has been in the on-site export of services such as customized software development, mostly on-site (Arora et al 2001). It was also shown that Indian firms have been operating mostly at the lower end of value chain by carrying out low-level design, coding and maintenance (Kattuman and Iyer 2001). As a result, revenue per employee in 1999 ($ 16,000) is found to be only about one-tenth of Israel and one-fourth of Ireland (Arora et al 2001).

Though, the packaged software has its origin in 1980s, given the weak copy right regime and resultant software piracy, many of the firms in India did not consider package development as a strategic option[8]. To address this problem, the government initiated a series of measures[9]. As a

[7] The first ones to come into being were those at Bangalore, Pune and Bhubaneshwar in August, October and December 1990 respectively. In 1991, four more STPs were set up by the Department of Electronics at Noida, Gandhinagar, Trivandrum and Hyderabad.

[8] The magnitude of the problem has been illustrated by an estimate from Lotus Development Corporation, that in the early 1990s of the 150,000 copies of Lotus 1-2-3, 140,000 were pirated. (Schware 1992).

[9] The copy right of computer software has been protected under the provisions of Indian Copy Right Act of 1957. Major changes were made to the Copy Right Law in 1994. Accordingly, it was made illegal to make or distribute copies of copy righted software and therefore punishable. Section 63 B of the Act stipulated a minimum jail term of 7 days extendable up to three years. The Act further provided for a fine ranging from Rs 0.05 million to Rs 0.2 million. In

result, the piracy rate in the country has come down from 89 per cent in 1993 to 60 per cent in 1997 (NASSCOM 1999). These initiatives, apart from reducing software piracy, acted as an inducement mechanism for the domestic firms to enter into software products. Accordingly, Indian companies, both large and small, began entering into software product development. For most of these firms, domestic sales accounted for substantial part of their revenue (Joseph 2009). A number of even smaller software companies have developed packaged software, which is sold in domestic market[10].

At the same time, various institutional interventions were also undertaken by the government explicitly with a view enhance the supply of skilled manpower and R&D capability (Kumar and Joseph 2005). Over the years, the sector has been able to move up the value chain. It is evident from the fact that Indian firms are now increasingly getting engaged in highly skill demanding areas like chip design and R&D and thus are moving up the value chain marked by a shift away from Business Process Outsourcing to Knowledge Process Outsourcing. Now the firms are increasingly entering into high end consulting, embedded software development, engineering and R&D services with the development of domain expertise and export of packaged software. As a result the share of high value adding and innovative segments - that include engineering services, R&D and software products – in the total value of output and export is estimated to increase from less than five per cent in 2005 to over 10 per cent in 2011.

Since the conventional measures of innovation like R&D intensity (measured as R&D expenditure as proportion of sales) has certain limits in capturing innovation in a service sector like ICT, a study (Joseph and Abraham 2005) developed an Index of Claimed Technological Competence (ICTC) using firm level information on their areas of specialization. The theoretical base of the index has been drawn from the literature on technological opportunity. The estimated index has shown an upward mobility of firms. To illustrate, in 1998 over 56 per cent of firms were in the low index category (less than 30%) where as in a short span of three years the share of such firms declined to around 44 per cent. Similarly in the higher index category (greater than 60%) the share of firms increased from 5.3 per cent in 1998 to 8.3 per cent. in 2001[11].

In a context wherein the MNCs have been looking for complementary capabilities (Ernst and Lundvall 2000), foreign firms began to invest either directly in their own R&D centres in India or partnering with Indian firms in highly skill intensive areas like chip design and R&D. This was marked by a shift away from Business Process Outsourcing to Knowledge Process Outsourcing (Parthsarathy 2006). The increasing incidence of off shoring of high end value added services like research and development thus heralded India's transition from global production network to global innovation network.

The only available secondary data on foreign R&D centers is related to a survey of FDI in R&D conducted by Technology Information, Forecasting and assessment Council (TIFAC 2006) of the Department of Science and Technology Government of India, for the period 1998-2004[12]. It was

addition, the government, in co-operation with the Nasscom, conducted regular anti piracy raids to discourage software piracy.

[10] For example, Tally, a popular accounting package for small and medium enterprises which is being used by 50,000 companies and has been approved by the Accountants' professional bodies in India and the UK has been developed by a smaller highly specialized software company (Kumar, 2001)

[11] The estimated index of leading IT firms like Infosys, Wipro, TCS and Satyam were found to be more than 75 per cent. The rise in the level of index was not confined to the high index category. In the middle index category (30-60%) as well the proportion of firms increased by 10 per cent point.

[12] The data and information presented in rest of this section is drawn from TIFAC (2006)

reported that during the period 1962-90 only six cases of foreign R&D centres were reported. But during 1990-2000 the number increased to 49 and within four years since 2000, 46 more cases got established indicating an acceleration of the pace at which R&D has been internationalized since 2000. In terms of the country-wise distribution, it is found that while the US accounted for 53 per cent of the number of units, their share in actual investment (71.6%) and employment (69%) was much higher (see table 1). Going by all the four indicators, USA is followed by Germany. It is worth noting that China has a notable position in terms of both employment (2.2%) and actual investment (5.3%)

In terms of the location of such R&D ventures it is found that 45 per cent of them were in Bangalore, followed by Delhi (10%) and Mumbai (8%). While the state of Maharashtra (Mumbai and Pune) accounted for 17% of the number of units, three southern states Karnataka (mostly Bangalore 45%) Andhra Pradesh (Hyderabad 7%) and Tamil Nadu (Chennai 4%) together accounted for 56 per cent of the total number of ventures. Studies have shown that these states are known for their relatively vibrant regional innovation systems (Kumar and Joseph 2005). In terms of regional concentration FDI in R&D depicts more or less the same picture as that of general FDI indicating that, the presence of a vibrant regional innovation system is an important factor that governs the location decision of foreign R&D units.

Table 1: Country-wise wise distribution of foreign R&D centres in India (up 2004) (%)

Country	Number	Planned	Actual	R&D employment
USA	53	60.59	71.59	69.20
UK	7	0.54	2.14	4.15
Switzerland	2	0.14	0.67	0.74
Sweden	2	0.46	0.10	0.35
South Africa	1	3.71	0.06	0.22
Norway	1	0.01	0.00	0.00
Netherlands	3	3.49	1.62	2.31
Mauritius	2	1.13	1.01	1.15
Korea	3	2.40	6.86	2.83
Japan	7	3.66	0.83	0.87
Germany	7	18.34	6.78	8.92
France	5	4.75	1.84	4.22
Denmark	1	0.00	0.00	0.02
China	2	0.65	5.31	2.22
Canada	3	0.16	1.00	2.58
Australia	1	0.00	0.20	0.22
Total (%)	100	100.00	100.00	100.00
Total (actual Rs Million		209167.9	50989.2	22979

Source: Derived from TIFAC (2006)

It is evident that software is an area that attracted maximum foreign R&D that accounted for nearly 23 per cent of the cases (table 2). If we include ICT hardware and communication, the share increases to over 39 per cent (based on TIFAC 2006). This evidence tends to suggest that the relatively vibrant sectoral innovation system in India's ICT sector, evolved over the years (Joseph 2009), should have been acting as a pull factor in a context wherein the foreign firms are looking for complementary capabilities.

In terms of the nature of activities undertaken by the units, it is found that 53 per cent of the cases involved shifting of in-house R&D activities from the home country to offshore locations. Needless to say, it is with a view to take advantage of the available manpower at a relatively low cost as compared to the home country. These units are found entirely catering to the needs to the home country requirements. There are no cases reported wherein R&D services are exported to multiple clients through open market system. However, in case of engineering, chemicals and agriculture there are many cases that cater to the domestic market as well. In terms of equity/ownership, 51 percent of the companies never had any partnership with the local firms as they work only for the parent company. About 43 per cent are found having partnership with local firms. The local firms are found to be well established large firms like Infosys, Wipro, HCL with very little presence of small firms as local partners. About six per cent of the companies started with a local partner but did not have a local partner as on 2004 when the survey was undertaken.

Table 2: Area of specialization of foreign R&D centres

Areas of R&D	No of companies	%
Software	31	22.96
Computer Hardware, Chip Design etc	7	5.19
semiconductors analog	3	2.22
Internet OS development	4	2.96
Wireless development	6	4.44
optical net work	3	2.22
Auto Design	9	6.67
Drug Design, Agro Chemicals, Leather Chemicals, Dyes	16	11.85
Others (aerospace, engineering, bioinformatics etc Medical, Engineering, Power, Aerospace)	56	41.48
Total	135	100.00

Source: Derived from TIFAC (2006)

Here it needs to be noted that India's participation in Global Production Network in the form of software services was with a view to earn foreign exchange as it was a period where in the country was constrained by foreign exchange shortage. But its entry into Global Innovation Network was not so much induced by the need for export earning as the country by the late 1990s was having a comfortable external balance as is evident from an accumulated foreign exchange reserve of nearly

$300 Billion. Here, the factors that induced India's entry into GINs seem to be at variance with that of its entry in GPN. Both in case of GPN and GIN, foreign firms have been attracted by the availability of manpower at lower cost and large domestic market. But viewing from India's side while participation in GPN provided an opportunity to earn foreign exchange its entry into GIN, to be beneficial, it needs to contribute towards strengthening its innovation capability.

9.4.2 Skill scarcity in the IT sector

The increasing participation of India's ICT sector in GINs had been however occurring within an environment of skill shortages. Though India, along with China, is often considered as a country with abundant supply of skilled manpower, there are evidences to indicate that when it comes to availability of highly skilled manpower for R&D and other skill intensive activities firms are confronted with severe manpower constraint. At the macro-level Gross Enrollment Ratio (GER) in tertiary education in India is only about 11 percent which compares very poorly with OECD countries and USA and even with emerging countries like China (23%) and Brazil (24%). Moreover, as is evident from table 3 share of population that completed tertiary education in India (19.6%) in 2010 compares very poorly with that of China (31.7%), and Brazil (24.3%). More importantly while the share of population with tertiary education in China increased by more than 10 per cent during 2005-10, India recorded only a marginal increase (1.5%). This indicates that that the higher rate of growth of the economy recorded during the recent past has not been accompanied by a commensurate increase in the supply of skills which is likely to bridle the growth of Indian economy driven by service sector in general and knowledge intensive sectors in particular.

The situation gets further aggravated on account of brain. India reports one of the largest rates of emigrations of tertiary educated workers, especially to the United States. About 4.5 percent of the students in the US were migrants from India, which increased to nearly 7 percent by year 2008[13](Mani, 2009). There are also evidence to indicate that there is a significant skill mismatch between what the university system produces and what the industry requires. A study commissioned by National Association of Software and Service Companies, (Nasscom), found that out of the 0.4 million engineering graduates who graduate each year, only about 20 per cent are employable (NASSCOM)[14] .

Table 3: Share of population that completed tertiary level of education (%)

	Age Group	China	Brazil	South Africa	Russia	India
2005						
	20-24	5.6	1.1	0.1	1.9	3
	25-29	5	5.4	0.4	2.9	3.9
	30-34	4	6	0.7	3	3.4
	35-39	3.7	6.4	0.7	8.6	3.7

[13] http://www.nistads.res.in/indiasnt2008/t1humanresources/t1hr5.htm

[14] Another report by Aspiring Minds, published in The Economic Times on April 11, 2011 state that only 4.5 percent of the IT graduates are employable. The rest were deficient in the required technical skills, fluency in English or ability to work in a team or deliver basic oral presentations.

	40-44	3.6	6.4	0.6	11.8	4.1
	20-44	21.9	25.3	2.5	28.2	18.1
2010						
	20-24	9.6	4.6	0.1	1.9	3.5
	25-29	8.8	1.9	0.4	2.9	4.7
	30-34	5.1	5.4	0.4	3	3.9
	35-39	4.5	6	0.7	3.4	3.8
	40-44	3.7	6.4	0.7	8.6	3.7
	20-44	31.7	24.3	2.3	19.8	19.6

Source: Barro, RJ and JW Lee (2010)

It also needs to be noted that this skill shortage in the economy is not a short run disequilibrium which may get corrected in the long run. This is so because of both the peculiar nature of both demand and supply of skills. The demand for skills emanating from the knowledge based sectors of the economy would have corrected through wage rate movements to equilibrium levels in the short run itself had these sectors operated in a closed economy model with high degree of market integration. However, these sectors are essentially export oriented, and hence wage corrections depend on the relative wage rates in competing firms in other economies such as Ireland, Israel, and the South East Asian economies. Given the fact that India's growth trajectory is narrowly concentrated within a few sectors, when compared to other competing economies, the relative abundance of skills in India would ensure that the local wage rates would equate with the global averages only very gradually. From the supply side, enhancing the skill supply would require institutional interventions that enhance the quantity and quality of skill supply, which again are not short run solutions.

9.4.3 Skilled labour movement, attrition and wages

The starkest manifestation of the impact of the entry on MNCs into the R&D sector in a context of skill scarcity had been the exceptionally high rate of growth in the salaries of IT professionals and persistence of high worker attrition rate. In a survey conducted as early as in late 1990s, 57 per cent of the firms interviewed indicated that manpower and skills shortage as their major problem (Arora *et al*. 2001). A survey conducted in 2004 on the IT sector shows that nearly 60 percent of the workers had moved to a new firm within the last two years and 90 percent of them shifted their place of work in the last four years (Abraham, 2005). This has induced collective action by the IT firms at the instance of NASSCOM and agreement among them to discourage poaching. Reports in 2007, however, stated that though there was no uniform view on the rate of attrition in the sector it was widely believed that the attrition rate was anywhere between 40 to 60 percent in a year[15].

[15] See for example "Firms Struggle To Retain Talent As Economy Booms", Indian Express , 15 February, 2007.

Survey done as late as in 2011 also reported that skill scarcity continues to be major problem that nags the sector[16].

The entry of foreign MNCs into the R&D sector in a context of skill shortage in the IT sector has led to stiff inter-firm competition for the available skilled manpower. This inter-firm rivalry for skilled personnel, especially after the entry of MNCs for R&D, has led to an unprecedented rise in wage rates for workers in the IT sector. As a result, the entry-level salaries in the software industry have risen by an average of 10 to 15 percent in recent years. It has been reported that the rate of increase in the wages and salaries in India has been the highest in Asia-Pacific[17]. This in effect has led to an escalating wage bill for the firms. Analysis of the firm level data on IT firms from CMIE revealed the share of wages and salaries in total sales has more than doubled during 2000-09 and the observed increase is much higher than the other sectors. More importantly, skilled labour movement effect induced increase in wages and salaries appear to have adversely affected the stand alone firms as compared to the MNC (both local and foreign) firms. To be more specific, during 2000-09 share of wage bill in sales for the standalone firms more than doubled from a low level of 20 per cent in 2000. But when it comes to MNCs, both foreign and local, the observed increase was of a much low order (see table 4). The table further indicates that while the foreign MNC subsidiaries and Indian MNCs had successfully reduced their wage bill after an initial rise, for the standalone firms, the wage cost component appears to have become a major growth restraint.

Table 4: Trend in the share of wage bill in sales across different type of firms in India's IT sector

year	Foreign MNC	Indian MNC	Stand alone Firms	Average
2000	0.20	0.29	0.20	0.23
2001	0.29	0.65	0.33	0.40
2002	0.38	0.67	0.40	0.46
2003	0.42	0.34	0.49	0.45
2004	0.49	0.57	0.45	0.48
2005	0.42	0.36	0.53	0.49
2006	0.41	0.35	0.39	0.38
2007	0.34	0.36	0.50	0.46
2008	0.32	0.38	0.44	0.42
2009	0.37	0.41	0.50	0.47
2000-2009	0.32	0.36	0.39	0.38

Source: Estimates based on CMIE data

[16] http://articles.economictimes.indiatimes.com/2011-05-20/news/29564781_1_talent-shortage-indian- employers-skilled-trades

[17] It has been reported that Multinationals -- from Pepsico and General Electric to Citibank and Accenture -- are a part of the problem. As they seek to tap into India's growth, they have helped fuel an explosion in wages, especially in the tech and outsourcing sectors. For years they have offered Indians top salaries, opportunities to work abroad, and prestigious credentials, but as both domestic and foreign companies push deeper into new areas such as retail and industrial engineering, the bidding for qualified labor is heating up. Today, salaries for senior managers at some Indian companies nearly equal those at multinationals.

9.4.4 Skill movement and Innovation

As predicted in the model, the skilled labour movement effect is likely to have its implications on the innovation capability of the stand alone firms. As is evident from the INGINEUS survey about 62 percent of the firms had claimed that they had a new product in the last three years. While it was 67 percent of the firms in case of services. But there are considerable differences across the organizational type of the firms their ability to succeed in various types of innovation activities. For instance, while 50 percent of the stand alone firms claimed new products, it was 88 percent in case of MNC head quarters and 69 percent in case of MNC subsidiary (table 5). Such differences in the innovation activity based on organizational types are visible across all types of innovation activities. MNCs with head quarter in India are the most innovative firms in Indian ICT sector across various categories of innovation activities, followed by MNC subsidiaries, while stand alone firms being the least innovative.

Table 5: Distribution of firms in terms of reported innovation in past three years (2006-09) across different organizational categories (%)

	Stand alone	Subsidiary of MNCs	Head quarter of MNCs	Total
New products	50.30	68.87	88	62.04
New services	56.29	75.47	86	66.98
New or significantly improved methods of manufacturing or producing	42.51	56.6	78	52.47
New or significantly improved logistics, distribution or delivery methods for your inputs, goods and services	44.31	51.89	80	52.16
New or significantly improved supporting activities for your processes (e.g. purchasing, accounting, maintenance systems etc.)	43.11	55.66	84	53.4

Source: Estimates based on INGINEUS survey data

Moreover as is evident from table 6, the stand alone firms had a poor innovation record as compared to their counterparts. While MNCs head quarters and MNC subsidiaries were reporting most of their innovations as either new to the world or new to the industry in case of standalone firms innovations were mostly new to the firm. This pattern was found holding good, be it product, or service, or any form of innovation.

Table 6: Distribution of firms based on nature of innovative outcomes in past three (2006-09) years (%)

	Stand alone	Subsidiary of MNCs	Head quarter of MNCs	Total
New Product				
New to the world	11.98	14.15	22	14.2

New to the industry	23.35	39.62	60	34.26
New to the firm	18.56	15.09	10	16.05
New Service				
New to the world	10.18	16.04	14	12.65
New to the industry	23.35	34.91	54	31.79
New to the firm	25.15	24.53	22	24.38
New Process				
New to the world	4.19	6.6	12	6.17
New to the industry	19.76	31.13	46	27.47
New to the firm	19.76	18.87	24	20.06
New Distribution				
New to the world	7.78	4.72	6	6.48
New to the industry	17.37	31.13	46	26.23
New to the firm	20.36	16.04	32	20.68
New Manage				
New to the world	6.59	4.72	2	5.25
New to the industry	12.57	37.74	50	26.54
New to the firm	25.75	13.21	32	22.53

Source: Estimates based on INGINEUS survey data

The Indian MNCs and foreign MNCs engage in a number of strategies to reduce attrition rates in their firms, other than wage corrections[18]. One of the most important is the learning environment of MNCs. Studies show that the learning environment in the firms was the most important incentive for the worker to continue with the IT firm (Abraham, 2007). Given the fact that IT industry is not only skill intensive but also experience high rates of skill redundancy and obsolescence, the typical IT worker needs constant skill upgrading. MNCs through their GINs are engaged in interactive learning processes through innovation networks that tap into global knowledge sources.

The INGENIUS survey results also indicates that the differential innovative outcomes across different organizational categories cannot be delinked from the differences in terms of their innovation strategies. It is observed that the Indian MNCs and Foreign MNC subsidiaries are relatively more globally networked for their knowledge sources as compared to standalone firms. For instance, while more than 73 percent of the stand alone firms depend on their own in-house technological inputs for innovation in case of MNC subsidiaries this dependence was only a lower level (46 percent) and when it comes to MNC heads quartered in India the share further declines to 23 percent (see table 7). On the other hand 16 percent of the MNC subsidiaries and 21 percent of the MNC head quarters reported that their own branches of MNCs were the most important technology source, which differentiated them from standalone firms. Further, the largest difference between MNCs and stand alone firms seems to stem from technology purchases from other MNCs. The stand alone firms are by and large dependent more on the domestic collaborators while MNCs and subsidiaries of MNCs depend more on foreign actors for collaborations for their innovation

[18] Other popular strategies to retain workers, apart from salary hikes and learning opportunities include, recruitment through employee referral system, which exploits kinship and friendship based ties to retain workers; productivity based incentive component in the wages which acts as a sieving mechanism to retain productive workers; providing equity options with a lock-in period for realization and enhancing career mobility within the firms.

activity. For instance, while MNC subsidiaries and MNC headquarters had nearly 80 percent of their client's collaboration from foreign countries, for standalone firms this was only 56 percent.

Table 7: Most important source of technology for enterprises in India's IT sector

	Stand alone	Subsidiary of MNCs	Head quarter of MNCs	Total
We produce most technological inputs in-house	73.13	46.08	22.92	56.45
We buy most of our inputs from other branches of our own MNC	7.5	15.69	20.83	12.26
We buy most of our technological inputs from non-MNC firms	6.88	14.71	8.33	9.68
We buy most of our inputs from MNCs with which we are not formally connected	11.25	20.59	41.67	19.03
We buy most of our inputs from public-sector organisations, e.g. research institutes, universities etc	1.25	2.94	6.25	2.58
Total	100	100	100	100

Source: Estimates based on INGINEUS survey data

The embedded nature of the global network is visible from table 8. MNCs with headquarters in India have strong formal linkages with various actors of the network and they serve as the sources of new knowledge. More than 80 percent of the Indian MNCs have strong network relationship with foreign clients, while nearly 87 percent of the MNC subsidiaries had such formal linkages, while only 67 percent of standalone firms had such formal linkage with foreign clients. These varied degrees of linkages across various foreign actors follow very similar pattern, with MNC subsidiaries and MNC headquarters exhibiting high degree of linkages while standalone firms have relatively low levels of linkages.

This environment of learning embedded in large MNCs provides the worker with the opportunities to acquire relevant skills along with the evolution of the industry in an informal but continuous learning process. In many cases the worker engages in direct interaction with many of these sources of knowledge and ultimately become the carriers of new knowledge in their place of work. This apart, the large MNCs in India, as well MNC subsidiaries operating in India engaging in such formal and informal learning environment provides them with another advantage. These firms do not have to seek highly skilled workers with high levels of technical qualifications as their employees. For these firms, the largest share of their fresh recruitments occurs through campus placements. Fresh graduates without industry experience are usually preferred. Studies show that many firms recruit new employees not on the basis of their specific IT qualifications but on the basis of their adaptability and 'learnability' (Rothboeck et al., 2001; Abraham and Sharma 2006).

Table 8: Formal linkages with foreign actor groups across different type of firms (%)

	Stand alone	MNC Subsidiary	MNC head quarters	Total
Clients	66.5	86.79	80.0	75.23
Suppliers	50.9	74.53	72.0	61.92
Competitors	34.1	56.6	60.0	45.51
Consultancies	40.1	63.21	68.0	52.01
Government	35.3	58.49	72.0	48.61
Universities/RI	27.5	44.34	46.0	35.91

Note: the figures represent the share of firms with a particular type of linkage in total number of firms in the specific firm type.

Source: Estimates based on INGINEUS survey data

However, for the standalone firms, typically smaller in size, and very weakly networked to global sources of knowledge experience a low level of the firm's informal internal learning environment. Its narrow product range and smaller size limits its ability to provide large scale formal training for new employees. This would imply that these firms, have limited choice to meet the problem of worker attrition, ultimately resorting to wage corrections to retain workers. This has led to the escalation of the wage bill in the standalone firms as shown earlier.

The innovative abilities of these MNCs in turn get translated into higher profits and larger volume of sales. The Indian MNCs and foreign MNCs had been consistently having a much higher ratio of profit to sales ratio compared to the standalone firms (see table 9). On the average, during the period 2000 to 2009 the profit to sales ratio of foreign MNC subsidiaries and Indian MNCs was 15.5 per cent and

Table 9: Size and profitability (profit to sales Ratio %) of different types of firms in India's IT sector.

	profit to sales ratio (%)					Average sales per firm (Rs. million)			
Year	Foreign MNC	Indian MNC	Stand Alone Firms	Average		Foreign MNC	Indian MNC	Stand Alone Firms	Average
2000	25.7	18	11.1	17.6		4.24	11.31	1.16	4.09
2005	17.3	20.8	3.4	17.1		12.55	36.17	2.86	10.66
2006	17.5	21.1	9.8	19.6		17.72	49.7	1.75	13.13
2007	13.6	22.7	11.2	20.6		20.35	70.17	2.55	18.35
2008	12.5	22.3	10.6	20		24.91	86.15	3.78	23.36
2009	13.3	10.1	8.5	10.3		31.02	107.76	4.17	28.05
2000-2009	15.5	18.3	7.4	16.6		12.95	37.36	2.25	11.58

Source: Estimates based on CMIE data

18.3 percent respectively where as it was only 7.4 percent in case of standalone firms. The higher innovation capability of the MNCs (both local and foreign) also enabled them to expand their sales volume such that the average standalone firm had a sales volume of only Rs 2.25 Million per annum, while the Indian MNCs were nearly seventeen times larger and foreign MNC subsidiaries was on average six times larger than the standalone firms. More importantly, the observed growth in the sales of standalone firms has also been at a much lower rate as compared to their counterparts. While sales of foreign MNCs and local MNCs recorded nearly eight fold and nine fold increase during 2000-09 that of standalone firms increased only by less than four times.

9.5 Concluding observations

The Global Innovation Networks are here to stay and the participation of firms from developing countries is likely to be more than ever before during the years to come. This has been induced by both push factors from the developed countries and pull factors from the host developing countries. It has also been facilitated by the liberal trade and investment policies on the one hand and increased use of information technology on the other which in turn reduced the uncertainty as well as the cost of coordination and transaction that undermined the power of centripetal forces. The GINs are also perceived as intrinsically having the potential to emerge as the key catalyst in enhancing the innovation capability of firms in host developing countries. Yet our understanding on the implications for host developing countries on their participation in GINs remains at best rudimentary because of the deficit in theoretically informed empirical research on this issue. The present study, therefore, drawing insights from the Dutch disease economics and the underlying specific factors model, explored the implications of India's increased participation in GINs by taking the case of India's ICT sector with a view to draw policy implications.

This study has shown that the generally held view - India is a country with abundant supply of skilled manpower - does not empirically hold. Instead, given the much lower proportion of people with higher education, the skill intensive sectors like ICT are confronted with severe skill shortage as manifested in high rate of employee attrition and higher rate of growth in wages and salaries. Under such conditions, India's entry into Global Innovation Network, as manifested in the growing FDI in R&D, result in an intense competition between local stand alone firms and MNCs for the available skilled manpower. This in turn adversely affects the innovation capability of standalone firms *vis a vis* their MNC counterparts (both foreign and local). Thus viewed, the current environment confronted by the relatively small stand alone firms is entirely different from what the today's Indian MNCs enjoyed in the past and the scope for the stand alone firms to emerge as Indian MNCs is limited.

To the extent that the state played a crucial role in making India's ICT sector attractive for foreign MNCs, the state has to play a crucial role in the current juncture wherein in the GINs appears to bridle the local innovation capability. This will call for new institutional arrangements and policy initiatives with respect to innovation policy in general and FDI policy and human resource development policy in particular to harness the potential spillover effects of GINs. In the absence of such interventions, the global innovation networks might turn into global innovation traps with serious adverse consequences.

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10 MULTINATIONAL STRATEGIES, LOCAL HUMAN CAPITAL, AND GLOBAL INNOVATION NETWORKS IN THE AUTOMOTIVE INDUSTRY: CASE STUDIES FROM GERMANY AND SOUTH AFRICA

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Abstract: Until recently, innovation in the automotive sector was highly concentrated in a few developed countries. However, the centripetal forces driving this concentration may be increasingly countered by centrifugal forces that favour increased knowledge-intensive activity in developing countries, and hence the formation of Global Innovation Networks (GINs). The availability of the requisite competencies and capabilities in host countries is one of the key drivers of this process. Using Lall’s capabilities approach, and against a backdrop of recent trends in the global automotive manufacturing sector, we interrogate five case study firms to learn more about the relationship between multinational strategies, local human capital, and the formation of GINs. The firms include three German multinationals with subsidiaries in South Africa, and two South African firms with subsidiaries in Europe. The German multinationals undertake an array of measures to access or internally develop the competencies and capabilities required for technological upgrading and increased knowledge-intensive activity, some of which entail incipient GINs. The South African firms adopt different strategies in response to structural constraints and local skills shortages, including the initiation of GINs. One of these strategies is the purchase of knowledge assets in developed countries. However, these purchases do not guarantee knowledge flow – this takes time, capabilities upgrading and the careful organizational management of tacit knowledge. The various strategies exhibited by the case study firms respond to the sectoral dynamics of the automotive sector and to the human capital landscape in South Africa. This renders a generalized model of GIN formation, both from North to South, and from South to North.

Keywords: Global Innovation Networks, Multinational Strategies, Human Capital

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10.1 Introduction

This paper focuses on the relationship between strategies of Northern and Southern firms, mostly multinational enterprises (MNEs), and human capital in Southern host countries in the automotive supply industry, and the implications of this relationship both for the management of technological change and for the constitution of global innovation networks (GINs). We define GINs as global networks in which some knowledge-intensive activities are based in developing countries. They differ qualitatively from the better known global production networks (GPNs) where Northern MNEs traditionally control the key technological assets, while outsourcing the supply of parts and components or assembly to contract manufacturers. In particular, we use firm-level case studies to explore the micro-determinants effecting the evolution of GINs (which can evolve from and be nested within GPNs).

GINs are a result of the emerging geography of knowledge-intensive activities in the global economy. On the one hand, the increasing complexity of knowledge required for global competitiveness, shorter innovation and product cycles, and the associated cost pressures have led MNEs to offshore and outsource R&D (Archibugi and Iammarino, 2002; Wooldridge, 2010). On the other hand, the spread of technological capabilities in a number of advanced developing economies, including lower middle-income countries such as China and India, have opened opportunities for design, applied development, and even basic research (UNCTAD, 2005). What is new is not the offshoring or outsourcing of R&D per se (OECD, 2007), but the gradual involvement of firms and other actors such as universities and research labs from a few developing countries in what until a decade or so ago played itself out exclusively among the advanced Triad economies plus a few latecomers from East Asia, notably Korea and Taiwan.

The evidence concerning GINs is not comprehensive. To date it is primarily based on indications of CEOs or R&D managers of important Northern MNEs who participated in surveys (Dilk, Gleich, and Wald, 2008; UNCTAD, 2005) or on descriptions of individual examples of such GINs, often in the business press (Wooldridge 2010). The most comprehensive and recent source of data is from the European Commission's INGINEUS project, which in 2010 included a survey of 1215 companies in six European countries and in Brazil, China, India and South Africa in three industries (agro-food, automotive, and ICT). It was found that 25 per cent of these firms offshored either production or R&D, and that, next to market access, the availability of specialized competencies at lower cost than in the home region, as well as access to knowledge infrastructure and services in the host region, were the most important location-specific advantages. Between five and six per cent additionally reported that subsidiaries in developing countries were responsible for strategic management, product development, and technology and process development (see the Appendix A for more information about the survey).

While the existence of GINs is not in doubt, their evolution is less clear. We do not know much about the micro-determinants shaping the formation of GINs that are anchored within GPNs. Dutrénit (2004) pointed out that the literature on technological upgrading in developing countries had only ever asked how firms graduated from simpler to more sophisticated capabilities, without looking at subsequent trajectories that would bring them closer to the global technological frontier (see also Lorentzen, 2009). To some extent, this simply reflected an empirical reality, namely that the majority of developing country firms did not "innovate" in the sense of pushing the frontier.

Yet apart from the fact that there were important Southern firms that did not fit the idea of "innovation" only as "adaptation" (Hobday, Rush, and Bessant, 2004; Kim, 1997) – Samsung's overtaking of Sony is but one example (Chang 2008) – the small size of this phenomenon does not justify the neglect of the conceptual and theoretical treatment afforded to the evolving technological trajectories of developing country firms toward new-to-the-world activities. Apart from the fact that it was always unlikely to remain small, it is incumbent upon researchers to recognize the limitations of the existing literature and think more systematically about how developing country firms master the hardly trivial process of moving from a merely operational understanding of technologies (as part of a GPN) to an understanding of the principles behind these technologies that is required for innovation activities (as part of a GIN).

The present paper is an attempt to contribute to a better understanding of the micro determinants of GINs. Since the INGINEUS survey indicated that the availability of specialized lower cost competencies and knowledge infrastructure and services were critical location-specific advantages, we have focused this paper on the role of human capital in developing countries. Lall (2001) analysed the relationship between education and skills systems, and technological trajectories in East Asia. He showed how education and skill strategies must anticipate technical change in order for host economies not only to become and remain attractive locations for multinational investment, but also to exploit the associated knowledge transfer and spillover in support of economy-wide upgrading. Yet he did not look at R&D capabilities.

This paper extends Lall's analytical framework to include R&D and innovation activities. Against a background of data describing host country absorptive capacities (with a focus on education and skills data and foreign direct investment data), and a review of current dynamics in the automotive sector, we interrogate a set of case studies from a European car producing economy (Germany), whose assemblers and suppliers have investments in important advanced developing countries (South Africa). We also look at some South African firms that invested in Europe to access knowledge from more advanced suppliers. These case studies aim to illustrate how sectoral dynamics and local human capital conditioned the embedding of South African automotive manufacturers into (sometimes incipient) GINs.

The automotive sector is suitable for this analysis because it includes a range of different technologies, which illustrate different technological learning trajectories. The sector also offers clear delineations between skills levels in the organization (worker, supervisor, engineer, management, scientist), which facilitates an analysis according to Lall's understanding of technological upgrading being reliant on upgrading at all skills levels. The firm locations in Germany and South Africa illustrate North-South relationships; although there are unique aspects to these countries, they nonetheless have value as illustrative cases of a developed and a developing country. In this context, our analysis of the case studies focuses on specific instances of technical change, how they were supported by human capital upgrading, what difference this made (or not) for the control of technological progress within each value chain, and how all this influenced the evolution of GINs from GPNs.

10.2 Conceptual framework: MNEs, human capital, and technological learning in developing countries

The unit of analysis for this paper is people, and the skills, competencies and capabilities that they embody. We make distinctions between these terms based on the work of Van Tunzelmann (2009). Here we refer to *competencies* as specific sets of skills and knowledge which are usually generated outside the firm, for example through education institutions, but can also be generated inside a firm, for example through internal training programmes. When a Northern firm is investigating the possibility of investing in a developing country, the availability of the required competencies is a key factor. On the other hand, *capabilities* refers to the functional capacity of (people inside) a firm to complete specific tasks required for its role as a supplier, producer, or consumer. Capabilities are usually built up from inside a firm, for example through experience, the gaining of tacit knowledge, and organizational innovation. If a Northern firm is seeking to purchase a Southern firm, it is the capabilities embodied in that firm that offer value. We use the term *human capital* as an umbrella term that refers to and includes the notions of competencies, capabilities, absorptive capacities, the strength of education and training institutions, and creativity.

MNEs thus embody certain capabilities while at the same time looking for new ones in a few advanced developing countries. At the same time, they must be able to transfer their technologies to subsidiaries or JVs in these developing countries. Absorptive capacity is thus a key consideration - Cohen and Levinthal (1989, 1990) define absorptive capacity as the extent to which external knowledge can be internalised. In the South, education and training systems are an essential element of high absorptive capacities which in turn are a prerequisite for GINs. The relationship between foreign direct investment (FDI) and local human capital is two-way. On the one hand, educational achievements attract inward direct investment (Noorbaksh et al 2001, Te Velde 2005, see also Dunning 1993). On the other hand, MNEs exert influence over education and training systems post-entry, both directly (Borensztein et al 1988, Lall and Narula 2004, Lorentzen 2008, Spar 1996, Tan and Batra 1995) and because they increase competition (Chuang 2000, Grossman and Helpman 1991, Moran 1998), while accelerating skill-biased technological change (Berman et al 1988, Te Velde and Xenogiani 2007).

Lall analysed dynamic upgrading (2001, esp. Chapters 5, 7) by linking the capability approach with an analysis of human capital. Important elements of firm-level capabilities and, hence, learning include the following. First, since technologies make different demands on learning requirements, the learning process is technology specific. What works in an electronics plant where an essentially codified new technology may be embodied in a new piece of capital equipment, is not necessarily relevant for an automotive supplier facility where an emerging technology may be a lot more tacit (Jung and Lee 2010). This also means that when tacit knowledge is important, the role of geographic proximity rises. The breadth of skills and knowledge required to master new technologies also differs, as does the time to take them on.

Second, different technologies depend to differing degrees on external sources of information. In the extreme case one might think of an almost self-contained cluster as opposed to a global technology network to which different firms and research institutes or migrating knowledge workers contribute. Third, relevant human capital inside the firm includes everybody from the shop floor to senior management. The design of a new product may primarily be in the hands of a few R&D engineers. Yet whether their research leads to a commercially successful innovation also depends on the efficiency and quality with which workers turn prototypes into products. Thus our analysis of skills availability in host countries includes specific foci on the level of the worker, supervisor, technical, engineering, management, and scientist.

Fourth, technological trajectories cannot be successful by relying exclusively on the mastery of operational know-how. It is also necessary to understand know-why, which implies deeper capabilities that include an understanding of the principles of the technology. This is especially important in the context of GINs as opposed to GPNs; for the latter the exclusive pursuit of operational know-how may be a feasible strategy, but know-why is critical to GIN formation. Fifth, technological learning takes place in an environment characterized by externalities and linkages which in turn depend on institutional characteristics. Education and training institutions are among those that matter prominently

In looking at the specific linkages between MNEs and local human capital, it is pertinent to distinguish between internalized as opposed to externalized transfers of technology. When a MNC chooses to keep (proprietary) technology to itself, the transfer of know-why (but not typically of know-how) may suffer, unless local R&D capabilities are already high (which in developing countries they of course often are not). Either way, local firms must develop the skills and the knowledge to master the tacit elements of whatever it is that is being transferred.

Much as early and later stages of catch-up require different kinds of skills and competencies, there are presumably differences in terms of the level of sophistication at which latecomer countries, regions, firms or other actors get involved in GINs. These differences may play out within the very same country – for example, whereas a university may be involved in basic research that feeds into the design part of a GIN, a firm may contribute productive activities that are mere assembly. So although the terminology of *national* technological capabilities is a useful way of thinking about the technological trajectories of countries, it of course does not mean that entire countries get slotted into GINs at specific levels of (high or low) technological sophistication, but rather at a range of activities (see also Hobday et al 2005). Undoubtedly however, the emergence of GINs implies that education and training systems can on average no longer provide a merely literate and numerate workforce, as they may have done at the very beginning of technological capability building.

10.3 Methodology

In order to identify the effects of firm strategies and local absorptive capacities on the nature and quality of technical change and GIN formation, we first selected German first-tier supplier MNEs with investments in South Africa. Research teams in each of these countries contacted their respective firms and arranged interviews with managers in charge of R&D, technology, or innovation as well as of human capital. This rendered matched case studies where the teams interviewed both headquarters and subsidiary. These cases were supplemented by interviews with South African firms that had invested in subsidiaries in Europe. These 'South-North' cases were complementary, in that they illustrated the formation of GINs from a Southern origin and perspective.

We compiled profiles for each firm, based largely on trade magazines and other specialist literature. The interviews were semi-structured and focused on upgrading and location strategies, human capital, and the management of technological change. In line with Lall's observation that skills at all levels matter in processes of dynamic upgrading, the human capital dimension of the interview included questions about all skill levels of the workforce, from shop floor workers to scientists. Within each case we then focused on a specific instance of technological change that required upgrading across some or all skill levels of the firms' workforce, and identified the requisite learning as well as the actual form this upgrading took

These instances of technological change were then analysed within Lall's conceptual framework, and against the backdrop of sectoral dynamics and the availability of local competencies. These rich cases provide concrete illustrations of the array of factors that shape the emergence and evolution of

GINs, both from North to South and from South to North, with a focus on the role of human capital availability. We set out to establish to what extent GINs are emerging from GPNs, what their technological trajectories are, how these are influenced by contextual factors. Our case studies examine how the various pressures within the automotive sector articulate with local human capital availability to inform firm strategies with regards to technological trajectories and GIN formation. The strategies of both German MNE and South African originated firms are explored, with a focus on how they manage technological upgrading, both through accessing technology transfer from outside the firm and through internal knowledge production such as R&D.

Interviews took place in the second half of 2010 and lasted up to two hours. Researchers produced a synthesis of the conversation which they submitted to the interviewees for the vetting of accuracy. The firms were assured confidentiality. The case studies include five firms, of which three are German MNCs with subsidiaries in South Africa, and two are smaller South African firms with subsidiaries in Europe and other developed countries (see Table 1).

Table 1: Case studies description

Firm	Turnover 2009	Locations	Product range	Interviews conducted
Drivetraincomp	€5-10 bn	Global: 180 locations in 50 countries	clutches and bearings	South Africa
Exhaustcomp	€1-5 bn	Global: locations in more than 20 countries	exhaust systems, heating systems	Germany, South Africa
Tempcomp	€1-5 bn	Global: 22 production locations, 11 development centres, and two fully equipped R&D centres.	heating and cooling systems	Germany, South Africa
Elecsys1	€0-1 bn	HQ and manufacturing in South Africa, sales and R&D centres in the UK and US	electronic components	South Africa

Note: Turnover is given in ranges to protect anonymity.

10.4 Sectoral dynamics: trends in the global automotive manufacturing industry and their effects on innovation

10.4.1 Global growth and the market shift from West to East (and North to South)

Global vehicle production more than doubled between 1975 and 2007, coinciding with rapid globalization and the restructuring of global automotive value chains (GVC). The relative weight of developing countries, especially India and China, in vehicle output has increased, whereas production and sales have shrunk in Western Europe and North America (Sturgeon et al, 2009). Between 2007 and 2009, the share of developing country original equipment manufacturers (OEMs) in global production increased from 1.9 per cent to 7.5 per cent, largely due to growth in China. During this period the Asia-Pacific region was the only one to increase its proportion of both global sales (by 2%) and global production (by 7%) (Automotive World Automotive Passenger Car OEM Quarterly Data Book, 2009).

The onset of the world financial crisis in 2008 accelerated this trend. Prior to the crisis, analyses of the structure of the automotive market tended to underline the importance of regional markets, since OEMs historically produced and sold most of their cars in their home regions in Europe, Japan, and North America (Sturgeon at al, 2009). Both political (the iconic stature and the influence of the industry) and economic (such as just-in-time requirements and logistical problems associated with heavy components) factors militated in favour of regionalisation. The market shift eastwards was characterized as gradual and unlikely to change global dynamics dramatically. However, with the financial crisis it became clear that the shift had accelerated and that it was likely to cause far-reaching changes in global value chains, and consequent changes in the geography of production and innovation (Wad, 2010).

10.4.2 Global value chain re-structuring

Value chains in the automotive industry are producer driven (Gereffi, 2005), which means that lead firms, namely the OEMs and a few large global suppliers, all of which are still located in developed countries, account for the bulk of innovation activity, the production of most engines and transmissions, and almost all vehicle assembly functions. These firms have strong co-ordination capabilities and huge buying power, and the top-ten automotive groups dominate the global market (Wad, 2010). The largest first-tier suppliers have become system integrators; they take on an increasingly larger role in R&D, innovation, production, and the allocation of investment. This has increased their bargaining power within the supply chain (Becker, 2006; Birchall et al, 2001; Chanaron and Rennard, 2007).

In the re-structuring of global value chains in the 1990s and 2000s, MNEs took majority control of many joint-venture assembly operations. Suppliers from the OEMs' home regions set up operations in proximity of foreign locations of the assemblers, a process referred to as follow-source. In addition, domestic suppliers were largely relegated to the second or third tier, or were taken over (Barnes and Kaplinsky, 2000; Barnes and Morris, 2008; Humphrey et al, 1998; Humphrey and Memedovic; 2003; Rutherford and Holmes, 2008).

The financial crisis increased cost pressures on the industry, turned up the heat on OEMs, and accelerated supplier consolidation. The number of first tier suppliers fell globally from 8,000 in 2002 to around 2,000 by 2010, driven by the weak financial position of the industry, acrimonious relationships between OEMs and suppliers, and low capacity utilisation (Barnes and Morris, 2008; Osterman and Neal, 2009; Maxton and Womald, 2004). The growth of large global suppliers – for example Bosch, whose turnover rivals that of smaller assemblers – will possibly lead to the eventual emergence of six to ten globally dominant first tier systems integrators. FDI into developing countries added to global overcapacity, further fuelling cost pressures (Sturgeon and Van Biesebroeck, 2010).

10.4.3 Innovation and upgrading

Market changes and value chain dynamics strongly influence innovation drivers in the sector, which in turn is likely to impact on the role of human capital in the formation of GINs. Firstly, the concentration of power within a few lead firms has implications for the structure of innovation.

Innovation takes place at large firms – OEMs like Ford and Daimler are consistently among the top spenders on R&D worldwide (Dehoff and Jaruzelski, 2009) and moves in a top-down fashion. Assemblers create unique standards and specifications, necessitated by the high level of inter-relationships in the performance characteristics of components that differ for every model. Together with the absence of open industry-wide standards, this undermines value chain modularity and makes supplier investments relationship-specific. This creates a consistent demand for R&D among the large firms in the sector, particularly among assemblers and first tier suppliers, but it also acts as a centripetal force that concentrates R&D within the highest tiers and largest firms. Since barriers to entry are raised by investment requirements and by the top-down direction of design specifications, the scope for innovation among smaller firms is further reduced. The close collaboration between suppliers and assemblers also leads to agglomerations of firms near the headquarters of assemblers and large tier 1 suppliers, further concentrating innovation in these clusters. The industry effect is a limit to economies of scale in production and of scope in design.

However, vehicle and component R&D has achieved greater global integration than production, as firms have sought to leverage their design functions across multiple products and end markets, a process referred to as follow-design, while eventually adapting each model to its specific market conditions (Humphrey and Memedovic, 2003; Sturgeon et al, 2009). This also creates high barriers to entry and limits prospects for upgrading by smaller firms and firms in developing countries.

At the same time, contrasting dynamics are influencing the conduct of innovation in the industry. Very large and growing markets such as Brazil, China, and India make it profitable for assemblers to adapt existing or even to produce specific models (Brandt and Van Biesebroeck, 2008). OEMs thus establish regional headquarters as well as regional design and innovation centres. In turn, this creates pressure for lead suppliers to follow suit and to source inputs from local second tier suppliers which might end up supplying assemblers directly. Similarly, OEMs use advanced developing countries, whose markets do not justify specific models but are large enough to warrant local assembly, as regional production hubs. In countries such as South Africa, Thailand and Turkey, this opens opportunities for local suppliers, including for export. By contrast, developing countries that are close to and can supply on a JIT basis to a regional trade block (for example Morocco, Mexico, or Turkey), tend to specialise in labour-intensive components. If capability upgrading occurs, opportunities may arise for the production of capital intensive parts and even assembly (Carillo, 2004; Lorentzen, Møllgaard, and Rojec, 2003).

In sum, technological trajectories depend on the interplay between both Northern and Southern MNE strategies and local absorptive capacities, mediated by geography (cf. Sturgeon and Van Biesebroeck 2010). Some trajectories depend more on external sources of knowledge and technology, while other have a greater role for internal sources such as R&D. The most straightforward channel for technology transfer is internally from MNEs to their subsidiaries (e.g. Ivarsson and Alstram 2005). Such transfer can, but need not, take place in JVs (e.g. Nam, 2010; Sadoi, 2008). Technological upgrading can also take place when a Northern supplier transfers technology to a Southern assembly plant or when a Southern assembler acquires the competencies of a Northern firm, a strategy followed by Chinese OEMs Sichuan Tengzhong Heavy Industrial Machinery Company, Geely, and Beijing Automotive Company (BAIC), with their purchases of Hummer from General Motors, Volvo from Ford, and rights to Saab styling and technology, respectively, or Indian OEM Tata's acquisition of Jaguar and Land Rover.

Of course none of these strategies are guaranteed short-term success in terms of transfer, especially of the tacit knowledge that would allow the Southern firm to bridge existing technology gaps. Firm strategies are also mediated by the availability of skills at different levels. The establishment of production facilities as part of a GPN may require skills mostly at the lower levels (worker, supervisors, technicians), while the establishment or growth of innovation activities or an R&D Centre will require skills at the higher levels of engineering and management. The availability of these skills in host countries may act as a determinant of technological trajectories and the evolution of GINs within GPNs.

10.4.4 Global innovation networks?

By comparison to other industries, notably electronics, it is evident that GINs do not (yet) characterise the automotive sector. The most important OEMs and suppliers continue to be located in a few regions in a few developed countries. They control a very hierarchical value chain, based on follow-design and follow-source, and centralise (most) R&D. Due to the nature of automotive technology, investments are often asset-specific and closely tie suppliers to system integrators and assemblers. Finally, the industry is already highly concentrated and this is likely to increase further. The general consensus in the literature is that the combined effect of these characteristics is to curtail opportunities for new-to-world innovation for Southern firms.

However, it is also evident that the industry, especially in the context of the global financial crisis, is changing. Markets in Asia are slowly outgrowing the automotive heartlands in the Triad economies. The design of specific new models as well as adaptations of existing models rely in part on local design and innovation centres that create demand for R&D. At the same time, two decades of production of cars for global markets by developing country producers have raised their technological capabilities. Some of these firms are sufficiently confident to acquire Northern assets to advance their upgrading yet further towards the frontier. In addition, cost pressures on the industry make it irrational to neglect stronger absorptive capacities in developing countries, including in R&D. Taken together, this does not mean that the emergence of GINs is a foregone conclusion. But it does mean that the literature is wrong to neglect or dismiss powerful economic arguments in favour of R&D offshoring and outsourcing and advance an interpretation of automotive industry dynamics based more on the past than on a consideration of possible future developments, as well as incipient instances of knowledge intensive activities in the South that point to a gradually evolving, different landscape.

In sum, trends in the automotive industry do not all point in the same direction (see Table 2). Features that have been characterizing the industry since the early 1990s – hierarchy, knowledge architecture, and consolidation – do not on balance favour the evolution of GINs. On the other hand, cost pressures which have been around for decades but which the global financial crisis has exacerbated, bringing a few OEMs to the brink of bankruptcy, and the eastward shift of markets both for production and sales open up opportunities for firms in countries like Brazil, China, and India. They can combine their advanced capabilities with market-seeking investments by OEMs to work on adaptation as well as dedicated new vehicle models. OEMs and lead suppliers, in turn, can adjust to cost pressures by exploiting high-level capabilities in R&D that firms and research institutes in these countries offer at more competitive prices.

Table 2: Characteristics of the automotive industry

Feature	Does not favour GINs	Favours GINs
Value chain hierarchy	A few OEMs and system integrators in the North control all activity. Unique standards and specifications require asset-specific investments. OEMs insist on follow-design.	
Value chain knowledge architecture	Division of labour in R&D between OEMs and lead suppliers leads to agglomerations in the North and to follow-source.	Follow-source in large emerging markets involves local second-tier suppliers that can move up the hierarchy.
Consolidation	Raises barriers to entry for small and developing-country firms.	
Cost pressures		Opens opportunities for high-level capabilities in traditionally high-cost activities from lower-cost sources in developing countries.
Market size and growth		Production and sales in Brazil, China, and India are catching up on automotive heartlands. Adaptation of existing and design of new dedicated models create demand for R&D.

10.5 Automotive foreign direct investment, competence availability, and absorptive capacity in South Africa

Germany has a long history of investment in South Africa’s automotive manufacturing sector. Volkswagen has been assembling vehicles in South Africa since the 1950s, and BMW and Mercedes since the 1970s. These assemblers have been supported by a number of German suppliers who have subsidiaries in South Africa. All three assemblers have had a similar technological trajectory: they began as ‘completely knocked down’ assemblers of imported components or semi-assembled car kits, moved to higher value added assembly with a larger domestic supply base, and since market liberalization in 1995 have absorbed technologies from their parent companies and upgraded to become Word Class assemblers that are integral parts of GPNs. Their supply based has evolved along with the assemblers.

A key factor in the allocation of more knowledge intensive activities to South African assemblers and suppliers has been their capacity to absorb new technologies from Germany. The characteristics of local absorptive capacity in the South African automotive sector can be gauged by examining previous FDI patterns (as historical indicators of absorptive capacity) and educational output data (as indicators of the availabilities of the required competencies).

Due to South Africa’s history of unequal development, the country suffers from severe skills constraints, within which are nested pockets of higher-level competencies and capabilities. Although the country spends massively on education and achieves comparatively high enrolment rates, in many indicators the education system ranks at the bottom of international league tables, especially in math and science education and the availability of scientists and engineers. Brain drain is also a problem. At the same time, the country has relatively good public research organizations, business schools, and university-industry linkages (see Appendix B for key indicators comparing South Africa with other developing countries and with Germany).

But these are average assessments. More important is how skills constraints affect automotive firms, how firms address them, and with what effect. Historically, the skills required for the growth of South African firms and their integration into competitive GPNs have been available, through competences developed both externally and within firms. Until the early 1990s, the South African automotive industry, which included most large OEMs, was largely cut off from international competition, investment, and value chain relationships. It primarily supplied the domestic market and was not internationally competitive. Following political changes in the country in 1994, the OEMs returned to South Africa and reacquired their assets. They were attracted by market liberalization and the Motor Industry Development Plan (MIDP), an industrial policy aimed at attracting inward direct investment and featuring an import-export complementation scheme, by which component and vehicle exporters could earn credits to offset import duties (Barnes, 2000).

Just as in other developing and transition economies, component producers followed suit. Between 1997 and 2003 sourcing from domestic multinational subsidiaries increased from 26 per cent to 37.5 per cent of the supply base, while the use of local firms with local technologies declined from 25.8 per cent to only 10 per cent (Lorentzen and Barnes, 2004). Between 1997 and 2008, investments by assemblers amounted to ZAR31.2bn of which eight per cent was devoted to R&D and engineering (Gastrow and Gordon, 2010). This paled in comparison to investments undertaken in Brazil, Mexico, China, Thailand, and Central Europe (Black, 2009). However, BMW, Daimler, and VW positioned their South African operations as a key element in their globalization strategies of the 3-series, the C-Class, and the Golf GTI, respectively, seeking not only greater production efficiencies but export capabilities, and invested accordingly. Between 1995 and 2008 South Africa’s production increased from 278,000 to 563,000 units, largely driven by exports, which increased from 16,000 unit in 1995 to 284,000 in 2008, or from four per cent to 51 per cent of total production (Gastrow and Gordon, 2010).

The result of investment in plant and human capital upgrading was that the local industry significantly improved its performance to reach world-class levels. In terms of cost control, quality, flexibility, reliability, human resources, and product testing, South African plants closed the gap to their international competitors, a gap which in the early 1990s had been rather large. In terms of quality, local plants ranked better than the international average (Barnes and Morris, 2008), and the performance of local subsidiaries such as the BMW plant in Roslyn occasionally exceed their parent operation in Germany (Goldstein, 2003, quoting the JD Powers Gold Quality Awards, 2002). In sum, the technological and organizational performance of the industry as a whole and the capabilities of its human capital improved over the last decade and a half.

Thus, in contrast to data describing national skills availability, while the industry increased investment, production, and exports from the second half of the 1990s (bolstered by market liberalization, policy support, domestic market growth, and increased investment), the availability of mid- and high-level skills was largely sufficient (Black, 2009). OEMs played a major role in upgrading unskilled and semi-skilled workers as well (e.g. Lorentzen, 2007). This suggests that automotive firms had established means of creating or harnessing the skills they needed to grow and to technologically upgrade.

Thus human capital in South Africa has historically been sufficient for the integration of local automotive subsidiaries into GPNs. There have also been pockets of innovation activity and R&D. Previous research has described these activities (Gastrow, 2007; Gastrow and Gordon, 2010). It was found that assemblers and component suppliers could find sufficient skills to undertake niche R&D activities, mostly related to adaptation for the local market, and occasionally the design of new models for the local market. However, the marginal availability of local skills is small, and this was found to be a constraint on increased R&D activity at these firms.

10.6 Case study analyses

Each of our case studies represent a specific case of movement along a technological trajectory. Within this, there is a focus on specific instances of technological upgrading. Each of these reflects a strategic decision to undertake a process or product change in a specific location, and each of these strategic decisions is influenced by the availability of the requisite human capital (amongst other factors). Ceteris paribus, the closer the change is to R&D as opposed to other forms of upgrading, and the more it takes place in South Africa as opposed to Germany, the more evidence there is of a (potentially) evolving GIN.

R&D strategies of the case firms range from no to complete offshoring. The German MNEs are more or less reluctant R&D offshorers. Exhaustcomp and Tempcomp undertake very little innovation activity in South Africa. Their South African subsidiaries can be described as being at the very incipient stages of integration into a GIN that is emerging from within a GPN. Both of these cases explore the role of human capital at this early stage of GIN development, and both also contrast innovation at the South African firms to innovation centres that have been established in India by the same MNEs. Drivetraincomp undertakes small pockets of development activity for the South African market, and is somewhat more evolved. This case study focuses on the role of local market adaptation in stimulating innovation in the host country.

The smaller South African firms illustrate GIN formation originating in the South. Elecsys2 undertakes its R&D in South Africa, and channels this knowledge to its subsidiaries in Europe and Australia. Conversely, Elecsys1 undertakes its entire R&D abroad, following the purchase of a knowledge-intensive firm based in Europe and the US, but undertakes production at the South African headquarters. These cases illustrate how human capital, and the search for it, shape the formation of GINs not just extending South from the developed world, but extending North from the developing world.

10.6.1 German MNEs with subsidiaries in South Africa

The three German MNE case study firms are all 'mittelstand' firms that originated in Germany in the late nineteenth century or early twentieth century, and have grown to become global suppliers to the automotive sector on the back of continuous R&D. Drivetraincomp, in addition to headquarters and operations in Germany, has an additional 180 locations in 50 countries. The group manufactures a broad range of products and is a major supplier to global OEMs. The South African subsidiary focuses on the production of clutches and related components. This subsidiary has consistently supplied several of the OEMs with assembly operations in South Africa, and also supplies the aftermarket. Exhaustcomp is also headquartered in Germany, and has subsidiaries in over twenty countries. The firm produces exhaust systems and related products for OEMs across global markets. The South African subsidiary was established to supply local OEMs and also to export back to Europe to earn import complementation credits according to South Africa's automotive development policy scheme. Tempcomp provides heating and cooling systems to global OEMs. The firm has a global footprint of nine development sites, 22 production sites and ten joint ventures worldwide. There are three production facilities South Africa, supplying mostly domestic customers.

All interviews at the German-owned firms reported that skills availability in the home country is sufficient to support the core R&D functions of the firm, usually located in proximity to headquarters. In Germany an excellent education system and vocational training system produce large quantities of high-level skills, and moreover the recent contraction of the sector has resulted in floating skills being available in the labour market. Thus human capital availability is not a driver for outsourcing innovation activity from Germany to other countries; rather, it is human capital availability in host countries that influence these decisions. One important factor is the availability the requisite skills and absorptive capacities at a lower cost; another is proximity to large final markets, where adaptation to local tastes and conditions might be a preferred strategy for growing market share. The contrasting cases of India and South Africa illustrate how differences in these pull factors lead to different outcomes in terms of the allocation of knowledge intensive activity and the trajectories of technological upgrading.

R&D has been part of Drivetraincomp's strategy since its origins in the late nineteenth century, and has played a major role in establishing its global market position. The group traditionally conducts basic R&D as well as pre- and product development at its headquarters, and centrally coordinates global innovation activity. This is typical of the sector in Germany. It invested in a new R&D centre in the US in the early 2000s and more recently in China, both of these being responses to market opportunities and the need to be geographically and otherwise closer to their customers in these markets. The South African subsidiary only undertakes applied development. For example, Drivetraincomp SA designed a specific drivetrain component for a Japanese OEM. For this contract it interacted directly, not via the parent, with the customer. Its knowledge of local road surface and load conditions allowed it to develop an adaptation of an existing component to the much tougher requirements faced by commercial vehicles in developing countries. Its technology was subsequently passed on to the Brazilian subsidiary. This example illustrates how pressures to adapt products to domestic markets create opportunities for innovation in developing countries.

These opportunities, however, can only be grasped if the required capabilities exist. Despite skills shortages at the aggregate national level, Drivetraincomp's South African subsidiary reportedly can access most of the competencies required for applied development, and over time the firm had built up development capabilities. While average literacy and numeracy levels in the country are low (see appendix B), an unequal education system appears to produce sufficient high-level skills to meet the firm's engineering and innovation needs, although the interview reported that the small size of this pool acted as a constraint on the growth of knowledge-intensive activities, particularly with regards to engineering. Where skills gaps occur, local engineers make use of the group intranet to access the requisite skills from colleagues in Germany or other countries. For example, they consult with mathematicians and physicists based in Germany with regards to basic research issues, or they can consult with specialists based in Brazil if there is a particular matter of applicability to developing country conditions. Communication is horizontal and does not go through headquarters. Thus, in this case, an organizationally 'flat' GIN is nested within a deeply hierarchical global value chain.

Similarly to Drivetraincomp, Exhaustcomp's and Tempcomp's principal R&D facilities are located in Germany. This reflects high local R&D capabilities and the need for proximity to OEM customers – as indicated in the literature and as reported in the interviews. Both companies have established development centres in other countries where market size and characteristics warrant and demand adaptation of existing products. Exhaustcomp has four such centres and Tempcomp has 11 in different parts of the world. Both companies opened R&D facilities in Pune, India, during the last decade – a move in line with the sectoral dynamics of increased cost pressures and market shifts. These centres now undertake work that used to be done either only by their parent companies themselves, or was outsourced to specialized engineering service firms in Germany. Although some of the offshored work consists of standardized tasks, in both cases this is a departure from their previous practice to retain complex R&D tasks exclusively in Germany, and entails an advancing technological trajectory among their Indian subsidiaries.

The Indian subsidiaries illustrate how MNE's respond to large developing markets with available human capital. In the South African case, a different set of conditions have rendered a contrasting set of responses. While Drivetraincomp's South African subsidiary undertakes some product development for the local market, the Exhaustcomp and Tempcomp subsidiaries conduct almost no product innovation, and are limited to a narrow scope of process innovation. In both cases the headquarters give the South African subsidiary little leeway in influencing process innovations, although local managers claim that they have the necessary capabilities. For example, the South African Exhaustcomp plant reported a reject rate of 60 to 80 parts per million, compared to about 200 in the equivalent German plant. Because of the large finished goods stock held in the logistical pipeline to their international customers, the South African subsidiary suffers far higher costs from production rejects. It thus modified its production processes to lower reject rates to below that of the German plant. In the interpretation of the South African management, the existing division of innovation labour is due to group internal hierarchies rather than a reflection of lack of capabilities on their part.

Exhaustcomp also has some product innovation capabilities. Where OEM customers request components for vehicles that are marketed exclusively in South Africa, the subsidiary is involved in product innovation for those vehicles, in partnership with the OEM and suppliers. However, they are not involved in development activities for any other products produced by the group. It thus appears that a major constraint on innovation activity at the subsidiary level is related to the firm strategy of 'reluctant outsourcing', rather than being dominated by issues of human capital availability.

In the cases of South African subsidiaries, the strategic reasons for retaining R&D in Germany (centralized control, proximity to customers, lower co-ordination costs) outweigh the benefits of allocating R&D to the subsidiary (lower labour costs, adaptation capabilities for local markets) – with some exceptions. This leaves limited process innovation and niche areas of product innovation for local market design and adaptation in the hands of the South African subsidiaries. By contrast, the Indian market offers sufficient incentives to MNCs for them to allocate R&D activities to their subsidiaries in the country: a plentiful supply of skills and a large and growing market.

10.6.2 South African firms

Elecsys1 used to be a South African company that produced electronic components for OEMs, with a focus on customized engine management systems. After the market liberalization and value chain changes that took place after 1994, the firm was in danger of being substituted by a follow-source supplier – its domestic customers were re-aligning their value chains with the agreements their groups were reaching with their global suppliers. In order to retain access to the OEM market in the long term, Elecsys1 needed a development facility that was recognized for its capabilities, specifically to design the components required by the OEMs. The firm could not find the requisite domain competencies locally; in addition, since global value chain re-alignment favoured suppliers based near the headquarters of OEMs, it was imperative that the firm establish a foothold in near its customers. Thus, in the mid-2000s, the firm acquired an engineering services consultancy based in Europe, previously owned by an OEM. The acquisition gave it access to one R&D centre each in the European and North American markets. Much like the purchase by Chinese firms of developed country assets such as Jaguar, MG, and parts of Volvo, the company bought assets that were technologically more advanced than its own.

This established the basis of an emerging GIN, in which knowledge began to flow between the Southern headquarters and the newly purchased Northern subsidiaries. However, this does not imply immediate technological upgrading; the division of labour remains similar, in that the developed-country operations undertake R&D, while the South African operation focuses on manufacturing, using the designs originating in the subsidiaries. However, the locus of control is now in South Africa, and the developed country operations have become a tool for access to customers and product development to meet their needs. The company now supplies very advanced engine management systems for upmarket vehicles that it develops in-house. This R&D-based product innovation would not be possible without the acquisition. In combination with the advantages of flexibility that characterize the South African manufacturing operation (which is small and labour intensive, and therefore more flexible), the enlarged firm is carving out a niche as a non-Triad first tier supplier to global OEM customers.

Elecsys2 manufactures electronic security systems for OEMs and the aftermarket. Although it exports to global markets, the firm develops many of its products in South Africa. All R&D is conducted internally. It owns a subsidiary in Australia, where R&D is performed to adapt the firm's products to the Australian market, while the South African headquarters provide technical support and training. It does not do basic research, but undertakes applied development on the basis of high-tech components that it sources globally. For example, the firm imported breathalysers from the UK and integrated the technology into an automotive application (an immobilizer). When the market for breathalysers grew and the UK company was not in a position to meet increasing quality standards and higher volumes, Elecsys2 re-engineered the product. At the assembly level, this required very little adaptation because it is essentially a standard process. Components may vary in size and so on, but operators familiar with electronics assembly can easily be trained to make a breathalyser instead. This is a capital-intensive process that minimises human error. Hence, changes in competencies are more relevant at the level of engineers, and it is typically they who drive the change in the first place. That is, they suggest a new application, then design the requisite process to produce it. This is essentially an engineering solution to a human capital problem: the firm struggles to find sufficient shop-floor skills, so it limits the locus of technological change to the engineering level, where it can find skills – particularly because it has a close relationship with a local university, from which it routinely recruits graduates.

10.6.3 Technological upgrading, technology transfer, and R&D

From a certain level of technological capability, most firms do not either only upgrade or innovate, but do both (Hobday et al 2005). In some areas they still re-engineer or adapt, while in others they already engage in new product or process design. But it is possible to distinguish between firms – or their subsidiaries – with new-to-the-world activities, and those that operate at a considerable distance from the frontier.

The South African operations of Drivetraincomp and Elecsys2 undertake knowledge-intensive activities, and Elecsys2 has significantly increased its research intensity over the past decade. Yet both companies engage essentially in applied development, recombining complex sources of knowledge to design components and systems. Neither engages in basic R&D, nor are they likely to do so in the future. Hence their technological trajectory merely confirms the larger story of upgraded supplier competencies in the automotive industries of developing countries over the past two decades. Neither firm faces insurmountable skills constraints, and both have developed a variety of strategies to deal with these constraints.

For example, faced with low skills levels on the shop floor, when Elecsys2 develops a new product, the primary skills requirement is at the engineering level. At the assembly level, new products require very little adaptation because the electronic components they produce essentially employ a standard, capital intensive assembly process that minimises human error as much as possible. Hence, skill is less important at the shop floor level, and more important at the engineering level, where the firm manages to find adequate skills.

Another example is the development by Drivetraincomp of a clutch for a major Japanese assembler. The primary purpose of this development was to modify the existing design to cope with the rougher and more varied driving conditions in South Africa; in addition, the South African designed product was also produced by the group's subsidiary Brazil. In this instance Drivetraincomp had access to the necessary skills to develop the product and successfully bring it to market in South Africa. This access was secured through a variety of means: contact with the local university, attendance at internal group technical conferences, participation in internalized knowledge networks, and active recruitment of senior management and engineering staff.

By contrast, Elecsys1 and the two other German MNEs engage in activities that are qualitatively different from merely reaching world quality standards. Human capital influences these strategies in opposite ways. In the case of Elecsys1, R&D offshoring to Europe is the result of the local absence of the requisite capabilities. In the case of Tempcomp and Exhaustcomp, R&D offshoring to India is manifestly not the local absence of such capabilities in Germany, but their presence abroad at a much more competitive price. In both cases, human capital thus acts as a pull factor. In the South African subsidiaries of the German firms, pockets of limited process innovation and niche opportunities for product adaption for the local market need to be supported by sufficient skills. These skills can be accessed through similar means to Drivetraincomp. However, these is not much room to maneuvre: current skills availability is sufficient for current needs, but not sufficient to support substantially larger scale or more advanced R&D – so skills supply is not an operational constraint, but is a constraint on the firms' technological trajectories and participation in GINs.

10.6.4 The management of tacit knowledge

R&D offshoring presupposes the existence of advanced capabilities in the destination country, but in an industry in which tacit knowledge plays a major role in technological progress, the existence of highly qualified engineers and scientists is not sufficient – what also needs to happen is the management of this knowledge across large distances, time zones, languages, and cultural divides.

Cultural divides were not reported to be a major concern in the German MNEs South African operations. The transmission of knowledge, including codified (such as product designs), embodied (such as capital equipment) and tacit (such as workplace culture) was not reported to be a problem. This may be due to the long standing German presence in the sector, and the relatively narrow cultural gap between South African and German management. This situation may be contrasted with the transmission of knowledge between South Africa and India. Interviews in Germany and South Africa among all three German MNEs reported that the Indian subsidiaries, including the new R&D centres, face significant challenges in these areas. In response, the German firms use cross-cultural communication and the migration of knowledge workers. When Exhaustcomp opened an R&D facility in India, the Indian manager was transferred to headquarters in Germany for over a year. There his experience and training included the absorption of tacit knowledge by collaborating in different departments and getting to know the "mindsets" of the researchers at headquarters. Once back in India, he had to reconcile this experience with local processes. He therefore acts as a knowledge bridge between India and Germany. This organisation of learning is used across the group. At headquarters, there are engineers from several countries where the firm is present, some undergoing training before they return to their home countries, others permanently appointed in Germany to be the contact point for the related subsidiary abroad.

Tempcomp faced similar challenges of knowledge transfer between Germany and India, and in response commissioned a knowledge management expert from within the company to investigate possible responses. This formed part of an "action-oriented" PhD project. Their aim was to improve opportunities to relocate design tasks from the German R&D centre to the Indian centre through means of knowledge management, including information technology, the organisation of activities, the content of communication and interpersonal communication. Their findings suggested five main sets of measures. First, one of the main problem areas was identified as intercultural communication. A training course on intercultural communication for German and Indian engineers, hosted by a Tempcomp employee with cultural ties to both countries, was developed and undertaken in both Germany and India. Second was an attempt to codify the tacit knowledge held in Germany for the benefit of Indian staff. This included IT-based guidelines, checklists and procedure manuals informed by experiences in technical problem solving. Third, to improve the familiarity of Indian engineers with Tempcomp's products and value chain, the firm established short term assignments of Indians to Germany and visiting programmes to suppliers and production plants. Fourth, further organisational rules were implemented in India to overcome internal hierarchical communication barriers. Lastly, the firm implemented a gatekeeper model, transferring three Indian engineers to the German headquarters and having three Germans/Americans at the Indian location to capture the tasks, inform their colleagues (in India) and check the quality of the deliverable.

10.7 Discussion

In the automotive supply industry the relationship between the strategies of both Northern and Southern firms, and human capital in Southern host countries, has an interesting set of implications for the management of technological change and for the evolution of GINs. The five case studies above explore some of the micro-determinants of these relationships. On the whole, they are illustrations of incipient GINs, nested within GPNs. This is interesting because until recently innovation in the sector was highly concentrated in the Triad economies, and because the centripetal forces concentrating knowledge intensive activities in the developed world may be increasingly countered by centrifugal forces driving these activities to advanced developing countries; the 2010 INGINEUS survey makes it clear that the main forces in this regard are access to large and growing markets, the availability of specialized competencies at a lower cost than in the home region, and access to knowledge infrastructure and services in the host region.

To help understand the detailed drivers behind these global trends, our case studies focused on specific instances of technological change, how these were influenced by human capital conditions in the host country, and how this relationship influenced technological progress and the formation of GINs. In line with Lall’s capabilities approach, we interrogated some key features of these relationships: technology-specific elements of the learning process, the roles of internal and internal sources of knowledge, the roles of human capital at all skills levels, the contrast of know-how to know-why, and the roles of externalities and linkages such as education and training institutions.

Key sectoral drivers also frame our analysis. Some changes over the last two decades have militated against GIN formation, for example a value chain hierarchy and knowledge architecture that concentrate power and R&D at the apex of the sector, and high barriers to entry for small and developing country firms. However, some more recent trends favour the formation of GINs, including the upgrading of local second-tier suppliers within GPNs, increased cost pressures leading to an advantage for developing countries, and increased market size and growth in developing countries such as China, India and Brazil, and regions such as Sub-Saharan Africa. These more recent trends open up opportunities for advanced capabilities in developing countries to be harnessed by market-seeking OEMs and lead suppliers.

In South Africa, technological performance and capabilities have improved since re-insertion into global value chains in 1995. During this process, the availability of mid- to high-level skills was largely sufficient for technological upgrading to World Class standards, and OEMs played a major role in developing their local skills base. However, the small marginal availability of these skills did act as a constraint upon further growth in knowledge intensive activities such as R&D. This can be contrasted with the case study firms’ Indian subsidiaries, where the availability of these skills facilitated the establishment of dedicated R&D centres that receive tasks outsourced from Germany. In South Africa, R&D has been constrained to niche pockets of product adaptation, occasional product design for the local market, and process innovation to suit local input and supply chain conditions.

In line with the structural pressures described in the literature on the automotive sector, all three German MNE case studies conduct their core R&D and co-ordinate their global R&D networks in their home countries, in proximity to their headquarters. Since the supply of high level skills is plentiful in Germany, the key human capital consideration in outsourcing knowledge-intensive activities was reported to be, in line with the INGINEUS survey findings, proximity to major markets and the availability of the requisite absorptive capacities and skills at a lower cost. The contrasting cases of Indian and South African subsidiaries of these firms illustrate how differences in these factors lead to different technological outcomes.

The case studies illustrate firms at different stages of GIN formation. Tempcomp and Exhaustcomp report involvement in incipient GINs – they respond to opportunities for minor process innovation, or occasional product innovation for the local market. These instances are constrained by management structures that do not allow for much innovation at the subsidiary level in South Africa. Drivetraincomp is somewhat more evolved, and this case illustrates how, even in the relatively smaller Sub-Saharan Africa market, pressures to adapt products to local conditions create opportunities for local innovation – and for this innovation to feed into the firm's global knowledge network (in this case, into the Brazilian production centre). Drivetraincomp manages to find sufficient skills to undertake this product development.

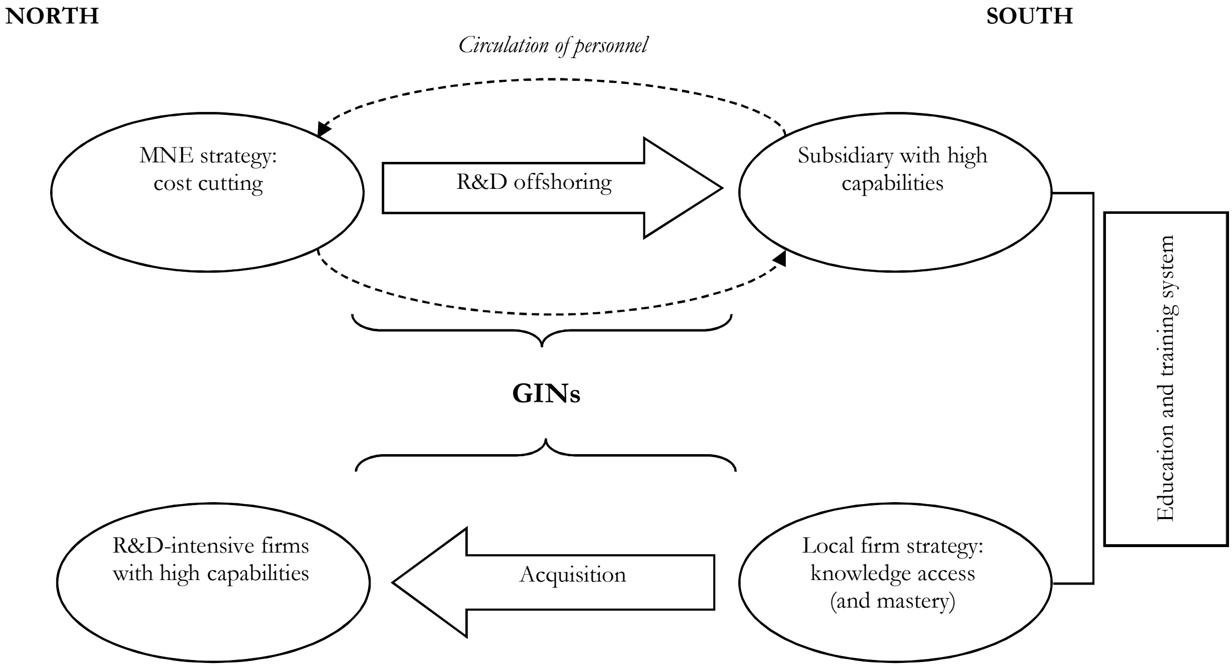
All three German MNE subsidiaries undertake an array of measures to access or internally build up required competencies and capabilities, including staff exchange within the group, internal group knowledge networks (for example, access to specialists in other countries through the intranet), and relationships with local universities. Internalised knowledge networks tend to be horizontal, contrasting with the deeply vertical nature of the value chain.

The South African firms provide illustrations of GIN formation that originates in the South. The first of these strategies is the purchase of knowledge assets in developed countries. Elecsys1 needed a foothold near its main customers and access to specialized competences not available in South Africa, which led it to purchase a knowledge-intensive firm with locations in the EU and US. This established a proto-GIN. However, it is important to note that most of this firm's knowledge intensive activity remains in these developed countries; the South African operation still does not have the capacity to absorb the tacit or the codified knowledge that would be required to undertake these activities. The purchase of knowledge assets does not guarantee knowledge flow – this takes time, capability upgrading, and the management of tacit knowledge.

Elecsys2 reveals a different response to a different kind of skills shortage. Because of the different kind of technology in question, the primary skills shortage was at the lower levels, and the firm could access the required higher level skills it needed to develop and modify its products. In response it concentrated the process of technological change within the engineering level, reducing the scale and complexity of change on the shop floor. At the same time, R&D within Elecsys2 is mostly carried out in South Africa, and the relevant knowledge distributed to its subsidiaries in developed countries.

The various strategies exhibited by the case study firms respond to the sectoral dynamics that characterize the automotive sector. This renders a generalized model of GIN development, both from North to South, and from South to North, as illustrated in figure 1.

Figure 1: GINs in the automotive sector



The management of tacit knowledge was also identified as a key factor enabling the formation of GINs. While the transfer of tacit knowledge from Germany to South Africa was not reported to be a major obstacle, the contrasting case of India illustrates the kinds of challenges that can arise, and the organizational changes firms must make to overcome these.

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Appendix A

Response rates and total sample distribution by sector, country and firm size.

Sector/county	dataset	responses	response rate (%)	% over total sector obs.	R&D active firms	% of R&D active firms over national sample
China[1]	9119	243	2.7	26	181	74.5
Estonia	121	17	14	1.8	2	11.8
Norway	519	179	34.5	19.1	53	29.6
India[2]	1287	324	25.2	34.7	195	60.2
Sweden	1662	171	10.3	18.3	76	44.4
Total EU	2302	367	15.9	39.3	131	35.7
Total	10407	567	5.4	60.7	376	66.3
Total ICT	12709	**935**	**7.3**	**100**	**507**	54.2
Denmark	210	49	23.3	37.1	5	10.2
Norway	2	2	/	1.5	0	/
South Africa	325	81	24.9	61.4	27	33.3
Total EU	212	**51**	24	38.6	5	9.8
Total	325	**81**	24.9	61.4	27	33.3
Total Agro	535	**132**	19.6	100	32	24.2
Brazil[3]	241	69	28.6	46.6	17	24.6
Germany	963	53	5.5	35.8	31	58.5
South Africa	2	2	/	1.4	0	/
Sweden	168	24	14.3	16.2	13	54.2
Total EU	1131	77	6.8	52	44	57.1
Total	243	71	29.2	48	17	23.9
Total Auto	1374	**148**	10.8	100	61	41.2
TOTAL EU	3645	495	13.6		180	36.4
TOTAL	10975	719	6.6		420	58.4
TOTAL	14620	**1214**	8.3		600	

[1] The Chinese sample was extracted from two regional databases: (i) the *Beijing database* and (ii) the *Schenzhen database*. The questionnaire was distributed in the five most developed provinces in China: 146 questionnaires came from Beijing, which account for 60% of the total questionnaires; 51 came from Guangdong province, which account for 21%; 35 from Shanghai, 14%, 10 from the Zhejiang province, representing the 4%, and only 1 from Shandong province.

[2] The Indian sample was extracted from the *NASSCOM Directory of IT firms 2009-2010*, distributed across the main cities and regions as it follows: 281 in Bangalore, which account for 21.8% of NASSCOM Directory; 256 in Delhi/Noida/Gurgaon representing the 19.9%; 185 in Mumbai(14.4%); 72 in Pune (5,6%); 147 in Chennai (11.4%); 184 in Trivandrum (14.3%); 107 in Hyderabad (8.3%) and 55 in Kochi (4.3%).

[3] The Brazilian sample was extracted from the *Annual Registry of Social Information (RAIS)*, a registry of social and balance sheet information collected by the Brazilian Labour and Employment Ministry. The total number of firms classified in the automotive sector in Brazil is 2625. Out of these, 233 companies are located in the state of Minas Gerais and, of these, 107 (46%) have employed, in 2008, 30 workers or more. From the dataset all automotive firms from the state of Minas Gerais were selected, provided the firm declared over 30 employees.

Appendix B

Indicator	SA	Brazil	India	China	Germany	Source
Public sector education expenditure as % of GDP 1999	6.03	3.88	4.47	1.91	n/a	a
Public sector education expenditure as % of GDP 2007	5.34	5.21	3.18*	3.22**	n/a	a
Public sector education expenditure per capita (2007) USD	316.86	374.27	27.21*	231.35**	n/a	a
Gross tertiary enrolment as a % of the total 18-24 age cohort 2000	12.9#	16	10	7.8	n/a	b
Gross tertiary enrolment as a % of the total 18-24 age cohort 2007	16.2#	30.01	13	22.05	n/a	b
Brain drain ranking***A19	62	39	34	37	31	c
Quality of educational system****	130	103	39	53	18	c
Quality of math and science education****	137	126	38	33	39	c
Availability of scientists and engineers****	116	68	15	35	27	c
Quality of management schools****	21	73	23	63	31	c
Quality of scientific research institutions****	29	42	30	17	6	c
Internet access in schools****	100	72	70	22	39	c
Extent of staff training****	26	53	59	57	8	c
University-industry linkages****	24	34	58	25	9	c
Local availability of R&D services****	49	36	51	50	2	c
Top 200 ranked universities	1	0	1	9	10	d
% of tertiary graduates in science fields 2008	4	6.77	n/a	n/a	13	e
% of labour force with a tertiary education	13	8.6#	n/a	7##	24	e
Thompson Reuters' Science Citation Index publications % change 2002-2008	48.3	110.6	91.7	174.7	24.1###	f
Patent output 2007 per million of population	1.86	0.65	0.64	118.02	9713	g

Notes: * = 2006, ** Source: People's Daily 2009, *** A lower ranking indicates greater brain drain, ****WEF rankings out of 139 countries, #=2006, ## = http://english.peopledaily.com.cn/, ###=EU total

Source: a = World Bank 2010; UNESCO 2010a, b = World Bank 2010; # Department of Education, 2007, c = WEF Global Competitiveness Report 2010-2011, d = QS World University Rankings 2010, e = UNESCO 2010a, f = UNESCO 2010b, g = UNESCO Science Report 2010

11 GLOBAL INTERACTIONS BETWEEN FIRMS AND UNIVERSITIES: THE ROLE OF SOUTH AFRICA AND BRAZIL IN GLOBAL INNOVATION NETWORKS

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Abstract: The importance of hierarchies for the formation and dynamics of Global Innovation Networks has been underestimated in the current literature on GINs. This paper aims to fulfil this gap by investigating a key component of such networks, the interactions between firms and universities. To accomplish this task the paper proposes a theoretical framework to integrate global innovation networks and interactions between firms and universities. Second, it locates the very specific position of South Africa and Brazil. Third, the paper analyses survey data on the nature of technology activities of firms and how they collaborate with universities and research institutes. This analysis clearly differentiates countries and NSIs regarding the nature and quality of their role in global interactions between firms and universities. Finally, the main patterns of two case studies in South Africa and Brazil are compared to understand how local R&D departments and activities in local subsidiaries are integrated within the network of MNCs – and how hierarchical relationships are present, especially in the current stage of development. The conclusion summarizes the prospects for countries like Brazil and South Africa, and evaluates the value of the proposed framework.

Keywords: University-firm Interaction, Global Innovation Networks, Brazil, South Africa, Technological Upgrading

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Introduction

The emergence of Global Innovation Networks (GINs) holds out the promise of technological upgrading, competence building and economic catch up for developing countries of the South. 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 Southern firms investing in advanced Northern economies and building external knowledge networks in order to overcome the constraints of weak innovation systems, but the resulting global knowledge flows can 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, p.1) note, the global changes 'evoke optimism, even utopian visions' for sharing in economic growth.

11.1.1 Hierarchies matter?

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 – extremely 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 China and India, which 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 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 Hart, 2008; Ernst and Naughton, 2008).

However, at the same time, there is evidence that such global changes are uneven and not equally distributed (Ernst and Hart, 2007), and that the extent to which hierarchies matter has 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. Is the trend to subvert global knowledge hierarchies unique to China and India? Or are other Southern countries increasingly able to access global knowledge flows through university-firm interaction, whether inward or outward bound? What kinds of interaction are more likely to facilitate access to global knowledge flows?

South Africa and Brazil share sufficient features with China and India to be classified together as the BRICS group, but South Africa and Brazil share many challenges and opportunities that differ considerably from China and India, making them an excellent comparative focus.

The paper thus explores the nature of interaction between universities and firms, and whether the role of universities in global innovation networks in Brazil and South Africa reflects the preservation of hierarchies, thus constraining more advanced, technology-rich international interactions, or whether global integration and technological upgrading is facilitated.

11.1.2 Methodology

The paper draws on a threefold methodology common across the INGINEUS project: a review of literature, quantitative data trends from an original survey of firms, and in-depth case studies. The literature review aimed to understand how MNCs form networks of research between home and host countries, the role universities and public research organizations play in the emergence of GINs, and how these networks impact the formation of national innovation systems in the host country. Relevant survey items were analysed pertaining to the role performed by local and global universities and public research organisations in the knowledge flows between MNCs, their subsidiaries and local firms. Case studies aimed to identify the diverse knowledge flows represented and to investigate forms of interaction in depth. 'Best practice' cases, of as mature a GIN as possible were selected, in which universities and PROs based in home and/or host countries play active roles. Data sources for the case studies included interviews with managers responsible for innovation and for R&D in the MNC in the home and the host country, interviews with scientists in universities involved in the home country and in the host country, interviews with relevant sectoral bodies or organizations in the national system of innovation, and documentary sources on the firms' and universities' strategic directions.

11.1.3 Paper outline

The paper begins by presenting a theoretical framework to analyse the nature and direction of knowledge flows in the interactions between firms and universities at the global level (Albuquerque et al., 2011).

The second step is to identify the very specific position of South Africa and Brazil in the science and technology scenario – a first approximation to understand the specificities of their universities' roles within GINs. The next step is an analysis of firm strategies, showing how both the presence and the nature of interactions between firms and universities follows a logic dependent on each country's position in the international division of labour.

Having set the stage, the fourth step is a comparison of case studies to examine how local universities collaborate with the R&D departments of MNCs and their local subsidiaries, and the ways in which they are integrated within the global innovation networks of those MNCs. The literature on GINs has tended to focus on firms in the ICT sector, and thus, to allow for the investigation of the nature of interaction in diverse sectors, we selected the agro-food processing sector in South Africa, and automotive sector in Brazil. The two sectors have a long tradition of international production, and agro-processing has a tradition of internationalisation of R&D (Patel, 1995). Both sectors were thus likely to yield cases for investigation. The analysis considers the strength and direction of knowledge flows, and the possibilities for subverting hierarchical relationships.

The conclusion summarizes the prospects for countries like Brazil and South Africa, and evaluates the value of the proposed framework.

11.2 Global interactions between firms and universities: towards a framework

11.2.1 MNCs and national systems of innovation as drivers of Global Innovation Networks

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 South, is a process that goes far beyond the limited push of capital 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. For example, the rise of talent pools is a consequence of investments in science and engineering that shape NSIs. Therefore, there are two movements reshaping and reorganizing the international division of labor – both MNCs and national systems of innovation. This reshaping of the international division of labor, in turn, affects the internal decisions of MNCs and the actions of their subsidiaries, pushing further changes in the international division of innovative labor.

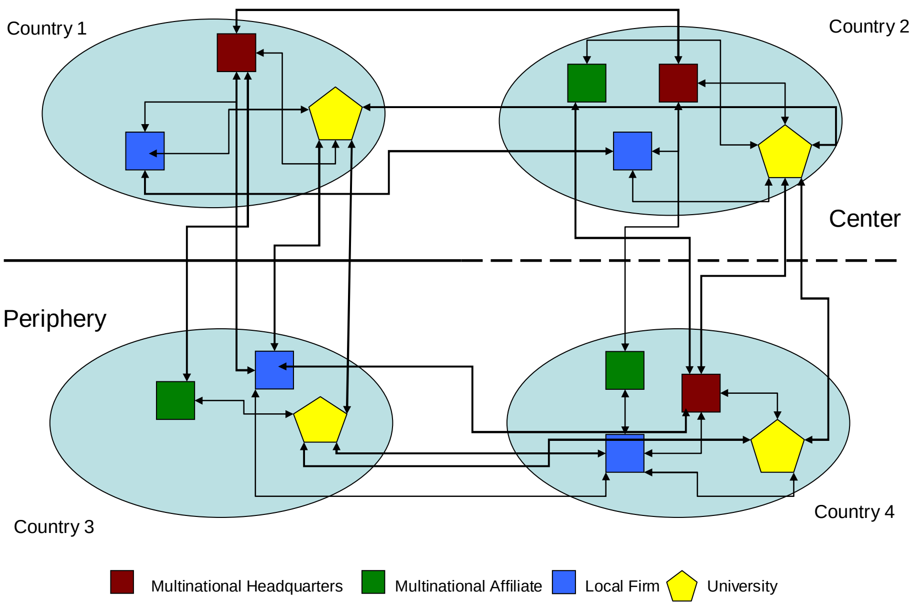
The combination of these two drivers leads to a complex picture, where the nature of NSIs matters for the formation of global innovation networks, their main characteristics and the nature and scope of the international hierarchies established.

11.2.2 A framework of global interaction

A tentative framework to synthesis these insights is suggested in Figure 1 (Albuquerque et al, 2011). Firms - local and MNCs - universities and their links, are reflected in a hierarchical world, divided between a historical center and a periphery (Furtado, 1982), and the implicit social and political forces that shape NSIs defining the major countries' characteristics and possibilities within a global innovation system in the making.

Figure 1 reflects a division between center and periphery. However, in the context of GIN formation and dynamics, this divide has two defining features: the first is portrayed as a continuous line, the other as a discontinuous line. The difference is intended to express graphically the possibility of catch up – the emergence of a country that successfully overcomes underdevelopment, such as the case of South Korea during the 1980s and 1990s. The framework foregrounds the role of university-firm interaction in such evolutionary possibilities.

Figure 1: Global Interactions between firms and universities – a tentative framework



The framework is based on our synthesis of two strands of the literature on innovation (Albuquerque et al, 2001) – the literature on university-firm interaction (Klevorick, et al., 1995; Nelson, 1993) and the literature on GINs (Ernst, 2006; UNCTAD 2005; Dunning and Lundan, 2009; Narula and Molero, 2003). The main arguments that underpin the logic are summarized here. The starting point is the body of work that conceptualizes the interactions between firms and universities in developed countries, based on interactions within a single country (Klevorick et al, 1995; Cohen et al, 2002). These relationships are reflected within Country 1, in Figure 1. This work has been elaborated to examine the interactions between firms and universities in developing countries, again, interaction within national boundaries, but which may include MNCs’ subsidiaries in those countries (Rapini et al, 2009, Lee et al, 2009, Kruss, 2009). These interactions are reflected within Country 3 in Figure 1.

A limited set of interactions between countries is suggested by Patel and Pavitt (1998), who are very cautious about the internationalization of innovation. They stressed the ways in which firms in developed countries may use other countries’ scientific infrastructure as sources of information, where national systems are not able to meet the needs of innovating firms. These are represented as interactions between MNCs in Country 2 and universities in Country 1 and vice-versa.

A critical work that links the two strands of literature is an UNCTAD (2005) study that demonstrates the chain of MNC connections between developed and developing countries, linking Countries 1 and 3. Ernst’s (2009) taxonomy of GINs further informs the elaboration of the links between Countries 1 and 3. These are typically intra-firm networks in which MNCs either ‘offshore’ aspects of innovation to subsidiaries and affiliates, or ‘outsource’ to specialized suppliers and public research institutes, particularly universities.

Ernst’s (2009) elaboration of a third type of GIN, of a MNC which is based in a country at the periphery and which interacts with universities at the center, further informed the framework. This is reflected as the connection between a MNC with headquarters in Country 3 or 4 and its subsidiaries in Country 2 and universities in Country 1 or 2. Likewise, Azevedo (2009) analyzed a transnational firm based in a peripheral country that has research collaboration with 70 universities and research centers abroad (a firm from Country 3 interacting with universities in Countries 1 and 2 – or multiple countries at the center). OECD (2008b) research on Japanese MNCs and their networks with universities in China, India, Japan, and the US illustrates a different set of possible connections between MNC headquarters, MNC subsidiaries (including in the US) and universities. These are reflected as connections between Country 1 and 2 and between Country 1 and Country 3 and/or 4.

The literature also highlights a growing trend towards connections between firms based in different countries at the periphery, for instance, biotechnology inter-firm networks (Thorsteinsdóttir, 2010). Those firms were typically born as spin-offs of local university research, with their international connections. These are represented as connections between local firms in Country 3 and local firms in Country 4.

The significance of connections between universities only – the science networks – is also included in the framework. There are strong "engines of internationalization" of science, old and new (Zitt et al, 2004). For developing and catch up countries, the networks of science and related educational investments may be the first networks to be established, to connect one country with the global knowledge networks centered in the leading countries. Examples are global research consortia such as the *International Human Genome Sequencing Consortium*, with research institutes from the US, China, France, Germany, Japan participating. It is important not to underestimate these scientific networks. These scientific networks connect universities only in all four countries in Figure 1.

Supported by this literature, Figure 1 graphically represents a tentative framework to analyse the nature of global interactions between firms and universities. This framework yields four main types of interaction, with variations depending on their home-base location. More complex types evolve over time, and multiple types co-exist in any one period in a specific country.

11.2.3 Four main types of interaction

Type 1. LOCAL firms interacting with local and/or foreign universities

Interactions between local firms and local universities do not 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). In earlier stages of capitalism at the center, they could be the typical and most advanced interactions with universities. Now, this type of interaction may be located in firms at the periphery.

Interactions between local firms and foreign universities are the first and simplest form of cross-border transfer of knowledge. In Figure 1, this flow would connect a local firm in country 1 and a university in country 2. Local firms would typically interact both with universities in their home countries and with foreign universities. Historically, this type would have first connected developed countries (countries 1 and 2). Currently, this type of interaction would be important for local firms at the periphery looking for knowledge that the local science infrastructure would not be able to provide.

Type 2: MNCs interacting only with home country universities

This would be the typical relationship reported in the literature on internationalization of R&D. The 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.

Type 3: MNCs interacting both with home country and host country Universities

This would be the more recent pattern of interaction, what the literature would identify typically as a global innovation network. There is a broader division of innovative labor within the MNC, with the possibility that a subsidiary assumes contacts and creates new contracts with the host country university. The nature of this relationship will depend on the nature of the subsidiary's role within the MNC, ranging from limited adaptive activities – which would require contacts with local laboratories or engineering departments – to 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.

Firms (local or transnational) may establish contact with one specific university (local or foreign) but would take advantage of the other universities (local or foreign) that are linked to the first university through their existing scientific and educational links. This is important, given the natural trend to the internationalization of science, with its formal and informal links. The interactions of firms with networks already established among universities are rich in multidirectional knowledge flows.

Type 4: International consortia between firms and universities

This type involves firms, universities and research institutions, 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.

A fifth type is logically possible, but not yet existent. This would be a non-hierarchical network between MNC headquarters and subsidiaries and their connections with universities. Given that asymmetry and hierarchy are "defining characteristics of both previous GPNs and existing GINs" (Ernst, 2009), this type of interaction must be included to benchmark prevailing international networks - it could be seen as the desired feature of a global innovation system, and poses a challenge to policy.

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. For example, the formation of international networks that may combine interactions at MNC headquarters that have inter-firm connections with local firms in a foreign country, and this local firm may have interactions with local universities. Another example is a MNC that establishes contacts with foreign universities either in countries where it does not have a subsidiary or directly with a foreign university, bypassing its local subsidiary.

This framework provides a means of analyzing 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 hieararchies.

11.3 South Africa and Brazil in the global scenario

Where do South Africa and Brazil fit in the international division of science and technology? Using science and technology indicators as proxies to compare countries and their national systems of innovation, Ribeiro et al (2006) divided the world into three different 'regimes of interaction'.[1] The national system of innovation of both Brazil and South Africa may be categorized as Regime II, alongside India and China. In these countries, the national system of innovation is immature, and the rate of conversion from scientific production to innovation is moderate and variable – unlike countries in Regime III such as Japan, the United States and Taiwan. In Regime III countries, the national system of innovation is fully formed, connections between components such as firms and universities are strong, and there is a high rate of conversion from scientific production to innovation.

One trend evident in the Regime II group of countries is that existing "points of interaction" have strong historical roots. For instance, interaction is long established between firms in the mining sector and public research institutions in the South African case (Kruss, 2009; Pogue, 2006), and in relation to agricultural products, iron and steel and airplanes in the Brazilian case (Suzigan et al, 2009). Analysis of a list of the top 100 non-financial MNCs based in countries of Regime II (UNCTAD, 2005) shows the correlation between each countries' largest home-based MNC, and its home base scientific specialization, reinforcing the significance of such 'points of interaction', and their uneven presence in these countries. The nature of these home-based MNCs may open space – through an active insertion in the international division of labor – for a less subordinate role and more positive inclusion in GINs.

However, unlike China and India, South Africa and Brazil seem to suffer a "Red Queen Effect", in that they spend a great deal of effort to retain their current global position, and do not move forward significantly. The threshold between Regime II and III has increased rapidly, and scientific production in South Africa and Brazil is not increasing rapidly enough – or as rapidly as in India and China – so that the risk of falling behind and the challenges to stay ahead are greater. This is a consequence of the persistent income concentration problems that block the spread of successful "points of interaction" through the whole economy and the national system of innovation.[2]

[1] In this division, Korea and Taiwan are in the group of leading countries – both countries have joined this group in 1998, according to Ribeiro et al (2006), leaving an intermediate level populated by countries as Brazil, South Africa, Mexico, India and China. Therefore, there is a difference between Ribeiro et al (2006) and UNCTAD (2006), since for UNCTAD Korea and Taiwan still are "developing economies".

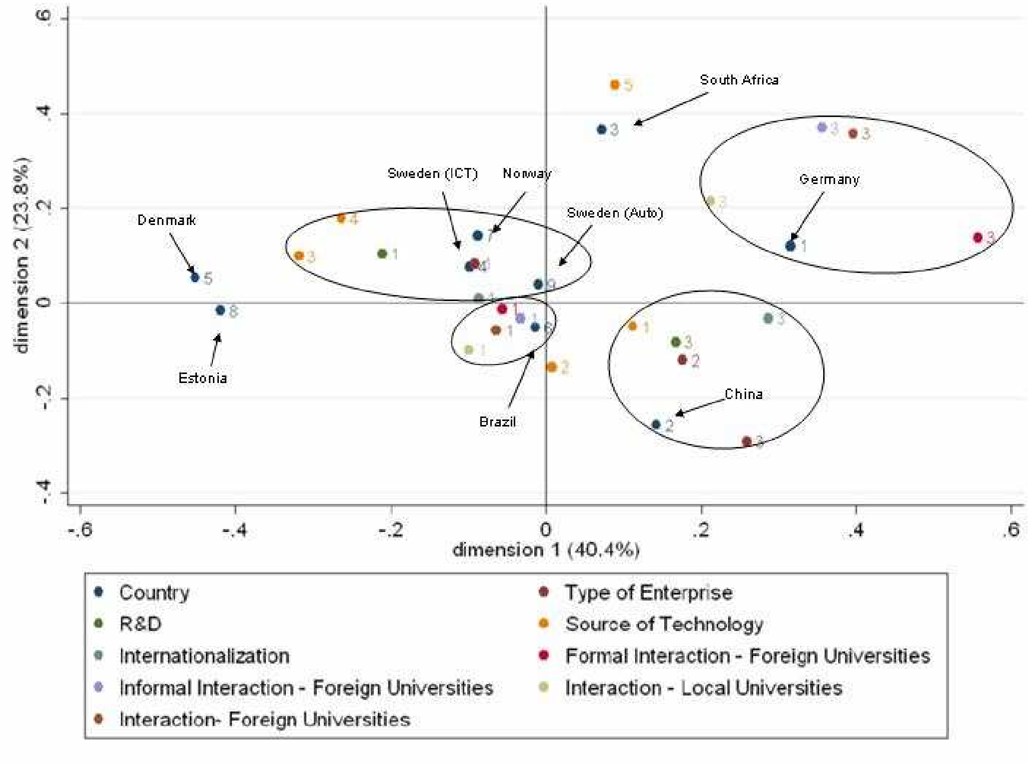
[2] Technological revolutions at the center may only reshape existing structural problems in less-developed countries: there is a polarity "modernization-marginalization" that is typical of underdevelopment (Albuquerque, 2007).

11.4 An analysis of firms and their interactions with local and foreign universities

This section investigates the existence of different profiles of firms and their interactions with local and foreign universities. Using our framework, it was hypothesised that the different countries would be divided between distinctive profiles, defined according to their firm characteristics and their interactions with the university system both locally and globally. The statistic multivariate method of Multiple Correspondence Analysis was used in order to read the survey data.[3] Figure 2 below represents the correspondence chart obtained for the analysis of eight selected countries in three sectors: South Africa and Denmark in agro-processing, Brazil, Sweden and Germany in the automotive sector, China, Sweden, Norway and Estonia in the ICT sector. Each one of the chart axes represents a new dimension that summarizes the information of a set of nine relevant variables, enabling the representation in a simple two dimensional plane. The distribution in Figure 2 allows us to define four different profiles, represented graphically by each of the chart's quadrants. The central characteristics of these profiles can be identified and interpreted according to the variable 'country'.

[3] The Multiple Correspondence Analysis (MCA) is a multivariate statistical method that allows to verify the association between more than two categorical variables. This technique aims mainly at transforming qualitative information available in a table in an instrumental chart, in order to make the analysis of data easier (Grenacre, 1994). The display of categories related to observed variables on a Correspondence Graph allows us to evaluate its association to determine into which profiles the observations comprised in the sample can be divided.

Figure 2: Multiple Correspondence Analysis for ICT, Agro-processing and Automotive sectors



Source: INGINEUS *Survey*. Authors' elaboration.

The first profile observed is identified in the quadrant on the top right hand side, by the presence of Germany. It can be observed that the variables that indicate the existence of interactions between universities and firms are arranged in a position farther to the right in that quadrant. Hence, its most striking feature is the relevance of interactions between firms and local and foreign universities or research institutes, to the predominance of Type 3 forms of global interaction[4]. The presence of Germany in this profile is corroborated by fact that of the eight countries, it had the highest proportion of firms that reported some type of interaction with local universities and research institutes, and also, indications of interaction with foreign universities. The arrangement of variables in that region of the first quadrant can therefore define it as a profile of interaction between universities and firms typical of innovation systems in Regime III.It is also possible to identify the presence of South Africa in the first quadrant, but positioned in a far more diffused manner than the other variables. The 'outlier' position leads to the interpretation that this economy has a peculiar profile. The only other variable that presents a strong association with South Africa is one that indicates that universities and research institutes are main sources of technology for agroprocessing firms. There may thus appear to be a tendency to interaction by local firms in South Africa, but the diffused position in the quadrant confirms a distinction between South Africa and

[4] When characterizing this profile, we noticed that the variable 'Formal interaction with foreign universities' can be a found a little further than the other shaping it. That is why, it is possible to say that this variable contributes less in determining it, as a stricter analysis in shaping the groups would cut it off this profile. Given this variable is strongly related to the ones that characterize the profile, we have opted for a more flexible criterion in shaping it.

Germany in relation to their main characteristics. The German profile is evidently marked by strong interactivity between universities and firms, whereas the South African profile is more likely to be defined by local firm dependence on scientific development, rather than interaction. It is likely that type 1 forms of interaction, between local firms and local universities, predominate.Moving clockwise, in the second quadrant on the bottom right hand side of the correspondence chart, the dominant characteristic of the profile marked by the presence of China is a tendency towards large companies with international scope. This analysis is based on the correspondence of variables that indicate the existence of significant R&D, the internal search for technology and the presence of firms that have some kind of internationalization of R&D or production processes. Those characteristics are usually related to large scale companies. The variable "type of company" has two categories in this profile, indicating that it is characterized by the presence of multinational corporations, both subsidiaries and headquarters. Again, triangulation with the descriptive trends evident in the survey confirms this interpretation. China has a prominent position as the country that shows the largest number of multinational companies in both categories, besides having the largest number of firms participating in the survey. This suggests the predominance of type 3 forms of interaction, of home and host based MNCs interacting with local and foreign universities in the Chinese ICT sector.In the third quadrant, bottom left hand side, Brazil figures in a profile that is characterized by the absence of formal or informal interactions with local or foreign universities. This profile is in stark contrast to the interactive profile characterized by the presence of Germany. Brazil is one of the countries polled in the survey that showed a lower proportion of positive responses to the variables indicating interaction between universities and research institutes both domestically and abroad, which helps to understand the country's position in this profile. Therefore, this profile is marked by the absence of interactive activities.The fourth quadrant, top left hand side of the correspondence chart, reflects a profile formed by the Nordic countries. A strong association between Norway and Sweden is observed, which may be explained by the fact that both focused on firms in the ICT sector. Sweden has two sectors represented in the database, and the analysis discriminates between them, evident in a differentiation between ICT firm participants in Sweden and Norway, and the automotive sector participants in Sweden. Also evident is that the profile shows a significant presence of independent firms rather than subsidiaries or headquarters of multinationals, that is, smaller-scale enterprises. Other notable characteristics are the absence of R&D and the purchase of knowledge from other firms - MNC's or not – as the main source of technology for the company. Estonia is quite isolated in the fourth quadrant, as is Denmark in the third quadrant, both showing a strong proximity to the horizontal axis, which indicates the tendency of a lack of association with the variables in the analysis.

In sum: the analysis highlights the distinctive position of South Africa and Brazil in global interaction. The statistical technique of Multiple Correspondence Analysis shows a clear differentiation of countries and sectors, using the data related to interactions with universities. For the automotive sector – that includes Brazil – there is a clear delimitation that shows Germany (characterized by the headquarters of MNCs, internal R&D and intense interactions with universities) in one quadrant, Brazil (characterized as host country of MNCs, low R&D and a very low level of interactions with universities) in the opposite quadrant, and Sweden with yet a third contrasting different profile (characterized by stand alone smaller firms). For the agro-processing sector – that includes South Africa – likewise there are two distinct profiles, very well defined, that cluster South Africa and Denmark in different quadrants. The analysis of the firm data, therefore, stresses the dependence of global innovation networks upon the nature of NSIs and the presence and spread of home-based MNCs through an economy, associated with patterns of university-firm interaction. Although China may also be characterized as within regime of interaction II, a strengthening national system of innovation and the spread of home-based MNCs in the Chinese ICT sector are reflected in the predominance of Type 3 forms of interaction, a pattern of home and host based MNCs interacting with local and foreign universities. The survey data suggest that South Africa and Brazil are not being drawn into global innovation networks in ways that will subvert hierarchical knowledge flows and facilitate technological upgrading on a significant scale. These dynamics are explored further in the following section, through an in-depth case study in each country.

11.5 Interaction between Universities and R&D departments in South African and Brazilian subsidiaries

The case studies were selected to probe patterns in the same sector as the survey in each country, agro-food processing in South Africa (Dairyco) and automotives in Brazil (Carco). Both may be classified as a Type 3 form of interaction, a MNC from the North interacting with both its 'home' universities in Europe, and with 'host' universities in the South. Type 1 interactions, between local firms and local universities, have grown in both South Africa and Brazil, encouraged through policy support, government funding programmes and other incentivisation and support mechanisms such as technology platforms, incubators and science parks (Kruss 2005, 2006, Rapini et al 2009, Albuquerque et al 2010). A focus on Type 3 allows elaboration of the nature of university interaction in the global innovation networks that are a feature of this phase of the internationalization of science. Table 1 provides a comparative summary of key features of the two cases.

Table 1: Comparison of cases of global innovation networks in South Africa and Brazil

	Dairyco South Africa	**Carco Brazil**
Innovation strategy	Competitive strategy to promote the nutritional and health benefits of its products, rooted in an environmentally friendly operation Develop products with nutritional quality adapted to the profile and taste preferences of local populations	Competitive strategy focused on volume and diversity, focus on small economy cars (entrance segment) Vehicle platforms restyled and adapted for developing country market
R&D departments	Basic scientific research, clinical research and new product development driven by research headquarters in Europe - two principal research centres Hierarchical global network of R&D centres in 15 countries, some integrated into main business divisions, some transversal conducting scientific research on health and nutrition aspects of products	R&D and basic research concentrated in central Development Centre in parent company in Europe, the largest private research institute in the home country Applications research centre in Europe, to integrate basic research and product development for complete industrial innovation cycle 118 R&D centres in the MNCs units worldwide Development centre in Brazilian subsidiary plant, with the MNC's only design conception capacity outside Europe
Division of labour: Central R&D	Innovate and develop complex products, patent and roll out globally	Conducts all basic research Develops new vehicle platforms

	Dairyco South Africa	Carco Brazil
	Network organizational culture, connect to country units through structured communication network and collaboration between central and subsidiary teams	
Division of labour: local R&D department	South African group as base for growing regional markets: research unit with capacity and mandate to conduct internal R&D and develop new products for local conditions that may attract new markets Research into flavours, nutrients, textures and recipes tailored for South African market Intellectual property generated becomes property of the group New product developed in SA rolled out by subsidiaries in other countries and circulate through group	Brazilian group as base for regional markets: coordinates and centralizes competences for 8 R&D centres in companies of the group in the region Restyling of vehicle platform to suit developing country market Develop design of new vehicle, build prototypes and conduct validation tests Global leaders for group in niche areas related to local conditions
Where decisions taken	Innovation and research expertise primarily concentrated in headquarters and other developed economies Annual meeting to identify innovations of interest for entire group Countries organized in zones that communicate internally so that potential new products developed in one country may be adopted in others Limited range of R&D activities offshored to SA subsidiary	Headquarters have strict oversight of all product development Decentralisation strategy and increased independence of subsidiary, shift from pure product adaptation mandate Innovation projects in subsidiary driven by entrepreneurial individual champions
Collaboration	Country units collaborate on R&D, share expertise and resources with European and developing country partners Group prioritises scientific collaboration with universities and specialized research institutes, primarily in Europe and USA SA subsidiary has limited relationships with local universities, outsourcing on a contract or consultancy basis to tap complementary expertise, such as new packaging or nutritional analysis of new target markets, but not product development	R&D and innovation centres collaborate with broad range of universities and research institutes in home country (particularly a close collaborative partnership with the polytechnic in the headquarter city that includes a custom tailored automotive engineering programme) and across Europe, attracting EU and government funding MNC centre: chain of basic research in European university, accelerated knowledge transfer in R&D centre, and process to development of product in innovation centre Interaction in the form of consultancy, contract joint research and firm sponsorship of university research, as well as informal exchange Brazilian subsidiary has formal interaction with local universities and public research institutes, in the form of extensive government funded joint R&D projects and exchange of university personnel to the R&D centre in Europe
Project example	Development of a low-cost, vitamin enriched product that can be stored at	Advanced suspension technologies developed in response to Brazilian road conditions, when

	Dairyco South Africa	Carco Brazil
	room temperature for a period of time, for low income market segment in emerging economies, marketed through a novel micro-distribution system based in townships with unemployed women as sales agents through informal outlets and door to door sales	financial viability verified by headquarters, spun out to involve different parts of the MNC as well as outside partners to finalise project, involving movement of local engineers to European research centre Biofuels studies and tests and products centralized in Brazil to take advantage of local competences and avoid duplication of costs

11.5.1 A common pattern

A common pattern is identified – the host subsidiary firm and the host universities play a subordinate role in the R&D networks of the MNC, indicating the strongly hierarchical nature of the global innovation network. Carco is a large automotive MNC that focuses on the segment of small economy cars, and has a large operation in Brazil established more than 30 years ago, which served as its centre to access Latin American markets. Dairyco is a large agro-food processing MNC that focuses on nutritional and health benefits of its products. It entered the South African market more recently, in the mid 1990s and the subsidiary has expanded rapidly as a base to access Southern African markets.

The innovation strategy of both MNCs is similar in that they aim to be technological leaders in their niche globally, and the subsidiary is tasked with adaptation for the local market. The structure of the interaction is alike. The MNC interacts with home universities, with the subsidiary and host supplier firms, as well as host universities and public research institutes in a hierarchical network. It also interacts in more horizontal collaboration networks with high reputation universities, research institutes and suppliers based in the home country.

R&D and innovation in both cases is organized on a decentralized model, with basic research and new applications research controlled by the central unit in the home country, outsourcing complementary basic and strategic research to universities in the home country networks. Interaction also takes the form of MNC sponsorship of research facilities, programmes or scholarships, particularly in the home country but to differing degrees in the host country.

Design and adaptation to local market tastes or conditions is offshored to the host country networks. A shift over time is that with growing technological capabilities, rather than simple adaptation of mature technologies to facilitate production, the host networks are engaging in more complex and novel adaptations of a technology platform, as in the examples cited in Table 1. Dairyco has developed a low-cost vitamin enriched product with improved storage properties to suit emerging economy markets and Carco has developed advanced suspension technologies in response to local road conditions. The results of such incremental innovation may be adopted within the group, to other host countries with similar conditions or the subsidiary may even become the centre of expertise for the MNC in that niche area. In these instances, technology transfer and capability building is more likely, and the subsidiary firms are evolving towards a less hierarchical relationship and less subordinate position within the global innovation network.

11.5.2 Differentiated insertion into hierarchical global relationships

At the same time, despite the similar dynamics and nature of interaction, comparison of the two cases serves to emphasise that there are different ways to be inserted in a hierarchical global relationship. Dairyco subsidiary drew on complementary university expertise in relation to marketing or packaging and not to the R&D required for the product innovation. The MNC had very few instances of formal interaction with universities, and this took limited, less knowledge intensive forms such as short term consultancy on nutritional needs, or firm sponsorship of university activities. Carco in contrast, had a greater number of links with universities and public research institutes, and these interactions took more knowledge intensive forms. The Brazilian subsidiary built ongoing relationships in the form of human resource exchange (within the MNC between home and host country, and between the firm and universities in the home and host networks). More long term interaction in the form of customized education and training programmes were established in the host universities, which could have beneficial impact on the public science system in Brazil. Similarly, joint research and engineering contracts allows for knowledge intensive technology transfer and upgrading. These forms of interaction occurred alongside but went beyond the forms of consultancies or sponsorships as in the South African case.

The difference between Carco and Dairyco relates to the uneven match between the industrial and science systems within the immature national system of innovation in each host country. In Brazil, automotive engineering expertise in the universities has coevolved with the automotive sector, as a matched area of strength between the science and technology systems. Government policy and funding, particularly at the regional state level, prioritised the automotive sector as core to regional systems of innovation, and actively promoted and incentivized interaction. The South African automotive sector similarly, has more knowledge intensive forms of interaction on a wider scale.

The opposite is the case for the agro-food processing sector in South Africa. There is a mismatch between industrial and scientific capabilities. Agro-processing capacity in public research institutes and universities has declined steadily over the past few years; government funding has focused on technology platforms to promote interaction between universities and SMEs rather than MNCs; and the extensive national prioritization of funding for biotechnology has concentrated on downstream agricultural processes.

The similarities and differences between the cases thus illustrate the way in which the role of universities in global innovation networks is shaped by both the strategies of MNCs and the level of development of the national – and sectoral - system of innovation.

11.6 Conclusion

The combination of the literatures on GINs and on interactions between firms and universities defines a framework to analyse different types of global interactions between firms and universities. This framework helps to unveil the variegated flows that are running between diverse countries. Four main types can be distinguished, starting with the more basic exclusively local interactions between domestic firms and universities, going through increasingly intricate international interactions, and ending with sophisticated international consortia.

However, there is no guarantee that interactions will progress from one type to another. On the contrary, as the case studies illustrate, progress from one type to another, say from a local firm to a home-based MNC with connections with institutions in diverse countries, is rather complex and difficult process.

The framework emphasizes the importance of both national systems of innovation and MNCs. A careful investigation of MNCs, of their country of origin, brings decisive information to understand the relationships established by GPNs and GINs. The size, diversity and stage of formation of national systems of innovation are also key to understand how those global interactions are formed and in which direction they evolve. The nature of national systems of innovation impacts on both the quality of the foreign R&D that universities in one country attract, and on the number and nature of home-based MNCs. In short, the characteristics of MNCs and NISs are inextricably intertwined in the formation of global networks of the various types.

The framework is useful to identify GINs as a specific channel of global interactions and it is instrumental to investigate the role of hierarchies in those global interactions. We began by questioning how hierarchies are shaped and reshaped within GINs. Ernst (2009) showed the possibilities of subversion in emerging Asia in ICT related technology sectors, but the cases of South Africa and Brazil confirm the hierarchical division of labor in the automotive and agro-food processing sectors. The subordinate and limited role of South African and Brazilian firms and universities in those types of interactions is a consequence of their position in the global science and technology scenario. South Africa and Brazil are in a regime of interaction that faces the curse of the "Red Queen Effect": their upward movement is not enough to reduce the gap to the threshold limits of the "regime" of developed countries.

Changes in the existing hierarchies are not easy. Our investigation has led us to believe that the current phase of internationalization of R&D is indeed reshaping NSIs, but it is also dynamically preserving pre-existing technological hierarchies. This is clearly stated by Jefferson: "[j]ust as the phenomenon of FDI and R&D offshoring leads to spillovers that induce Chinese firms to establish rudimentary operations, the same pattern of offshoring is also motivating the United States and other OECD MNEs to upgrade and diversify their R&D operations in order to maintain control over the development and deployment of critical technologies" (Jefferson, 2007, p. 213).

The paper has evaluated whether global innovation networks in emerging countries are a path for improvement within the international division of labor or a blocking factor for the development of national innovation systems globally integrated. Our answer is in line with a recent evaluation from Ernst (2009, p. 6 and p. 38): GINs may be a "mixed blessing", even a "poisoned chalice". On the one hand, the preservation of hierarchies is a barrier to more advanced, technology-rich, international interactions. On the other hand, existing GINs may under certain conditions, trigger processes that may lead to technological upgrade of peripheral countries. However, as Ernst (2009, p. 38-48) emphasizes, public policies matter for a more positive development of GINs. In our theoretical framework, this is one feature of the NSI determining the nature of GINs.

The development of global innovation networks, the present phase of internationalization of R&D, the processes of NSI formation and improvement may provide South Africa and Brazil with new avenues to escape subordinate roles in global innovation networks. The pattern of GINs that would really contribute to the evolution of their NSIs would be those that involve local universities in knowledge intensive forms of interaction. The creation of truly non-hierarchical networks could be an experiment in the way to a formation of a truly global innovation system – but for now they are not more then a desired goal.

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12 INTELLECTUAL PROPERTY RIGHTS AND SOUTH-NORTH R&D LINKAGES

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Abstract: This paper explores the role of intellectual property rights (IPR) protection in the globalization of innovation and the formation of R&D linkages from emerging economies (South). Using both survey-based data on Chinese and Indian firms in the ICT sector and global bilateral patent data, we find the impact of IPRs to vary depending on the type of R&D linkages, the location of enforcement, the national identity of firms/researchers and the sector/sub-sector under study. Stringent IPR regimes abroad tend to discourage the formation of global R&D value chains and foreign patenting by firms in the South. On the other hand, IPR protection in the home country tends to play a crucial role for the engagement of domestic Southern firms in global innovation linkages. The results also emphasize how sector-specific characteristics determine the correlation between IPR protection and the internationalization of R&D. The ICT industry, particularly the hardware segment, relies on the IPR regime when engaging in the international outsourcing and offshoring of innovation or in patenting activities abroad. Finally, the harmonization of IPR protection across country pairs tend to foster South-North R&D linkages.

Keywords: Innovation, Intellectual Property Rights, Foreign Patenting, R&D Linkages, Gravity Model, Information Communication Technology.

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12.1 Introduction

The growing demand for technology in an increasingly competitive global market is changing the geography of innovation. Today multinational enterprises (MNEs) seek not only to exploit knowledge generated at home in other countries, but also to source technology internationally and tap into worldwide centers of knowledge (OECD, 2008a). We now observe a faster pace for the internationalization of R&D, a wider range of actors involved worldwide, and a greater scope of international innovative activities in the form of integrated networks.

As knowledge starts to flow more freely across the globe, Intellectual Property theft remains the most important risk for global innovation networks (OECD, 2008b). While most R&D investments still go to OECD countries (also referred to as North), non-OECD countries have attracted an increasing amount of R&D investments in recent years. With Newly Industrialized Countries (NICs, also referred to as South) taking a lead in developing technologies of global standards, the view of high-technology companies with headquarters in the South towards intellectual property rights (IPRs) takes a new meaning. Previous literature on the catching-up process of the South has mainly emphasized on North-South technology transfer highlighting the trickle-down effect from technological frontier (Acemoglu, Aghion and Zilibotti, 2006) or globalization arguments, such as decreasing transportation and migration costs, coupled with the non-rival nature of technology.

This paper sheds light on the development of innovation capacities and the internationalizing of R&D by the new class of firms in and from the South. It investigates the relevance of IPRs from a South-North perspective to study the incentives of actors in emerging countries to tap on to international knowledge networks. In so doing, we define different measures for R&D linkages to assess the degree to which emerging countries globalize their R&D and find out how IPR protection contributes to this phenomenon.

To address the issue we rely on a firm-level survey that has been specifically designed to gather information on firms' behavior in terms of international innovation activity. Across four continents, firms were asked to provide information about experiences with regulation, practices and jurisprudence around IPRs faced in the internationalization of their innovation activities. We focus on Chinese and Indian firms active in the ICT sector in which the use and development of new technologies through innovation is more pervasive and sector specific.[1] Our empirical findings based on survey data suggest that depending on the definition of R&D linkages and the sub-sector under study, a credible IPR regime can influence Southern firms' engagement in internationalization of R&D. More specifically, IPRs tend to matter more for the participation of domestic Southern firms in global innovation networks. However, it proves more relevant for the offshoring or outsourcing of innovation in the hardware segment of the ICT sector.

To validate our findings on a global scale, We use an empirical gravity model designed to capture the extent of NICs involvement in the internationalization of innovation activity, in particular in OECD countries. To do so, we first define an appropriate variable to measure the phenomenon, related to the number of patents that NICs nationals file in OECD patent offices. We then regress

[1] This is partly driven by the survey design, which lets each partner-country select one sector of particular economic relevance. The ICT sector has been selected by both Indian and Chinese survey partners, letting us obtain indications for emerging economy-, country- and industry-specific policies. A description of the firm-level survey design and implementation is provided in Appendix 1.

this variable on country and country-pair specific variables such as IPR protection in both countries, degree of ICT-specificity of exports, together with standard gravity model specific controls such as distance, GDP per capita, common language and common border dummies. Using data on patents filed by nationals from 14 NICs in 31 OECD countries in a gravity framework, we show that the location of IPR enforcement also matters for South-North innovative activities. In particular, South-North foreign patenting is positively related to domestic IPR enforcement, whereas enforcement in the receiving country *discourages* patent applications from NICs. We relate this latter result to defensive patenting or a market power effect that obstruct entry by new firms, or the difficulty faced by NICs with less advance technologies to obtain patents in countries with a tougher IPR regime. Finally, the analysis confirms the crucial importance of IPR protection for international innovation activities in the ICT sector, primarily for the hardware segment.

The reminder of the paper is organized in the following way: the next section gives a short background on the recent patenting activities in major emerging economies. Section 3 presents survey data and the related empirical analysis. In section 4 we report methodology, data, and results for the cross country gravity estimation. Section 5 concludes.

12.2 IPRs and innovative activities: recent trends in China and India

The increase in the 'propensity to patent'[2] by 20 percent in less than 20 years in OECD countries is generally attributed to technological change, economic transformations, and a shift of patent policy since the 1990s (OECD, 2004). The same trend has occurred in emerging economies after reforming their legal framework of IPR protection according to WTO standards. In 1985, the total number of patents granted in China was only 138. This number increased to 100,156 in 1999 (Sun, 2003). The total amount of patent applications in China today exceeds 7 million ranking as the third largest patent office in the world and fourth in terms of Patent Cooperation Treaty (PCT) filings. In some new technical areas, such as digital communication, telecommunication and high-speed trains, 20% of the total of PCT applications in the field of digital communications have come from China in the years 2008-2010 (Tian, 2011). China accounts for 3.5% of triadic patents and aims to join the top five countries receiving triadic patents by 2015 (Zhao, 2006). The first Patent Law came into force in China in 1985 and the two major rounds of modifications occurred in 1992 and 2000.

In India, the Patents Act, 1970 was amended in 1999, 2002 and 2005. Since the country became signatory to the PCT in 1998, patent filings in India have registered a sustained growth up to 43%.[3] Trends in ICT-related patent applications to the European Patent Office (EPO) show that India ranked second after China between 1995 and 2003. Over the period 2004-2007, the country presented the highest average growth rate in terms of patent applications (26.3%) reaching 36,812 applications in 2008 (WIPO, 2010). If we look at the contribution of local inventors to foreign-owned patent applications, 65% of Indian inventors and 43.9% of Chinese inventors are associated with foreign PCT applications, ranking respectively 1st and 5th in the world.

Indian IT sector is estimated to aggregate revenues of 88.1 USD in 2011, with the software and service sector, excluding hardware, accounting for 86.4%.[4] Conversely, China accounts for 14.6%

[2] That is, the number of patents taken per dollar or euro of R&D, assuming the productivity of R&D constant.
[3] WIPO Magazine 10, 2002.
[4] NASSCOM cited by India Brand Equity Foundation, 2011.

of the global electronics hardware production (Bhattacharya and Vickery, 2010). Indeed, the large share of Chinese patent applications in ICT-related areas is associated with the considerable focus on ICT hardware production (van Welsum and Xu, 2007).

12.3 IPRs and global R&D linkages in the South: firm-level analysis

12.3.1 The survey data

We have obtained the data by administrating a survey to firms representing three sectors in 9 countries across 4 continents.[5] The sectors targeted were ICT (in China, India, Sweden, Norway and Estonia), agro-processing (in South Africa and Denmark), and automotive (in Brazil and Germany), selected to represent a range from high to low tech industries. The aim was to collect empirical evidence to study the determinants and the extent of globally dispersed innovation networks.

To assess the presence of R&D linkages in the sample, we define two different dependent variables. The first, *GIN*, defines firms that have established collaborations with foreign actors for the development of their most important innovation, i.e. global innovation networks. Such actors could be indistinctively clients, suppliers, competitors, consultancy companies, governmental institutions, Universities, research institutions or open source communities. Differently, *OUT* considers firms that perform some specific/core innovation activities through offshoring or outsourcing abroad. These activities include product and process development, operations, procurement, logistics and distribution, building and maintenance of IT systems.[6]

Table 1 presents the distribution of the dependent variables across countries in the sample. Comparing the distribution of *GIN* and *OUT* at country level, the latter provides a more restrictive definition of international collaborations for innovative activities, nonetheless with some exceptions.[7] Looking at the correlation coefficients across sectors of the dependent variables, they all result particularly low, from 0.29 for ICT firms to 0.47 for agro-processing firms. This highlights that two variables capture different activities firms may perform in the internationalization of their innovative activities.

Table 1: Distribution across national samples of GIN and OUT.

	China	India	Brazil	Denmark	Estonia	Germany	Norway	South Africa	Sweden	TOTAL
GIN	35,80%	56,17%	21,74%	34,69%	52,94%	41,51%	29,83%	45,24%	47,69%	42,55%

[5] The sample of firms is not representative at the level of country or region, so the policy implication of the findings in this section should be treated carefully, without pushing too much issues of external validity.

[6] The selection of activities included in the set of 'innovation activities', has been conducted by looking at what firms defined as 'innovation'. Firstly, we looked at the set of firms that indicated to conduct 'offshoring innovation'. Secondly, we constructed dummies that included the possible combinations of functions that respondents perform through offshoring. The highest correlation coefficient was found in correspondence of the dummy including the group of functions listed above.

[7] We observe that *OUT* is more widespread than *GIN* in Germany and Brazil. This could be driven by sector peculiarities. Indeed, observing the distribution of the independent variable across sector, the difference between *GIN* and *OUT* is less pronounced for the automotive industry than for the ICT.

OUT	11,11%	43,21%	23,19%	20,41%	17,65%	45,28%	13,26%	25%	25,64%	25,93%

Source: Authors' calculation based on INGINEUS survey.

The presence of R&D linkages prevails in the ICT sector if we look at *GIN*, but not in the case of *OUT*. Moreover, *GIN* is more widespread in the Indian ICT sector and in the German automotive only. It's worth noticing that having significant R&D activity does not necessarily mean a greater involvement in global innovation networks. The correlation coefficient between having significant R&D activity and the variables *GIN* and *OUT* resulted 0.32 and 0.14 respectively. Indeed, there is a relevant fraction of firms in the sample that outsource and offshore innovation abroad without conducting in-house R&D (21.7%), indicating that the core of their knowledge has foreign origin. This is also confirmed by looking at the most important source of innovation for firms. Among respondents, 40% of the sample do not consider their headquarters as the most important source of technology inputs and 29.4% have as technology source an entity external to the firm.

After having highlighted results for all countries and across all sectors represented in the survey, we focus now on China and India, whose involvement in ICT is of primary importance. The survey reveals India to be the only emerging economy with a strong and positive probability of being part of an international R&D linkage while China in all cases results amongst the least involved. In our sample, Chinese ICT firms are amongst the most unsatisfied with regard to relevant labour force skills (68.3%). On the IPRs side, the Chinese sample presents the greatest percentage of firms requiring more stringent IPR regulations to consider future innovation activities (64.2%).[8] Alternatively, India results more open in conducting research activities with foreign partners even if it presents a lower R&D intensity compared to China.[9] These observations call for a more in-depth analysis of the Chinese and Indian ICT firms.

12.3.2 Empirical analysis

Given the *open* nature of technology attainment, in what follows we concentrate on factors relevant for the internationalization of firms' innovative activities. These are (i) human resource development, the key area in supplying quality skilled workers for global and local markets, and (ii) the legal environment for IPR protection.

In our simple linear probability model, our main regression equation is:

$$LINKi = \beta 0 + \beta 1\ HRi + \beta 2\ IPRi + \mathbf{\beta 3X}i + \delta c + \delta s + \upsilon i, \quad (1)$$

where LINKi takes our two definitions of R&D linkages *GIN* and *OUT*, and subscript *i* indicates firms. The main explanatory variables denote firms' experience with regard to (i) HR: relevant labour force training and skills, (ii) IPR: regulation, practice and jurisprudence around IPRs. These are treated as dummy variables taking value one if the firm indicates a positive experience with

[8] The relative value increases if we look specifically at those firms that make part of a global innovation network.

[9] Looking at the size of the R&D units (measured as number of full time R&D employees by firm size) in the ICT sector for the Chinese and Indian sample, in China they result on average larger than in India with only exception being very small firms with less than 10 employees. Chinese firms result more R&D intensive, employing a greater number of individual in R&D than Indian firms do. This may confirm recent studies on the Indian ICT sector that, despite public efforts, investments in R&D by the private sector is still relatively low and largely based on the outsourcing market (Bhattacharya and Vickery, 2010).

above factors. **X**i is a vector of further controls, such as type of ownership of the firm (domestic or foreign) and sub-sector (hardware or software). When the regression equation is performed with *OUT* we further control for the region of origin of its innovations partners. Finally, to control for unobserved heterogeneity, we include dummies at the country and sector levels, δc and δs, respectively.

After defining the main dependent and independent variables, we perform OLS estimates of Equation (1) for each definition of R&D linkages. We estimate our linear probability model for the Indian and Chinese sample, and control for country fixed effect in all estimations. The aim is to look at the IPR environment as a determinant of R&D linkages at the country level, and observe whether the same conclusions can be applied equally to the domestic and foreign ICT firms located in China and India. We also conduct a sub-sector analysis considering that firms within the ICT sector may rely differently on patents in the hardware segment compared to software programming, data processing and systems design.[10]

Table 2 reports the results of the OLS regressions to shed light on whether having had a positive experience with the analyzed factors has contributed to building international R&D linkages. Findings in columns [1] and [2] affirm that having had a positive experience with IPR regulations increases significantly the probability of networking with foreign actors for innovative activities, especially when *GIN* is the dependent variable. Chinese (Indian) firms are less (more) likely to be involved in a global innovation network, but there is not a differential effect of IPRs on GIN involvement among firms from a particular country. The control variable *hardware* resulted positive and statistically significant only when we looked at *OUT*. This may indicate that in the hardware segment the activity of offshoring and/or outsourcing abroad is more widespread than networking with foreign partners.

Table 2: IPRs as determinants of global R&D linkages for Chinese and Indian ICT sector

Dep. Variable	GIN	OUT	GIN	OUT
	[1]	*[2]*	*[3]*	*[4]*
IPR	0.204 (0.058)***	0.131 (0.057)**	0.197*** (0.070)	0.105 (0.067)
IPR_China	-0.059 (0.084)	-0.113 (0.070)	-0.062 (0.084)	-0.130 (0.071)*
China	-0.150 (0.065)**	-0.240 (0.055)***	-0.087 (0.068)	-0.211 (0.059)***
HR			0.092 (0.051)*	0.146 (0.067)*
Foreign			0.327 (0.076)***	0.170 (0.072)**
IPR_foreign			-0.183	-0.075

[10] The *hardware* segment includes (i) the manufacture of communication equipment and (ii) other information technology and computer service activities, such as, computer disaster discovery, setting up personal computers and software installation.

			(0.095)*	(0.091)
Hardware	0.001 (0.041)	0.106 (0.036)***	-0.093 (0.061)	0.014 (0.047)
Constant	0.425 (0.052)	0.289 (0.050)	0.306 (0.051)	0.267 (0.049)
Obs	567	567	544	544
R-sq.	0.0706	0.1460	0.1193	0.1460

Robust standard errors in parenthesis; (*) p-value<0.1; (**)p-value<0.05; (***)p-value<0.01

In column [3] and [4] we control whether human resource availability can be another explanation for the involvement of Chinese and Indian firms in global R&D linkages and find IPRs to play a more important role for the *GIN* variable. We then investigate the extent to which the relevance of IPRs as a determinant of R&D linkages may vary according to the type of ownership. The control variable *foreign* indicates that being a subsidiary of an MNC increases significantly the probability of being part of international innovation linkages. The impact is greater when MNCs seek to establish innovative collaborations abroad than when they outsource and/or offshore innovation. The negative coefficient of the interaction term IPR_foreign shows that even if it turns out that foreign firms are *per se* more involved in R&D linkages than domestic ones, IPRs tend to be a more essential factor for the participation of *domestic* firms in global innovation networks (*GIN*). It is important to notice that the same argument does not hold for international R&D value chains (*OUT*). Moreover, including the new arguments results in IPR losing its significance for the *OUT* variable.

Table 3: IPRs as determinants of global R&D linkages for ICT sub-sectors

Dep. variable	GIN	OUT	GIN	OUT
	[1]	[2]	[3]	[4]
IPR	0.171 (0.060)***	-0.008 (0.043)		
fIPR			0.198 (0.060)***	-0.065 (0.053)
IPR_hardware	-0.015 (0.083)	0.157 (0.074)**		
fIPR_hardware			-0.070 (0.083)	0.153 (0.049)**
hardware	-0.020 (0.064)	0.003 (0.057)	0.010 (0.059)	0.017 (0.057)
China	-0.172 (0.042)***	-0.293 (0.035)***	-0.225 (0.042)***	-0.297 (0.036)***
foreign	0.205 (0.045)***	0.102 (0.042)**	0.217 (0.045)***	0.108 (0.042)***

constant	0.398 (0.053)	0.347 (0.049)	0.415 (0.048)	0.388 (0.035)
Obs	544	544	544	544
R-sq.	0.1031	0.1525	0.1043	0.1471

Robust standard errors in parenthesis; (*) p-value<0.1; (**)p-value<0.05; (***)p-value<0.01

In Table 3, we focus on hardware and software firms when studying R&D linkages. Here we look at the relevance of their experience with the intellectual property framework (IPR) and to their need for more stringent IPRs when considering their future innovation activities (fIPR). Again, we control for country and type of ownership. Columns [1] and [3] indicate that IPRs remain a determinant of international networking activities, while the hardware segment is not, per se, more involved in global innovation networks or more reactive to IPRs. Perhaps more interestingly, columns [2] and [4] reveal that IPRs do no play a role in firm's activity of outsourcing and offshoring innovation abroad. The coefficient takes a negative, although insignificant, sign for both IPR and fIPR. However, IPR_hardware and fIPR_hardware show that firms in the hardware sector react positively to IPR protection when deciding on the internationalization of their R&D value chains.

12.3.3 Conclusions of the survey-based research and limits

The conclusions from our micro-analysis are threefold: first, the analysis suggests that the protection of IPRs is among the determinants of the participation of firms in the South to global innovation networks, but not in the internationalization of their R&D value chain. Second, focusing on differences between the foreign and the domestic sector operating in these countries we found that IPRs are more relevant for domestic (hence Southern) than foreign firms, even if foreign firms are in general more involved in R&D linkages. From a Southern perspective, these findings may indicate that the capability of introducing and securing new and sophisticated technology at home and/or abroad determines the opportunity for a Southern firm to be globally engaged in innovative activities.

Finally, looking at both measures of experience and need of more stringent IPRs across ICT sub-sectors we find while securing intellectual assets is a determinant of international R&D collaborations for the ICT industry, it proves more relevant for the hardware segment when engaging in international R&D linkages through outsourcing and offshoring activities

Even if the survey data allows us to differentiate between the type of global R&D linkages under study, it does not let us allow for considerations with regard to the location of IPR enforcement. Furthermore, the role of IPRs results ambiguous. On one side, the positive and statistically significance of its impact (when considered alone) may reflect the general argumentations on the impact of the IPR framework on the business environment and its relevance for the internationalization of R&D activities. However, its lower significance when considered in concomitance with other factors, under different definitions of R&D linkages, or if observed for specific countries or sectors may confirm that stronger IPRs must be embedded in a broader set of complementary initiatives, such as human capital development, to be effective. Furthermore, they may indicate that there are emerging trends or new factors affecting innovation and decisions regarding the internationalization of R&D activities. Several issues that emerge from the above firm-level analysis could only be verified when accompanied by a more general analysis that applies global data. We undertake this task in the following section.

12.4 IPRs and internationalization of Southern R&D: macro-level analysis

12.4.1 Data and methodology

In this section we extend the analysis to a cross country level. Specifically, we try to generalize the firm-level findings in the previous section to the country level, while concentrating on the impact of IPRs on *South-North* R&D linkages. To this end, we look at the filing of patents in OECD countries' patent offices by researchers resident in NICs. We believe the foreign patenting activities of the South could at least partially capture the idea of internationalization of innovation activity in the spirit we have highlighted earlier: theoretically, this would include a (team of) researcher(s) working at the NIC-located branch of a MNC that files a patent through its headquarters in an OECD country. [11]

Given the nature of our analysis, i.e. looking at the determinants of NICs' R&D linkages with the OECD countries, we make use of an *oriented* empirical gravity model. Rather than considering bilateral flows, the standard practice in gravity estimation of trade flows (see, for example, Frankel and Rose, 2002) or international invention activity (see Picci, 2010), we specifically look at the number of patents filed in the patent office of an OECD country (the destination country) whose first applicant resides in a NIC (the origin country).[12] Succinctly, our dependent variable PAT_{ijt} is the (log) average number of patents filed in the time period t by an applicant residing in country i in the patent office of country j, where index i runs over 14 NICs and j runs over the 31 OECD countries.[13] Note the different pools from which i and j are taken and that, in general, $PAT_{ij} \neq PAT_{ji}$. The variable *PAT* has been constructed using data from the World Intellectual Property Organization (WIPO), that has information on 189 countries of origin of applicants and 139 countries (and groups of countries, such as the African Intellectual Property Organization or the European Patent Office) that host a patent office.[14] Information is available for years 1995-2008, so

[11] One could argue that foreign patenting could also represent for instance Chinese researchers working in Chinese firms who seek protection in a foreign market. However, over 90% of foreign (primarily OECD and the Asian NICs) applications for Chinese invention patents have claimed foreign priority, suggesting that patent applications had earlier been filed for the inventions with foreign jurisdictions (Hu, 2010). See Appendix 2 for more details on our dependent variable.

[12] We decided to look at the number of patent applications instead of granted patents because has the advantage of allowing an analysis of more recent data. Indeed, although any application is published by eighteen months after the date of filing or the earliest priority date, the patent grant procedure takes about three to five years from the date of the application (EPO, 2010).

[13] Countries officially considered as NICs are: Brazil, China, India, Mexico, Malaysia, Philippines, Thailand, Turkey and South Africa (Mankiw, 2007). In our definition of NICs, we also included countries around which consensus in the economic literature is not yet reached. They are Argentina, Chile, Egypt, Indonesia and Russia, (Paweł Bożyk, 2006). OECD countries are Austria, Australia, Belgium, Canada, Switzerland, Czech Republic, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Hungary, Ireland, Iceland, Italy, Japan, Korea, Luxemburg, Mexico, Nederland, Norway, New Zealand, Poland, Portugal, Sweden, Slovakia, Turkey, USA and South Africa.

[14] Since WIPO registers the residence of the *first* applicant of a patent, our measure could underestimate the real measure of patents whose applicants' reside in a country different by that of patent office. This is the case of multiple

we construct averages for three periods: 1995-1999, 2000-2004 and 2005-2008, hereafter referred to as 1995, 2000 and 2005 respectively. We take averages for two reasons related to the IPR protection index. First, data are only available for 5-year intervals and second, even if we had data on a yearly basis, IPR protection varies slowly in general, with large jumps when agreements are set in place: taking the averages helps to smooth out these irregular movement. Our framework partially draws from Yang and Kuo (2008), that use the same dependent variable. However, their analysis is limited to the 4 contiguous years of 1995-1998 and do not study South-North relations, but study bilateral relation between 30 chosen WIPO members. While their aim is to uncover the influence of trade and IPRs in the destination country on outward patenting activities, we focus on the IPR regime on both sides of the activity and its harmonization between the country pairs. The empirical model we estimate, written in general terms, is the following:

$$PAT_{ijt}=G_t+ D_i+ D_j+\boldsymbol{X}_{it}+\boldsymbol{Y}_{jt}+\boldsymbol{D}_{ij}+\boldsymbol{D}_{ijt}+u_{ijt} \quad (2)$$

The term G_t is a common year-specific factor and we use year dummies to capture for it. Similarly, D_i and D_j take into account country-specific fixed effects. The monadic terms $\boldsymbol{X}_{it}$ and $\boldsymbol{Y}_{jt}$ include variables common to both origin and destination countries, as well as variables only specific to either one or the other set of countries. [15] Among the monadic variables there are (logs of) GDP per capita and population: instead of having only GDP as mass variable, we separate size (population) and development (GDP per capita) effects as in Head et al. (2010), so to better interpret our results. We expect that both GDP per capita and population in the origin country should have a positive effect on innovation activity, including the filing of patents abroad.

We have a measure of IPR protection from Park (2008) for both the origin and the destination country.[16] A priori, IPR protection in the destination country could have either a positive or a negative impact on foreign patents: according to Allred and Park (2007), a positive effect of IPR protection on patenting in developed countries comes from increased appropriability of invention and a market expansion effect (i.e. a larger market creates innovation spillovers, so that new innovations are easier to produce), while negative effects can derive from defensive patenting or market power effect. About the effect that IPR protection level in the origin country could have on innovation, Picci (2010) suggests that poor IPR protection could result both in less internationalization of innovation (due to standard appropriability considerations) or more, if the branches of MNEs located in NICs patent innovations in their headquarters. We also have the counterpart of the firm-level analysis' variable human resources, that is the Barro and Lee (2010) data on the share of 25+ year old people holding at least tertiary education in both the original and the destination countries.

$\boldsymbol{D}_{ij}$ includes all the time-invariant dyadic variables, collected by CEPII. We use (log of) distance between i and j, commonality of borders and commonality of language. These variables have proved to have strong explanatory power in gravity equations for trade flows, foreign direct investments and services. With this respect we want to compare the elasticities of internationalization of innovation activity. The term $\boldsymbol{D}_{ijt}$ collects dyadic time-variant variables, that

applicants of different residence, with the first applicant residing in the same country of the patent office in which the patent is filed.

[15] According to Baldwin and Taglioni (2006), we should include a full set of country times year fixed effects, but the short time variability would make it impossible to have enough degrees of freedom.

[16] The technical details related to the construction of the index can be found in Park (2008).

in some specifications will be the distance between IPR protection between country *i* and country *j*, or the impact of harmonization of the IPR regime between each country pair.

The theoretical number of observations should be $I*J*T$=1302, coming from 14 NICs, 31 OECD countries and 3 time periods. However 3 countries are coded as both NIC and OECD (South Africa, Mexico and Turkey) so we exclude these pairs. The number of observations we have for the empirical work is therefore 1293 and for 649 of them the number of patents is positive. The distribution of patents filed in country *j* by an applicant residing in country *i* has a strong positive skew: it takes values between 0 and 3563.25, the average number of patents is 20.45, the median is 0.75 and standard deviation is 154.2.[17] Looking at the time dimension, the number of patents filed more than doubles every five years: in 1995 mean of *PAT* is 6.39, in 2000 it is 15.87 while in 2005 is 39.87, suggesting a remarkable increase in the international collaboration in patenting activity. The rise in average patents is due to both the intensive and extensive margin. The latter refers to the number of zeroes, that represents country pairs that are not collaborating: they are 87, 68 and 57 in the 1995, 2000 and 2005 periods, respectively.

To look at specialization in the ICT sector, first recall from the previous section that the greatest percentage of respondents requiring more stringent IPR regulations where Chinese firms. This could be driven by China's ICT sector's specialization in hardware production, which may rely on patent protection more than the software segment. To control for this, we will use the share of exported goods belonging to the ICT sector interacted with the IPR protection Index among other controls.[18] We use the share of exported goods belonging to the ICT sector in 2000, obtained from World Bank's World Development Indicators, to account for the degree with which NICs should care about IPR protection.[19] As discussed above, *ceteris paribus* the more the production mix is biased toward technological goods, instead of software, the more IPR protection should be a factor that fosters innovation, since issues of appropriability of patents are more relevant. This measure varies a lot across NICs, ranging between 0% of Chile to 69% of Philippines. Within this group, India ranks fourth in 13 with 1.4% while China ranks ninth with 18.9%.[20]

12.4.2 Empirical results

We start estimating the parameters of Equation (2) in a parsimonious specification. First, we want to pin down the values that the coefficients of the standard independent variables used in empirical gravity model take, so to compare our results with those established in literature. Our results are collected in column 1 of Table 4, where OLS are performed using a specification in which distance, dummies for common language and common border, population and GDP per capita are included among the controls. In all the specifications reported in Table 4, the dependent variable is the log of number of patents, so only country pairs showing a positive number of patents is included in the

[17] The number of patents can take fractional values because we take the average across years.

[18] Data on the share of exports in the ICT sector (that exclude software) comes from World Bank's World Development Indicators Database. They are relative to year 2000.

[19] The definition of this variable is: "Information and communication technology goods exports include telecommunications, audio and video, computer and related equipment; electronic components; and other information and communication technology goods. Software is excluded."

[20] The rank is over 13 instead of 14 NICs because no figures are available for Egypt.

sample. As in all the following specifications, two (out of three) time dummies are included, together with NICs and OECD country dummies.[21]

Table 4: Determinants of strengthening South-North formation of GINs.

	(1)	(2)	(3)	(4)	(5)	(6)
DIST_ij	-0.59 (0.08)***	-0.59 (0.08)***	-0.58 (0.08)***	-0.49 (0.09)***	-0.59 (0.08)***	-0.59 (0.08)***
COM_LAN_ij	1.11 (0.15)***	1.12 (0.15)***	1.13 (0.15)***	1.25 (0.17)***	1.13 (0.15)***	1.12 (0.15)***
COM_BOR_ij	0.00 (0.31)	0.01 (0.31)	0.03 (0.31)	0.19 (0.32)	0.03 (0.31)	-0.00 (0.31)
POP_it	6.99 (1.73)***	6.44 (1.84)***	5.14 (1.85)***	4.88 (2.06)**	5.14 (1.93)***	6.37 (1.79)***
POP_jt	8.49 (2.25)***	7.74 (2.25)***	6.69 (2.25)***	5.09 (2.64)*	7.47 (2.25)***	8.59 (2.25)***
GDP_pc_it	1.04 (0.23)***	1.07 (0.22)***	1.02 (0.23)***	0.74 (0.29)**	0.90 (0.24)***	1.05 (0.22)***
GDP_pc_jt	-1.08 (0.40)***	-0.49 (0.43)	-0.49 (0.43)	-0.69 (0.50)	-0.47 (0.43)	-1.00 (0.41)**
IPR_it		0.05 (0.11)	-0.01 (0.11)	-0.23 (0.18)	0.05 (0.11)	
IPR_jt		-0.77 (0.21)***	-0.72 (0.21)***	-0.65 (0.25)***	-0.78 (0.21)***	
ICT_IPR_it			1.54 (0.49)***	1.83 (0.59)***		
EDU_it					0.12 (0.06)**	
EDU_jt					-0.02 (0.02)	
dist_IPR_ijt						-0.04 (0.03)
Obs.	649	649	632	476	649	649
R^2	0.79	0.80	0.81	0.78	0.82	0.80

Dependent variable: log of number of patents filed in country j by residents in country i (all specifications include monadic country dummies and time dummies).

Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

[21] These dummies already control for a lot of variation: a regression that uses only those delivers an R^2 of 0.74.

Distance shows an elasticity of -0.59 that is comparable with the upper bound found by Picci (2010), even though he uses a different measure for patents. Language proves to be an important determinant, while the common border dummy does not, probably because of the low variability: only 11 out of 649 observations report a one. Size measures (population) of origin and destination country have a positive impact and comparable magnitudes, while income per capita has a positive effect in the origin country and negative in the destination. Referring to GDP per capita, the former effect could be the result of higher human capital and/or higher R&D spending, measures that are usually associated with higher GDP per capita. On the contrary, GDP per capita in the destination country negatively impacts on international patenting activity. This could be driven by the fact that NICs tend to collaborate with countries that are more similar to them in terms of level of development.[22]

In column 2 we introduce the IPR protection indices for both origin and destination country. The IPR protection index for the former country is positive but not significant, while the latter is negative and strongly significant. These results are opposite to those obtained in Yang and Kuo (2008), who find a positive and significant relation between IPR regime of the destination country and foreign patenting activity that takes place there. The negative effect could be a symptom of defensive strategies by Northern firms that block access to important technologies needed by Southern firms to realize their own innovations. These could include the market power effect (a more concentrated market impeding entry by new firms) or increased incentives by firms in the North to engage in defensive patenting (Hall and Ziedonis, 2001), most common in the hardware and software industries. The strategy of defensive patenting, also referred to as 'patent blocking', aims at preventing rivals from applying for the same or similar coverage.[23] As suggested by Allred and Park (2007), while the market power effect may negatively impact both developed and developing countries' markets, defensive patenting is mostly associated with Northern countries. Also, since NICs are on average less technologically advanced than OECD countries, the former may find it easier to patent an innovation in OECD countries with weaker IPR regimes. This occurs because the technological frontier of the most developed OECD countries is difficult to reach, therefore few patent filings are recorded. We will take this into account in specifications that use the distance between IPR protection indices within each country pair. Note that the introduction of the indices results in the loss of significance of GDP per capita in the destination country, that could be due to the high correlation of this variable with the IPR index (0.70).

Column 3 reports a specification in which we add to column 2 the interactions of the IPR protection index with the share of exported goods belonging to the ICT sector in 2000 for NICs. As highlighted above, countries like China, whose production (and therefore exports) is oriented toward ICT goods, should benefit comparatively more from the protection of IPR. As expected, the interaction between the share of exports in ICT sector and the IPR protection index in NICs is positive and strongly significant.[24] In column 4 we replicate the last results excluding country pairs

[22] A regression using the squared difference of GDP per capita of origin and destination country, rather than the two separate variables, gives a negative and significant coefficient.

[23] An example of defensive patenting is the 17,000 patent portfolio held by Motorola Mobility Holdings Inc. and bought in August 2011 by Google to protect HTC Corp. and Samsung Electronics Co. who produce phones based on Google's Android software. Indeed, in April 2011, Apple sued Samsung in the US and subsequently claimed against it to prevent the imports of Galaxy Tab 10.1 and Galaxy Smartphones in Germany, Ireland, Netherland, Sweden and UK. (Kwong, R. and Jung-a, S., "Google's Motorola deal a boon for Asia", Financial Times, 16 August 2011; Zeman, E., "Apple wins another round against Samsung in Germany", Information week, 09 September 2011)

[24] The direct effect of the share of ICT cannot be estimated because it is collinear with NICs' country fixed effects.

involving China or India, two countries that host many headquarters of MNCs. In these cases PAT would be a spurious mix between genuine cross-border innovation collaborations and innovations carried on within China (India) by Chinese (Indian) MNCs that only register their innovations in foreign patent offices, subsequent to filing a domestic patent. Results hold even if less significant in some cases, possibly due to the smaller sample. Specification in Column 5 add tertiary education measures for both origin and destination country to that in Column 2. Only education in the origin country turns out to be positive and significant. We tried to add the interaction term of tertiary education and ICT, paralleling the regression in Column 3, but nothing changes. In column 6 we replicate specification 1 while using the squared distance between IPR protection indices within each country pair instead of the two IPR indices. This variable is negative as expected but not significant at conventional levels.

Table 5 collects results using different specifications and different estimation techniques, that we perform in order to check for the robustness of our findings. Our main concern with the results obtained is that half of the observations are not used because PAT takes a value equal to zero, causing a missing value for its logarithm. Also, differently from the case of bilateral trade flows, PAT is a count variable, for which the Poisson estimator has been suggested (see Picci, 2010 and Santos Silva and Tenreyo, 2006 among others). In column 1 we report results for the Poisson version of the specification 2 in Table 4. The distance variable is precisely estimated and the point estimate is around 0.3. Signs previously found are consistent, while now the IPR protection in NICs turns out to be positive and strongly significant. The significance being driven by the inclusion of more than 600 zeroes in the analysis suggests that IPR protection works at the extensive margin.

Table 5: Determinants of South-North formation of GINs.

	(1)	(2)	(3)	(4)	(5)
Method	**Poisson**	**Poisson**	**Poisson**	**Poisson**	**Negative Binomial**
DIST_ij	-0.27 (0.02)***	-0.27 (0.02)***	-0.28 (0.02)***	-0.27 (0.02)***	-0.63 (0.07)***
COM_LAN_ij	0.53 (0.04)***	0.53 (0.04)***	0.54 (0.04)***	0.55 (0.04)***	1.06 (0.13)***
COM_BOR_ij	0.19 (0.10)*	0.16 (0.10)	0.17 (0.10)*	0.17 (0.10)*	-0.05 (0.28)
POP_it	2.98 (0.56)***	1.29 (0.58)**	3.52 (0.56)***	3.50 (0.57)***	7.41 (1.74)***
POP_jt	1.86 (1.07)*	6.18 (1.33)***	2.92 (1.07)***	-0.02 (0.98)	5.65** (2.30)
GDP_pc_it	1.33 (0.08)***	1.10 (0.08)***	1.08 (0.08)***	1.30 (0.08)***	1.27 (0.22)***
GDP_pc_jt	-0.99 (0.16)***	-1.56 (0.20)***	-0.97 (0.16)***	-0.65 (0.15)***	-1.08 (0.39)***
IPR_it	0.61 (0.02)***	0.59 (0.03)***	0.43 (0.03)***		

IPR_jt	-0.41 (0.13)***	-0.37 (0.13)***	-0.49 (0.13)***		
EDU_it		0.20 (0.02)***			
EDU_jt		0.02 (0.00)***			
ICT_IPR_it			3.29 (0.15)***		
dist_IPR_ijt				-0.12 (0.01)***	-0.07 (0.03)***
Obs.	1293	1293	1293	1293	1293
Pseudo-R^2	0.95	0.95	0.95	0.95	0.43

Dependent variable: number of patents filed in country j by residents in country i (all specifications include monadic country dummies and time dummies).PAT
Standard errors in parentheses. (***) p-value < 0.01, (**) p-value <0.05, (*) p-value <0.1

Our explanation is that MNCs open up research branches in NICs only if IPR protection is large enough, while once research branches are operative, the level of IPR protection plays a limited role in defining the intensive margin of innovation activity. In column 3 we add education variables to the previous Specification. As in the OLS case, tertiary education in origin country is positive and significant and now also education in the destination country has a positive effect, even if ten times lower than the effect in the origin country. In column 3 we replicate specification reported in column 4 of Table 4. There is little change with respect to the results in column 1 and the interaction term, as for the OLS case, is positive and strongly significant. In column 4 we substitute the two distinct measures of IPR protection (in NICs and OECD countries) with the distance between IPR indices within country pairs, as we did in column 6 of Table 4. The coefficient is again negative but it is now strongly significant, suggesting the extensive margin of patent production to also be at play when the similarity between IPR regimes are concerned. Finally, in column 5 we estimate the previous specification by means of the negative binomial method, that should improve estimates when the dependent variable is over-dispersed (Hausman et al., 1984), i.e. the variance to mean ratio is greater than one, as it is in our case. Results are broadly confirmed, together with the gain in significance of the positive effect of population in OECD countries.

12.5 Conclusions

This investigation can be viewed as an initial attempt to explore the different roles IPRs can play for the globalization of Southern innovation with respect to the location of enforcement, the identity of firms/researchers and the (sub-)sector under study. While the debate on the protection of IPRs has often been placed in a 'North-toward-South' perspective, this paper addresses innovation that originates in the South. The investigation attempts to answer the question whether stronger IPR protection home and away or its harmonization to global levels foster the internationalization of R&D from the South.

Using both survey-based data on Chinese and Indian firms in the ICT sector and country-level data on the foreign patenting activities of NICs in OECD countries our analysis confirms IPRs to play varying roles in the formation of global innovation linkages. While the survey data revealed that IPRs do not necessarily foster innovation outsourcing and offshoring activities of Southern firms, our country level analysis showed that they could indeed have a negative impact in foreign patenting by NICs. The firm-level tests pointed out the relatively higher importance of IPRs for domestic firms to engage in global innovation networks, whereas the macro-study showed the necessity of a strong IPR regime at home for MNE research branches to be operative there in the first place. Finally, both levels of study also suggest the importance of sectors and subsectors in the role of IPRs in global R&D linkages. We found the ICT industry, particularly the hardware segment, to rely on IPRs when engaging in the international outsourcing and offshoring of innovation or in patenting activities abroad.

Appendix 1 - Survey design and implementation

The survey was administered online from November 2009 to June 2010 by the INGINEUS project, [25] after significant work in designing and pre-testing the questions. The overarching goal of the survey was to establish the presence of global innovation networks: how global, how innovative and how networked the sample was. Each institute chose the survey delivering method according to past experiences and knowledge of the best methods utilised in the country for high response rates.[26] Indeed, it was delivered electronically by mail or link, by face-to-face interviews, through telephonic interviews or by written mail. Furthermore, while in European countries and South Africa the survey was managed at national level, in Brazil, China and India, it was conducted at regional level.

The survey included a number of questions relating to the respondents' background, such as main product (goods or services), firm size, percentage of sales activity abroad and R&D activity. In addition, to extract information on firm behavior, questions on (i) source of technology, (ii) geographic networks and collaborations established, (iii) factors determining offshoring activities and (iv) policy-factors for the internationalization of innovative activities were designed.

In Table 1 we report the distribution of the sample across sectors, countries and firm size[27], as well as the response rate registered and the representativeness of each national sample within each sector group. The survey received 1214 responses from the 14620 companies contacted, which is a response rate of approximately 8.3%. China and Germany registered the lowest response rates of respectively 2.7% and 5.5%.[28] The combined INGINEUS sample results dominated by the ICT sector (77%). This is due to the size of the Indian and Chinese markets, which represent respectively 26.7% and 20% of the entire sample (and 34.7% and 26% of the sample ICT firms), but it could be also attributed to the nature of the agro processing and automotive industries which tend to be more concentrated.

Observing the number of R&D active firms over total national sample, there is concern with regard to the presence of a response bias in favour of firms that perform R&D, mostly within the group of Indian and Chinese ICT firms.[29] Nonetheless, as we are interested in looking at the determinants that make an innovative firm go global, such response bias should not affect our analysis.

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[25] INGINEUS is an international research project funded by the European Commission that studies global innovation networks. It involves 14 research institutes and universities in seven European countries plus Brazil, China, India and South Africa. For further information on INGINEUS project please see www.ingineus.eu.

[26] For instance, in both China and India, the survey was run mostly through face-to-face interviews or telephone interviews give the low electronic response rate experienced.

[27] Given the large number of small firms in the Swedish and Norwegian ICT databases, it was agreed that the minimum size of a firm for the survey would have been five employees, while no upper ceiling was defined.

[28] Low response rate in surveys conducted to assess international innovation by Chinese companies has been detected also in other studies. See: Chen J (2003), *Global Innovation*, Beijing: Economic Science Press.

[29] This could lead to affirm that the ICT sector in emerging economies is more R&D active than in Europe.

Table A.1: Response rates and total sample distribution by sector, country and R&D activity.

Sector/country	dataset	responses	response rate (%)	% over total sector obs.	R&D active firms	% of R&D active firms over national sample
China[30]	9119	243	2.7	26	181	74.5
Estonia	121	17	14	1.8	2	11.8
Norway	519	179	34.5	19.1	53	29.6
India[31]	1287	324	25.2	34.7	195	60.2
Sweden	1662	171	10.3	18.3	76	44.4
Total EU	2302	367	15.9	39.3	131	35.7
Total emerging economies	10407	567	5.4	60.7	376	66.3
Total ICT	12709	935	7.3	100	507	54.2
Denmark	210	49	23.3	37.1	5	10.2
Norway	2	2	/	1.5	0	/
South Africa	325	81	24.9	61.4	27	33.3
Total EU	212	51	24	38.6	5	9.8
Total emerging economies	325	81	24.9	61.4	27	33.3
Total Agro-processing	535	132	19.6	100	32	24.2
Brazil[32]	241	69	28.6	46.6	17	24.6
Germany	963	53	5.5	35.8	31	58.5
South Africa	2	2	/	1.4	0	/
Sweden	168	24	14.3	16.2	13	54.2
Total EU	1131	77	6.8	52	44	57.1
Total emerging economies	243	71	29.2	48	17	23.9
Total Automotive	1374	148	10.8	100	61	41.2
TOTAL EU	3645	495	13.6	-	180	36.4
TOTAL emerging economies	10975	719	6.6	-	420	58.4
TOTAL	14620	1214	8.3	-	600	

[30] The Chinese sample was extracted from two regional databases: (i) the *Beijing database* and (ii) the *Schenzhen database*. The questionnaire was distributed in the 5 most developed provinces in China: 146 questionnaires came from Beijing, which account for 60% of the total questionnaires; 51 came from Guangdong province, which account for 21%; 35 from Shanghai, 14%, 10 from the Zhejiang province, representing the 4%, and only 1 from Shandong province.

[31] The Indian sample was extracted from the *NASSCOM Directory of IT firms 2009-2010*, distributed across the main cities and regions as it follows: 281 in Bangalore, which account for 21,8% of NASSCOM Directory; 256 in Delhi/Noida/Gurgaon representing the 19,9%; 185 in Mumbai(14,4%); 72 in Pune (5,6%); 147 in Chennai (11,4%); 184 in Trivandrum (14,3%); 107 in Hyderabad (8,3%) and 55 in Kochi (4,3%).

32 The Brazilian sample was extracted from the Annual Registry of Social Information (RAIS), a registry of social and balance sheet information collected by the Brazilian Labour and Employment Ministry. The total number of firms classified in the automotive sector in Brazil is 2,625. Out of these, 233 companies are located in the state of Minas Gerais and, of these, 107 (46%) have employed, in 2008, 30 workers or more. From the dataset all automotive firms from the state of Minas Gerais were selected, provided the firm declared over 30 employees.

Appendix 2 – South-North foreign patenting

We consider all (and only) foreign-oriented patent families of NICs looking specifically at the destination of their foreign applications, restricting such observations to OECD patent offices.

As well-known, under the PCT, patent applicants may submit applications in multiple jurisdictions. This implies that a single application can, in theory, potentially lead to patent grants in 144 member states. For the purposes of the analysis of indicators of global patent activity by country of origin PCT applications may not be appropriate as they present duplicates.[33] However, this is not our objective. Our objective is to look at the determinants of demand for protection of emerging economies in high-income markets.

Patent activity of NIC in multiple OECD jurisdictions can provide a proxy indicator for technological transfer and may let us advance considerations concerning its impacts on competition (i.e. exports) and other economic effects, such as rent transfers to the jurisdictions of patent holders.

However, considering only the first applicant's country of origin in patent applications has some limits: our measure doesn't catch the participation of foreign inventors in the research process of a firm, that is, a German or Chinese engineering's contribution to an invention owned by an Indian firm is not taken into account. Our dependent variable PAT considers: (i) domestic firms set in NIC who seek protection in a foreign high-income market and (ii) foreign subsidiaries of an MNC set in NIC who seek protection in a market different from the one where they operate. Such foreign market could be the country where the HQ of the MNC is set as well as other third markets. For instance, if one of the TATA steel production plants in UK or Netherlands apply for patent protection on a new rail steel in any European country or in India, such patent applications are excluded from our observations. While, if the new TATA steel production plant set in South Africa would apply for patent protection in UK, this would be included in our observations as South African invention seeking protection in UK. Differently, if TATA consultancy services Ltd, set in Mumbai, applies for patent protection, for instance, on a new system for vehicle security able to monitor the cardiac activity of a driver,[34] and it applies first for patent protection in India, as it is generally done to save the priority date, and then through PCT procedure in UK, Germany, US, Japan and Korea, this application is considered as 'foreign-owned', namely Indian-owned, in each designated destination market, but the Indian one. Therefore, we focus on innovations (or potential innovations) developed in Southern countries that can meet the supply of Northern markets, including also innovations that both Northern and Southern MNC subsidiaries set in NICs develop not simply to adapt their products to the local markets, but that aim to meet the global demand of technology. Another limit of our dependent variable PAT is set in the possible presence of more than one applicant in a patent application that differ in terms of country of origin. That is, joint ownerships of patents between a firm set in an OECD country and a firm set in an NIC is not grasped. This may lead to an underestimation of international collaborations in science and technology as well as an underestimation of NIC contribution to the global market of technology if they are listed as second applicant.

[33] Over the years, the percentage of patent families covering at least two patent offices has increased considerably. Among the top countries, there is considerable variation in this share. For example, fewer than 7% of patent families created by residents of the Russian Federation (1.5%), China (3.4%) and Brazil (6.6%) contained at least two patent offices between 2003 and 2007. In contrast, more than half of all patent families created by residents of France (51.5%), Sweden (54.3%) and Switzerland (60.5%) include at least two offices (WIPO, 2010).

[34] International application number WO2111111056, date of publication 15-09-2011, priority date 12-03-2010.

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13 RESULTS FROM THE INGINEUS WORKSHOP ON POLICY FORESIGHT

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13.1 Introduction

INGINEUS has been an FP7 research project - INGINEUS being an acronym for *Impact of Networks, Globalisation and their Interaction with EU Strategies*. As one of the concluding steps of this project, a Foresight Exercise was held in Brighton, Sussex, U.K. on September 8th-9th 2011. This began with a presentation of the INGINEUS project, and a discussion of issues arising from it. The workshop then proceeded through a series of structured conversations in plenary and break-out groups, to examine policy implications arising from this work. This note summarises the major points of the workshop. The participants in the workshop are listed at the end of this report, which is of course based on their contributions. These were provided under Chatham House Rules" - so points of view are not attributable to individuals. All participants are thanked for their invariably valuable contributions.

As always, the rich discussion was extremely diverse, with ideas and conclusions expressed in many different ways according to the specific discourse that was underway. It has been necessary to impose some consistency in order to aid readability, and an effort has been made to formulate points in terms that reflect the gist of the argument. Any failure to capture the content or spirit of the workshop is the responsibility of the author of this report.

If there is one major conclusion from the workshop, it is almost certainly that INGINEUS has identified an extremely important topic, with practical implications for many stakeholders; just how the topic affects the broader innovation strategy for Europe is a matter of considerable debate. The need for further research is routinely identified in social and economic studies: in this case, however, the need is particularly strong, with many themes deserving sustained and systematic attention. INGINEUS was welcomed for providing good insights into a complex and rapidly changing topic; it is more than the first word on the subject, but it is far from being the last one.

13.2 INGINEUS: main results and issues arising

INGINEUS is concerned with Global Innovation Networks - GINs - and the opening discussion clarified the nature of GINs and explicated some major conclusions from the empirical research. Whether through firms that are 'born global', developing open innovation strategies through global networks more or less from their foundation, or through more established firms gradually transforming their approach from traditional in-house innovation activities towards open and network-based innovation processes, or through other patterns of evolution, the general assumption is that Global Innovation Networks (GINs) are becoming more important. The project has set out to establish how far it can get a handle on these networks, and then assess their scale and importance.

Helena Barnard and Susana Borrás kicked off the workshop with a pair of presentations that summarised the project methods, the concepts and definitions used, and the major results achieved. One definitional issue is that GINs are more than global production networks and supply chains. (They may well come into being through upgrading of the knowledge exchanges and innovation cooperation within such production networks, but this transformation cannot be assumed. Indeed, it seems still to be relatively rare.) The starting definition of GINs was that they are "globally organized network[s] of interconnected and integrated functions and operations by firms and non-firm organizations engaged in the development or diffusion of innovations" (Barnard). A view of globalisation as inexorably extending into more and more features of economic life would lead us to expect that firms will move on from exporting their products internationally, from producing their goods and services with operations and partners across the globe, to undertaking innovation globally, drawing on a rich network of partners (including as well as firms also such bodies as business schools, research institutes, and the like). But such a deepening of globalisation may not just be an extension of the activities of transnational corporations. As implied by the distinction between "born global" and multinational firms, there could be scope for new players to play leading and leadership roles in GINs. The extent to which this is happening is an empirical question – the scope for its emergence in the future takers us into the territory of Foresight.

As well as examining existing research, INGINEUS surveyed firms in 10 countries (6 in Europe, plus a set of important emerging economies - Brazil, China, India, and South Africa) The survey was intended to aimed at determining the extent to which innovation is taking place in GINs, and was designed to enable the comparison of either traditional low-tech (e.g. agro-processing), medium-tech (e.g. automobile), or high-tech sectors (e.g. ICT), in a more developed and an emerging economy. Few of the firms surveyed were participating in GINs, but then relatively few were actively innovation, networking, or operating on a global scale! Of the firms that were global and networking, about a quarter were actively engaged in GINs; more of the innovating firms were in GINs than were innovators who were networking for innovation, or operating at a global scale; though more innovative firms were doing none of these things.

The sectors differed – the automobile industry appeared to have a tiered hierarchy and limited networking, while GINs did exist in the IT industry and the agro-processing sector (note that this did not necessarily fit the low-tech image, however, since biotechnology firms producing enzymes by novel methods featured here). GINs do seem to be emerging from two quite different processes, as hinted above – (1) multinationals (mainly US-originating) improving their innovation capacity for a range of reasons, and (2) emerging economy firms (not always multinationals) accessing global knowledge to compensate for local shortages. Very small firms were not taking leadership roles - firms between 50 and 1000 employees were involved, presumably since they were large enough to need to access resources globally, but were small enough to manage that complex process.

GINs do exist, but certainly do not dominate the innovation landscape, let alone the international economy. Nevertheless, the existence of innovation-related networks with a global scale is of considerable potential significance to firms' strategies, their competitive positions, and to the countries and regions in which key actors are or are not located. The question also arises of how far innovation-related policies, and some of the foci of these policies (knowledge producing institutions, national and regional innovation systems, etc.) have a shaping influence on GINs and the outcome of their activities. Under what conditions, to what extent and in what ways, do innovation-related policies, institutions and systems enable or constrain the globalization of innovation?

European firms surveyed by INGINEUS were asked to indicate the extent to which a range of factors represented a challenge or barrier for them when developing a new good or a new service in collaboration with firms, universities or other organisations located abroad. Most of the firms did report barriers, though not generally of high intensity; the difficulties are not so strong as to deter European firms from engaging in GINs. The most prominent barrier is that of “managing globally dispersed projects and cultural differences”, followed closely by “changing the current locations of operations and the associated costs thereof”; “harmonizing tools, structures and processes” is third. Other factors like “Overcoming organizational barriers and gaining management acceptance”, “Finding relevant knowledge” and “harmonizing tools, structures and processes” are slightly less problematic. Thus the main problems emerge as the management of cultural dimensions in the process of collaboration, and the costs of changing location, are the most important challenges for European firms when operating in GINs. The results seem to be quite consistent here across different areas. The implication may be that policy-makers should pay more attention to the importance of supporting and improving the organizational and managerial skills within European firms for them to operate successfully in an increasingly internationalized innovation process.

The most important driver for European firms’ participation in GINs is access to human capital, followed by the rather similar issues of access to specialised know-how, and to knowledge infrastructures and services. Since the mid-1990s:there has been an overall increase of European firms’ off-shoring of R&D – mostly to the Triad countries but with an increasing role for BRICS, where India is the most important country of destination. Significant drops in R&D FDI have followed the economic crisis since 2007. There has also been an increase of inward R&D FDI in Europe. Large differences across industrial sectors are apparent.

The discussion that followed these presentations (which have only been summarised in scanty fashion above) took up many issues. There were some challenges to the data, with mention made of other studies (such as a DG Research examination of corporate R&D flows). There was considerable uncertainty about how best to conceptualise GINs, with much of the experience which participants could draw upon coming from cases which are not necessarily full GINs (e.g. examples of single bilateral linkages). Different definitions and data sources all seem to be yielding only fragments of a very complicated picture, with clear requirements for further empirical research into the topics opened up by INGINEUS. The point was also made that Foresight in this area will need to be aware of the possibility of trend breaks. For example, with the economic crisis in the West, China may emerge as an increasingly important player in GINs, and one that takes on quite new roles here. There are numerous different stakeholders to take into account, including not only the firms choosing to participate (or not) in GINs, but also firms in their value networks, regional and national policymakers, Higher Education Institutions (HEIs), and others.

What also became clear is that the phenomenon of GINs is so new – and quite possible so diverse – that it is rather unclear as to what costs and benefits they may offer different parties. While there may be win-win situations across countries and regions, this need not always be the case. In competitive environments, some firms are very likely to be winners and others losers. When this spurs efficiency improvement and better goods and services, in a context of growing employment opportunities, the concerns that this raises are liable to be relatively localised. But if we see the realisation of threats of migration of R&D and high-tech production out of some areas, then matters are more complicated. A participant from an emerging economy expressed concern that a new international division of labour might be emerging, in which lower value-added activities are widely dispersed but higher value added activities are substantially agglomerated (albeit in new ways, with MNCs are organising within networks to take advantage of locational factors); there are some experiences of firms effectively disconnecting their high-value activities from their countries of origin, or from other locations where they have historically had strong bases. There was some debate as to how far this might work in favour of countries and regions of different types.[146]

From an EU perspective, the rationale for supporting EU companies' involvement in GINs was seen as problematic by some discussants. Engagement in GINs is not an end in itself. Companies follow this strategy (or choose not to) for reasons of profitability and shareholder/manager value, rather than for some concept of the public good – though some companies are taking corporate social responsibility and sustainability to heart. Fears that European companies may be "too footloose" are every bit as strong as those that these companies are failing to involve themselves sufficiently in global activities. From a purely European perspective it is widely seen to be desirable for non-European firms to be attracted to make FDI into innovation activities within Europe, especially if they are networking with local firms (and of course with the research base in the public sector). The levers of action are a matter of debate; topics such as access to European Universities and laboratories, and some features of Intellectual Property rules, look to be ones where some impact on practices within GINs might be attained. This may not be an area of competition across European regions where we risk a "race to the bottom" – rather than concentrating on providing low-cost environments, the challenge may be to establish knowledge hubs (with good facilities, expertise, quality of life, etc.).

Some of the researchers' experience did suggest that involvement in GINs can be beneficial for innovation networks among firms within Europe. One set of results concerning the more technologically advanced parts of the agro-food sector in Denmark found that firms' networking overseas to access new knowledge and applications of that knowledge, was associated with strong mobilisation of Danish innovation networks. (The dynamics behind this were complex ones, with, for example, one company with global networks leaning on other local firms to build up their competences and capabilities to work with global partners to access cutting edge knowledge and markets. Such tightening of national innovation networks, prompted by GIN experiences, was not, however, the case in the lower tech segments of the sector.).

[146] It was also pointed out that the bulk of existing research focuses on MNC experiences, and it is important also to take into account the role of SMEs and other players. INGINEUS suggests that SMEs are currently mainly focused on intra-European networks, but this state of affairs may change with evolution of the global economy.

Among the uncertainties that were expressed in the discussion are the following:

- What sort of taxonomy of GINs and of GIN strategies across firms might be most useful for thinking about the implications of networking and the scope for, and possible impacts of, policy interventions? Are variations across early-stage research, more applied research and development, across projects aimed at different sorts of outcome (different technologies, complex products of varying scales, etc.) liable to be influential, and if so would policies (and strategies for all stakeholders) need to be tailored differently?
- A GIN of a particular type might have different implications depending upon how it is operated, not just on how it is constituted. Since it is likely that there are process and management considerations within GINs that also impact upon their outcomes for the stakeholders involved, to what extent can these be benchmarked and targeted for action?
- Are the benefits and impacts of GINs simply related in a linear fashion to degree of network involvement, as we typically assume, or could there be an inverted U-curve relationship, so that there can be too much, as well as too little, participation?

The policymaker perspective on these discussions could be summarised as "tread carefully". More understanding is needed before launching initiatives aimed at promoting or shaping one or other type of GIN. This is particularly important, as policy-making should address real identified problems. And those problems can only be defined on the basis of a good knowledge of the features of Global Innovation Networks.

13.3 Foresight exercise: trends and drivers of change

The Foresight activities proceeded through fairly traditional stages, first assessing different forces influencing change in GINs ("drivers") and then reviewing some major implications of these.

Some major trends and factors motivating participation in GINs had been presented in the opening sessions. The text that follows combines the points made in a series of break-out groups. Each of these was assigned two of the categories of the STEEPV (Social, Technological, Environmental, Economic, Political, Values) system, and asked to discuss and report back on the main drivers arising under these headings. Inevitably, these drivers are likely to influence each other in numerous ways. A wide range of drivers need to be taken into account by those concerned with the future evolution of GINs. Some are relatively stable features of the world economy, that are likely to persist and influence the evolution of GINs across any scenario we might care to consider. Some are much more uncertain, and could fruitfully form the basis for alternative scenarios in a fully-fledged exercise of multiple scenario analysis, should this be undertaken in later studies.

Key sets of drivers, then, included:

Technological and knowledge/skills factors

Information Technology is anticipated to continue to be increasingly widely available and powerful, although security risks and other vulnerabilities should not be neglected. ICT is a vital infrastructure supporting the operation of global innovation networks (GINs), and new approaches to its use (social media were mentioned) can be expected. Major innovation opportunities are opening up around a range of other technologies, and there are hopes for breakthroughs in developing solutions (or at least, the technological elements of solutions) for many of the major problems that confront the world. (“Grand Challenges”, in European terminology.) The increasing reliance on advanced technologies is underpinning a global trend to a knowledge-driven society, where many different disciplines and professions frequently need to be brought together in the course of innovation and diffusion of innovations.

A wide range of expertise and skills is required in knowledge-driven economies (though the picture is far too complicated to be summarised in terms of an upgrading of all work – if anything, there are signs that middle-range positions are being squeezed in the more advanced economies). There is great disparity in the quality of education and the skills available across regions of the world. Actors in GINs are influenced by perceptions of the quality of – for example - engineering graduates in emerging countries like India and China, where there are large numbers of young people emerging from training (even though they may constitute a small share of the overall workforce at present|). GINs are often forged in order to access high quality or highly specialised skills in regions of excellence, though firms also take the cost of access to skills into account. Decisions as to where to locate production may follow a different logic.

Economic factors

There was a strong emphasis on the economic **growth of BRICS (Brazil, Russia, India, China and South Africa)** during the exercise. It was widely believed that more BRICs would become players comparable to China on the world stage. Some other countries might also begin to enter the picture, though relatively few have the scale to make such an impact as these.

These new sources of economic dynamism were expected to become increasingly important **markets** for Europe, though tapping into them successfully is liable to be a highly competitive business. GINs could be an important part of this, and European firms should be aware, if they are not already, that technopoles (comparable to Silicon Valley, according to some speakers) are appearing in new places. Nevertheless, the current prospects are for a world of continuing large economic inequalities, both across and within major global regions. These economic disparities might serve as constraints on growth, through limited economic investment in times of crisis, or through domestic instability and international conflict.

Political factors were seen thus as liable to affect the development of BRICS, and also that of more industrialised regions. The economic integration of Europe is of course very contingent upon European politics. **European integration** was seen both as an influence on GINs, a factor to be considered, and as being in many respects an unfinished project. How far and under what conditions, engagement in GINs supports or even acts against such integration, and is itself facilitated by moves in this direction (which were generally felt to make Europe more attractive for FDI), remains unclear. Some nationalistic/protectionist sentiments in public life, however, might portray GINs as in some way being anti-European (integration). Similar sentiments, and political action based on them, might also be apparent ion regions like the USA, possibly part of wider obstacles to further opening of international trade.

Regional integration extends beyond the EU enlargement and integration, and could also be influencing the pattern of global innovation activities, the cross-cultural flow of knowledge and the development of global innovation hubs. Regional economic dynamics are complex, with relationships crossing countries, but not necessarily engaging all geographic territories of these countries.[147] Thus there are geographic regions within EU, or the Greater China region (some of the regions of mainland China, together with Hong Kong, Singapore, Malaysia and Taiwan), the Andean countries, and so on. Such regional communities may have close economic cooperation combined with advantages of shared cultures (and perhaps some disadvantages of these, too) The regional integration would mean greater growth opportunities for globally active MNCs in terms of new market opportunities, greater possibilities to combine the knowledge accessed from various regions, and greater collaboration on product development. In the context of regions, there are the). However, the Supra-regions are considered to be above the national policy framework and conditions. Hence the challenge here is that this would mean a need to look beyond the state. On the other hand, there are the specialised sub-regional clusters or other intra-national regions, which again challenges the state to balance the fierce competition for regional resources, skills etc, arising from conflicting regional parties within the country.

Environmental factors

While future environmental conditions are a highly contested topic, it was widely expected that we will see **Climate Change and Its Impacts** (whether anthropogenic or otherwise). This will certainly influence the attractiveness and in some cases the viability of specific locations, and quite possibly the economic performance of some major nations. The implications of GINs are ambiguous, and may be most prominent as the indirect influences that might follow the disruption of existing global production chains. "Climate refugees" might affect cross-border mobility of highly qualified labour – both by rendering some professionals more footloose, and by triggering efforts to establish new immigration controls on the part of regions experiencing surges of inward migration.

Possibly a more direct influence would be on the problems which innovation is required to address, with efforts to address various "insecurities" - water, food, energy security – and to achieve more sustainable modes of operation (use of renewable energy, overall reduction in energy and materials intensity, etc.). GINs might well be mobilised around new energy technologies, agro-biotechnology, new techniques for water purification, and the like. There

[147] The word "region" can apply to subnational regions, as well as to supranational ones. The point here is that often a country's economic dynamism is in reality largely accounted for by the performance of a few particularly active subnational territories – often city regions. While regional integration across countries may be reflected ion treaties and trade agreements, for example, there is often a de facto process of networking between subnational regions, for examples city-regions in different countries that border each other.

was also some emphasis on the resource **scarcities** that many commentators anticipate. GINs themselves would be expected to be more efficient in their use of resources, but the implications of this might be diverse across different types of network and innovation.

Political and values factors:

Numerous topics were raised here. We have already mentioned the role of **political instability** – which is not confined to emerging economies (the current case of Greece was mentioned) - and the prevalence of various forms of corruption was also noted as a source of resentment and a factor influencing GINs membership and behaviour. There are often great differences in **enforcement of institutional norms** between the developed world and the developing world. While not wishing to claim that everything in the developed nations is perfect – far from it, constant vigilance is shown to be necessary, not least by the current economic crisis – they do tend to feature greater political will to ensure that the rules and regulations are adequately and transparently enforced. In the GIN context, it is suggested that robust intellectual property rights (IPR) regimes and effective implementation of the corresponding rules has been a significant factor in attracting R&D FDI in Europe and the US. In contrast, it is suggested that multinational companies (MNCs) are reluctant to undertake some R&D and innovation activities in certain developing countries due to the risks arising from weaker IPR enforcement there.

A topic that relates to regulations, but also has a strong linkage to more general issues of values, is **the establishment of technical standards** – which was considered to be a major attractor for inward FDI, networking, and R&D location, and indeed as a driver of networking more generally, not least in relation to collaboration to define technical standards. In the advanced countries higher standards prevail. Most governments have defined a set of mandatory technical standards in areas of consumer protection, human health and safety, as well as environmental protection. Relevant regulations are stronger and strictly enforced. In general there is a greater demand for the development and in the implementation of mandatory, quasi-mandatory or voluntary technical standards etc. Those institutions and companies that take a leading role in developing new technology and industry standards can gain advantages. Globally accepted technical standards offer tremendous market potential and opportunities for revenue generation, so greater innovation activities are instituted to establish and meet those technical standards.

We have also already noted the topic of **Attitudes to, and Policies concerning, Migration** – which received a good deal of attention. This can influence GINs through affecting firms' domestic innovation activities (in Europe or elsewhere) and their strategic decisions on where to locate and network with R&D and innovation activities. Stringent migration policies can already make it difficult to employ the knowledge workers needed for highly specialised functions, leading to offshoring (including offshore outsourcing) to different regions in search of new skills. The group heard personal testimony of how researchers from outside the EU faces barriers to working in the EU – requirements for visas and the like can seriously affect networking, limiting mobility other than simply attending meetings. The issue of regional specialisation will be mentioned in the next section, but in the present context, it was noted that different types of knowledge worker may be required in different regions, so migration policy would do well to take account of these diverse requirements.

Finally, there was much discussion around the thorny question of the role of cultural factors such as attitudes to risk taking and entrepreneurship, interest of young people in STI and related educational opportunities, and to national/local identity (influencing who one wants to work with and for, as well as what products one wishes to acquire). A great many such factors are ones that are evidently highly important, but in ways that are often poorly understood, and that are ones where "social engineering" can be highly problematic.

13.4 Normative views: success in a world of Global Innovation Networks (GINs)

Having reviewed the various forces shaping the development of GINs in the first afternoon of the workshop, in the following morning a session was organised to discuss: what would be the elements constituting a successful future for Europe in the GIN context? We considered the period up to 2020 as the horizon which should be considered. Again, a mixture of brainstorming and group discussion was used to explore various features of success, and to choose those that appeared most important to consider further. The focus was "features of success", though in practice the discussion sometimes slipped into the related, but distinct one, of "success factors". The point was underscored that we should not be viewing GINs as good or as bad things – they are a phenomenon in the modern world, and the question is one of how to most effectively live with them. There are many uncertainties – in this discussion, for instance, the question of whether and when it is better to join in with existing GINs or seek to build new ones was posed, but few answers were forthcoming! Likewise, reference was made to work by Dieter Ernst as suggesting that US companies are more engaged in GINs than European ones, and are making more productive use of them – but how far and in what ways this is accurate, and what the implications are for practice of European firms and other stakeholders, remains unclear.

Many possible aspects of success were considered, with the ultimate criteria very much being seen in terms of a continuation of the Lisbon agenda – Europe as a sustainable knowledge-driven society, generating more and better employment and a higher quality of life with stronger social cohesion and inclusion. Thus we would see the achievement of targets for reduction in Greenhouse Gases, alongside the creation of full and meaningful employment, as indicative of a successful EU. (Phrases such as "bio-based", "post-carbon", "closed loop", "industrial ecosystem" were used to describe this. Just what GINs mean for this is still not altogether clear, but several critical aspects were highlighted.

First, GINs should be used as far as possible to enhance **Cohesion across Europe**, with Europe taking advantage of its diverse industrial and cultural landscape. This would mean developing many thriving industrial clusters and having more distributed science, technology and innovation activities within Europe. Much discussion concerned the extent to which leadership and excellence involved concentration of efforts in relatively few centres, or whether a more networked environment would permit great dispersion of (coordinated) activities across many locations. The challenge was seen to be that of balancing two things. On the one hand, success means avoiding a fragmented Europe in which regions and member states compete fiercely and effectively undermine each other's performance. On the other hand is the promotion of centres of excellence, and taking on board the point that it is impractical for every locality to aim to be at the forefront of every line of innovation – some regional specialisation is inevitable. There are many spheres of productive activity in which regions may excel – the generic technologies that are evolving so rapidly have a vast range of potential applications, and thus the range of things in which regions can specialise are also immense. Thus, instead of a "race to the bottom" approach, we could see a rising up across numerous innovation frontiers. This is not something that can be imposed by some centralised planning committee, of course - but awareness of social cohesion as an element of European success in world of GINs appears to be rather fundamental.

Each of the three break-out groups in this session actually specified some elements of cohesion as important for European success – both as inputs to success, and as desirable outcomes. Given the current crises around the euro, it was not even to be taken for granted that the European Union will survive as an entity, desirable though this was generally felt to be. Participation in cross-European networks was seen as favouring cohesion of this sort. How far participation in GINs could do so is ambiguous, though if this can boost sustainable growth, such participation would be positive. Related issues that were raised included aiming for further reductions in digital divides across Europe, with GINs being yet another argument for improving information infrastructures in general.

The general aspiration was for Europe to be displaying and maintaining STI leadership across many areas of innovation – perhaps especially those which can help ensure security in terms of energy, food, water and the like. This was seen as a matter of leveraging the diverse regional strengths – cultural as well as economic and scientific - and fostering innovation in both technology and business models. It would enable firms to gain and maintain competitiveness in global markets. Europe would be a hub for excellence in applied as well as fundamental science, and operating in a sustainable and efficient way. (As the term "efficiency" implies, innovation would be exercised in public services, as well as in globally competitive firms and networks of firms; public service innovation might also serve as the basis for expert activities and GINs, and is liable to be involved in the sustainability agenda.) One indicator of success would be a substantial European role in establishing new global standards.

13.5 Implications for action

Finally, with the various features of a successful future specified as discussed above, the discussion turned to the actions that might help achieve progress toward this vision. The discussion concerned a range of actors, since it was clear that national and EU policy makers are only part of the equation, and numerous stakeholders will need to play their roles in the evolving system. Policy settings can encourage and facilitate action, but firms of all types, higher education institutes (HEIs) and research organisations, civil society actors, all have vital roles.

13.5.1 Policymakers

There seem to be two particularly important types of action for policymakers at EU, national and local levels. First is creating an attractive setting for GIN partners. This means creating the skills and expertise, the STI infrastructure and institutions, and the quality of life conditions that are attractive to inward investors in R&D and innovation activities, and to potential partners in GINs. This could be “the next step in cluster policy”. Second is helping to empower local stakeholders to articulate on beneficial terms with GINS, hopefully in leadership roles but in other types of roles where this is a reasonable option. This can involve awareness raising and providing knowledge, skills, and access to various support resources. Both of these lines of policy activity can and should be infused with the broader policy goals that are being pursued, since there is not yet any clear consensus on how far and when GIN engagement is beneficial for EU innovation systems.

It will be apparent that a third line of policy action is not outlined above. This is the rather classical approach of actively seeking to build networks, providing funding for participation in them of at least the academic/research participants, and the like. There were several reasons for caution here, including:

- There is still considerable uncertainty about:
  - The distribution of costs and benefits of GINs (more precisely, of different types of, and different types of participation in GINs),
  - The policy levers that might be most effective here, and how far existing policy tools (like incubators, public procurement, IPR rules, support for academic-industry links[148]) can be "tuned" to take advantage of GIN potentials
  - The impacts that policy actions might have on more spontaneous initiatives. (That said, it is likely that some policy actors will respond to GIN developments with tactics of their own, and these should be carefully assessed.)
- There were very mixed feelings about the ways in which support for research networks have proceeded in the past through EU institutions, with much criticism from some participants of the past experience with Networks of Excellence under the Framework Programme. The experiences with that particular instrument, whose terms of reference were modified dramatically in a nontransparent process, was not seen as boding well for top-down efforts to establish a framework for GINs. While that instrument did in principle encourage bottom-up identification of areas for collaboration, the case was that a much more bottom-up steerage was required, working with existing and nascent centres of excellence across Europe.
- Policy intervention might be better aimed at encouraging entrepreneurship and start-ups, and building innovation capacities and networks at local and European levels; strengthening European networks continues to be a worthy goal, with such networks allowing for participation in GINs on better terms, and hopefully enabling better local capture of the value created through GINs.

Thus the main issue was seen as empowering European stakeholders to themselves take decisions about GIN participation. This might involve some financial support – e.g. tax breaks for SMEs that are undertaking such activities. There might also be need to consider how migration and other regulations might need to be “tweaked” to allow for the access to

[148] One idea proposed in this context was that of tax breaks on the line of R&D tax breaks, or credits similar to innovation credits, for firms collaborating with HEIs and RTOs.

knowledge that is required. There might be awareness-raising and similar forms of gentle encouragement, as mentioned above.

Despite the reservations about policy action to promote GINs, the point was made that public bodies have a vital role to play in promoting innovation that can help us deal better with Grand Challenges. Here the ways in which fruitful collaboration can be fostered should be examined carefully.

Finally, there was a case for examining the ways in which some of the more problematic features of GINs might be regulated. Global production networks have often been criticised for allowing offshoring of polluting activities to more tolerant countries, creating local and in some cases more general environmental impacts; and for supporting poor working conditions in developing countries. GINs might be thought to be less prone to such problems, but among the possibilities mentioned were – GINS that might be actively aimed at undertaking risky geoengineering projects whose governance should not just be a matter of an innovation consortium; GINs that involve dubiously ethical procedures by way of trials of drugs and other medical (and reproductive) interventions in countries with limited control over such trials; GINs that involve working with toxic chemicals and other hazards (e.g. some types of GMO, some nano-artefacts). GINs are like any other human activity, with risks as well as opportunities, and policymakers are beholden to consider the wider risks – even if they should attempt to do so in ways that which not stifle opportunities. There are policies – and also initiatives from the private sector around Corporate Social Responsibility and sustainability – that already bear on the more familiar risks (environmental degradation, health and safety at work), and the task is to examine how these might need to be extended in the GIN context.

It is also necessary to examine the contribution of other key stakeholders – firms and HEIs/RTOs. Highlights of the discussion are outlined below. Policymakers are encouraged to consider whether and how they may support the actions mentioned.

13.5.2 Firms

Firms are critical players in practically all innovation processes, and in global innovation networks (GINs). They are active partners, and hence a (not unbiased) source of intelligence about the evolving ecology of GINs. For that reason, firms might be encouraged to share their experience in open and transparent ways. GINs pose new challenges to innovation management. In particular, they are a challenge regarding the skills and capabilities required to decode whether or not to participate in them (and how), and to make the most out of them. For that reason, firms of all types might be forced to identify and nurture these skills, as well as to engage in proactive recruitment and training strategies. This may be particularly difficult for small and medium-sized enterprises (SMEs), and larger firms may play a role, together with higher education institutions (HEIs), in sharing knowledge of good practice and learning opportunities.

In particular, it was seen as important for firms to learn to engage in sustainable GINs, where the risks of network collapse as a result of one partner pulling out, or as a result of one partner sucking out the key knowledge, are minimised.

GINs are underpinned by modern information and communication systems, and there have been a variety of significant developments in recent years in terms of providing tools for design, project management, knowledge management, collaboration, crowdsourcing, decision making, and the like. There are many players active in developing such tools, many of them private sector firms in their own right. Having access to the tools, and capabilities to use them, is important for the main players in GINS.[149] More generally, there are tangible assets – laboratories and other physical facilities – and less tangible ones – access to local market and labour market knowledge, capacity to undertake effective risk management, etc. – that are requires in the GIN context. These are things that larger firms may be able to establish single-handedly, but often they will benefit from collaboration between firms, HEIs and public authorities in specific localities.

13.5.3 Higher Educational Institutions (HEI) & Research, Technology Organisations (RTO)

There were many ideas about the roles of these stakeholders, and while some of this may have reflected the fact that many of the workshop participants came from this sector, it also derives from the important role of these institutions in the knowledge-driven economy. To some extent these bodies have been seizing opportunities associated with the globalisation of innovation, but it was felt that there was much more that could be done. As noted at the outset, more research, leading to a better understanding of the GIN phenomena, is essential – HEIs are places where such research can be conducted, and their own strategy should benefit from the results that are forthcoming.

In general, the message with regard to HEIs and RTOs is similar to that developed for firms and industrial clusters. This is that enhancing Europe's innovation strengths in general will provide a better base for decisions about participation in GIUNs, and for capturing the benefits of such participation. Universities have their role to play, for example, in ensuring that innovation matters are properly incorporated into the curriculum, and in supporting training in innovation management and the like, as well as in encouraging academic entrepreneurship and enhanced academic-industry links.

By engaging in the delivery of **new academic courses on GIN management**, for students at several levels, from both within and outside Europe, HEIs could gain funds, maintain relevance, and play an important role in facilitating and mobilising networks. The courses could address such problems as the challenges in managing IP, human resources, and cross-cultural and cross-disciplinary teams. Executive education, MBAs, and research degrees are all possible here, often in collaboration with overseas HEIs, corporate sponsors, and alumni networks. Cross-cultural management was repeatedly identified as an important capacity to build – one where Europe may be able to draw on the strengths of its population with origins in other world regions.

Taking part in GINs: HEIs and RTOs can often have roles to play as bases for research in GINs, as well as in some instances playing "honest broker"/neutral roles where there may be competing interests across industrial partners. Universities often act as intermediaries or

[149] Though it was stressed that there are big issues – e.g. different time zones and cultures – that cannot simply be resolved by applying new technology!

agents by creating a platform to bring together various parties with complimentary ideas and to enable strong linkages between interested organisations for sharing scarce resources and knowledge. GINS could be used proactively by European HEIs and RTOs to help them better commercialise the results of their research – development activities may be facilitated through international linkages, which can also help establish new markets for knowledge, for knowledge generation and reproduction (teaching) activities, and for the products that result from this knowledge. This may require investment into physical and virtual facilities to facilitate technical collaborations and associated social and educational interactions; some of this investment may stem from FDI or other industrial funding. At least some regions in Europe should be able to enhance their attractiveness for foreign MNCs' R&D activities, and to become indispensable hubs in the GINs. HEIs and RTOs can also seek to achieve specific goals through GINs. For example, they may support the entry of SMEs in their own regions into the networks (through training, incubators, introductions, joint projects); their role as intermediaries can be substantial…. Or again, they may work to strengthen indigenous capacities in BRICS and elsewhere (through collaboration with HEIs and RTOs in these regions, through sharing best practices in the industry such as efficient and transparent research contracts, clinical trials, IP licensing, development of standards, etc).

HEIs are important venues for the development of interpersonal links and social contacts, and this role should be encouraged. Such linkages often form the underpinning of subsequent economic and scientific collaboration. In this light, the high fees charged by many European HEIs may be acting against some of the GIN potentials that exist here. Administrators and strategists in the sector should take this into account. Creating opportunities for exchange, and for students to travel outside the EU will be important – as will efforts to ensure that such activities actually build networks in which the European institutions participate.

13.6 Final comments

The world of global innovation networks (GINs) is complex, with different participants, in different locations, experiencing very different demands and outcomes from engagement in these networks. It is evolving rapidly, and the long-term impacts of the current economic crisis remain to be seen. While individuals that have been involved in specific activities may have richly detailed knowledge of the dynamics of the particular cases, there is much uncertainty about the broader contours of the topic. Rather than reiterate the call for more research into this phenomenon, at this point we prefer to stress another issue that was a steady undercurrent in the workshop.

This is that while we are unclear about many aspects of the costs and benefits, the risks and opportunities, associated with GINs, there is much scope for mutual learning. Policymakers and stakeholders of all kinds need to look for, and build, occasions when experiences can be shared, where different attitudes can be expressed and confronted with the lessons acquired by those who have participated in such networking. In this way, those who may be able to join in with, and contribute to the framework conditions for, GINs can make better informed choices. Indeed, such occasions may themselves be seen as a form of networking that can underpin Europe's fruitful embedding into GINs. In this light, it is important to include more than the usual suspects – the MNCs who are already most active (and most studied) - and take account of linkages that are forming among SMEs, Universities, and other such players.

This workshop could be seen as a small-scale version of such an event, and one weighted more toward the research community than to that of other practitioners. The liveliness of the contributions demonstrated the salience and topicality of the theme; the openness of the contributors demonstrated the eagerness to learn more about it. These are good omens for future building and sharing of knowledge.

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14 CONCLUSIONS AND POLICY IMPLICATIONS

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14.1 INTRODUCTION

The previous chapters of this comprehensive report have presented the most significant findings and evidence collected over the course of the INGINEUS research project. The objective of this research project was to determine the extent to which European firms are involved in global innovation networks (GINs), and consider the effects of this in a wider sense. Many European firms, particularly large multinationals, have engaged with and created GINs. However, the extent to which the existing anecdotal evidence is widespread praxis is still unclear. With this purpose in mind, the main research questions of INGINEUS were: What are global innovation networks and why are they created?; How are European firms generally performing in terms of creating and participating in these global networks?; Is Europe an important node within those networks in terms of knowledge competences and knowledge sources?; and What can European policy makers do in terms of reaping the benefits and reducing the potential costs and risks associated with the current trends towards global innovation networks?

The methodological framework of INGINEUS was based on the collection of three different but interrelated sets of data. The first data set comprises descriptive statistics from different sources, with a special focus on R&D outward and inward investments to and from Europe. Second is a set of qualitative data derived from original case studies based on in-depth desktop analysis combined with interviews with the relevant firms. Finally, the third data set is quantitative data collected through a specifically designed survey that investigates the patterns of GINs. The methodological considerations regarding the overall INGINEUS data can be found in chapters 2 (Borrás and Lorentzen 2011) and 3 (Barnard and Chaminade 2011) of this comprehensive research report, and in other relevant deliverables of the INGINEUS project.

This concluding chapter focuses on the policy implications for European and emerging market policy-makers that might be suggested on the basis of the findings of the INGINEUS project. In order to address this, and make sense of the large amount of findings from INGINEUS project, this chapter takes the following three steps.

Firstly, the general policy implications related to the gradual emerging phenomenon of GINs are addressed. These general policy implications were identified in the course of the foresight exercise organized in the last months of the INGINEUS project, in which top civil servants, policy-makers and stakeholders from European governments, emerging economies and the European Commission participated.

Secondly, this chapter looks specifically at the European policy implications (both for the EU and national governments), drawing from the INGINEUS survey's findings on European firms' perceptions about the challenges and barriers they encounter when engaging in GINs. The INGINEUS survey findings offer a unique insight into European firms' explicit and direct views on this matter. This data is of paramount importance when thinking about policy implications specifically geared to ease the problems for European firms that engage in GINs.

Thirdly, this chapter examines the policy implications for emerging economies, as the policy-related issues are related to competence building and development in a different way than in Europe. The findings of INGINEUS on how GINs affect innovation and economic dynamics in those countries provide the building blocks of this specific part of the chapter.

Finally, the concluding section will summarize the results of this chapter and offer some general remarks that will put all this into a broader perspective, namely the challenges of globalization and the deep financial and economic crisis in Europe.

Hence, this chapter addresses the following:

- General policy implications regarding GINs
- Policy implications for Europe
- Policy implications for emerging economies

14.2 GENERAL POLICY IMPLICATIONS

What are the general policy implications of the INGINEUS project? The foresight exercise organized by the INGINEUS project in September 2011, near the end of the INGINEUS project's lifespan, brought together key policy-makers and academic experts from the EU and national levels in a two day session. The participants of the foresight exercise discussed the findings of INGINEUS, paying particular attention to the policy implications in a future context. The participants took part in a series of sessions in which they brainstormed on a series of policy implications. These brainstorming sessions left a large number of (not always entirely coherent) lines of possible policy action. This material has been further elaborated within the work package 10 of the INGINEUS project, in terms of identifying the general guidelines for policy recommendations that are most suitable from a careful interpretation of the evidence provided by the project. In other words, not all the ideas that came out of the foresight exercise have been slavishly taken into consideration, as some of them were open-ended ideas and some contradicted other ideas. Hence, the INGINEUS team made an effort to systematize and organize those suggestions, and in so doing, gave priority to policy recommendations that are both consistent with the findings of our research and are coherent with each other. With this purpose in mind, the objective of this chapter is to provide a useful set of policy recommendations. On this basis, we formulated the following six general policy implications.

Firstly, the evidence of INGINEUS shows that GINs are still not a widespread phenomenon, but rather an emerging one. As demonstrated by the evidence in this comprehensive report, particularly in chapter 3 (Barnard and Chaminade 2011), the actual share of firms in our survey with high levels of globalness, innovativeness and networkedness is, in fact, quite small. This means that there are few global innovation networks of high intensity. In contrast, there seem to be many global innovation networks of low-medium intensity. In fact, around 50% of our respondent firms indicate some degree of these three variables (‘globalness’ ‘networkness’ ‘innovativeness’). This implies that there is a cautious implication for policy-makers, namely that so far there seems to be little reason to create policy interventions that directly address GINs. The trends towards GINs are still in an emerging stage; their limited nature means that there are no identifiable problems that require direct policy action. Hence, it calls for policy-makers to be extremely careful and avoid engaging in public action directed toward GINs in the absence of real problems. To quote the popular saying: “if it ain’t broke, don’t fix it”. Time will reveal whether the trends we have found, in terms of gradual emergence of GINs, become consolidated and expanded. In that future situation, direct policy intervention towards GINs might be relevant if concrete problems are identified. Therefore, since GINs are still a limited phenomenon, policy-makers might consider policy actions of a more indirect nature, creating policy actions that address the more general context in which GINs operate, as opposed to policy actions that are explicitly directed towards GINs themselves.

The second general policy implication of the INGINEUS findings is that any policy action that addresses issues towards firms’ GINs must take into consideration the knowledge base upon which GINs are based. As the previous chapters of this comprehensive research report have shown, the dynamics and reach of GINs based on ‘home-augmenting’ knowledge are different from those GINs based on ‘home-exploiting’ knowledge (Kuemmerle 1999). ‘Home-augmenting’ knowledge refers largely to knowledge of analytical nature (Asheim, Ebersberger et al. 2010) which is more on the “R” side of the R&D acronym; it is cutting-edge new knowledge. By contrast ‘home-exploiting’ knowledge is synthetic in the sense that combines existing knowledge in new ways, and hence is more on the “D” of development side, exploiting existing knowledge to develop new products or processes that fit into specific needs. The findings of INGINEUS (chapter 6 of this report) indicate that innovation networks based on home-augmenting knowledge tend to be more globalized and have a more positive impact on the national system than those based on home-exploiting knowledge (Borrás and Haakonsson 2011). From a policy action perspective this is an important aspect to take into consideration in any measure affecting the conditions in which GINs operate, as policy-makers need to understand the specific dynamics of these networks.

Thirdly, and related to the above, the INGINEUS findings tend to underline the importance of continuous support of the knowledge base and capacity-building at national level. Extensive research prior to the INGINEUS project showed that the stronger the knowledge base of a firm is, the greater its chance of innovative success and tapping successfully into other external sources of knowledge (Laursen and Salter 2006). This feeds into the findings of the INGINEUS project, which indicate that European firms’ and universities’ participation in GINs is largely associated with the pre-existing knowledge capacities of these firms and universities. In other words, the increasing globalization of innovation, and the gradual emergence of GINs, requires a continuous effort on the part of policy-makers to maintain and build knowledge capabilities in their firms and universities.

Fourthly, the role of small and medium enterprises (SMEs) in GINs might merit some attention from policy-makers. SMEs are typically more locally and regionally anchored than large firms. For this reason, SMEs can work as an important linchpin between the emerging GINs and the local dimension of innovation. GINs can also be seen as a second stage of innovation networks’ historical evolution: they are first anchored regionally/across Europe, and in a later stage they become engaged globally. Policy-makers must be aware of the context in which SMEs are embedded, and facilitate the way in which SMEs could play a more active role in linking local-regional innovation networks to global networks. More precisely, this might require policy-makers in Europe to encourage the entrepreneurship of so-called 'born global' small firms', namely SMEs that are globally oriented from their very origin, through incubators and other local-based /university-based relations.

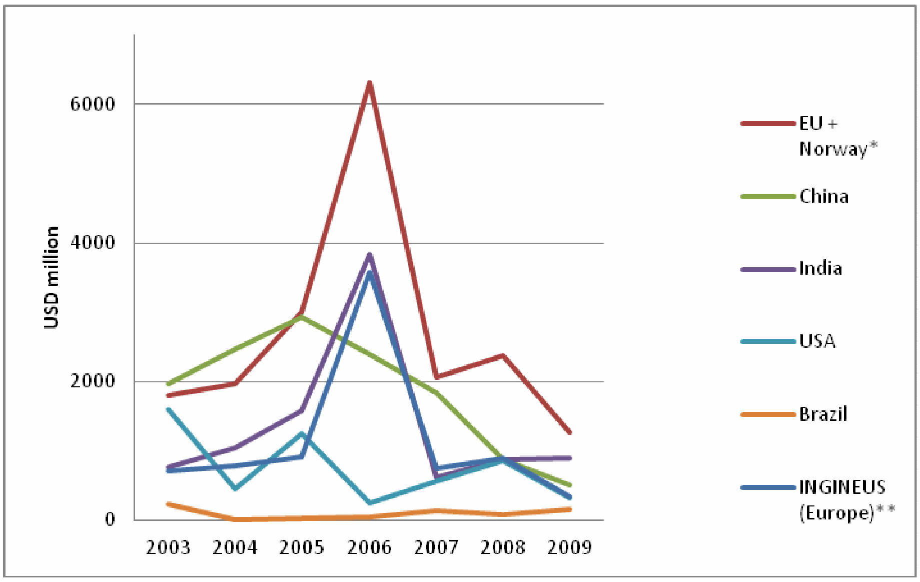
Fifthly, many national and regional governments across Europe have defined internationalization strategies of their research and innovation activities. Quite often those strategies put emphasis on attracting inward research-oriented foreign direct investment (FDI), and on improving the knowledge aspects of export products for expanding into new foreign markets. These are obviously very valid goals from a national point of view. The findings of the INGINEUS project tell us that the network-based interactions in innovation are becoming increasingly globalized, and that internationalization or globalization is occurring through bi-directional dynamics (inward and outward dynamics from the national system). This might require policy-makers in Europe (local, national and EU levels) to re-examine the internationalization strategies of their research and innovation policies, in order to bring in this 'network' approach which takes into consideration the mutual benefits of cross-national and global network interactions.

Last but not least, the case studies of the INGINEUS project in the industrial sectors of automotive, ICT and agro-food, tend to show that the management of GINs is not easy or without problems. European policy-makers must consider the possibility of supporting the development of management techniques in European firms for a better management of complex innovation networks, particularly GINs. This might include increasing the supply of international business management courses and improving the cultural dimensions in business education. Likewise, support for the development of ICT platforms for online meetings or managerial aspects of geographically distributed innovative activities might also need some policy attention.

14.3 SPECIFIC POLICY IMPLICATIONS FOR EUROPE: OVERCOMING INSTITUTIONAL BARRIERS

During the past decade, Europe has become an interesting destination for R&D-based FDI. The figure below compares the amount of inward R&D FDI in Europe and in the major emerging economies in the world. Overall, figure 1 indicates an important trend towards the globalization of science, technology and innovation (STI), particularly previous to the financial and economic crises of 2008. The figure also tells us that the EU continues to be an attractive location for R&D FDI.

Figure 1: FDI in R&D by destination country, capital investment



(Borrás and Haakonsson 2010)

Source: Financial Times FDI intelligence 2009

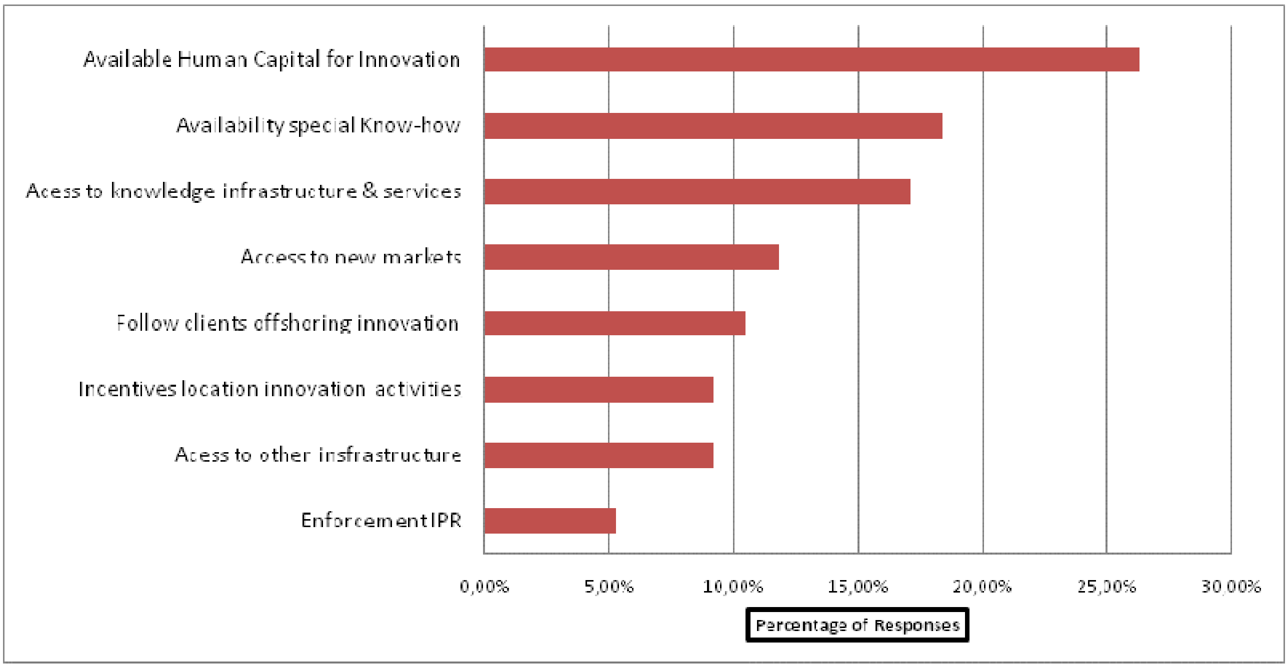
* EU + Norway data is the aggregated incoming investments from all countries, including intra-EU investments. According to the OECD intra-European investments account for approximately between 95-98% of total (OECD 2010).

** INGINEUS countries in Europe: Denmark, Norway, Sweden, Estonia, UK, Italy and Germany. Aggregated data, see above.

The other aspect of relevance here is the outward side of these dynamics. Therefore, it is important to analyse the reasons why European firms take part in GINs. This is still largely unknown in the literature; what are the driving factors behind firms' engagement in GINs?

The INGINEUS survey put this question to almost 500 European firms: "*Which regional factors in the host region/ regions to which you moved were important in your company's decision to offshore production and/or R&D and innovation activities?*" As figure 2 shows, most firms indicated the reason of '*Availability of human capital for innovation*', and to a lesser extent '*Availability of special know-how*' and '*Access to knowledge infrastructure & services*'. It is important to note that these three factors share an important 'knowledge' element. Therefore, our findings point to the fact that 'knowledge capabilities' are factors with relatively higher importance for firms rather than strictly market-related factors (like '*Access to new markets*' or follow clients' off-shoring) (Borrás and Haakonsson 2010).

Figure 2: European firms' reasons for taking part in GINs.



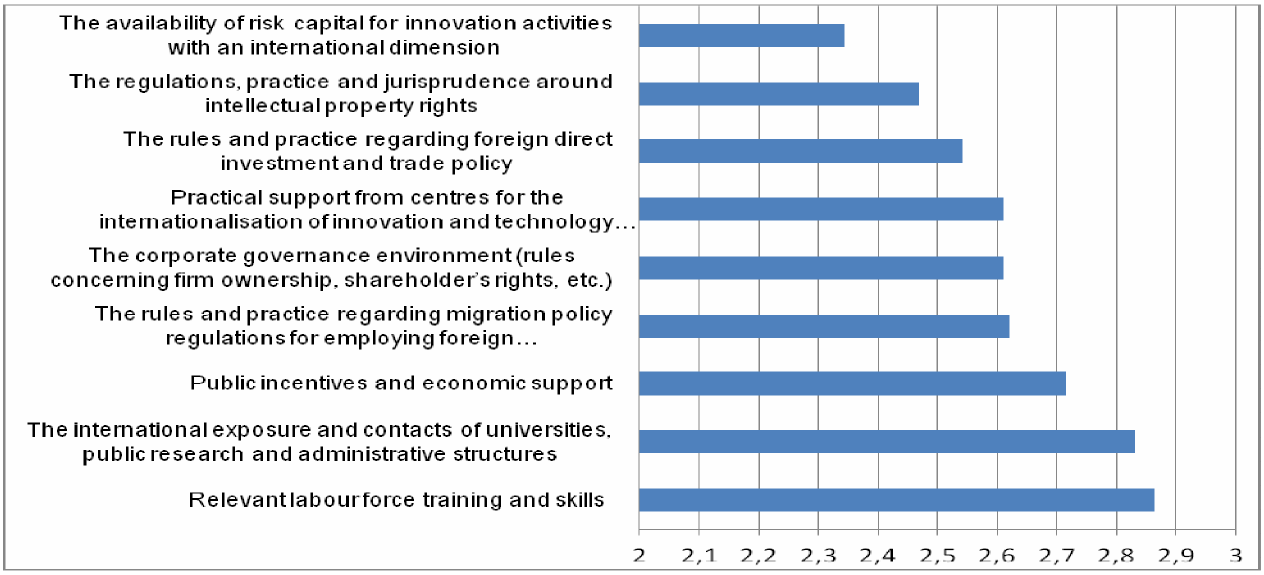
(Borrás and Haakonsson 2010)

Source: INGINEUS survey, N=76

These findings seem to confirm the widespread assumption that the main driver for globalization of R&D activities and innovation is largely associated with the access to appropriate and advanced forms of knowledge production. Tapping into complementary knowledge sources in the form of human resources, infrastructure or services that are outside the national boundaries seem to be a major reason. These are interesting results, but more information about why and how this happens is needed. According to aggregated data, much of this phenomenon happens within the same firm (multinationals intra-firm cross-border R&D investments) or within pre-existing linkages with 'foreign affiliates' (foreign companies whose administration is under control of the R&D investing firm) (OECD 2008). Combining our survey results with these aggregated data would suggest that what we are witnessing is a process not only of tapping existing knowledge resources in a decentralized way within pre-existing networks, but also that there is a genuine decentralized creation of new knowledge largely embedded in specific local contexts (Chaminade and Vang 2008). Locational factors seem to be visible in aggregated terms as well, as patent data show a high degree of intra-country concentration in a few sub-national regions that are internationalized, measured by the number of patents with co-inventors located abroad (OECD 2009). Another important finding is that proximity to clients and markets is an important reason to engage in GINs, though less so than is access to knowledge. This finding has been confirmed by qualitative case studies in the INGINEUS project.

When asked about their own experiences during the past three years regarding the policy-related factors in the internationalization of their innovation activities, our sample of European firms were generally positive. In figure 3, most of the factors score above the 2.5 threshold on a scale from 1 to 4. This means that European firms have a medium level positive view on the policy-related factors in relation to their internationalization of innovation. In particular, the three factors that were most positive for firms' internationalization of innovation activities are: 1) the availability of relevant labour force training and skills; 2) the international exposure and contacts of universities, public research and administrative structure; and 3) the availability of public incentives and economic support. It is interesting to note that the international exposure of research institutions like universities plays an important positive role (indicated in chapter 1 of this report) (Borrás and Lorentzen 2011). This might suggest that, in many circumstances, there is a positive relation between the local networks of innovators and the internationalization of firms' innovative activities. These findings seem to indicate that the impact of GINs in European innovation systems is more positive than hitherto assumed, contravening unsustained political concerns about the 'hollowing out' of innovation systems in Europe. In fact, these survey findings seem to support the hypothesis that GINs might have a mutual 'mobilization effect' of local and national networks in terms of knowledge sources and national networks' own internationalization (Borrás and Haakonsson 2011).

Figure 3: Policy-related factors in the internationalization of innovation activities *during the past 3 years* (European firms)



(Borrás and Haakonsson 2011)

Source: INGINEUS survey

Legend: Average responses of the following scale: 1= highly negative factor; 4= highly positive factor; N=495. All respondents are European companies.

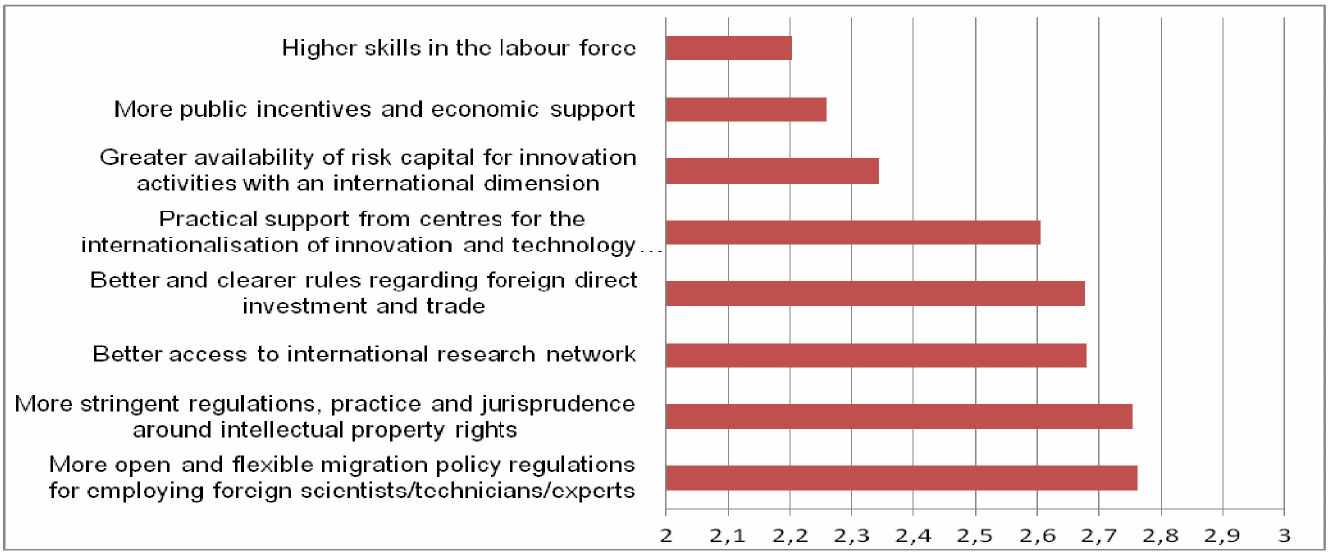
In contrast, the three factors that have been most negative are: 1) the availability of risk capital for innovation activities with an international dimension; 2) the regulations, practice and jurisprudence around intellectual property rights; and 3) the rules and practice regarding FDI and trade policy.

It is not at all surprising that our respondents point to the limited availability of risk capital during recent years. Apart from the current problems associated with the economic and financial crisis, Europe suffers from a more structural problem due to the relative scarcity of venture capital

(Mohnen, Palm et al. 2008). In a context where innovation processes are becoming more international, venture capital seems to play an important role (Saxenian and Sabel 2008). Our respondents also indicated that regulatory issues like intellectual property rights and trade-related regulations are problematic in their eyes. The complexity of these regulations requires a detailed and careful analysis that is beyond the scope of the INGINEUS project. Intellectual property rights protect different aspects of innovation (industrial design, trademarks, patents, copyrights, etc.), all of them in different regulatory sets at several jurisdictional levels (national, European and international). Yet, it is worth noting that in Europe the least complete and integrated regulatory set of intellectual property rights (IPR) is precisely the one legal figure that has most importance for innovation, namely patents.

The INGINEUS survey poses another question about policy-related factors. European firms were asked about their views on the future. Specifically, the question in the survey reads: "*Considering your future innovation activities, please assess the need for improving the following factors*". The findings are shown in figure 4 below.

Figure 4: Firms' needs for policy-related factors in relation *to their future innovation activities*.



(Borrás and Haakonsson 2011)

Source: INGINEUS survey

Legend: Average responses of the following scale: 1= highly negative; 4= highly positive; N=495. All respondents are European companies.

Figure 4 provides very relevant results. First of all, just as in the previous figure, most of the factors score just above the 2.5 threshold, indicating that firms have a medium level of positive expectations for policy needs in the future. It is worth highlighting the fact that the factors that are most positive or negative in the past and future are different. From the point of view of their needs for the future, it seems that European firms would like to have more open and flexible migration regulations for employing foreign scientists and technicians, as well as more stringent regulations, practice and jurisprudence around intellectual property rights. Other policy-relatedareas for future improvement include better access to international research networks, and better and clearer rules for FDI and trade.

All in all, the INGINEUS survey revealed that European firms encounter low-medium levels of barriers when collaborating with other firms or organizations from abroad. In general this is good news, as the current level of barriers is not high. Firms also pointed out at some current and future policy needs, though they indicated only a medium-level of 'need'. On this basis we might identify four policy implications for Europe.

First, and perhaps most importantly, there is a need for policy-makers to focus their efforts on making Europe a hub for GINs. Policy-makers need to foster a view of Europe as an innovation centre with constant movement inward and outward, rather than as a magnetic pole only attracting talent. This is so because the globalization of innovation is taking place through very dynamic networks that aim at tapping into knowledge resources and market opportunities in mature and new markets, and therefore there is a need to accept the bi-directionality of these activities. These dynamics require a policy approach that praises the openness of research and innovation activities as virtually the only possible way to keep ahead in rapidly changing scientific and knowledge-based environments, as well as market developments. This view of Europe as a hub is particularly important in times of economic and financial crisis, when scarce public and private resources might tend to foster attitudes of protectionism and isolationism. Such a view would have pernicious effects on Europe's ability to stay ahead of rapid innovative developments taking place everywhere in the advanced capitalist and in the emerging economies.

Second, Europe must make an effort to strengthen its knowledge-intensive competences. The recent proposal of the European Commission of the Horizon 2020 programme (December 2011), suggesting a bolder and larger investment in research and innovation in Europe, is a step into the right direction. However, in view of the substantial retrenchment of public budgets at the national and regional levels in Europe, policy-makers at all levels must make sure that there is an appropriate level of public investment in the production and dissemination of knowledge. A lack of adequate levels and forms of advanced knowledge in Europe will hinder the hopes for economic growth and recovery in Europe, particularly since competing on labour costs is no longer an option in a globalized economy. Besides, reducing knowledge competences in Europe will force European firms to seek that knowledge abroad in a much stronger way we are seeing today, hence potentially undermining the idea of Europe becoming a hub for innovation. Strengthening the knowledge competences in Europe is one important aspect to avoid a potentially negative scenario in the medium-term.

Third, openness and flexibility of migration policies, and creating a true European labour market might be necessary. During the past decade, firms in some European countries (Germany, Denmark, Sweden, etc.) have consistently complained about the shortages of specialized and knowledge-intensive labour skills in some specific technical areas (engineers, biotechnitians, etc.). This is associated with the problem of young Europeans enrolling less and less in scientific and technical education programs. The current economic crisis, with high labour unemployment, might have levelled this down a bit (lower job demand from firms and higher enrolment in technical education programs). However, there still seems to be a gap between European firms' skills needs and labour force availability in some specific segments of the labour market of highly advanced skills. While this continues to be the case, and Europe is unable to produce the necessary specialized skills, developing more flexible migration policies for highly skilled workers at the national level and fostering a true European free labour market at the European level, are important areas of action. In fact, our European firm respondents made reference to this matter in their opinions regarding the future needs of public policy action, in spite of the crisis.

Fourth, the survey above indicates with all clarity the need to focus on the regulation and enforcement of intellectual property rights. Although the question in the survey did not specify where (in Europe or elsewhere), it is important to note here that the network dynamics of producing and sharing knowledge puts considerable stress on firm's efforts to protect their knowledge. Fruitful knowledge collaboration in networks takes place on the basis of contractual agreements that determine the mutual obligations and responsibilities for the use of existing and future knowledge. Partners pool their resources only once they have defined the terms of the future accessibility and rights over the new knowledge. For that reason, cheap, reliable and accessible intellectual property rights and their legal enforcement, is of paramount importance in this collaborative knowledge production - more so when those networks have a global nature and several jurisdictional matters regarding national idiosyncrasies in IPR regimes might be a complex matter. Policy-makers in Europe have struggled with this in recent years, attempting to create a single regulatory framework for IPR in the EU context, particularly the Community patent (a single patent right valid in all EU27). These efforts are important, and are all the more relevant as the scope of innovation networks becomes more international and global.

Last but not least, the issue of venture capital availability is an important policy implication for European policy-makers. In continuation with the remarks above about the importance of SMEs in GINs, many 'born global' firms operate in highly specialized market niches in the global context and engage in GINs at an early stage. They need access to appropriate venture capital that values this global dimension of their operations, but venture capital has traditionally been a weak point in Europe when compared to the USA. The 'credit crunch' of the financial and economic crisis since 2007 has made this even more acute. However, if Europe is to recover from this crisis by strengthening its competitive position in knowledge-intensive industrial segments with highly globalized innovation networks, then risk-willing capital is needed. The problem is that the uncertain financial context in which Europe finds itself at the moment does not foster risk-willing investment attitudes; on the contrary, small firms and high-tech start-ups are today facing their hardest times to get access to capital. Yet, the crisis is an opportunity like no other to create new types of business and engage in path-breaking economic activities, here focusing on the rapidly growing emerging markets.

14.4 SPECIFIC POLICY IMPLICATIONS FOR EMERGING ECONOMIES

The INGINEUS project has generated a considerable amount of evidence regarding the organization and dynamics of GINs involving northern (in this case European) and southern partners (in our case the emerging economies). INGINEUS has focused on the following countries: Brazil, India, China and South Africa (BICS). The project's evidence brings forward some policy implications that are specific for emerging economies. When considered together, a series of four specific policy implications seem to be relevant.

Firstly, many of our case studies highlight the importance of intellectual property rights. Whereas in Europe the problem is the high costs and multiple jurisdictions of patent regulations (in spite of effort towards legal harmonization in the context of one single European market), the problem in emerging economies is primarily an issue of coherent legal framework and its actual legal enforcement as shown in chapter 13 of this report (Comune, Prarolo et al. 2011). Naturally, there are no easy or ready-made solutions for that, as these are complex problems. Nevertheless, policy-makers in the emerging markets must be aware that the legal uncertainty associated with unclear/broad IPR regulations and poor legal enforcement are a real obstacle for European firms to increase their investments in innovation activities here including collaborative network-based activities.

Secondly, building and expanding knowledge capabilities is of paramount importance for the BICS countries. BICS must consider expanding these resources and capabilities in view of becoming an attractive partner in the high end of knowledge generation, and not just being the 'sweat floor' and assembling line of outsourced production as shown in chapter 11 of this report (Lorentzen and Gastrow 2011). Furthermore, we know that investment in knowledge and education is a crucial factor in catch-up processes (Fagerberg and Godinho 2005). This is, of course, easier said than done, as investment in education and knowledge-intensive training and skills cannot be done overnight; it takes a considerable amount of time. Nonetheless, the BICS countries are industrialized countries and have substantial knowledge resources already. Therefore, they are in a position to create world-class universities and research centres in some specific knowledge segments that are related to their production structures. Such efforts would not only foster the overall knowledge capacity in their regional and national context, but would position them as nodal points in the future, particularly if the emerging trends towards GINs expand in number and scope. We know from the INGINEUS project that access to knowledge is a crucial factor for European firms to engage in GINs.

Thirdly, some researchers have pointed out possible problems of 'crowding out effects' of the labour market of emerging economies as shown in chapters 9 and 10 in this report. FDI in R&D activities has created a high demand of specific technical skills in some regional contexts, like, for example, in India, as this comprehensive report has shown. Whereas Indian firms in the ICT industry have upgraded their knowledge-intensive activities over time (Parthasarathy and Ranganathan 2011), they have also created a rapidly growing demand of labour skills. It is still unclear whether this has had a negative effect on the rest of the local labour market, crowding it out, however it is important to note that temporary gaps in the demand of labour might generate problems for existing local industry (Joseph and Abraham 2011). Policy-makers in the emerging countries must be aware of this possible problem, and monitor it closely. If tensions emerge in this direction, policy-makers could foster framework conditions that create a sustained level of adequate knowledge-intensive human resources.

Last but not least, some of the issues identified by INGINEUS indicate that a certain level of hierarchical relations continues to exist in some GINs. These hierarchical relations put pressure on the autonomy of suppliers, customers and universities/research centres involved in GINs, as the strongest knowledge competences are still located in the European multinational firms - as shown in chapter 12 of this report (Albuquerque, Kruss et al. 2011). For that reason, policy-makers in emerging economies must promote policies that aim to anchor external knowledge sources in the local context. In other words, policy-makers from emerging economies might focus on how their local economies and local knowledge organizations can benefit from the knowledge that comes with the GINs. Other than making them less dependent on hierarchical structures, this might help expanding knowledge capacity building in less developed areas. Yet, this ‘anchoring’ is perhaps easier to promote in local contexts with ‘thick institutions’ (as indicated in chapter 4 of this comprehensive report) (Chaminade 2011), as they have already good knowledge basis organizations to link with.

14.5 CONCLUSIONS AND PERSPECTIVE

This report has underlined the gradual and emerging phenomenon of GINs. A careful word on this is in order. GINs, in their highest intensity, are still a limited phenomenon. However, the low-medium level of networking, innovativeness and globalness seems to be widespread (almost half of our sample), and this might indicate that in the coming years there will be a gradual trend towards more GINs. This, however, will largely depend on how the economic and financial crisis in Europe evolves. If Europe falls deeper into recession and economic downturn, these trends might stop or even reverse. Likewise, deep economic crises like the one we are experiencing in Europe offer the social conditions to generate path-breaking dynamics. It is too early to draw definitive conclusions, as the crisis is perhaps showing its worst hours and uncertainty about the future of Europe has never been higher. Yet the INGINEUS project has shown that during the past decade or so there have been some exciting new dynamics as European firms are increasingly linking with partners in emerging economies when developing new knowledge that lets them access new markets.

The general policy implications are that there is no need for direct policy actions towards GINs; policy-makers must be aware of the differences regarding the knowledge base of GINs; there is a need to strengthen knowledge capacities in innovation systems; policy-makers must support SMEs’ global innovative networking; policies for the internationalization of R&D must take a network approach; and, last but not least, policy-makers must consider the need to improve international business management skills & ICT tools.

Why are these issues relevant? Governments in Europe are today facing one of the largest challenges ever; coping with the problems associated with loss of competitiveness and productivity levels in a context of deep economic and financial crisis. GINs in highly knowledge-intensive segments offer opportunities for European firms to access new knowledge sources and markets, while developing competences in niche markets with a global reach. In other words, the possibility to stay ahead of the intensified competition by positioning themselves as world leaders in specific high-tech and advanced knowledge market niches. GINs are mechanisms developed by firms in Europe to achieve this, and hence constitute an interesting yet emerging phenomenon that is worth monitoring and investigating further in future.

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