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Dedicated to Jo Lorentzen.

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Synthesis report on fragmentation of GINs and capability building in the automotive, ICT and agro-processing industries

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Executive summary

The objective of Work Package 6 is to better understand the role of human capital in the emergence and evolution of Global Innovation Networks (GINs). We define GINs as global networks in which some knowledge-intensive activities are based in developing countries. This Work Package therefore examines the relationship between strategies of both Northern and Southern firms, mostly multinational enterprises (MNEs), and human capital in host countries, and the implications of this relationship both for the management of technological change and for the emergence and evolution of GINs. Since this requires a focus on the competencies and capabilities that firms seek when formulating their strategies for the global allocation of knowledge-intensive activities, we work within the ‘capabilities approach’, which draws on Lall (2001), but extend this to include an analysis of R&D activity.

While the evidence for the existence of GINs is growing, their evolution is less clear. We do not know much about the micro-determinants shaping the formation of GINs. The high ranking in the INGINEUS survey of specialised competencies as an incentive for offshoring knowledge-intensive activity, and the confirmation that a significant share of firms undertakes such offshoring, underscores the importance of understanding the role of human capital in GIN formation. Against a background of data describing host country absorptive capacities (with a focus on education and skills data and foreign direct investment data), and reviews of current dynamics in the three chosen sectors, we interrogate a set of case studies from European firms that have investments in the participating emerging countries (Brazil, China, India, and South Africa). We also look at Southern firms that invested in Europe to access more advanced knowledge

The methodological framework of this work package consisted of empirical inputs from the INGINEUS survey, desk research, and in-depth firm-level case studies. Desk research included background reports on foreign direct investment and education and training systems from each of the developing country partners (see D6.2). The primary source of data is the case studies. Of these, five were ‘matched’ cases of large globalised firms, in which interviews were conducted in both the home country of the firm in Europe and at subsidiaries in host countries. Interviews were semi-structured and focused on upgrading and location strategies, human capital, and the management of technological change. These instances of technological change were analysed within Lall’s conceptual framework. The rich case studies 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.

The sectoral context of each firm influences the drivers and characteristics of innovation. Different sectors operate at different levels of technological intensity, have different levels of dependence on tacit and codified knowledge, and have differing demand for incremental development, adaptive development, new product development, and basic research. The key difference to emerge from analysis of the case studies is the role of tacit knowledge, which is more significant in the automotive sector, and less significant in the ICT sector.

The profiles of Foreign Direct Investment in the developing countries contrast dynamics in China and India, on one hand, and Brazil and South Africa, on the other. China and India offer huge internal markets with the prospect of continued rapid growth. This is highly attractive for European firms facing stagnant domestic markets. Brazil and South Africa have smaller populations, smaller markets, and lower growth rates. However, they both act as economic gateways to their respective regions, which incentivises firms to invest and also to undertake adaptive innovation for the regions.

There is a further difference of scale between Brazil and South Africa, where Brazil's population and market are substantially larger, and growth has recently been more rapid.

Education and training systems in Europe provide a plentiful supply of the high-level skills needed for innovation activity. All the firms interviewed in Europe reported that they could find the skills they needed in their home market, with the exception of certain domain competencies, for which they scan globally. The key factors influencing the fragmentation of GINs in all cases thus were reported to be pull factors from developing countries, rather than push factors from the home country.

In addition to being attractive investment destinations, emerging economies are also increasingly the sites of large pools of talent. The massification of higher education in India, Brazil China and South Africa since the 1990s has increased the global pool of talent, and greatly increased the proportion of competencies that reside in developing countries. Again, this process leads to somewhat differing responses for China and India, on one hand, and Brazil and South Africa, on the other. China and India are very large countries, where even a small proportion of the population passing through the education and training system amounts to a significant cohort of skills. The smaller size of the Brazilian and South African populations means that their markets are smaller and their pools of human capital are smaller in terms of both scale and scope. Massification has strained education and training systems in all four Southern countries, which achieve lower levels of quality in relation to their European counterparts. The high levels of inequality in the developing countries also affect their educational outputs. In an environment of great inequality, it is possible for pockets of excellence to exist within a generally weak system. It thus appears that in the search for skills, firms are seeking pockets of excellence that emerge from the challenging environment of rapidly expanding education systems in developing countries.

Within this context, our cases reflect two generalized patterns or macro-determinants of GIN formation. Emerging countries with large populations and growing markets (such as India and China) are more likely to have the market pull and human capital base to attract large corporate R&D centres. Medium-sized emerging countries (such as Brazil and South Africa) have smaller markets and more restricted human capital. They attract fewer and smaller R&D centres, and innovation demand is more focused on adaptation and product development for local markets. In all cases, dynamic upgrading is facilitated, with deepened integration into internalised and externalized knowledge networks, as well as other forms of knowledge transfer such as staff circulation and capital equipment flows.

At the same time, the cases reveal complexity at the level of micro-determinants. Firms balance a number of dynamic and interacting factors when developing their strategies articulating human capital availability and GIN fragmentation. In the synthesis report analysis, we examine selected cases from the much wider research output of Work Package 6, with a focus on cases that illustrate key micro-determinants of the relationship between human capital and GIN formation. Each case study represents a unique combination of these determinants; at the same time, patterns emerge. Table 1 summarises how these determinants have been relevant to the selected cases of North-South GIN formation, while Table 2 illustrates South-North cases.

Table 1: Determinants of North-South GIN formation

Firm	Countries	Key micro-determinants (pull factors)
ICT3	Sweden/Estonia	Availability of specialized human capital, Geographical proximity, Low cultural barriers
Auto1	Germany/South Africa	Regional gateway, Long logistical pipeline, Demand for local product development and adaptation, (management constraints on innovation activity at the subsidiary)
Auto9	Germany/South Africa	Regional gateway, Demand for local product adaptation, Regional commonalities with Brazil
Auto4	Italy/Brazil	Regional gateway, Demand for local product development and adaptation
Auto3	Italy/Brazil	Regional gateway, Demand for local product development and adaptation, Policy incentives
Auto1	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Auto2	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Auto9	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Agro1	Denmark/South Africa	Regional gateway, Local demand for adaptation, Regional commonalities (with Brazil), Tacit knowledge acquisition, Specialised knowledge acquisition, Local network acquisition
ICT1	Sweden/China/India	Large domestic market and growth potential, Large available human capital pool at lower cost, innovation management structures
ICT2	Sweden/China/India	Large domestic market and growth potential, Large available human capital pool at lower cost
ICT2	Sweden/South Africa	Regional gateway, Demand for local product development and adaptation

Table 2: Determinants of South-North GIN formation

Firm	Countries	Key micro-determinants (push factors)
Auto10	South Africa/UK/USA	Local skills shortages, proximity to customers
Auto11	South Africa/Australia/New Zealand	Proximity to customers

We began Work Package 6 by postulating that the tale would be one of (Northern) MNCs that embody certain capabilities, while at the same time looking for new ones, and of education and training systems (in the South) that are an essential element of the very absorptive capacities that INGINEUS conceptualizes as a local or national building block of GINs. The case study analysis confirms this generalised conceptualization, but it goes further, to identify the complex set of micro-determinants of the relationship between competences and capabilities, and GIN formation.

The key micro-determinants that emerge from the analysis are:

- *Market:* size, growth potential, local demand for adaptation, local demand for new product development
- *Human capital availability*: scale, scope, technology-specific competencies and capabilities, strength of the National System of Innovation, specialized knowledge assets, tacit knowledge assets, network assets
- *Sector*: role of tacit knowledge versus codified knowledge, sector-specific skills demands, value chain structures, sectoral innovation drivers
- *Geography*: geographical proximity, regional gateways, logistics, regional commonalities
- *Culture and tacit knowledge*: cultural/linguistic commonality, ease of tacit knowledge transfer
- *Infrastructure*: logistics, ICT
- *Policy*: IPR regimes, policy incentives
- *Management*: innovation management structures, strength of internalized knowledge networks, strength of value chain knowledge networks

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1. Introduction

The objective of Work Package 6 is to better understand the role of human capital in the emergence and evolution of Global Innovation Networks (GINs). We define GINs as global networks in which some knowledge-intensive activities are based in developing countries. This Work Package therefore examines the relationship between strategies of both Northern and Southern firms, mostly multinational enterprises (MNEs), and human capital in host countries, and the implications of this relationship both for the management of technological change and for the emergence and evolution of GINs. Since this requires a focus on the competencies and capabilities that firms seek when formulating their strategies for the global allocation of knowledge-intensive activities, we work within the 'capabilities approach', which draws on Lall (2001), but extend this to include an analysis of R&D activity.

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 was 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). Cognate research focuses on the global outsourcing of specific knowledge intensive activities, for example engineering (Manning et al, 2011), but does not focus explicitly on GINs. The most comprehensive and recent source of data is from the European Commission's INGINEUS project, which in 2010 included a survey of 1,215 companies in six European countries and in Brazil, China, India and South Africa in three sectors (agro-food, automotive, and ICT). The survey found that 25 per cent of these firms offshored either production or R&D, and that, next to market access, the most important location-specific advantages were 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. Between five and six per cent reported that subsidiaries in developing countries were responsible for strategic management, product development, and technology and process development.

While the evidence for the existence of GINs is growing, their evolution is less clear. We do not know much about the micro-determinants shaping the formation of GINs. 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 subsquent 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.

However, there are important Southern firms that do 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. New-to-the-world innovation in the South is unlikely to remain a small phenomenon, so it is incumbent upon researchers to recognize the limitations of the existing literature and think more systematically about how developing country firms master the process of moving from a merely operational understanding of technologies (as part of a GPN) to an understanding of the principles behind the technologies that are required for innovation activities (as part of a GIN).

The high ranking in the INGINEUS survey of specialised competencies as a incentive for offshoring knowledge-intensive activity, and the confirmation that a significant share of firms undertake such offshoring, underscores the importance of understanding the role of human capital in GIN formation. Against a background of data describing host country absorptive capacities (with a focus on education and skills data and foreign direct investment data), and reviews of current dynamics in the three chosen sectors, we interrogate a set of case studies from European firms that have investments in the participating emerging countries (Brazil, China, India, and South Africa). We also look at some Southern firms that invested in Europe to access knowledge from more advanced suppliers. These case studies aim to illustrate the macro and micro determinants that conditioned the embedding of Southern firms into (sometimes incipient) GINs, with a focus on human capital factors.

2. Theoretical framework

GINs are global networks of innovation activity in which some knowledge-intensive activities are based in developing countries. Research has identified a set of "centripetal forces" which induce the firms to centralize the R&D activities in the headquarters, and opposing "centrifugal forces" that work towards the dispersion of R&D activities across different locations beyond the home country (Rugman, 1981; Vernon, 1974). Centripetal forces include the need to protect firm-specific technology from unwanted leakage, the significance of scale economies in R&D, and the high cost of co-ordination and control as a centripetal force. Centrifugal forces include the need for adaptation to local market conditions (particularly in countries with a large domestic market and access to scientific and technological skills and infrastructures that are available in the host countries at more advantageous terms than in the home market. Work Package 6 focuses on this final centrifugal force, and seeks to position it among the other forces which shape the fragmentation of GINs.

The limited existing research on GINs (UNCTAD 1995; Ernst 2011) suggests that they are forming at an increasing rate, which means that certain factors are changing the balance of centripetal and centrifugal forces in favour of centrifugal forces (Albuquerque et al 2011), thereby compelling firms to locate their R&D activities outside their home countries. Once of the main reasons is the availability at a lower cost of human capital in emerging economies such as China and India (Stembridge, 2007). One way to conceptualise the role of human capital in this regard is to differentiate 'push' and 'pull' factors, where push factors are related to human capital availability in the home country, where some deficiency 'pushes' knowledge intensive activity outwards, and where 'pull' factors are related to human capital availability in the host country, where some asset attracts knowledge intensive activity inwards (see Research Paper 1).

The INGINEUS conceptual framing of Global Innovation Networks allows for a matrix of potential GIN formation (see Research Paper 1). Variability in the level of globalisation, proximity to the innovation frontier, and network strength, provides a matrix of possible GIN structures. A 'strong form' GIN is part of a highly globalised network that includes developing countries, conducts new to the world innovation, and participates in an extensive a network that includes actors beyond its value chain. Conversely, a 'weak form' GIN participates in a weakly internationalised network, for example, one restricted to Europe, conducts incremental or adaptive innovation, and participates in a weak network restricted to an internalised structure or within a single value chain. The range of combinations in between these two extremes render a number of distinct GIN formations.

Work Package 6 seeks to determine how capabilities across the world influence these GIN formations. Thus the unit of analysis for this Work Package is people, and the skills, competencies and capabilities that they embody. We make distinctions between these terms based on the work of Von 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 instutions, 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. 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 joint ventures (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. 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.

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 2007, 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 (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. In this report, we extend the range of this analysis to include capabilities for innovation and R&D. In our cases we highlight processes of dynamic upgrading, for example in-house training, knowledge networks, capital equipment flows, and staff exchange. Lall's framework identifies several determinants of firm-level capability-building, and hence learning. 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, as appropriate to each sector.

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 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 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.

The above framework has been used for the case studies included in the papers and case studies in the addendums. In the next section we show how this framework has allowed us to analyse case studies and identify micro-determinants of GINs.

3. Methodology

The methodological framework of this work package consisted of empirical inputs from the INGINEUS survey, desk research, and in-depth firm-level case studies, and analysis of these inputs through six research papers and three integrated case study reports. Two questions in the INGINEUS survey were directly relevant to Work Package 6, namely questions 12.4, which measured the role of local competences and capabilities in the internationalisation of innovation, and 13.4., which measured the role of skills as a future determinant of innovation activities. Together with questions that provided relevant contextual indicators, these items provided the main survey-based findings for the work package. There were also several components of desk research. Firstly, background reports on foreign direct investment, as well as education and training systems, were produced by each of the developing country partners. The developing country papers included critical information about absorptive capacity and competence availability at the national level. At the sectoral level, literature reviews were conducted into the sectoral drivers of innovation within the automotive, ICT and agro-food sectors. At the firm level, background information on all the case study firms was gathered in order to prepare for interviews and to contextualize and supplement interview findings. This was based largely on trade magazines and other specialist literature

The primary source of data is the case studies (see Table 3). Of these, five were 'matched' cases of large globalised firms, in which interviews were conducted in both the home country of the firm in Europe and at subsidiaries in host countries. The matched cases included firms from the automotive sector, the agro-food sector, the ICT hardware sector, and the ICT software sector.

Table 3: Case study sample

Firm	Sector	Interview locations	Relevant Outputs
Matched case studies:			
ICT1	ICT software	Sweden, India, China	ICT1 Case Study
ICT2	ICT hardware	Sweden, South Africa	Research Paper 5 Research Paper 6
Agro1	Agro-processing	Denmark, South Africa	Research Paper 1, Agro1 Case Study
Auto1	Automotive	Germany, South Africa	Research Paper 2, Research Paper 3, Auto1 Case Study
Auto2	Automotive	Germany, South Africa	Research Paper 2, Research Paper 3
Unmatched case studies:			
Auto3	Automotive	Brazil	Research Paper 4
Auto4	Automotive	Brazil	Research Paper 4
Auto5	Automotive	Brazil	Research Paper 4

Auto6	Automotive	Brazil	Research Paper 4
Auto7	Automotive	Brazil	Research Paper 4
Agro2	Agro-processing	Denmark	Research Paper 1
Agro3	Agro-processing	Denmark	Research Paper 1
Agro4	Agro-processing	Denmark	Research Paper 1
ICT3	ICT	Estonia	Research Paper 6
ICT4	ICT	Estonia	Research Paper 6
Auto8	Automotive	Germany	Research Paper 2
Auto9	Automotive	South Africa	Research Paper 3
Auto10	Automotive	South Africa	Research Paper 3
Auto11	Automotive	South Africa	Research Paper 3

The first step of the firm selection process was to identify European MNCs (from Germany, Denmark, and Sweden) with subsidiaries in the BICS countries, in each of the three sectors. Once candidate firms were identified, 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, as well as unmatched case studies were firms were only interviewed in one location. These included interviews with firms from developing countries that had invested in subsidiaries in Europe. These ‘South-North’ cases are complementary, in that they illustrate the formation of GINs from a Southern origin and perspective.

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 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. Interviews took place in 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.

These instances of technological change were then analysed within Lall’s conceptual framework, 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 the focus on the role of human capital.

4. The national and sectoral context

4.1 Sectoral context

The sectoral context of each firm influences the drivers and characteristics of innovation, both in the home country and the host country, which in turn effects the manner in which firms seek capabilities and competencies in host countries in support of their innovation activities. In this regard different sectors (and sub-sectors) operate at different levels of technological intensity, have different levels of dependence on tacit and codified knowledge, and have differing distributions of global demand for innovation. Different sectors also have differing levels of demand for incremental development, adaptive development, new product development, and basic research. Key innovation drivers in the automotive sector are explored in greater detail in Research Papers 2, 3, and 4, key drivers in the agro-processing industry are explored in Research Paper 1, and key drivers in the ICT sector are explored in Research Papers 5 and 6.

In the **agro-food** sector customers continuously demand new products, and ingredient companies must anticipate future needs and identify technological opportunities relevant to the customers ahead of time. Our agro-food case study firms are all headquartered in Denmark. Their R&D collaboration in the sector is mostly within the supply chain, with firms reporting that their collaboration is mostly with customers, suppliers, and consultancies, which are all predominantly located in Denmark and Western Europe (Ministry of Science and Technology, 2010). This concentration is also related to the localization of the sector: firstly, Denmark is home to agglomeration in the sector. Secondly, the nature of the agro-food industry favours local incremental innovation that can quickly respond to local customer needs and variations in local inputs.

Sector-specific skills are generally available in Denmark. The Danish food cluster is among the most innovative food clusters in the EU and is also export oriented (European Cluster Authority, 2010). Denmark ranks 3rd in the OECD for food patenting per capita, and has the highest number of scientific publications related to food per capita (Ministry of Science and Technology, 2010). The sector is also prominent in South Africa, which is home to several large agro-food companies, of which some have become global players that export knowledge services. South Africa has the most developed food processing and manufacturing sector in Southern Africa (DTI 2006). Consequently, the sector has attracted a number of international and local companies that use South Africa as a base to reach the domestic market, as well as other countries in Africa. The existing knowledge and physical infrastructure in the sector in South Africa, together with the country’s strategic position, incentivized investment from Denmark.

The automotive sector has a distinct set of drivers that influence innovation and the search for human capital. The key issues in this sector are value chain hierarchy, value chain knowledge architecture, consolidation, cost pressures, and changing market size and growth patterns. The origins of these issues are market changes: 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). The onset of the world financial crisis in 2008 accelerated this trend. (Wad, 2010). 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 account for the bulk of innovation activity. 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. The financial crisis increased cost pressures on the industry, turned up the heat on OEMs, and accelerated supplier consolidation (see Research Paper 2 and Research Paper 3).

Innovation in the sector is therefore concentrated within large firms at the top of the value chain. Basic research is concentrated at the main R&D facilities of assemblers and major supplers, while applied research can be cascaded down the value chain. 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. This creates a consistent demand for R&D among the large firms in the sector, 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

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 for these markets (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 (for example South Africa), as regional production hubs. Opportunities for technological upgrading can take place when a Northern supplier transfers technology to a Southern assembly plant or when a Southern assembler acquires competencies by purchasing a Northern firm.

However, unlike the ICT sector, much of the knowledge required for engineering and innovation in the automotive sector is tacit. This means that there are challenges when transferring knowledge across the globe, particularly across cultures. The German automotive firms with R&D centres and subsidiaries in India reported significant barriers to the transfer of certain forms of tacit knowledge, and had to initiate programmes of cultural bridging in order to mitigate the resultant communication gaps.

The ICT sector is distinguished by the greater role of codified technology, both in the hardware sub-sectors (ICT2, ICT3) and the software sub-sectors (ICT1, ICT4). This lowers cultural and geographical barriers and facilitates the globalization of innovation. Indeed, the case study firm that is arguably the most Global and Networked is in the ICT sector (see the ICT1 Case Study). In contrast to the automotive sector, tacit knowledge plays a relatively unimportant role in the software sector. The rewards for radical innovation in the sector are great. The rapid spread of the internet, and the development of more advanced underlying communications technologies, has brought about major technological disruptions and opportunities in the telecommunications software industry. Firms seek to take the advantage of these opportunities through innovation – the rapid growth and success of both ICT1 and ICT4 was predicated on radical software innovations. There is also a continuous demand at the local level for customized ICT solutions. As the ICT1 case study noted, emerging markets are changing rapidly, and a critical strategy for ICT firms is to keep track of these changing demands and develop appropriate solutions – a factor which was one of the incentives for R&D investments in India and China.

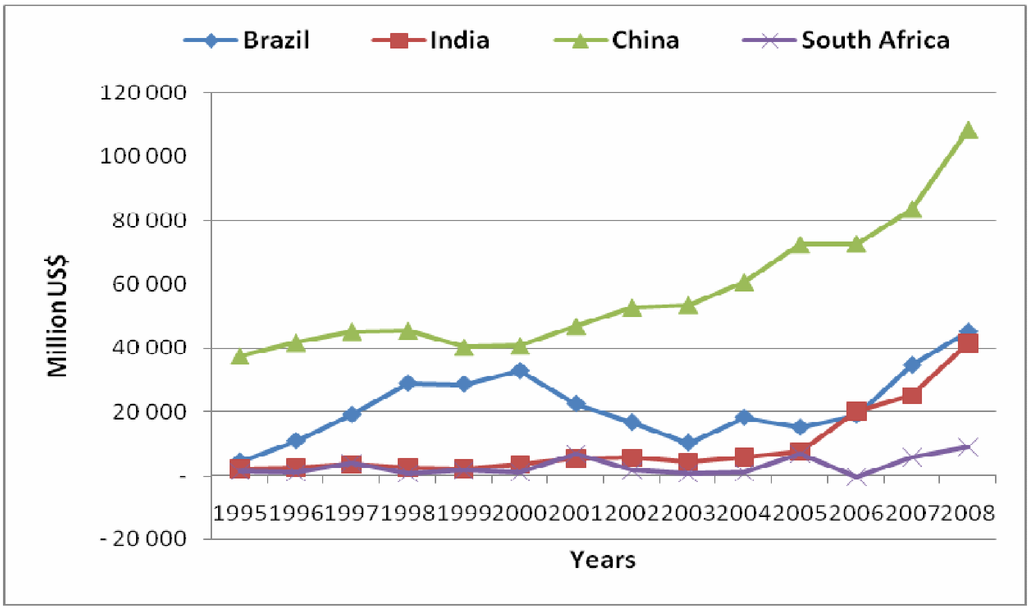
In the telecommunications hardware sub-sector, the 1990 saw the advent of the Global System for Mobile Communications (GSM) standard and the broad take-up of the mobile telephony services by consumers. Nordic telecommunications equipment manufacturers became the global market leaders, and the value chain remained largely located in the Nordic countries. The initial saturation of the market, the Nasdaq crash, and the emergence of the next generation (3G) mobile telephony standards led to a significant restructuring of the industry in the early 2000s. Asian producers rapidly built up their product development and manufacturing capabilities. Ready-made integrated platforms became readily available from semiconductor manufacturers, thus lowering barriers to entry. Market power has become the key strategic factor in the sector, so access to end customers in large emerging markets is increasingly important. Asia became both the greatest growing market and the largest manufacturing base. The mobile telephony production value chain has become truly globalised in the course of the last decade.

4.2 Foreign Direct Investment

Foreign direct investment in the emerging economies is explored in detail in D6.2 and Research Paper 4. These resources follow FDI trends in China, India, Brazil and South Africa from the market liberalisation during the 1990s to the financial crisis of 2008 and beyond.

The 1990s was characterised by widespread trade liberalisation. Brazil, India and South Africa joined the WTO at its inception in 1995, and China enrolled in 2001. Trade liberalisation followed at varying paces. Together with growing competitiveness and capabilities among these emerging economies, these factors contributed to an increase in inward FDI over the 1990-2008 period in Brazil, India, China and South Africa, especially in the two years before the financial crisis (Figure 1). In a context where low labour costs and incentives by developing countries are taken for granted, the capacity of the developing countries to participate in GPNs and GINs is governed by their ability to provide specialized capabilities that MNCs need in order to complement their own core competences. Countries that cannot provide such capabilities are kept out of the circuit of international production network despite their liberal trade regime (Ernst and Lundvall 2000).

Figure 1: Inward FDI flow, Brazil, India, China and South Africa, 1995-2008



Source: UNCTAD, 2010

China has the largest population in the world and a rapidly growing economy with a 10% average annual GDP growth over the 1994-2009 period (World Bank, 2010). It offers foreign investors an attractive combination of large and growing domestic market, and relatively low labour costs (Yunshi and Jing, 2005; Zhou and Lall, 2005). China's opening up to international markets was a gradual process. During the 1980s, Special Economic Zones and open coastal cities provided region-specific investment gateways. The 1990s saw a further easing of regulations and a marathon negotiation to join the WTO, which finally took place in 2001. This marked a remarkably rapid, massive, and sustained growth in FDI into China that continues today (see Figure 1) that has had profound effects on the structure of the global economy. Membership of the WTO provided a greater incentive for FDI. Market liberalisation also stimulated outward FDI; interestingly, in 2008 South Africa was the largest destination of this outward FDI (US$4.8 billion, or 9% of the total), highlighting the growing importance of investment flows between developing countries (source: Chinese outward FDI statistical communiqué, 2008).

India is the world's second most populous country, and has also experienced strong economic growth with a 7% average annual GDP growth over the 1994-2009 period (World Bank, 2010). Therefore, like China, it attracts foreign investment with its large growing market and low labour costs. India opened its economy to international trade in 1991, with the signing of the New Industrial Policy. Remaining restrictive conditions were phased out over time. This facilitated a prolonged and sustained growth in FDI. The sectoral distribution of FDI is dominated by construction and ICT sectors. Observed increased in FDI in the ICT sector has occurred in the context of a systematic effort by the state, since the 1970s, to promote ICT skills development and a sectoral innovation system. Joseph (2009) and Kumar and Joseph (2006) postulate that this relatively vibrant sectoral innovation system is one of the key factors that explains the FDI into these sectors by MNCs that seek to complement their own capabilities.

Brazil is the world's sixth most populous country (195 million in 2010), and had a 3% average annual GDP growth between 1994 and 2009 (World Bank, 2010). As the dominant geopolitical force in MERCOSUR, it also acts as a gateway to the Latin American market. Brazil thus attracts investors with a large, growing, and strategically important market. After decades of import substitution industrialisation, market liberalisation in Brazil occurred gradually in the late 1980's and early 1990s. The opening up of trade prompted increased investment by market-seeking foreign firms, prompting FDI growth that lasted until 2000. Large-scale privatisation also influenced FDI during this period: between 1986 and 1992 around US$100 billion in state owned enterprises was transferred to the private sector (Silva, 2004). Macroeconomic turbulence placed downward pressure on FDI from 2001-2003, but this recovered on the back of stronger economic growth, and FDI has been on an upward trajectory since then, reaching particularly high levels in the run-up to the global economic crisis. However, the primary sources of FDI did not change substantially during this period. In 1995, the major sources of FDI were the Netherlands, the USA, and Spain. In 2009 this remained unchanged, with the Netherlands (18.79%), USA (16.02%) and Spain (8.08%) still dominant (Brazilian Central Bank: www.bcb.gov.br).

South Africa has a smaller population than Brazil, India or China and a lower GDP growth rate than India or China. South Africa had a population of 50.5 million in 2010 and a 3.3% average annual GDP growth from 1994-2009 (World Bank, 2010). However, as an access point to Sub-Saharan Africa, which has a large population but a small GDP, South Africa has an additional strategic advantage for investors. South Africa's first democratic elections in 1994 lead to the country's opening up to world markets. In 1995 South Africa joined the WTO, and by 1998 foreign exchange control regulations were removed. Levels of FDI into South Africa increased after 1995, but have been volatile since then, with levels fluctuating significantly due to specific large-scale investments. For example, Barclay's Bank acquired 32% of ABSA, South Africa's largest bank, in 2005; in the same year Vodafone acquired 46.5% of Vodacom, a South African telecommunications company; in 2007 the state-run Industrial and Commercial Bank of China acquired a 20% stake in South Africa's Standard Bank fpr US$5.6 billion. The sources of FDI into South Africa are largely from countries with close historical ties. In 2008 87% of FDI originated from Europe, mostly from the UK. However, China and India play a growing role: China is South Africa's largest trading partner, and trade with India tripled between 2003 and 2007; increased investment levels from both counties are expected. From a low base, South Africa nonetheless had an average annual growth of 16.5% in FDI inflow between 1995 and 2008. This has largely been through market-seeking FDI, primarily in the form of acquisitions (Estrin and Meyer, 2004; Gelb and Black, 2004).

The profiles of FDI in the developing countries indicate different dynamics in China and India, on one hand, and Brazil and South Africa, on the other. China and India offer huge internal markets with the prospect of continued rapid growth. This is highly attractive for European firms facing stagnant domestic markets. Brazil and South Africa have smaller populations, smaller markets, and lower growth rates. However, they both act as economic gateways to their respective regions, which incentivises firms to invest and also to undertake adaptive innovation for the respective regions. There is a further difference of scale between Brazil and South Africa, where the former's population and market are substantially larger, and growth has recently been more rapid.

4.3 Education and training systems

Education and training systems in the emerging economies are explored in detail in D6.2 and Research Paper4. Competencies in Europe are explored in Research Papers 1,2,5, and 6. Education and training systems in Europe provide a plentiful supply of the high-level skills needed for innovation activity. All the firms interviewed in Europe reported that they could find the skills they needed in their home market, with the exception of certain rare domain competencies, for which they scan globally. The key factors influencing the fragmentation of GINs were in all cases reported to be pull factors from developing countries, rather than push factors from the home country.

In addition to being attractive investment destinations, emerging economies are also increasingly the sites of large pools of talent. The massification of higher education in India, Brazil China and South Africa since the 1990s has increased the global pool of talent, and greatly increased the proportion of competencies that reside in developing countries. The massification of education is reflected in the tertiary enrolment figures, which all increased between 2000 and 2007, particularly in Brazil, which may reflect the country’s policy of free public higher education (World Bank, 2010). At the same time, the near tripling of China’s enrolment rate during the same period, given its large population, represents a massive new cohort of skilled people. This cohort has already had a significant impact on the global distribution of innovation. The BICS countries still have a long way to go before catching up with Europe: in Germany the proportion of the labour force have a tertiary education is 24%, in Sweden 29.8%, in Denmark 30.6%, and in Estonia 33.7% - this figure is only 7% in China, 8.6% in Brazil, and 13% in South Africa (World Bank, 2010). However, this rapid expansion has put strain on education quality and the level of university teacher training and experience.

The issue of educational quality should be separated from the issue of educational quantity. Firm-level case studies repeatedly reported problems with the quality of graduates in developing countries. However, the high levels of inequality in these countries affects their educational outputs. In an environment of great inequality, it is possible for pockets of excellence to exist within a generally weak system. For example, in a global ranking of 139 countries (WEF, Global Competitiveness Report 2010-2011) the quality of South Africa’s management schools was ranked 21, above the ranking of Germany (31). In all four developing countries, the ranking for the quality of their scientific research institutions, and the ranking for the local availability of R&D services, were far higher than their rankings for the overall quality of their education system. With the exception of India, university-industry linkages were perceived to be strong in comparison to the overall quality of the education system. At the apex of the educational systems, the presence of world class (top 200) universities highlights the continued disparities between the sample countries. Germany is home to ten of the top 200 universities. After rapid improvement, China is home to nine. Brazil and South Africa each have one flagship institution in the top 200, while India has none. This illustrates the continued gap between developed and developing countries in terms of excellence, but also illustrates the great state-driven catch-up achieved by China. It thus appears that in the search for skills, firms are seeking pockets of excellence that emerge from the challenging environment of rapidly expanding education systems in developing countries.

Thus the evidence points towards the pursuit of pools of capabilities and competencies that are growing from the increasingly prolific education and training systems of developing countries. In the global search for talent, European firms are looking outward and seeking to match the availability of human capital with the investment considerations of market size and growth potential. Again, these lead to somewhat differing responses for China and India, on one hand, and

Brazil and South Africa, on the other. The former are very large countries, where even a small proportion of the population passing through the education and training system amounts to a significant cohort of skills. On the other hand, the smaller size of the Brazilian and South African populations means that their markets are smaller and their pools of human capital are smaller in terms of both scale and scope.

5. Human capital, technological change, and GIN formation

5.1. Micro and macro determinants of GIN formation

A focal point of firm-level interviews was the identification of a particular instance of technological change or GIN formation. Each focal point represents a set of strategic decisions taken by firms seeking to articulate their innovation requirements with the global distribution of human capital. These decisions often represent the dynamics present in the firm's broader context, such as sectoral drivers of innovation, market incentives, and the availability of competencies at the national level. These examples reveal differing strategic patterns as firms allocate their resources towards technological upgrading and innovation activities around the world.

Our cases reflect generalized patterns or macro-determinants of GIN formation. Emerging countries with large populations and growing markets (such as India and China) are more likely to have the market pull and human capital base to attract large corporate R&D centres. Medium-sized emerging countries (such as Brazil and South Africa) have smaller markets and more restricted human capital. They attract fewer and smaller R&D centres, but innovation demand is more focused on adaptation and product development for local markets (Sturgeon et al, 2009; Humphrey and Memedovic, 2003; Ivarsson and Alvstam, 2005). In all cases, dynamic upgrading is facilitated, with deepened integration into internalised and externalized knowledge networks, as well as other forms of knowledge transfer such as staff circulation and capital equipment flows.

At the same time, the cases reveal complexity at the level of micro-determinants. Firms balance a number of dynamic and interacting factors when developing their strategies articulating human capital availability and GIN fragmentation. Each firm faces a unique strategic position and negotiates its own complex array of factors including multiple strategies playing out within different parts of the same corporate group. In our analysis below we examine selected cases from the much wider research output of Work Package 6, with a focus on those cases that illustrated well-defined strategic stances and general trends. Since there is little previous research that has focused specifically on the micro-determinants of GIN formation with a focus on the role of human capital, it was not easy to systematize our cases to reflect their complexity. We have thus used an inductive approach to identify the key micro-determinants that shaped firms' strategic decisions in relation to human capital and GIN formation. These include factors related to market characteristics, sectoral characteristics, geography, infrastructure, policy, value chain dynamics, and innovation management. They are summarized in Table 4 and

Table **5**.

Our selected cases range from the most basic (incipient GINs), to intermediate (GINs focused on product adaptation) to the most complex (large GINs with a global distribution of new-to-the-world innovation).

5.2. A basic case of the search for lower-cost skills

ICT3 provides a classic case of the search for lower-cost skills for technological upgrading in a transition economy, Estonia. When Estonian independence was restored in 1991, the country reoriented its economy to Western markets. However the electronics industry that Estonia had inherited was not competitive in Western markets. The industry partially collapsed, with the result that an experienced workforce for the electronics industry was readily available in Estonia in the early 1990s (Tiits 2006). ICT3, a Swedish firm serving customers in the ICT hardware sector, started pilot production in Estonia, and formally established its first subsidiary abroad. Although initially Asian countries had been considered as a potential location, a better alternative was eventually found closer to home in Tallinn. One of the ICT3 veterans has described the creative destruction that took place in the early 1990s: "*It was a productive time, the industry had collapsed and the town was full of unemployed engineers*." The newly employed engineers were initially sent for training to Finland or Sweden. Later, training was increasingly organised locally in Estonia. By the late 1990s, ICT3 was producing mobile handsets in Estonia for two market leaders of the time.

ICT3 went on to form a regionalized production network, within which was embedded a weakly formed incipient GIN. This was facilitated by ICT3's basic strategy of pursuing technological upgrading in a location with the required human capital at a lower cost. The geographical and cultural proximity of the Baltic state was an additional benefit.

5.3. Technological change and GIN formation in Brazil and South Africa

Brazil and South Africa have smaller populations and smaller markets than India or China, although in both regards Brazil is larger than South Africa. Innovation strategies of MNCs and their subsidiaries in these countries are more likely to take the form of adaptive engineering, and occasionally new product development. They are less likely to absorb global outsourcing of innovation activities, or conduct innovation for global markets. Our Brazilian and South Africa case studies from the automotive sector illustrate the micro-determinants of incipient GINs, GINs for local adaptation, and GINs for product development for the local markets (see Research Papers 2, 3, and 4, and Auto1 Case Study).

Auto1's South African subsidiary provides an example of participation in an incipient GIN. The Auto1 Group has a global innovation network, with large R&D facilities in Germany and India. The South African subsidiary has no formal R&D unit, and participates only in very limited product and process innovation. For example, the subsidiary's position in the supply chain has necessitated process innovation: because of the large finished goods stock held in the logistical pipeline to their international customers, the subsidiary suffers far higher costs from production rejects than the German production plants. It thus modified its production processes to lower reject rates to below that of the German plant. The firm had the capabilities to undertake this independently. Auto1 South Africa has also developed parts for local assemblers (Original Equipment Manufacture, or OEM) customers that have designed vehicles specifically for the South African market, and have therefore had permission from their headquarters to collaborate directly with local customers and suppliers in the design process. However, these new technologies did not feed back into the group. Auto1 South Africa’s involvement in a GIN is thus weakly globalised (it collaborated mostly with local actors), weakly innovative (mostly minor product and process changes), and weakly networked (its collaboration was restricted to inside the value chain).

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: their management at headquarters in Germany does not accept any innovation originating from South Africa. Thus, while the requisite human capital for increased innovation is generally available at the subsidiary, innovation management at the group level is a micro-determinant that acts as a constraint. This incipient GIN may therefore evolve further if management constraints on innovation at the subsidiary are lifted, and if market demand for new products creates enough incentive.

More evolved GINs in Brazil and South Africa are largely concerned with adapting European products to the local market, and occasionally designing for the local market. This is particularly evident in the automotive sector, where operational conditions in the South are very different to Europe, which creates a tangible demand for adaptation. It also incentivises technology and knowledge transfer between Brazil and South Africa.

The Auto9 group is headquartered in Germany, but has a subsidiary in South Africa. The group traditionally conducts basic R&D as well as pre- and product development at its headquarters, and centrally coordinates global innovation activity. The firm invested in a new R&D centre in the US in the early 2000s and more recently in China and India, all 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. Our interview at the subsidiary found that Auto9 South Africa had 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, which faced similar market conditions, and therefore could make use of the technology. Here an additional micro-determinant of GIN formation is market commonality between regions: the new product developed for South African conditions was in this case also suitable for the Brazilian market.

Despite skills shortages at the aggregate national level, Auto9’s South African subsidiary reportedly can access most of the competencies required for applied development, and over time the firm built up development capabilities. South Africa’s 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. Communication is horizontal and does not go through headquarters. In this case, the use of internalized knowledge networks as part of the group’s innovation strategy is an additional micro-determinant of GIN formation. The innovation activity of the South African subsidiary can be described as being strongly global (includes partners in multiple countries in the North and the South), weakly innovative (it involves product adaptation rather than new-to-the-world innovation), and weakly networked (it relies on internalized networks). It thus participates in a low-intensity organizationally flat GIN that is nested within a deeply hierarchical global value chain.

The case of Auto4 in Brazil reveals a similar pattern. The primary purpose of innovation at the subsidiary is ‘tropicalisation’, or the adaptation of European designs to developing country conditions. Like Auto9, Auto4 responded to the demand for a drive-train component that could withstand the rougher and more demanding conditions in the developing country, as well as being a low-cost solution. As in the Auto9 case, the product was developed with a team that extended across the value chain, including suppliers and the customer. However, the Auto4 product had a higher level of novelty, introducing a technology to the automotive sector that had previously only been used in the farming equipment sector. This was possible because the firm had access to a larger human capital pool, and was also incentivized by a larger domestic and regional market. The innovation activity of Auto3 is also largely related to ‘tropicalisation’, but also includes some product development (but not basic research). The Brazilian subsidiary of Auto3 is the largest outside the home country in terms of production volume and sales, and is also the formal centre for the adaptation of Auto3’s products to developing markets.

The emerging market adaptation that takes place in Brazil is similar in structure to that in South Africa, but significantly larger in scale and scope, and includes both product adaptation and some new product development. Policies with regards to ethanol-based fuels and tax reductions on small engines both prompted research into these technologies, leading some of the Brazilian case study firms to contribute to the design of small engines, and to become world leaders in the field of ethanol and flex-fuel engines. Thus, unlike the South African cases, the Brazilian cases included examples of new-to-the-world innovation. In addition to local market demand for adaptation, and the availability of the requisite human capital, policy incentives have also acted as micro-determinants of GIN formation.

5.4. Comparative examples of the role of human capital availability

The role of human capital availability in GIN formation and evolution is illustrated in the case studies of German automotive suppliers operating in both India and South Africa (see Research Papers 2 and 3, and Auto1 Case Study). Despite having sufficient access to skills in the home country, Auto1, Auto9, and Auto2 have all recently established substantial R&D centres in Pune, India. As in the Scandinavian countries, the primary motivations for outsourcing from Germany were pull factors, rather than push factors (see Research Paper 2, Auto1 Case Study). The R&D centres have served a dual purpose of adaptation for the local market, and the outsourcing of some routine R&D functions for cost reduction purposes. By contrast, none of the firms have set up R&D facilities at their subsidiaries in South Africa – the size of the market wouldn’t justify it, and the requisite human capital is in any case not available. Competencies in South Africa are stretched thin by the existing level of knowledge-intensity activity in the sector, with interviewees reporting that the current level of human capital is not an operational constraint, but is indeed a constraint on growth in R&D activity (see Research Papers 2 and 3). Where there were knowledge gaps that constrained innovation, the South African subsidiaries drew upon the group’s global knowledge network, for example by using the firm’s intranet to consult with specialists in other countries. Similarly, in Brazil, a shortage of high-level skills acts as a constraint on innovation. Auto4 reported that there are not enough engineers locally to meet the firm’s innovation needs. As a result the firm has strengthened its research ties with its European headquarters (see Research Paper 4).

The issue of tacit knowledge is also salient here. Tacit knowledge is particularly important in the automotive industry (Jung and Lee, 2010). German automotive firms with R&D centres in India reported considerable barriers in the transmission of tacit knowledge and in inter-cultural communication (see Research Paper 2, Research Paper 3, Auto1 Case Study). In comparison, the South African and Brazilian subsidiaries did not report any cultural barriers or major problems in the transfer of tacit knowledge. Given the relative scale and scope of innovation investment and activities in the two countries, we can conclude that the incentives for carrying out innovation in India were sufficiently large to prompt firms to take action to overcome these barriers.

5.5. Purchasing knowledge assets and network assets: a case from the agro-food sector

The focal point of the Agro1 case study was the purchase, in 2010, of a specialist South African firm, and the incorporation of this into the Agro1 Group as a subsidiary. The South African firm was a local player with a small laboratory supporting bread-producing customers operating locally. In particular, the company was working on adaptation for local markets, including solutions to get low quality wheat rising with yeast, in order to supply international customers that are moving into South Africa. The key motives for this particular purchase were the acquisition of skills, strategic knowledge assets, insight into local market conditions, and a plug-in to an existing local innovation system. The key strategic knowledge asset was the capability of achieving rapid turnaround times when developing mixtures for customers in the baking sector. This required, in addition to codified knowledge, unique tacit knowledge of local conditions, particularly the characteristic of local inputs such as flour and yeast. The South African firm had well developed links with local universities, research institutes, and other firms active in the value chain.

After the purchase, the subsidiary's previously existing local knowledge network continued to be drawn upon, but was now supplemented by collaboration and knowledge exchange with Agro1 headquarters and with the regional HQ in Brazil. For the newly formed subsidiary, the primary engagement in the firm's internalized knowledge network was interaction with Brazil for product development. There have been numerous cases where intellectual property from South Africa is used in Brazil. If Brazil does not have the required knowledge, a broader global base can be accessed. Access to other regions is horizontal, and need not be channeled through Brazil. This example again illustrates how the market commonalities between South Africa and Brazil facilitate knowledge and technology networks between the two countries.

Agro1's national context in Denmark places an emphasis on 'pull' factors (the availability of human capital elsewhere) with regards to competencies and capabilities, rather than 'push' factors (the shortage of human capital at home). The Danish education and training system is very strong, substantially above the EU average (Innovation Union Scoreboard, European Commission, 2010), with high levels of tertiary education, PhD graduations, and lifelong learning. Thus educational levels are high and human capital is generally available. Due to the small size of the country, firms occasionally seek supplementary skills and specialists, which creates a (relatively small) push factor. Firms face barriers when it comes to importing brains into Denmark: it is difficult to integrate foreigners into the Danish system, so firms sometimes need to open in other locations that are attractive places for specialized labour. To serve this purpose firms' internationalization has predominantly taken place within Europe or the US, but destinations in Asia increasingly attract innovation related to FDI investments from Danish companies.

From the Danish perspective, key pull factors for the internationalization of innovation are, firstly, market-specific knowledge for the region and, secondly, complementary and specialized knowledge for global operations. Importantly, incentives for internationalizing research are not related to the need for cost reductions. According to interviewees, qualified people abroad, even China, earn as much as those in Scandinavia and besides, and in any case highly qualified people and partners are readily available at home. In the case of Agro1, the South African national context offers a range of pull factors. The South African agro-food industry is an important trading partner because of its counter-seasonality to Europe and its well-developed infrastructure. One of the more recent and important developments is the establishment of a cold chain in the South African transport sector. It also acts as a gateway economy to Sub-Saharn Africa. However, in the particular case of the purchase of the South African subsidiary, it was specialized local knowledge, including knowledge networks, that was the key consideration. Firm-level interviews down-played the importance of these factors in comparison to the pull factors.

A key reason for the Danish investment was related to the tacit knowledge component of agro-food research: the capability to develop bread mixtures in a very short lead time using tacit knowledge rather than the codified methods which require much more time. This is a major advantage in a time-sensitive sector. Since the tacit knowledge could not be simply purchased and shipped to Denmark, Agro1 was further incentivized to purchase the South African subsidiary in order to access this knowledge for the group.

The South African purchase was part of the Agro1 group's broader strategy of knowledge acquisition through purchases: the company has generally grown through takeovers, and uses venture capital to buy equity in promising start-ups. It therefore represents a strategy of GIN development through the purchase of an existing innovation network in the South by a firm from the North, effectively bolstering the group's existing GIN. The transaction allows the South African subsidiary to exploit IP from all over the world when introducing new products into sub-Saharan Africa, while also augmenting the group's innovation network through linkages into the region's region's sectoral innovation network. This example shows that MNE strategies for GIN formation need not have lower cost as a main consideration, and can instead focus on knowledge access, the search for competencies and capabilities, and the search for existing networks.

5.6. GIN development in the ICT sector in China and India

In contrast to the automotive sector, tacit knowledge does not play a major role in the ICT software sector. The case of ICT1 illustrates how the global distribution of human capital influences the global distribution of innovation in the relative absence of tacit knowledge related impediments. ICT1 is a large multinational, with 550 offices and 30 manufacturing sites across 165 countries. This GPN houses an extensive GIN, including a global network of R&D centres, including major centres in both India and China (but not in Brazil or South Africa). Innovation activity relies on a strong internalized network, and also incorporates an externalized network in an open innovation model. ICT1 is therefore a large strong-form GIN – highly globalised, highly innovative, and highly networked.

Interviews highlighted three main motivations for R&D offshoring to India and China: firstly, access to large and growing markets. Secondly, the capacity to react quickly to changes in those markets. Thirdly, access to the large pool of human capital in those countries. ICT1 interviews in China and India did not highlight any significant cultural or tacit knowledge barriers to these processes (unlike the cases from the automotive sector). Within the ICT1 group, the process of GIN formation is noticeably different in Asia and Europe. In Asia the firm established new R&D centres, sometimes in partnership with local actors. By contrast, when ICT1 opens an R&D centre in Europe it is primarily through the acquisition of local firms with R&D centres that are then maintained within the Group. This, while in Asia the primary purpose and motivation is the expansion of innovation capabilities in important growing markets, in Europe the presence of specialised knowledge held locally is the primary motivation for inclusion into the firm's GIN.

The case of ICT2 has a similar national context to Agro1, also being based in a Scandinavian country with a strong education and training system and a good supply of high-level skills. However, in Sweden there has recently been a reduction in the number of graduates and a reduction in the number of researchers available for the industry (SNAHE, 2010; OECD, 2010). According to the case study interviews, this change is not noticeably affecting the firm strategy – possibly because the scale of loss isn't sufficient to make an impact at this level. As in the Agro1 case, the key issues at the national level influencing ICT2's strategic decisions with regard to GIN formation are not related to skills availability in Sweden, but to pull factors emanating from large, lucrative, and growing Asian markets. The main consideration here is proximity to the local market, and the capacity to adapt products to local demands and standards. The secondary pull factor is access to specialized domain competencies which may not always be available in Sweden, and which might also be obtained at lower cost in developing countries.

The distribution of innovation within the ICT2 group thus also reflects market size and the availability of human capital. Currently India is the firm's second largest market, while China is one of the fastest growing ones. Access to competences was an important factor in this decision, that is, the availability of a large pool of qualified human capital in an array of domains needed to provide technologically complex solutions to clients. Compared to India and China, South Africa does not have the market pull or the science base to justify the development of a formal R&D centre. However, it is recognised as a gateway into the African market. In the context of consensus in the industry that 90% of the growth in the mobile subscription base will be in emerging markets, Ericsson SA regards innovation in very poor markets as a potential growth area for the future. ICT2 thus established a small innovation unit in South Africa, with only six full-time employees, who release three to four major innovations a year, and a series of smaller upgrades. When comparing this small innovation centre to the firm's large research centres in India and China, this case again illustrates how market size and human capital availability play a central role in determining the scale of innovation outcomes.

Differences between locations can also influence the scope of innovation tasks. Subsidiaries play a double role - they adapt existing products to the local markets, but they also develop new products and services that can be further developed for global markets. It seems that between China, India and South Africa, only China has a broad enough set of competencies, as India is considered to be specialized in a narrow set of competencies (mainly regarding software development). Thus China's R&D centre has a wide scope of application, India's a narrow scope, and South Africa's R&D centre is minimal in both size and scope, serving only a handful of local customers.

5.7. GINS originating in the South

Our analysis of firm strategies relating innovation drivers with local human capital conditions would not be complete without examples of Southern firms that have expanded their GINs into Europe. Auto10 used to be a South African company that produced electronic components for OEMs, with a focus on customized engine management systems. After market liberalization and value chain changes, the firm was in danger of being substituted by global suppliers. In order to retain access to its customers, the firm needed a development facility that was recognized 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 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. This acquisition followed a similar pattern to the purchase by Chinese and Indian firms of developed country assets such as Jaguar, MG, and parts of Volvo. This purchase established the basis of an emerging GIN, in which knowledge began to flow between the Southern headquarters and the newly purchased Northern subsidiaries. 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. 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.

Another Southern firm demonstrated that local skills constraints can be overcome by solutions at the engineering level. Auto11 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, the firm 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. 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.

6. Determinants of technological upgrading and GIN formation

The case studies illustrate general trends in the relationship between capability building in developing countries and the emergence and growth of global innovation networks. For European MNCs, the primary centrifugal forces are pull forces, rather than push forces. The strong education and training systems in Europe make most of the competencies they require for innovation, including high-level domain competencies, generally available to firms. Some exceptions do occur – for example, smaller countries like Denmark or Sweden might have local shortages of specific competencies, encouraging them to look elsewhere in Europe, and more recently in Asia. However, these skills shortages were described as minor and as being of low significance in shaping firms’ strategies for the global fragmentation of innovation.

European firms are primarily concerned with pull factors. They seek competencies and capabilities that facilitate access to emerging markets, including product development and adaptation capabilities. They also seek lower-cost skills for outsourcing components of R&D within the group to serve global innovation demand. Southern firms, conversely, are primarily motivated by push factors, investing in Europe to acquire knowledge assets that are not available locally.

Skills at all levels play a role. Skills shortages on the shop floor can influence innovation processes: for example by concentrating technological change at the engineering level. In most cases, it is the profile of higher level skills, particularly engineering skills, that influences the scale and scope of innovation activity and the formation of GINs. Access to engineers allows Southern subsidiaries to grasp opportunities for product adaptation, process innovation, and product development for local markets. The availability of more advanced and more specialized knowledge can facilitate insertion into more developed GINs.

When seeking to extend their innovation networks, firms seek ‘pockets’ of capabilities and competencies that respond to their demand for innovation. Great depth and scope in human capital availability in China and India (together with larger market size) has facilitated the establishment of R&D centres that serve both the local market and the needs of the global group. By contrast, the relatively limited size of the pool in Brazil and South Africa has acted as a constraint, with local innovation activities largely confined to adaptation to local markets. This distinction holds at the lower scale: Brazil has a larger market and larger human capital pool than South Africa, and consequently hosts more R&D and more evolved GINs, while South Africa hosts very little R&D, and often participates in low-intensity or incipient GINs. This generalized finding is supported by our case study evidence from China, India, Brazil and South Africa, including firms from all three sectors.

These generalized macro-determinants are contextualized by a wide variety of micro-determinants that affect the relationship between human capital and GIN formation. Each case study represents a unique combination of these determinants; at the same time, patterns emerge. Table 4 summarises how these determinants have been relevant to the selected case studies of North-South GIN formation, while

Table **5** illustrates South-North cases.

Table 4: Determinants of North-South GIN formation

Firm	Countries	Key micro-determinants (pull factors)
ICT3	Sweden/Estonia	Availability of specialized human capital, Geographical proximity, Low cultural barriers
Auto1	Germany/South Africa	Regional gateway, Long logistical pipeline, Demand for local product development and adaptation, (management constraints on innovation activity at the subsidiary)
Auto9	Germany/South Africa	Regional gateway, Demand for local product adaptation, Regional commonalities with Brazil

Auto4	Italy/Brazil	Regional gateway, Demand for local product development and adaptation
Auto3	Italy/Brazil	Regional gateway, Demand for local product development and adaptation, Policy incentives
Auto1	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Auto2	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Auto9	Germany/India	Large domestic market and growth potential, Large available human capital pool at lower cost, (tacit knowledge barriers, cultural barriers)
Agro1	Denmark/South Africa	Regional gateway, Local demand for adaptation, Regional commonalities (with Brazil), Tacit knowledge acquisition, Specialised knowledge acquisition, Local network acquisition
ICT1	Sweden/China/India	Large domestic market and growth potential, Large available human capital pool at lower cost, innovation management structures
ICT2	Sweden/China/India	Large domestic market and growth potential, Large available human capital pool at lower cost
ICT2	Sweden/South Africa	Regional gateway, Demand for local product development and adaptation

Table 5: Determinants of South-North GIN formation

Firm	**Countries**	**Key micro-determinants (push factors)**
Auto10	South Africa/UK/USA	Local skills shortages, proximity to customers
Auto11	South Africa/Australia/New Zealand	Proximity to customers

The key micro-determinants that emerge from this analysis are:

- *Market:* size, growth potential, local demand for adaptation, local demand for new product development
- *Human capital availability*: scale, scope, technology-specific competencies and capabilities, strength of the National System of Innovation, specialized knowledge assets, tacit knowledge assets, network assets
- *Sector*: role of tacit knowledge versus codified knowledge, sector-specific skills demands, value chain structures, sectoral innovation drivers
- *Geography*: geographical proximity, regional gateways, logistics, regional commonalities

- *Culture and tacit knowledge*: cultural/linguistic commonality, ease of tacit knowledge transfer
- *Infrastructure*: logistics, ICT
- *Policy*: IPR regimes, policy incentives
- *Management*: innovation management structures, strength of internalized knowledge networks, strength of value chain knowledge networks

We began Work Package 6 by postulating that the tale would be one of (Northern) MNCs that embody certain capabilities, while at the same time looking for new ones, and of education and training systems (in the South) that are an essential element of the very absorptive capacities that INGINEUS conceptualizes as a local or national building block of GINs. The case study analysis confirms this generalised conceptualization, but it goes further, to identify the complex set of micro-determinants of the relationship between competences and capabilities and GIN formation.

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Globalisation of innovation in the Danish agro food industry

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Table of contents

1. Executive summary

This paper is based on the model of internationalization of innovation developed by Archibugi and Michie (1995) – focusing on the globalization of technology. The model includes three types of organizing innovation that relate to stages, or levels, of internationalization. These three levels are matched by different ‘push factors’ for why off-shoring and outsourcing of research and development (R&D) appear in companies’ strategies, relating to the distinction between the strategies of knowledge exploitation and knowledge exploration as developed by Kuemmerle (1999). Likewise, the ‘pull factors’ vary according to location-specific factors and whether these are market related or relate to R&D, or production. By analysing the globalization of R&D in the Danish agro food industry and the strategies behind it, this paper will discuss whether different push factors have connections to different pull factors at the other end of the off-shore equation. The diverse strategies undertaken by the lead firms are likely to impact the host economy differently. For example the internationalization of innovation through exploitation may neither need nor develop local capabilities, while exploration strategies are more likely to both seek and engage with local competences in the host country. This differentiation will potentially provide a more nuanced understanding of how the internationalization of R&D shifts from international exploitation to global generation and techno-scientific collaboration.

Innovation in the agro food industry is increasingly internationalized and some Danish key actors (companies as well as universities) have developed into world leaders in certain products and research fields. However, their activities are still unevenly distributed in geographical terms. The internationalization of innovation in the Danish agro food industry has so far primarily been oriented towards Europe and the US. More recently, it is also oriented towards ‘emerging markets’. This onward process of the internationalization of innovation in food and ingredients into new markets has been following a similar path. Firstly, the companies enter new markets with their products developed in Denmark. Secondly, some companies start to adjust their products to the new markets (e.g. pancake ingredients to tortillas or chapattis). Thirdly, some of the most internationalized companies have also established techno-scientific networks in the foreign locations. These companies explain the need for techno-scientific networks as a strategy for ‘tapping into knowledge’ by collaborating with local research facilities and suppliers at the new market locations. Hence, the pull factors for the internationalization of innovation are 1) market specific knowledge for the region, and 2) increasingly complementary and specialized knowledge for global operations.

2. Introduction

The Danish economy has developed on the foundation of a high level of activities within the agricultural sector which has led to the development of a strong agro food industry. This industry is today one of the most innovative in the world. The agro food industry includes the large number of actors involved in the development and production of food products[1]. As most of these products are relatively freshly produced with limited shelf lives, and due to the fact that food tastes vary a lot over geographical regions, the products are predominantly sold within Denmark and Europe. At the European level, the agro-processing sector is one of the largest and most important manufacturing sectors. It accounts for 14.5% of total European manufacturing turnover (€917bn for the EU-27) and 14% of total employment in the manufacturing sector.

One of the main characteristics of the European, and within this the Danish, agro food industry is that it contains a very large number of small and medium enterprises (SMEs) and few large-scale multinational companies (MNCs). The larger companies are more engaged with innovation as well as internationalization and thus the case studies are selected from among the largest Danish agro food companies, the MNCs. In Denmark, the agro food industry accounts for approximately 20% of national exports of which 64% is sold within Europe. At the national level there are 3512 people employed in R&D in agro food in Denmark, of which approximately 60% is in the private sector. 246 of the Danish agro-processing companies have R&D. The Danish government traditionally has a strong focus on this sector and aims to develop the national food-industry into an Agro Food Valley by the year 2022 (Ministry of Food and Agriculture, 2009). The rationale behind the creation of this Agro Food Valley is based on the overall vision that Denmark should remain a lead location for agro food innovation in Europe and to increase the competitiveness of the industry. Furthermore, the vision is to sustain an environmental and sustainability focus including the strengthening of organic production. Finally, there is a focus on high value-added activities such as facilitating development within the gourmet value chain and tourism. One of the recent initiatives is the establishment of the Agro Food Park outside Århus in 2009. This park is designed to host between 40 and 50 companies and facilitates collaboration and knowledge sharing along and across the value chains within the Danish agro food industry. The location is close to the second largest university and some of the large Danish food companies. Two of these are among the leading Danish food producers, Danisco and Arla, which together have more than 500 people in R&D in the region.

3. Creating innovation beyond the home country

Archibugi and Michie (1995) have developed a taxonomy for the globalization of innovation. This taxonomy includes three main categories which are not necessarily mutually exclusive but are understood to have emerged in successive stages (Archibugi and Iammarino, 1999). The first category is international exploitation. International exploitation implies the marketing of nationally produced innovations beyond the company's home market, i.e. through exports, licensing and off-

[1] Products produced by this industry are: meat, fish and mollusks, fruit and vegetables, vegetable and animal oils, dairy products, grain mill products, bakery and farinaceous products, prepared animal feeds, etc.

shoring of production. The second category is global generation of innovation. This entails corporations re-organizing their activities beyond their home economy and (re-)locating R&D and other innovative activities both within the home country and in host countries. This could for example be intra-firm off-shoring of R&D (i.e. foreign direct investments in R&D) in order to adjust products to local conditions, tastes, or government regulation. The third category is global techno-scientific collaboration. In this, companies and universities collaborate in joint scientific projects and innovation networks across countries and continents. This would be for cutting-edge innovation, such as second generation bio-fuels and genomics.

In reality, MNCs may engage in all three types of internationalization of innovation and their engagement potentially differs according to different factors: intra-firm (size, products, innovations), features in the host economy (e.g. location attractiveness – see Haakonsson et al., forthcoming), and the home country of the MNC. Regarding location attractiveness, the three types of globalization of innovation relate to the MNC strategies of off-shoring and outsourcing R&D through knowledge exploitation and knowledge exploration/augmenting, as developed by Kuemmerle (1999). Although the literature has been looking into the push factors faced by MNCs which lead them to internationalize their activities, e.g. the need for larger markets to recover the costs of R&D (exploitation) or the need to access specialized knowledge not available at home (exploration) or something in between such as accessing cheaper human resources in low cost locations (exploitation and/or exploration), this has not been directly connected to the pull factors in the host economies (e.g. availability of skilled personnel, research institutions, national regulative framework, infrastructure etc.).

This paper looks at four of the largest and most knowledge-intensive Danish agro food companies, all four of which have developed into MNCs with global market reach and have internationalized production and markets. Two of the companies have specialized into production of ingredients and enzymes and are among the world leaders in their field. The ingredient and enzyme industry has a strong foothold in Denmark but supplies ingredients to food-producers globally. The other two companies are also knowledge-intensive and engaged in R&D. However, their products are final products for direct consumption. Hence, the aim is to unveil whether different types of companies in different segments of the agro food value chain show different patterns in the construction of global innovation networks and the possibilities of host economies in this regard. In other words: how can we understand the push factors situated in the home economy and pull-factors in the host economies of the large companies re-structuring their innovation activities into global innovation networks?

4. The conditions of the companies at home

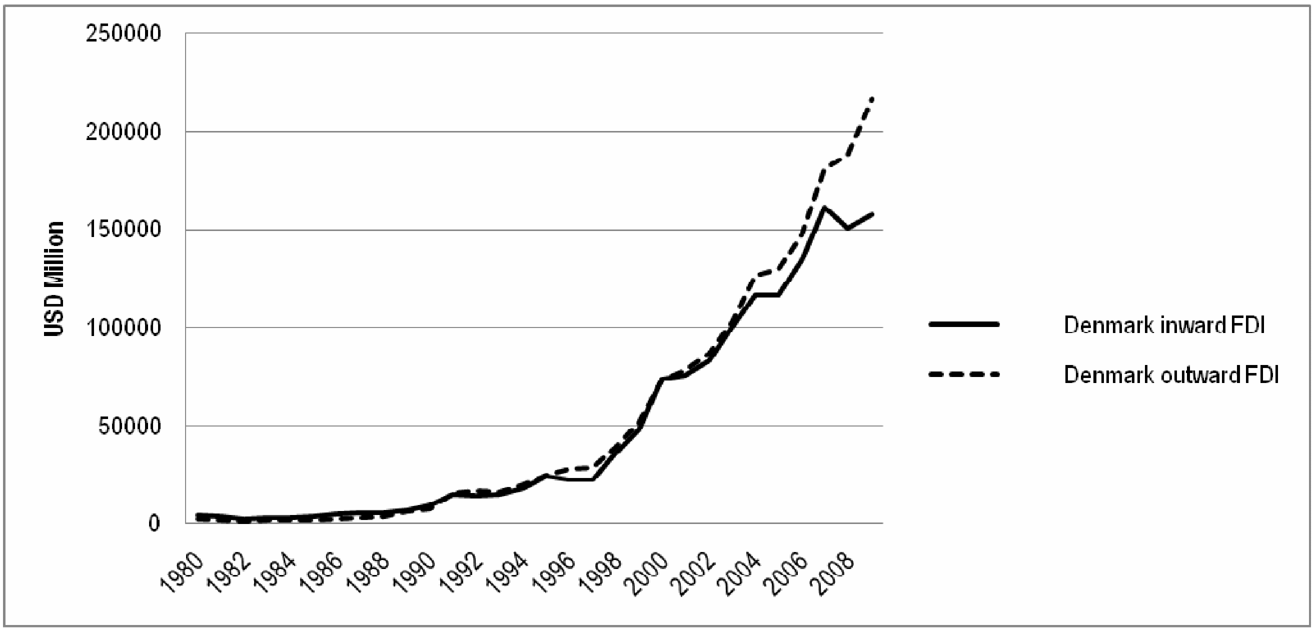
The Danish economy has a tradition of collaboration, with networks among public and private actors, which is one of the core comparative advantages, also within research and innovation. According to the annual Global Competitiveness Report (World Economic Forum 2010), Denmark ranks as number nine among the 139 countries in 'competitiveness'[2]. Put differently, the home conditions for Danish companies are good and the economy is an attractive location for Danish as

[2] http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2010-11.pdf

well as foreign companies. Moreover, the Danish economy is relatively small and open which potentially calls for a larger degree of internationalization of companies than would be the case in larger economies. Consequently, in order to cover the costs of introducing new products, companies need to go beyond their national market. Danish companies are highly 'Europeanized' in their market reach (Haakonsson and Thompson, 2010). However, main markets do not provide relevant information about the internationalization of companies.

Foreign direct investment (FDI) is an informed measure of the internationalization of activities and provides information about the amount of money spent abroad. As illustrated in Figure 1, inward and outward FDI in Denmark really took off in the late 1980s to early 1990s and both have grown considerably over the last decades.

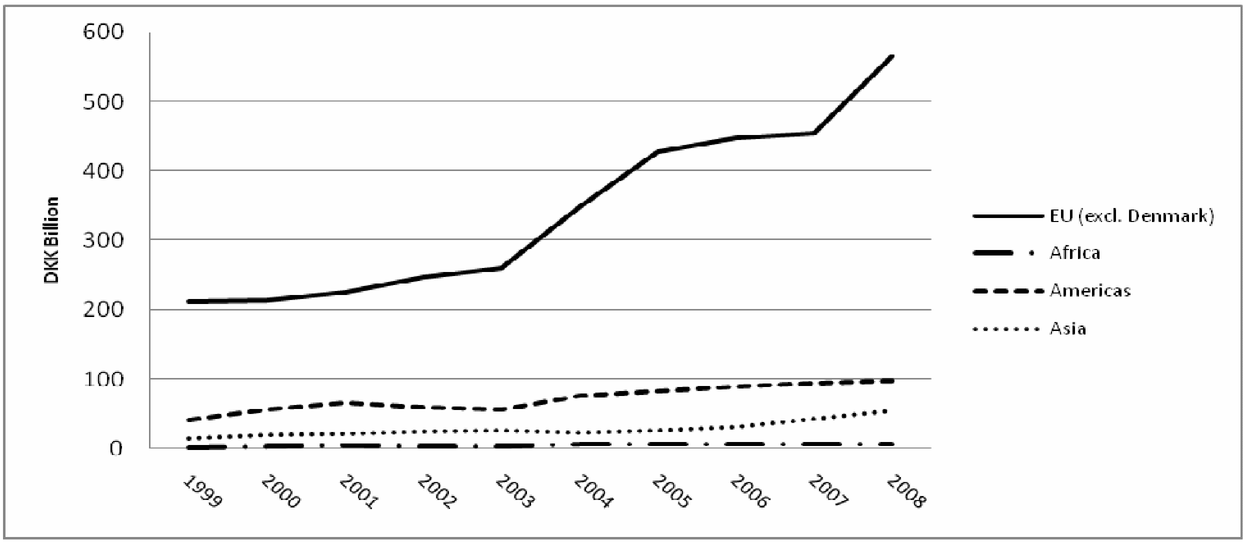
Figure 1: Denmark: Inward and outward FDI stock 1980–2009 (USD Million).



Source: UNCTAD, 2010

Looking at the direction of Danish companies' outward FDI it orients towards destinations within the European Union. Hence it may be argued that the Danish economy has generally undergone Europeanization rather than internationalization (Haakonsson and Thompson, 2010; Thompson and Kaspersen, 2009). However, as seen in Figure 2, although Europe dominates in the location of FDI from Denmark, investments into Asia and the Americas have increased over the last decade.

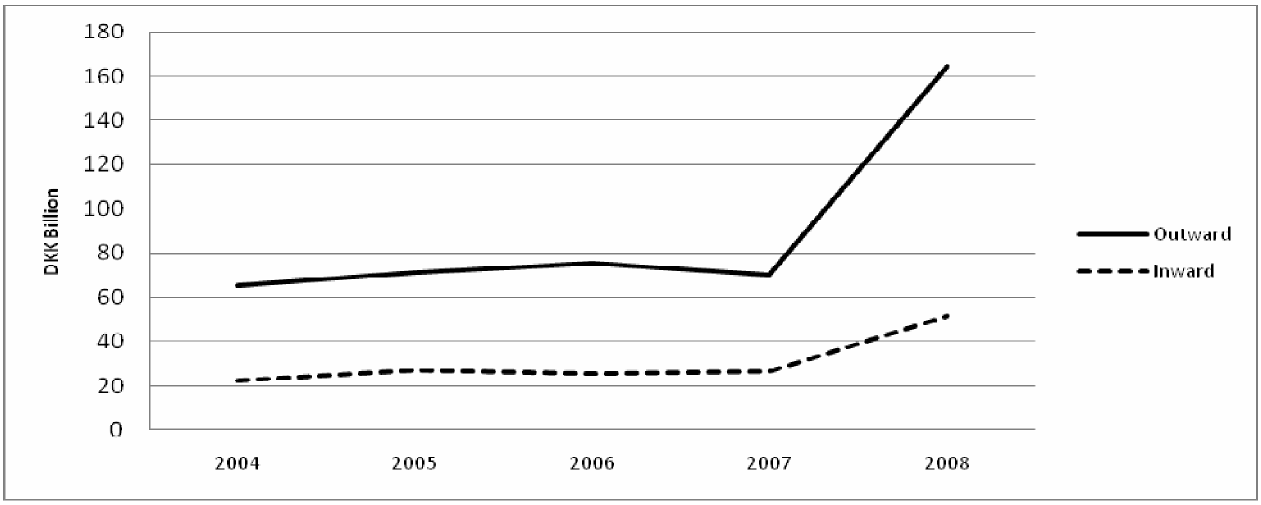
Figure 2: The four most important (world region) destinations of outward FDI from Denmark 1999–2008 (DKK billion).



Source: Statistics Denmark, 2010

Although it is only showing direct investments in and out of the Danish economy, i.e. the setting up of plants, laboratories and sales offices abroad and hence not showing other relationships such as outsourcing, contracting and innovation collaborations, this figure mirrors the general orientation of the internationalization of research within the Danish industry. Looking into the Danish agro food industry more specifically, the FDI levels follow the overall upward trends, however the level of outward investments compared to inward investments is higher in this sector (see Figure 3).

Figure 3: FDI in the Danish Agro-Food industry (stock, DKK Billion).



Source: Statistics Denmark, 2010

Denmark has a strong tradition in the agro food industry and is currently the third largest food cluster by employment in the EU according to the European Cluster Authority (ECA, 2010). Furthermore, the Danish agro food industry is perceived the most innovative among the food clusters in the European Union and is also export oriented (see Table 1).

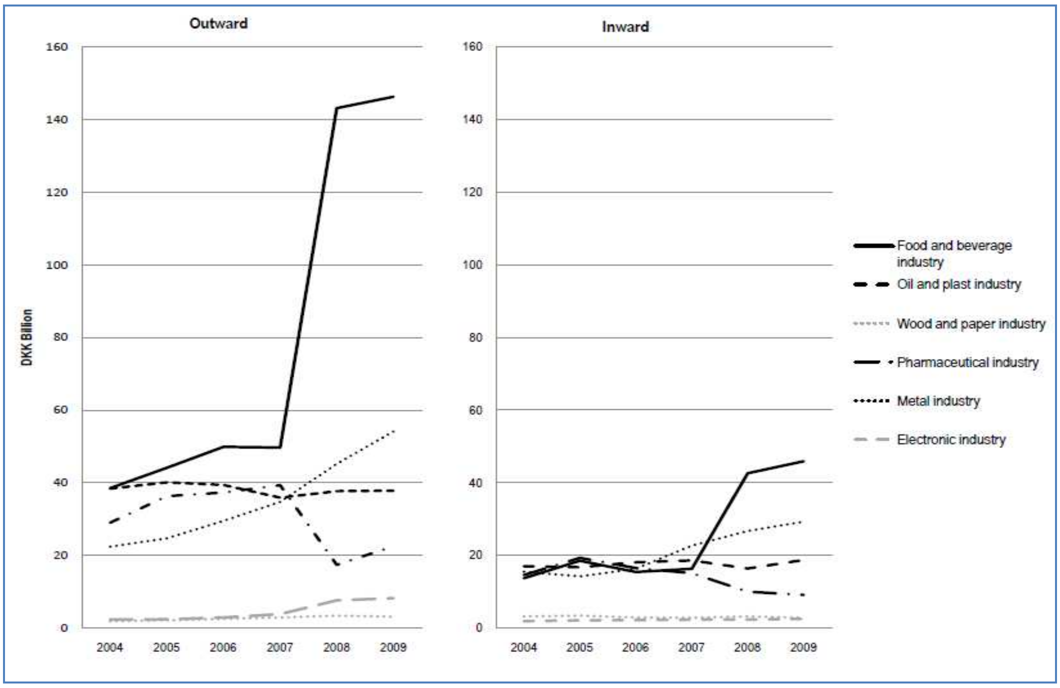
Table 1: The three largest agro food clusters in the European Union.

Cluster	Employment	Innovation	Export
Lombardia (Milan), Italy	107,806	Medium	Strong
Cataluña (Barcelona), Spain	103,066	Medium	Strong
Denmark[3]	76,203	High	Very strong

Source: European Cluster Authority, 2010

Over the last two years, the food and beverages industry has obtained the highest level of inward and outward FDI among the Danish industries (see Figure 4).

Figure 4: Inward and outward FDI flows by sector, DKK billion. Primary products and services are not included.



Source: Statistics Denmark, 2010

[3] Due to its small size, Denmark appears as a national region.

Meanwhile, the importance of this industry in the home economy has decreased both in terms of the number of companies and the reduction in employment by almost 10% (see Table 2). Over the last decade more than 4000 jobs have been lost and approximately 150 companies have closed or merged with others.

Table 2: Companies and employment in agro food 2000–2008.

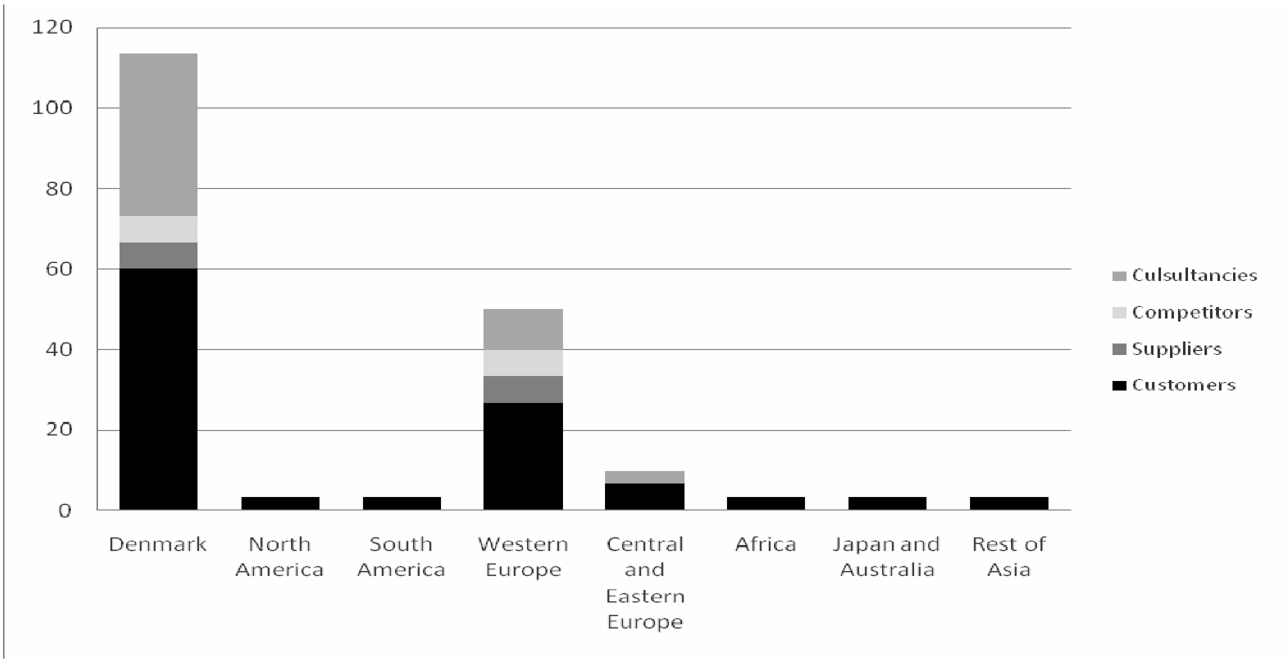
	2000	2001	2002	2003	2004	2005	2006	2007	2008
Agro-food companies	1596	1558	1556	1478	1500	1506	1498	1458	1442
Employees in agro food	42444	41490	41017	40476	38663	37475	37560	37840	38201

Source: Statistics Denmark, 2010

In order to understand collaboration in the agro food industry, we will look into our INGINEUS data. In Denmark the INGINEUS Survey covered the agro food industry.[4] The surveyed companies reported that most of their collaboration is with customers, consultancies, and suppliers. Furthermore, these customers, consultancies, and suppliers are predominantly located in Denmark and Western Europe (see Figure 5).

[4] The survey included all agro food companies with five or more employees excluding locally embedded companies such as local butchers and bakeries. Of the 200 companies receiving the questionnaire, 48 companies responded. This is an overall response rate of 24 percent.

Figure 5: Geographical location of Danish agro food companies' collaboration in the development of the most important innovation in the last three years, percentage of companies.



Source: INGINEUS survey 2010

Although FDI is increasing, there is little evidence of internationalization of innovation beyond Europe in this industry. When it comes to innovation, Danish companies tend to have a narrow geographical focus and this focus predominantly relates to upstream and downstream actors in their value chain and supplemented by national consultancy companies. The industry at large is highly embedded in the Danish national innovation. However, a few companies report innovation beyond Europe. These will be the focus of the case studies later in this paper.

5. Agro-food industry and its embeddedness in the Danish NIS

Those Danish companies that are among the world leaders are also the particularly knowledge-intensive and/or very specialized ones. Due to the characteristics of the Danish innovation system – a small open economy based on interpersonal networks (Haakonsson and Borrás, 2010; Katzenstein, 1985; Maskel, 2004), these companies' operations are embedded in more or less formalized networks, at the national level (e.g. windmills, agro food, clean tech, and transport) or as clusters with regional specialization, such as Medico-Valley in the Copenhagen region and the above-mentioned Agro Food Park at Århus. However, since the home market is small, being a successful player in industries driven by innovation implies potentially a high level of internationalization, at least in the market segment of their value chains. In the agro food industry, those of the Danish companies who have developed into lead firms within innovation have developed into strong international players. This is also the case within the clean tech (e.g. Copenhagen Cleantech) and transport (e.g. Blue Denmark) industries. Besides their international scope, Danish lead firms are characterized by their strong networks within the Danish innovation system, upwards as well as downwards in their value chains, and a supportive innovation system (Haakonsson and Borrás 2010).

Education and training is seen as one of the most important factors for competitiveness and hence a high political priority. According to OECD Stat (2010), the percentage of the Danish population graduating from tertiary education was 47.3% in 2007 (up from 37.3% in 2000). In addition to this, the number of PhD graduations from Danish universities has increased from 720 in 1996 to 1239 in 2009. Among these are a number of industrial PhDs whose programmes are co-funded by the universities and private (or public) companies. In comparison to the EU average, Denmark has a high-ranking educational system and a strong tradition for life-long learning with a high degree of enrolment. This is illustrated in Table 3.

Table 3: Higher education and life-long learning enrolment in Denmark and EU27.

Enabler	EU27	Denmark
Tertiary education (per 100 population aged 25–64)	24.3	34.5
Life-long learning (enrolled per 100 population aged 25–64)	9.6	30.2

Source: Innovation Union Scoreboard, European Commission, 2010

To sum up, the Danish economy and business context is both competitive and attractive. The educational level is very high and human capital generally available. Besides the high educational level, employees also develop their competencies throughout their working life via life-long learning programmes. However, due to the small home market, companies need to engage beyond the Danish economy in order to generate the capital needed for developing into innovative lead-firms. These companies' internationalization predominantly takes place within Europe and the US. However, destinations in Asia increasingly attract innovation related FDI investments from Danish companies. In the next section we will look into the sourcing undertaken by large Danish companies, i.e. the internationalization of production and innovation.

6. International sourcing by Danish companies

A study carried out by Statistics Denmark in 2008[5] on patterns and reasons for outsourcing by Danish companies showed that 19 per cent of medium and large scale Danish companies have sourced internationally, i.e. they engage with outsourcing and/or off-shoring. The most commonly sourced function reported was 'core business functions', reported by 52% of the sourcing companies, while 15% of the sourcing Danish companies were engaged in sourcing R&D (Statistics

[5] This is based on a special dataset developed by Statistics Denmark, Finland, Sweden and Norway in 2008 on outsourcing from the Nordic countries. The survey was mandatory and covers 97% of Danish companies with more than 50 employees.

Denmark, 2008). Less than 3% of Danish companies with more than 50 employees sourced R&D functions internationally.

Among the companies engaged in sourcing, the vast majority of their international sourcing was oriented towards destinations in the European Union (see Table 4). However, the percentage of companies sourcing from India and China is increasing. Approximately 30% of the medium and large Danish companies sourced from Asia (see Table 4). Compared to similar companies in the other Nordic countries, Danish companies are relatively more internationalized beyond the European Union. In fact, almost half of the sourcing from Danish companies came from outside the European Union; for manufacturing 49% and service 54% of the sourcing instances had destinations outside the European Union. Danish companies outsourced most of this to China.

Table 4: Geographical breakdown of core functions sourced internationally 2001–2006. Share of total number of functions sources (enterprises with 50 or more employees).

Destination	Denmark		Finland		Norway	
	Manuf.	Service	Manuf.	Service	Manuf.	Service
Old member states	17	25	20	24	21	36
New member states	34	21	34	39	40	29
China	24	16	21	8	23	-
India	4	9	7	9	-	17
Other countries	21	29	19	21	15	18
Within EU	51	46	53	63	61	64
Outside EU	49	54	47	37	36	36

Source: Statistics Denmark, 2008

According to the above survey, the motivation for international sourcing as stated by the Danish companies predominantly relates to cost reduction. Almost 60% of the sourcing companies stated reduction of labour costs as a motivating factor for outsourcing. Reduction of other costs was important for 39% of the companies whereas access to specialized knowledge was an important factor for 13% of the sourcing companies (see Table 5).

Table 5: Motivation factors for international sourcing. Share of enterprises having sourced internationally 2001–2006 and reporting 'very important' for the motivation factor concerned.

	Denmark	Finland	Norway	Sweden
Reduction of labour costs	59	42	43	58
Reduction of costs other than labour costs	39	21	29	29
Access to new markets	11	23	18	10
Following the behaviour/the example of competitors/clients	4	30	8	-
Improved quality of introduction of new products	9	7	9	-
Strategic decisions taken by the group head	24	42	51	59
Focus on core business	21	18	18	18
Access to specialized knowledge/technologies	13	11	12	12
Tax or other financial incentives	2	2	4	-

Source: Statistics Denmark, 2008

A main concern is the consequences of outsourcing for the home economy, particularly the loss of jobs at home. According to the companies in the Danish survey, the gross job losses due to international sourcing account for 25,000–35,000 jobs in total – or approximately 5,000 jobs annually in the period 2001–2006. This is an annual loss of less than 1 per cent of the Danish workforce employed in the companies with 50 or more employees. Furthermore, according to the companies those jobs moving abroad are mainly low-skilled jobs (two-thirds of all job losses were reported to be for unskilled labour). This is especially the case within the manufacturing sector (more than 75%). At the same time, the international sourcing process also generated new jobs. However, the survey also showed a total creation of 7,000–10,000 jobs in Denmark for the period 2001–2006 or approximately 1,400 jobs created annually in the observed period. The result is therefore a relatively low level net loss of jobs (around 3,600 jobs annually). The jobs created in Denmark due to the international sourcing activities of the enterprises were, to a large extent, reported as highly skilled jobs. A sector analysis of the outsourcing of knowledge intensive jobs in the Danish IT sector showed that the IT companies creating jobs outside Denmark (also within the knowledge-intensive activities) are also the ones generating most jobs at home (Haakonsson and Rasmussen, 2010).

So far, we have covered the 'global' in relation to the Danish industries and for the agro food industry where possible. Next we will look into the parameters for innovation and network.

7. Innovation and networks

Coming back to the Global Competitiveness Report, but this time looking into some of the innovation indicators, Denmark ranks as number 9 in terms of 'capacity for innovation' (see Table 6, World Economic Forum 2010).

Table 6: The rank of Denmark according to the World Economic Forum, 2010.

Rank	Indicator
9	Capacity for innovation
12	Quality of scientific research institutions
7	Company spending on R&D
8	University-industry collaboration in R&D
9	Government procurement of advanced technological products
19	Availability of scientists and engineers
15	Utility patents per million population

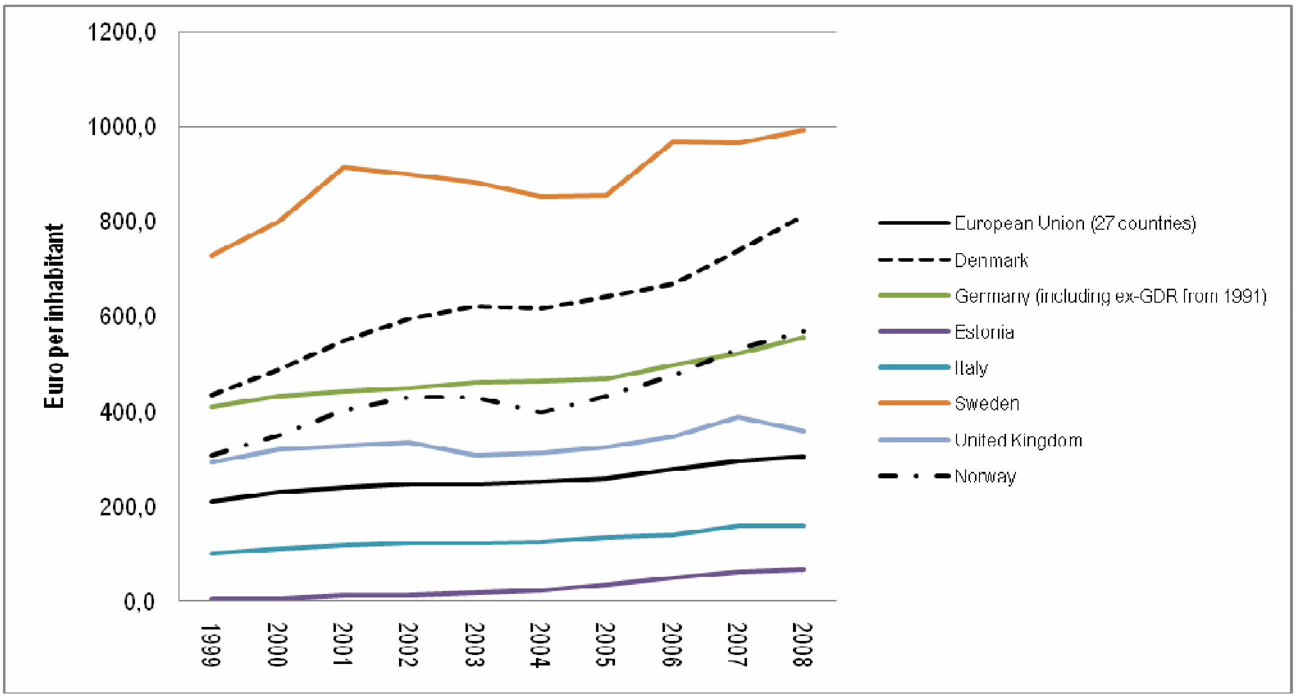
Source: www.weforum.org

The relatively high rankings may be explained by the educational system which we have seen produces many PhDs and engages the majority of the work force in life-long learning. Moreover, innovation is not necessarily taking place in R&D units but increasingly in 'learning organizations'. In addition to the innovation indicators, Denmark also ranks high in the World Economic Forum (WEF)'s 'Network readiness' indicator. In 2010 Denmark was number three (down from number one the two previous years).

8. Research and Development in Denmark

Looking at the amount of Euros spent on R&D per capita in each INGINEUS country and in EU-27 on average, Denmark has a high level of R&D expenditure. R&D spending per capita is more than double the EU-27 average and, among the INGINEUS countries, Denmark comes second after Sweden (see Figure 6). Over the last ten years the amount spent per capita in Denmark has doubled, which supports the findings of the previous section, namely that those jobs staying or being created in Denmark are more knowledge-intensive than those leaving.

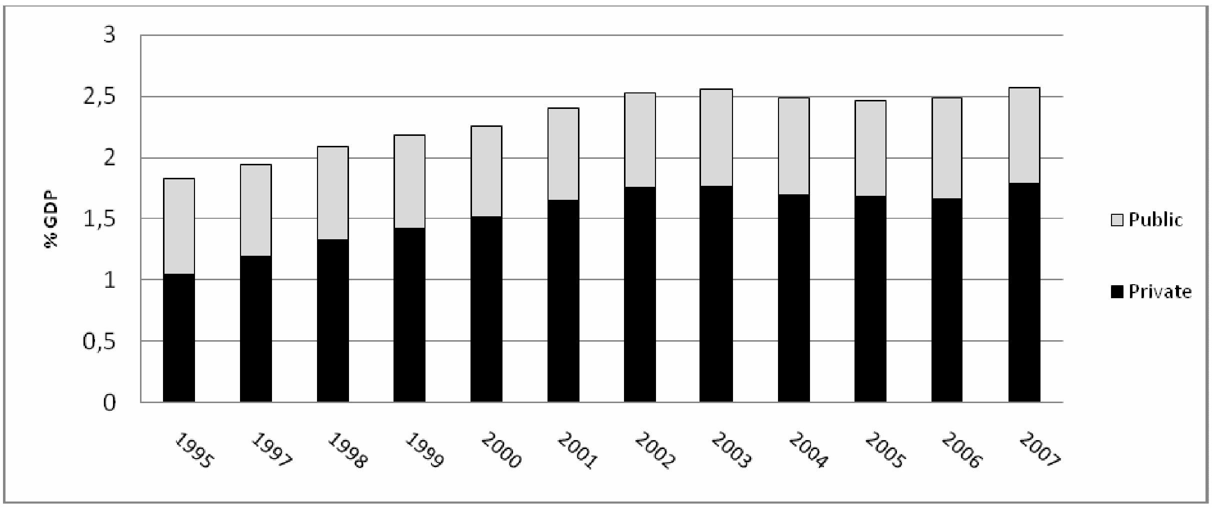
Figure 6: Total intramural R&D expenditure (Euro per capita) for the INGINEUS countries and EU27 average.



Source: Eurostat, 2010

At the national level R&D expenditure in percentage of GDP is also increasing (see Figure 7). This is relatively high and, as discussed below, it is particularly high in the food sector.

Figure 7: R&D at the national level as percentage of GDP.



Source: Statistics Denmark, 2010

The most problematic factors of doing business in Denmark do not relate to available competencies, innovativeness or network readiness. The push factors motivating Danish companies to shift activities such as innovation abroad, or keeping foreign companies from investing in Denmark, must be explained by other factors. According to the WEF, business survey companies report tax rates as the largest barrier for operating in Denmark followed by access to financing, tax regulations, inefficient government bureaucracy and restrictive labour regulations (WEF, 2010–2011). Hence, the push factors are not so much related to the 'warm bodies', e.g. the availability of qualified labour, but to the institutional system. Ironically, the same system that provides the workforce and makes Denmark attractive also functions as a barrier to investment in R&D and other innovative activities in Denmark (the high tax rates, limited venture capital, bureaucracy and labour regulation).

9. Innovation and internationalization: push / pull factors in the agro food industry

The Danish Food and Beverage industry contributes 8.53% of the Danish GDP and produces 20% of Danish exports in value terms. 64% of exports within the industry is sold within Europe. 85% of the companies are small and medium scale enterprises (less than 20 employees). This section is based on four in-depth case studies with some of the largest Danish innovative and internationalized agro food companies.

Regarding the level of R&D, there is a need to distinguish between the 'R' and the 'D', where *research* in this industry relates to innovation and the introduction of new products and services, while *development* is innovation in further developing existing products or applying these to new markets. Within the introduction of new products and core *research*, Danish companies are not concerned about *push* factors but they are interested in the *pull* factors elsewhere. In the interviews one of the companies expressed this by following statement: "not all good knowledge and innovation comes from Denmark". The case companies express that they are looking for supplementary skills, specialists, etc. Two of the companies have re-organized their R&D into 'global operations' in which projects are taken care of by the most specialized in the particular field, often spanning across R&D locations/sites.

With regard to *development* the companies are more dependent on the market. The agro food market is characterized by high diversity, e.g. in tastes, textures, raw produce, quality, etc. Therefore companies internationalizing their market need to engage in such development as adjusting their products to local markets, local raw materials, and local conditions. This relates to a market access strategy or exploitation (which is the second type in the Archibugi and Michie model). All four case companies are engaged in the development of their products within their markets. One good example is the investment of one of the companies into researching methods for using yeast for low quality wheat flour in South Africa, aiming at the African market in the longer term.

In terms of the competitiveness and location attractiveness of Denmark, the companies have concerns about barriers they face in regard to 'importing' brains from elsewhere. They explain this in terms of the difficulties of integrating foreigners into the Danish system. Therefore as will be elaborated more below, these companies need to change location to more attractive places for specialized labour.

10. Research in the agro food industry

Recently, there has been a mapping of ‘research and innovation in the Danish agro food industry’ (Ministry of Science and Technology, 2010). The main results were that this industry is the home of:

- Global leaders
- Networking companies and universities
- Activities of networking internationally
- A high number of strong patents
- A high level of academic publications

The food industry is of a medium size compared to the other Danish industries. Among the publicly funded research activities, the agro food sector gets 7% – a little more than, for example, the IT and energy sectors. Three universities are the most active in R&D within agro food. These are the University of Copenhagen, the University of Aarhus and the Technical University of Denmark. All three institutions collaborate with companies. Compared with the average research spending, the share of applied research is higher in the agro food sector (61%) than within other research areas (42%).

246 of the companies in the food sector are engaged in R&D. 2230 people are employed in R&D in companies in this industry of which 33% are researchers (see Table 7). The total amount spent by companies on R&D is approximately DKK 2.1 billion (ibid.). 90% of this was provided by the companies while 10% came from other sources in Denmark (6%) and abroad (4%). The 4% foreign sources are EU (2%) and companies within the same groups (2%).

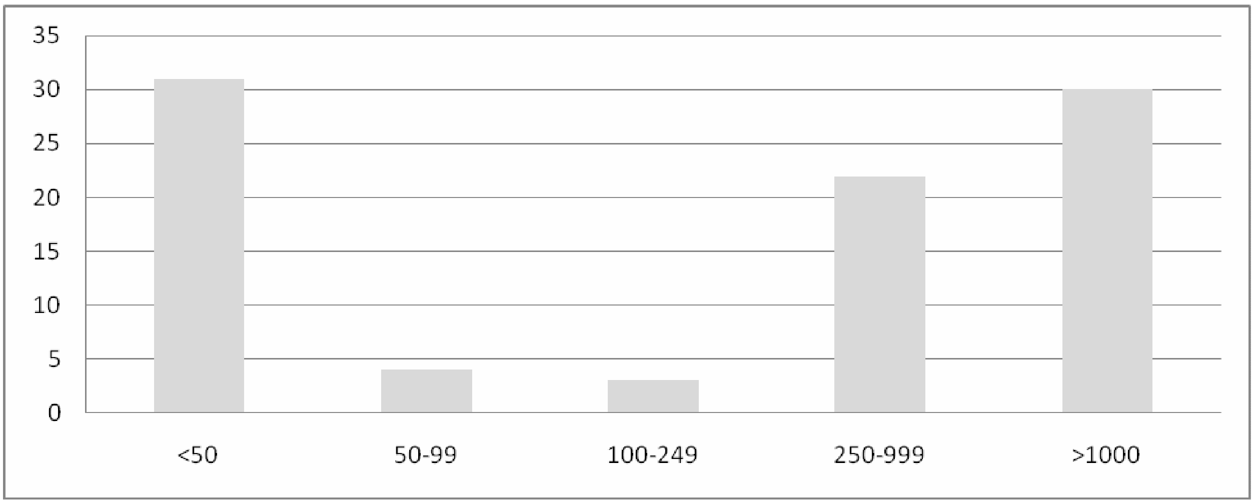
Table 7: Food companies with R&D.

Year	Companies	People in R&D	R&D expenses (DKK billion)
2008	246	2230	2067
2007	246	2172	1610

Source: Ministry of Science and Technology, 2010

R&D expenses are increasing. At the national level, the food industry also has a strong foothold in R&D. Research within food accounts for 6% of total research spending in the private sector and this is distributed in large as well as small companies (Figure 8).

Figure 8: Distribution of full time employees in food-related R&D sorted by company size.



Source: Ministry of Science and Technology, 2010

Denmark ranks third in the OECD in food patenting (by population size). 116 patent applications came out of the Danish agro food industry and research institutions in 2008 while 63 patents were granted by the European Patent Organisation the same year (from the previous year's applications). Along with the university researchers, a few companies are extremely dominant in this group; 11 companies took more than five food-related patents between 2004 and 2008 (see Table 8).

Table 8: Patents by companies in the Danish food industry.

Company (food related division)	Patents 2004-2008
Novozymes	62
Danisco	39
Novo Nordisk	32
Slagteriernes Forskningsinstitut	19
Aasted-Mikroverk	15
Gumlink A/S incl. Dandy A/S	15
Chr. Hansen	12
CP Kelco	9
Rhodia Chimie	6
Neurosearch	6
Egebjerg Maskinfabrik	6

Source: Ministry of Science and Technology, 2010

In addition to this there are strong and formalized forms of collaboration between companies and universities: 68% of the companies have participated in R&D collaboration, predominantly with suppliers (81% of the companies collaborating), secondly with customers (75% of the collaborating companies) and thirdly with public institutions (57%). Academic research within the food industry is also internationalized: 75% of the scientific publications within food research are co-authored with people from outside Denmark. The five most important foreign partners are UK (11%), Sweden (10%), US (9%), Germany (8%) and the Netherlands (7%). China comes in as number 19 with 1.8% of co-authored publications. Denmark is the country with the most scientific publications related to food, per capita.

11. What Danish agro food companies look for when internationalizing innovation

Knowledge-intensive activities are increasingly taking place across national boundaries and involve more actors than before. This is also the case for the large Danish agro food companies. Four companies were chosen for INGINEUS, which are all among the most research-intensive companies in the Danish agro food industry. All four companies have internationalized their R&D and other innovation activities and hence innovation is increasingly dispersed across national boundaries. These companies’ emerging global innovation networks are generally constructed through company subsidiaries linking into local research environments at the location, also in emerging economies (e.g. in Bangalore or Beijing). Most of the outsourced R&D activities carried out by the companies are kept in-house for various reasons – but the companies express a need and desire to link into local knowledge for two main reasons, namely exploitation and augmentation/exploration.

Exploitation is used as a strategy to adapt their current products to local tastes, raw materials and markets (e.g. as is the case with the development of yeast for local wheat varieties in places like Sub-Saharan Africa, or for identifying the use of enzymes for pasta into new products, such as noodles). For this type of internationalization local customers seem to be important, as are locally present global customers who are important partners in the innovation network (for those not producing for the end consumer). Augmentation is a strategy to tap into knowledge which the companies do not access elsewhere or which is better or cheaper in an existing setting (as when one of the companies bought an Indian producer of surface-grown proteins). For this type of internationalization – home base augmenting strategies – local institutions, competitors, universities, etc. are important actors. These two models of the internationalization of innovation are not mutually exclusive. Often both these strategies explain a company’s presence in a location and are often both part of its location strategy. As the FDI by Industry diagram shown above indicates, the food and beverage industry is, on average, more internationalized beyond Europe than are other industries. To get a more in-depth understanding of which processes are at play when Danish food-related companies internationalize innovation, this paper will now turn to in-depth case-studies with four of the Danish food-industry innovation leaders. The first two companies are specialized within the bio-tech related part of the industry and are both primarily involved in production of ingredients and additives. The other two produce more traditional products developed in Denmark but adjusted to local tastes.

12. Case companies

Among the companies two models were identified. The first is globalization of innovation and the second is internationalization of innovation. The first implies a re-organization of innovation processes at the global scale involving techno-scientific networks of specialized knowledge actors for research and development. For this the capital ‘G’ will later be used in relation to global innovation networks (GINs). The second implies a stronger internationalization – or Europeanization – of innovation, mainly as product development and in collaboration with actors upstream and downstream in the companies’ value chains; here the lower case ‘g’ will be used to indicate innovation networks that are not as global as those with a capital ‘G’. In terms of innovation – the ‘I’ in global innovation networks, the capital ‘I’ is used for companies who organize innovation across their global R&D and production sites and introduce new to the world innovations. The lower case ‘i’ is used for companies – or networks – that predominantly internationalize their innovation in order to adapt their products to new markets. The last letter for network, the capital ‘N’, is used when companies engage in collaborations beyond their own value chain, e.g. with universities and other research institutions, while the lower case ‘n’ indicates that the network mainly includes suppliers and customers.

12.1 The first model: companies who go through a genuine globalization of innovation.

Future oriented companies engage in the products of tomorrow and entering the markets of tomorrow.

Agro1: Knowledge is the main product of this company. They deliver solutions to customers based on recipes developed by the company – including their products as ingredients.

R&D is of high priority, 4.3 % of turnover is allocation R&D which is carried out predominantly in their five large R&D platforms plus some supplementary small research units. 870 people are working in R&D, of which 67% have a university degree. This company has a strong need for specialized knowledge at all levels. This is also the case when collaborating with customers as the core product is knowledge. While researching ingredients, the company has a high level of specialization and recruits a lot of people from the food sector. They come from specialized segments of the food industry. In order to remain at the top, the company’s culture is designed for innovation – the company encourages willingness to take risks, curiosity, freedom, trust, networks, room for all, open mindedness, experimenting at all levels and supporting entrepreneurs. To facilitate the development of ideas from within the company, the company has identified ‘Cre-actors’ who are internal professional consultants who support people who come up with ‘a good idea’ in bringing it further in the company.

Innovation as research is coordinated by an internal committee ensuring that the same structure and innovation management exists across the different locations. This committee is also responsible for the allocation of funding for R&D. For this type of R&D the company needs real experts – in bio-technology. Ten per cent of R&D spending is placed outside the company and this is often in collaboration with universities. The other type of innovation (as development) in the company is close collaboration with the customers. Food tastes are different around the world and even for the same products, the company needs local varieties. However, having a critical mass in a centre is prioritized more than a local presence. “Operations are specialized and we have developed a system of exchanging knowledge so that a problem in the bread industry in South America may be solved from our specialized team in Canada."

The two main reasons for off-shoring R&D are that 1) it is cheaper and 2) to serve the market there. China is a high priority for R&D as it is an important upcoming player in bio-technology: "they produce a number of highly qualified PhDs every year. This area is really exciting for our business. Some of our people in the US have spent 3–6 months at the China site to help developing the culture, etc." Representatives from the company also pointed out the following: "In addition to having access to highly educated staff and first class universities, we also find a mature biotechnology network in China, which we can use to continually enhance our advantages in the fields of enzyme discovery and protein engineering" (cit. Executive Vice President of R&D). Moreover, there is some evidence that the global production network of Agro1 as an existing configuration, did develop into the global innovation network this company is a part of today. Except for a takeover of a US company, the R&D centres have been placed nearby existing production facilities. Since R&D often takes place in collaboration with customers, there is a point of locating R&D and innovation near the new markets: Agro1 developed from exporting products into adjusting products to the local market. However, the leadership team decided that the costs of having too many R&D sites were too high. Consequently, today the R&D has been restructured into five platforms.

Push factors related to Denmark: "At the national level, i.e. in Denmark, we need more support for networking. We also need more flexibility for getting foreign employees to Denmark", for example tax holidays. According to Agro1, tax is a major issue for foreign high-ranking researchers. The company collaborates with Danish universities which they regard as being sufficient. Due to the long tradition of agro food industry and research in Denmark, there are many good niches for food-production and research at home. Many of the knowledge workers come from the Danish food industry. The company links to academic institutions at home and abroad through different programmes, for example through annual awards and the website 'innocentive'. Agro1 also plays a very active role in the agro food cluster at home, i.e. the Agro-Food Park.

Agro2: this company is also a global leader in its field. It is research-intensive, spending of more than 14% of the revenue on R&D. All R&D sites are placed in locations with significant sales and where the company can identify an interesting and well performing research environment. R&D projects are managed internationally, only 20% of a project team is located nearby the project leader. Researchers are based in different sites, so that they can engage with the people in these places: "Practically, it is easier to talk with people in Beijing if we have researchers placed there". Today research centres are placed in US, Japan, Brazil, Denmark, China, Japan, Switzerland, India, UK and Australia.

The R&D site in China was established in the mid-1990s after the company had been in the Chinese market for 23 years. The original strategy behind it was to develop into being a key player in the booming Chinese economy more than to access low cost labour. Today, the company holds a strong position in the Chinese market for enzymes. They have developed partnerships with state owned enterprises in China – which are only possible due to their local presence and the history of the company in China. From being a site of development – applying the company's products to the Chinese market, the R&D site has developed into being a part of the global R&D operations. 80% of the research carried out in China is of the company's global R&D operations. According to the innovation manager, having operations in China is a huge challenge, but the market is big enough to be worth it. The company has invested in upgrading the staff (also in language capabilities in order to be able to take part in the global operations) which has then become more attractive in the labour market. Hence, according to the company there is not so much a low-cost incentive for off-shoring R&D to China as a market incentive: "… costs are really not the issue. In China, salaries have increased a lot recently also because there is a shortage of English speaking researchers" (interview).

In India, the company took over one of its main competitors in 2007, including their R&D facilities and with this the 150 employees within a very specialized field which is supplementary to their existing global facilities. Hence, the acquisition added to the company's global product portfolio. The particular products are now only made in Bangalore but sold worldwide. In India the company can find the qualified people needed to meet international standards. In Bangalore the company is also able to find qualified people for their global R&D activities. The IIT and IIS are very prestigious in their product area and perform world class research: "it is easier to tap into these resources if you have local presence". As an HR strategy in India, Agro2 do head-hunting and networking and find these two highly interrelated, as new employees bring about new networks. Getting qualified people is easier in India.

As motivations to move abroad, one manager explained that Agro2 has the understanding that "not all good innovation can take place in Denmark". Competitiveness is a question about being present globally – and "you look more serious if you have local R&D". Still, the company has no plans of cutting down on its activities at home: "We are not moving R&D out from Denmark" – approximately half of R&D is located in Denmark and more people are hired there every year. However, the proportion of researchers being located in Denmark is diminishing. "One interesting question here is whether we can find the qualified people we need in the Copenhagen area at all, which is problematic", likewise, "it is easier to attract US personnel to North Carolina than to Denmark". "It is difficult to attract foreigners to Denmark. High taxes are frightening for most foreigners and they rarely stay for more than three years" (the tax holiday limit).

For the development of products for new markets a local presence is crucial: "sitting in Denmark thinking about what would work for preserving juice from fruits in India may not be the most brilliant thing to do" and, discussing the collaborations in Africa: "their bread is different and has a different look which is important to acknowledge when developing our products".

12.2 The second model: internationalization in somewhat traditional companies

With Agro 3 and Agro 4, the overall current tendencies are that 1) they collaborate more with academics, suppliers and customers than they did earlier, 2) they keep in-house R&D in Denmark, 3) some of the R&D is supplemented with smaller operations – either specialized or market-oriented ones – at foreign locations, 4) R&D focuses on improving existing products and processes.

Agro4: The overall strategy of this company is stated as the intention to become the largest producer of their products globally. Hence, the company strategy relates to growth of their production and market share. Therefore their R&D focuses on products and sustainability: one of their core issues is how to keep the products fresh. However, all R&D activities are centred in Copenhagen, centralized for all business lines in the headquarters. "Our corporate R&D focus is no longer linked to the supply chain, but to the marketing process and the end customer".

Agro4 has strong historical research ties with two of the largest universities in Denmark. Seven full time internal professors within very specialized research areas are employed in the company and, in addition to this, there are 40 PhDs and post-doctoral staff on their pay roll. They tend to move on, as was stated by the Innovation Manager: "most of them continue their careers elsewhere – and by doing so they create a foundation for further research collaboration". There is some internationalized research into developing the inputs in different natural environments in collaboration with local institutions, mostly in collecting samples of raw material, while the R&D is carried out in Denmark. In addition to this there are a few specialized R&D units elsewhere, for example one in Russia which is developing natural ingredients.

Products are not changing radically, but a number of alterations and incremental changes take place both in the production process – focusing on making the products last longer, extending the shelf-time – and in marketing (targeting other customer groups, e.g. women). Basically, the corporate R&D focus is no longer linked to the supply chain but to the marketing process and end-customer. In addition to this, there is a 'front-end unit' for each market that is in charge of identifying the needs for innovation of each brand in the particular markets. The front-end-units, whose role among others is to identify future needs for innovation, are also located in the HQ. This company has future plans to establish a research facility in Hong Kong because some of their competitors have. The company also considers more open innovation models.

Agro3: This company's focus is in fresh products. Their R&D is focused on ingredients and nutrition and is predominantly market oriented. It has experienced a degree of Europeanization and today has six R&D centres in Europe of which two are in Denmark and one each in Sweden, Finland, Netherlands and UK.

Collaboration is important in their R&D set-up as many research projects involve public funding and university partners. In addition to the R&D facilities in Europe, the company has two joint ventures (in Argentina and China). Most knowledge is produced in Denmark. This is explained by "Denmark has a strong tradition for agro food". "Danish research in the agro food sector is very specialized, as knowledge competences at Danish universities are very good, deep and specialized in some specific areas". In addition to their core products, Agro3 is engaged in basic research on genome for which they collaborate with the whole network of genome research in Denmark.

10–15% of R&D expenditure is used on external cooperation. This is carried out in long to medium term projects with universities, e.g. by industrial PhDs or short-term collaborations on specific projects. At the international level, collaboration happens in relation to very specific R&D activities (Intellectual Property Rights always stay in the company): "We buy this research or knowledge in universities where we know there are special instruments, or special knowledge competences." The company has a network of partners for this: 3–5 universities in the US, 1 in Germany, 1 in Sweden and 5 in Denmark. Furthermore, the company is part of an EU consortium involving partners in France and Spain.

For Agro3, internationalization of R&D is a strategy of moving closer to a market – also in terms of access to the authorities for approving the products, which is a big issue for this company. Comparative advantages of lower costs are not seen as an issue but rather access to technology and knowledge and extraordinary research capacity. For their ingredient operations, there is a lot of international down-stream collaboration with clients on potential product development. The company collaborates with two foreign global leaders within their technology, who get the first offer on new innovations, and likewise, Agro3 gets the first offer of developing new products. In addition to this, there is a series of collaborative arrangements with specialized suppliers for product and process development.

The company has certainly more collaboration today than ten years ago. The future plan is to establish collaboration frameworks rather than the ad hoc collaboration structure of today. The company also expressed some worries about recent tendencies in the Danish agro food industry: "The Danish agro food research sector is under pressure. We can save it now, or it will go in the wrong direction. The problem is that some competences that we need will disappear."

13. Global Innovation Network formations in the Danish agro food sector

The four cases show different models within the typologies of GINs related to the Danish agro food sector:

Table 9: Internationalization of innovation in the four case studies, Danish Agro-food industry.

	Global (G or g)	Innovation (I or i)	Network (N or n)
Agro1 **GIN**	5 large global R&D platforms	Future oriented, new to the world innovation. 4.3% of turnover into R&D 'Cre-actors'	Development: customers Research: 10% of R&D funding outside the company (universities)
Agro2 **GIN**	R&D projects managed globally 10 R&D locations spanning 5 continents	14.3% of turnover on R&D Bio-tech Bio-fuel research	Collaborations in China, + universities in Bangalore (IIT & IIS) DK universities
Agro4 **giN**	Some sample collections internationally R&D at headquarters in Denmark	Development into keeping products fresh, sustainability in production, marketing driven research focus on end-customer	Collaboration with University of Copenhagen 7 professors + 40 PhDs and post docs
Agro3 **giN**	6 R&D centres in Europe 2 joint ventures in South America 12% of products sold outside Europe	R&D is market oriented Some research into genomes	Collaboration and receiver of public research funding University partners 10–15% of R&D budget is spent externally

The first model as illustrated by Agro1 and Agro2 is indeed a model in which we can identify core innovation activities across a range of countries and continents – the companies depend on constant innovation, and they operate in networks across national boundaries. Hence, both are engaged in developing communication tools for sharing information among the subsidiaries. For some products they engage in techno-scientific collaboration with universities specialized internationally within certain research areas either for gaining knowledge or as a recruitment strategy. The model is global, providing new-to-the-world innovation and includes partners beyond their global value chain; they engage in **GINs**.

The second model as performed by Agro4 and Agro3 is where the companies maintain their product research and development at home. Their products are increasingly sold beyond the Danish market as the market is small. Some products are sold globally however with only little local adjustment of the products at the local production facilities (most food is produced locally due to shelf life and transport costs). So what we see for these companies is that R&D is in Denmark, and to some extent in Europe, whilst innovation is limited to adjusting products to their target markets and they engage beyond the value chains at home. They have developed **giNs**.

Another interesting point about these four cases is that for the two GIN companies, the GINs seem to have developed within their previously established global production networks, i.e. in places where they already have significant production and sales. Except for in certain cases where the company in question has merged with a competing company as was the case for Agro1 in the US and Agro2 in India. Reasons for establishing R&D outside Denmark are pinpointed in the following two citations: "not all good knowledge can be produced in Denmark" and "it is difficult to attract key foreign researchers to our R&D sites in Denmark". The two **giN** companies are either considering off-shoring research into Hong Kong (Agro3) or already have two minor joint ventures in South America (Agro3).

Relating these findings to the push and pull factor typologies introduced earlier in this paper, the companies can be placed according to the different push and pull factors:

Table 10: Drivers and strategies in the internationalization of innovation in the Danish agro food industry.

Pull factors:	1. International exploitation of nationally generated innovations	2. Global generation of innovation	3. Global techno-scientific collaboration
Push factors:	4. Exploitation (due to limited home market)	5. Augmenting/exploration (due to innovation at home too slow)	
Driver:	Market	Market/knowledge	Knowledge
Agro1	Market seeking Location by customers (development)	'Cre-actors' Internal committee	10% of R&D outside company Tapping into mature biotech network in China
Agro2	R&D placed in locations with significant sales	"Not all good innovation takes place in Denmark"	Where company identifies relevant research activity India IIT & IIS Collaborations with enterprises in China
Agro4	Market expansion strategy Research into tastes and durability	National	National

	(shelf life)		
Agro3	Market expansion strategy, moving closer to the market.	Europe	Minor joint ventures in China & Argentina

Table 10 shows the linkages between the push and pull factors. All four companies are internationalizing the use of their innovative products through a market seeking strategy of exploitation. For those companies whose products are intermediates/ingredients for other lead firms, this has led to a globalization of innovation (as Development) and following a strategy of exploration, i.e. through global generation of innovation which again has facilitated the establishment of global techno-scientific collaboration. However, this was not the case for Agro4, who did not follow the trajectory set out in the Archibugi and Michie Internationalization of Innovation model. Meanwhile, the locations differ according to the types of innovation activities that are internationalized. China and India are both perceived as important locations by these companies, mainly because these countries have both a growing market and large research communities, at least at a regional level.

However, both Agro1 and Agro2 also have activities in South Africa. The Danish agro food companies with internationalized innovation activities look for 'warm bodies' as in: customers and localized knowledge in tastes, ingredients and produce; specialized knowledge; particular researchers who are difficult to attract to Denmark, and participation in research environments.

14. Conclusions

The agro food industry is a core industry in the Danish economy. Due to a small home economy and high investments into innovation activities, the large companies internationalized their markets. The companies have experienced a need to move beyond the home market – these are the 'push factors' which are strongest among the large players in the industry. As the products relate to local tastes and food varieties, the same companies have started doing R&D in their new locations. This increasingly takes place in locations outside Europe. However, this internationalization of innovation is led by certain particular push factors. For companies that predominantly supply ingredients and enzymes for the global food-lead firms, there is a need to follow their customers in their exploitation of new markets. Likewise, these companies need to keep their position as turnkey-suppliers and to tap into all new knowledge within their fields. Hence, knowledge-augmenting strategies are relevant for these companies. Recently, one of the companies has engaged in innovation in South Africa. As parts of Africa seem to host the up-coming emerging markets this company needs to collaborate on matching their ingredients to the raw-materials available.

We will now turn into looking at the consequences in the host economies. Although this has not been the main focus of this paper, there are certain lessons to be learned about the impacts in host economies. For the ones looking to attract companies with home-augmenting strategies for internationalization of innovation, the knowledge capacity is highly relevant. However, this capacity needs to be specialized in local raw materials, local food culture, or highly technical within a certain field, as was the case with Agro2 in India. The benefit of providing this is that the local innovation system gains access to upgrading and knowledge transfer as it develops into a specialized ‘knowledge hub’. Furthermore, there is the possibility to tap into the established networks which the lead firm has at home, hence upgrading the innovation networks at home by linking to larger or more specialized ones abroad.

For companies producing directly for consumers, there is a need to expand into new markets. The location attractiveness for these companies is merely comprised of future market trends and economic growth. These companies have generally little internationalization of innovation. Hence, spill-over effects into the host economies are very limited.

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Case study on German automotive multinationals

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Table of contents

1. Introduction

Capability building in multinational companies is increasingly seen as a twofold process which brings company specific knowledge from the headquarters to locations abroad and simultaneously attempts to draw on local knowledge from locations abroad at home. Capability building then is a complex learning process aimed at improving the company's competitiveness at the global market(s). In this report, learning is allocated to persons, enhancing the individual's capacities both in the company's production and R&D activities. The report, therefore, focuses on new efforts from the company to improve its "human capital". These efforts have a clear-cut target, i.e. to maintain or foster the company's competitiveness by profiting from improvements in quality production at each location and from a new global division of labour within the company.

These processes are extremely diversified, depending from technologies and sectors and the companies' strategic behaviour in general and their motives to internationalize in particular. It is generally assumed that there is a sector and company specific mix of push and pull factors to internationalize. It is claimed in this report that these specifities have a major impact on the forms of global capability building within the multinationals. Building capabilities means establishing global knowledge pipelines, according to the literature. Knowledge "pipelines" are defined as organised and formalised ways of purposive communication in knowledge processes, either as open channels or closed conduits (Owen-Smith/Powell 2004). The following report is about how companies in the German automotive supplier sector learn to establish closed conduits within their international organisation in order to transmit and exchange knowledge, both for producing sophisticated products and developing innovation abroad. We would argue that German automotive suppliers are among the leading multinationals in the sector which most often follow a strategy of international growth based on the strength of their production plants and their most favourable environment in Germany. These home-based (global) players as they have been called by Kinkel and Zanker (2007) seem to follow particular ways in capability building. One of the reasons for this might be the particular type of knowledge dominating the sector, i.e. experiential knowledge in engineering, or so-called "synthetic knowledge" (Asheim/Gertler 2005).

The report is organized in the following way. Section 2 presents the German automotive industry in its domestic context and discusses possible drivers for internationalisation of innovative activities. Section 3 focuses on various ways of learning how to build a global pipeline of knowledge, both for improving the skills of the labour force abroad for acquiring responsibilities in production of new products and enabling the R&D personnel abroad for becoming integrated into the innovation activities of the company. This is based on three case studies of German automotive companies which, despite looking back on a rather long corporate history, only recently have established a global internal network of innovation. As one of the interviewees put it, "while other industries may have had a knowledge management strategy for one or two decades, the automotive industry is currently slowly developing one, but it is doing so". So, we are probably at a starting point of global knowledge management and global innovation networks in the sector.

Finally, section 4 draws some conclusions on the current state of companies having learnt to network in global innovative activities. Following INGINEUS' terminology on the meaning of G (for global), I (for innovation) and N (for network) we claim that the German automotive industry actually is in a state of gIN.

2. The German automotive industry

Germany is Europe's leading country in automobile production and one of the largest exporters in the world. In 2008, i.e. prior to the recent crisis, Germany was the world's fourth largest producer of passenger cars (with 5.53 Million units), following Japan (9.93 Million units), the US (8.45 Million units) and China (5.68 Million units), and it currently is the fourth largest producer of commercial vehicles (as of 9 March 2011, see VDA 2011). Germany's export rate in the automobile industry decreased from nearly 75% in 2008 to 69% in 2009, mainly because its premium models became too expensive on most markets during the crisis. However, in 2010 production and exports of premium models regained momentum. 70% of Germany's export markets are European countries (2008 70.3%; 2009 68.2%), 10% the US (2008 12.6%; 2009 10.5%); according to VDA (2010), the share of China has recently been increasing from 5.3% in 2008 to 8.8% in 2009.

For the German labour market and for industrial value addition, automobile production is one of the key sectors in the German economy. The total employment effects of all of the different sectors related to the production and usage of cars was estimated at 2.8 million persons or 14% of Germany's total labour force in 2005 (Stat. Bundesamt Deutschland 2009). The sector provided for 20 % of the annual turnover of all manufacturing industries in Germany, in 2009 (VDA 2010, 16) (see wp 9, sectoral paper).

In Porter's terms, the industry constitutes a cluster with considerable comparative advantages. At the top of the cluster are three large producers of "premium" cars (BMW, Daimler and Volkswagen with its Audi and Porsche brands), three volume producers (Ford, the GM brand Opel, and Volkswagen), and two producers in the commercial vehicle segment (Daimler and MAN). These OEMs are the very demanding customers of the automotive supplier industries.

2.1 Internationalisation in the German automotive industry

The automotive industry is characterized by a high degree of internationalisation and, thus, seems to be a rather globalized industry. However, its companies follow more often regionalisation strategies in the sense that world regions are considered as different market areas with different requirements from their clients. In Gereffi's terms, the automotive industry forms global producer chains where powerful automobile companies (the OEMs, original equipment manufacturers) "govern" in a hierarchical manner more or less dependent automotive suppliers. During the "second revolution in auto production", elsewhere termed as "Toyotism" or "lean production", a complex pyramid of companies has emerged in the auto production system. OEMs still are considered as the powerful drivers as they guarantee access to the markets but system and components suppliers are increasingly becoming important and independent in chains of production and product development. This applies to all "regional" auto production systems. But Germany is a particular case in point as "premium car" OEMs as well as large innovative system suppliers dominate the domestic auto production system and the way it extends to global "regional" markets.

In the recent two decades, the German automotive industry has become the main driver in foreign direct investment from Germany. Within a few years, its share in German FDI in manufacturing rose tremendously from 18% of total investment in 1995 to nearly 30% in 1998. Since then, it has had a constant share of 30 to 35% in manufacturing FDI or 8 to 10% of total FDI (Legler et al. 2009, 86f.). Between 2005 and 2008, foreign direct and indirect investment of the German automotive industry varied around 100 billion € with the bulk of this in Europe and the US –

confirming the notion of world regions in the industry – and increasing investment only in Brazil, China and India (see wp 9 country report). According to the literature, automotive suppliers have had two motives to relocate production abroad. First, they follow their clients (German OEMs) to the various world regions (US, Brazil, China), often initiated by the powerful OEMs. Second, caused by the tremendous competitive squeeze in the sector, they relocate "nearby" in low-cost countries (such as Eastern Europe and North Africa) in order to profit both from lower wages and relatively low transportation costs. Recent figures in R&D expenditures of German automotive companies reveal a reduction in foreign R&D and an increase in domestic R&D from 2005 to 2007 (Belitz 2010, 7).

The automotive industry is extremely important for innovation activities in the German economy, both in a quantitative and qualitative perspective (Legler et al. 2009, 90). It is by far the largest sector in terms of R&D expenditures (20.0bn € or 25 %) but it is not a high-tech sector as the R&D intensity fluctuated between 4 % and slightly more than 5% in the period from 1992 to 2006 (Legler et al. 2009, 93). Most R&D expenditures are spent intramurally. While the automotive industry at home spends the bulk of R&D expenditures of all manufacturing industries in Germany (35 to 38%), its share of R&D abroad was only 15.6 % in 2007 – which still amounts to 52% of the total of foreign R&D expenditures of German industry.

While some features of the organisational structure may be similar in other countries with a strong automotive industry, Sturgeon et. al. (2008, 308f.) point to a major difference in the governance of inter-organisational processes. Japanese OEMs are rather reluctant to interact with suppliers in co-development. US-American OEMs have a rather adversarial relationship to their suppliers and prefer short term collaboration in engineering activities. German OEMs, particularly those producing in the "premium" segment, most often keep long-term relationships with their main system and components suppliers in model development, based on trust and long-term collaboration.

2.2 Framing learning and innovation in the German auto production system

Automotive suppliers do not form a sector in the statistical sense. While statistics generally focus around similar technologies in a sector, large system suppliers are experts in combining rather different technologies. As a consequence, the automotive supplier industry is, in technological terms, extremely diversified and requires very different types of knowledge in learning and R&D processes. According to recent literature, the automotive industry is generally seen as a "sector" of prevailing synthetic knowledge, where "innovation takes place mainly through the application or novel combination of existing knowledge" (Asheim/Gertler 2005, 295). Basic research seems less necessary but the experience of engineers is crucial. Knowledge management, then, mainly has to consider forms of learning by doing and interacting as well as interpersonal knowledge exchanges. According to Dankbaar (2007) much knowledge in the industry is experiential. Although the industry has developed some kind of modularity in its products – which gave rise to the level of system and components suppliers in the industry – "interfaces are seldom standardized across the industry and interactions between the various modules and the performance of the car as a whole remain complex" (281).

During the 1990s, in the so-called second industrial revolution of the industry, OEMs widely outsourced production and reduced their own value added activities up to 25%. Simultaneously, they offshored production, mainly in the search for market access in the different world regions.

Since then, a pyramidal organisation of the industry has evolved, which is hierarchically governed by the large OEMs. Recent research on the organisation of R&D and innovation in the industry has revealed an even stronger hierarchical situation in innovation (Schamp et al. 2004). In this pyramid of model development in the automobile industry, much work has been outsourced to suppliers and engineering service providers in Germany. Suppliers followed in outsourcing innovative activities to engineering service providers. However, these service providers are largely embedded in the domestic innovation system. Because of their high wages, they have run into a cost trap during the recent crisis. As a result, both OEM and system suppliers have reduced outsourcing to engineering service providers in model development but started to relocate offshore. This is where the following section attempts to discuss learning processes at the level of the company.

Fig. 1: The model development pyramid in automobile industry (Schamp et al. 2004, 616)

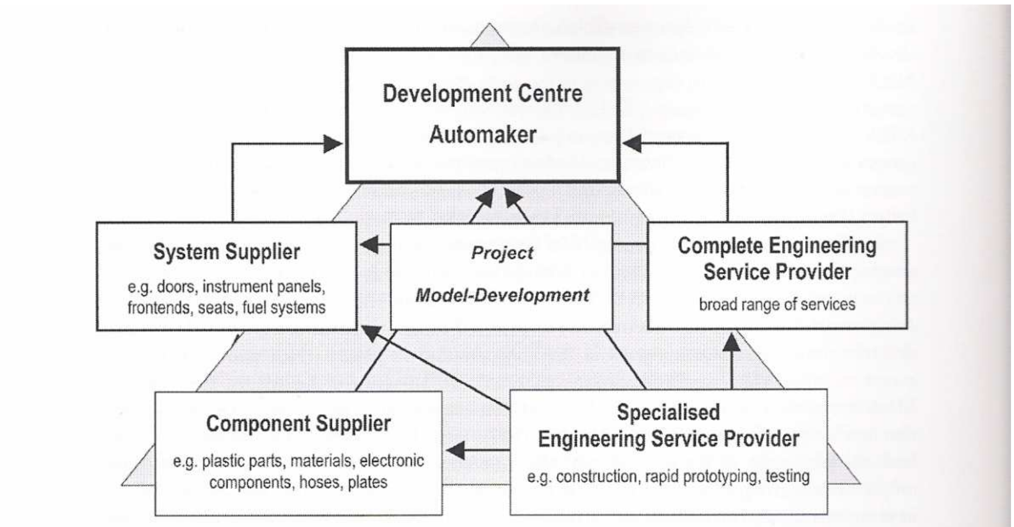


Figure 2. The network of firms in automobile design

R&D activities of the German automotive industry are embedded in networks at different geographical levels. Firstly, networks dealing with the fundamental issues of new technologies are national and combine the automobile producers association, large OEMs and system suppliers, research labs, universities etc. Secondly, networks have evolved in regional cluster initiatives, where automotive suppliers concentrate spatially, often initiated by regional authorities, local suppliers, universities etc. (Blöcker et al. 2009). They more often tackle problems of process development than product development. Thirdly, the giant R&D centres of the OEMs which have emerged in the recent decades attract a number of R&D offices of automotive suppliers and engineering service companies for mutual coordination (and control by the OEM) of model development to their location (in Germany) and thus form strong local R&D clusters. Technical and applied universities, many of them having a department or even faculty for automotive technologies, play a major role both in research and development and in educating engineers in sector specific technological fields. As a result, a complex web of embeddedness in innovation processes at different geographical levels has come into being, which mainly forms a strong home base of the automotive industry in innovation (for more detail see wp 9 sectoral country report).

Automotive companies see another major advantage at the home locations in the particular vocational education and training system in Germany that combines learning of general (codified) knowledge in public schooling with sector specific experiential knowledge at the company's shop floor. Although the German dual VET system has been "exported" to other countries, among them China, it nowhere delivers similar results in terms of broadly trained young employees at the shop floor level (see, e.g., Barabasch et al. 2009). Furthermore, the German dual VET system can lead to a broadly educated (vocational) master's degree at the supervisory level (for more detail see wp 3 country report on national innovation system).

Political agents and the media expect an increasing "lack of talent" in the future, however, both in number of young people and their willingness to work abroad. Major reasons seem to be the ageing and declining population, added by the current outward migration of qualified Germans in certain fields of competences, on the one hand, and changes in individual's behaviour, on the other. This would cause a problem for the multinational companies which would push them to look for talent abroad. However, some studies do not see a shortage in the qualified labour force neither currently nor in the near future (Brenke 2010). According to calculations of the Federal Institute for Vocational Education and Training BIBB, there is no imbalance to be expected in the mid-range between offer and demand even in the MINT disciplines (Helmrich/Zika 2010).

As a result, recent company typologies in the German automotive sector based on long-term strategic decision-making may not come as a surprise. According to a ZEW study (Kinkel and Zanker 2007), the huge majority of German companies are "home-based players" and only a few suppliers follow a strategy as "cost-oriented producer abroad" – looking for relocation to low wage countries – or a strategy as "market and client-driven producer abroad" who follows his client into other world regions. The home-based player still tries to keep his strong competence "at home", in Germany, while increasingly producing abroad. How likely is it that such a company following this strategic philosophy will establish global innovation networks? Or to put it in another way: if we agree that the home-based player comes under increasing competitive squeeze to internationalize, which activities in the innovation process will be subject to relocation and transfer to global networks and how will the company govern these activities?

The strategic problem in the eyes of the companies is how far local knowledge extant at other places in the world can be seized and low costs in knowledge-based processes at other places be used by the company without losing its strong control on knowledge processes. In the following, we attempt to answer this question based on three case studies in the German automotive industry.

There are two reasons to focus on automotive suppliers instead of OEMs. First, OEMs have relocated much of their production and, consequently, product development to the automotive suppliers in recent decades, following their strategy of "lean production". Suppliers contribute substantially to innovation in the automobile production system, nowadays. Second, automotive suppliers were more likely prepared to relocate production into low-cost countries, compared to OEMs. The question is whether they will be more likely prepared to relocate innovation activities and to establish a new international division of labour in innovation? A recent study on new investments by the German automotive industry in Central and Eastern Europe does not confirm this (Jürgens/Krzymdzinski 2010). But does this also apply to other world regions?

3. Case studies on learning how to offshore knowledge-based processes

Case study analyses depend from the companies' willingness to collaborate with the researcher. In this study, up to ten months were required to get access to managers in three automotive suppliers of considerable size for in-depth interviews of three to four hours per company. Managers from different departments were involved. Interviews have been transcribed and supplemented by various documents, both public (website) and private (company). The companies adhere to one technological field, i.e. the rather broad field of combustion engine technology. This technology has a long history and path dependence leading to accumulated technological experience and sophisticated problem solving in the development of increasingly complex products. A major driver for technological change are increasing requirements in environmental protection. Companies in this product range are therefore obliged to continuously look for innovations and combine knowledge inputs from various other technologies. As a consequence, the following case studies represent one of the most R&D intensive subsectors in the automotive industry. These companies cannot be compared to some other parts of the automotive supplier industry, particularly not to assembly industries such as seat or wiring harness production.

3.1 The companies

All three companies are located in the Stuttgart area in Southern Germany where a unique cluster of OEMs and automotive suppliers has emerged, among them many international suppliers and world market leaders in their specific market niches. All the companies are "mature" companies, having a life of at least one hundred years. All have been international for at least several decades. Thus, we could expect that the management has good experience in going global. Tab. 3.1 presents the companies according to their age, size and field(s) of activities. The companies are highly specialised in technological terms, resulting in the role of a "forerunner" in innovation, on the one hand. On the other hand, they produce different product lines, both for domestic and foreign OEMs and the passenger car and commercial vehicle markets. While systems and components for passenger cars are almost standardised, requiring only model applications, and are price-sensitive, systems for commercial vehicles are highly complex technical solutions, with a great need for R&D expenditures. Technical solutions for commercial vehicles cannot easily be transferred to passenger cars but many companies see an internal learning relationship between both markets.

The three cases correspond in organisational terms to what often has been described as "German SMEs/Mittelstand". Auto2 and Auto1 have been family enterprises for generations. Auto8 was founded by a private entrepreneur. It is currently owned by a foundation. As a result, none of the companies directly depends on the stock exchange and on a short-term shareholder value philosophy. The companies were formerly more internationalised within Europe, but have now become active around the world, principally in the BRICS countries.

Tab. 3.1: Companies selected for case study, as of 2009

company	year of foundation	annual turnover in billion €	employees	products	total sales abroad in %	R&D expenditures in % of sales
Auto2	1905	2.47	17,000	Thermo management in air conditioning and	39 (exclud. Europe)	8.3

				engine cooling		
Auto1	1865	1,34	5,200	Exhaust systems and heating systems	44	5.9
Auto8 (part)	1886	no information available	23,000	Gasoline systems	76	9.4

Auto2 started as a small workshop for car radiators in 1905 and has now become a leading producer of air conditioning systems for cars and engine coolings, both for passenger cars and commercial vehicles. While the company has been strongly oriented towards the premium model sector in passenger cars and sophisticated truck markets, it has recently started to enter low-cost markets, such as modules for the Indian Tata Nano model. It still is a family-owned company in the 3rd generation, owned by 3 families.

The company is still largely based on European markets, where half of it is Germany-based. It nevertheless has 22 production locations all over the world, and 11 development centres. However, there are only two fully equipped R&D centres, i.e. at the site of the headquarters and in the US. Although the company obviously has a centralised governance, its organisational structure is rather opaque for outsiders as the company acts as holding of numbers of “independent” companies and has entered into a large joint venture with two other suppliers, some ten years ago, thus forming a full system supplier of so-called frontends to passenger cars, including shock absorbers, engine coolings, lightening. Frontends are typically assembled in close proximity to the OEM assembly plant.

Auto2 used a typical “follow-the-client” strategy in its early internationalisation and went, first, to the Americas (US, Mexico, Brazil). Only recently, the company identified emerging countries such as China, India, Brazil and Turkey as the growth markets of the future. It nevertheless followed a cautious strategy by starting with joint ventures and only later investing in fully-owned subsidiaries. In 1997, opened a JV in India, supplemented by a Engineering Service Company in 2000. Later, Auto2 engaged in China and Turkey.

Auto1 was founded in 1865 but only entered the automobile production system in 1932 when it started to produce heating systems and sound absorbers. After WW2 it grew with the growing demand for a German volume producer at that time. The company started to internationalize during the 1980s, but only recently established a R&D centre abroad in 2000 in the US. It currently produces in 8 European countries, in the Americas (US, Canada, Brazil), in South Africa, East Asia (Korea, China) and India, and has some further licensed foreign production. Again, most of the production sites abroad do pre-assembly work in proximity to OEM assembly plants. The company has small R&D centres in India and Brazil, mostly for adaptation, and currently extends its capacities for development by establishing close contact to an Indian engineering service provider.

Auto8 is in fact part of a very large German system supplier whose organisation is rather complex. Auto8 refers to one of 10 activity fields in automotive, i.e. gasoline systems. The company was founded in 1886 and soon grew up into an international company, selling 88% abroad in 1913. The company has a very long experience in going global. Furthermore, it has for a long time been well-known for its innovative activities, having an average R&D rate of 8% in recent years. In a broad sense, more than 32.6 thousand employees are involved in R&D processes worldwide on innovation in the very different segments of the company. 1,300 of them work in the corporate research centre (basic research and pre-development) in Germany. The company has a global innovation policy approaching basic R&D labs abroad. For example, it opened its own software centre in India in 1998 and established close R&D collaboration with Stanford University in 2008.

3.2 Recent re-organisation of the innovation process

Product innovation by the companies has the following characteristics. The product life cycle is generally rather long and extends to six to seven years. During the cycle, several innovations for adjustment and improvement of the product appear necessary. Radical new innovation as a new exhaust system responding to a technical jump in environmental protection regulation need up to 5 years, from the early idea to its realisation. These new products combine different innovation from different technological fields. It appears that, finally, the experiential knowledge of the engineers matters most in product development.

The three case study companies have a long experience in organising production abroad, even globally, and in the governance of a foreign R&D centre. However, the only fully integrated and often the first R&D centre abroad was located in the US. Other R&D labs/offices abroad, allocated to emerging economies and Japan, most often act as observing posts for the search for information on "local" new technologies and product adjustment according to "local" customer's wishes. Towards the end of the 20th century, both in academia and the companies, new concepts of knowledge on how to manage knowledge processes came into being, including new organisational forms of integrating this into the historically grown management structures of the company. Among the companies in the automobile production system, new departments have been created such as on innovation management and new generic fields of governance have been established such as "competence management" and "knowledge management". Some of the OEMs and the global first-tier suppliers appear to be the first in implementing new management structures in Germany.

"Innovation management" has been introduced at some OEMs at the beginning of the 2000s (see in detail Blöcker et al. 2009, 21ff.), mainly aiming at strengthening the relationships between research, development and marketing functions of the company. This organisational innovation has been rather quickly implemented also in first-tier suppliers. Blöcker et al. (2009, 317) present as an example Continental Automotive Systems, who introduced innovation management in 2003. Auto2 to Auto8 have more recently established different forms of knowledge and innovation management.

Some years ago, Auto2 has established a new "department for development and knowledge management" and introduced various instruments of human resource improvement. On the shop floor level, for instance, Auto2 currently develops standardised training curricula for all plants world-wide. On the management level, Auto2 established a joint education programme (master degree) with a nearby university in Germany. Furthermore, the company looks for new ways to improve cross-border knowledge exchange between engineers.

Auto1 has recently started to improve its innovation management. First, the company has identified four different areas of its technical competences and established teams in these areas in order to improve both the production process and product development. Second, a five step phasing of the innovation process was established, inter alia in order to improve strategic decision making on the choice of product development from the host of impulses and ideas the company collects from the environment. Third, Auto1 qualified several persons as boundary spanners in order to improve the coordination and control of outsourcing/offshoring of standardised tasks in product development to an Indian service provider.

Auto8 started to alter its human resource management processes by introducing the new field of (personal) "competence management" in different business areas early in the 2000s. This was and still is being extended worldwide since the beginning of 2006. Also innovation management has been introduced since early 2000 but still is in its development.

None of these organisational changes has been fully implemented up to now in the companies. The companies claim to be still in a learning phase, where they more or less carefully and tentatively look for new ways of organising global knowledge management. This seems to correspond to a comment by Manning et al. (2008, 47), based on their offshoring research network survey: "many companies are struggling with operational efficiency and loss of managerial control, in particular when it comes to offshoring higher skilled activities".

We draw some conclusions from this with reference to the stylized figure on pre- and after-technological change in the companies (see fig. 2, p.21) which guide the following analysis of learning procedures for individuals within the multinational companies.

* First, there is indeed a new wave of introducing new organisational forms and tools in knowledge, innovation and competence management in the companies since some years.

* Second, this wave extends to all levels of "human capital" in the companies, from the workers' and technical's level at the shopfloor to management in production and in R&D. Companies follow multifarious targets at the same time at different levels of the organisation.

* Third, there is no clear-cut pre- and after-change phasing but processes of re-organisation and learning are continuous and do not yet reach a state of maturity.

* Fourth, the organisation's learning seems to develop most often in a top-down manner from the German headquarters and locations in Europe to locations abroad, at least in the implementation of new learning prodecures.

For reasons of simplicity, we differentiate two levels of learning within the organisation in the following. They need different external networking, among others. Seen from the end of the innovation process, the company needs sufficient capabilities of the workforce in foreign plants, not only at the management level but also on the shop floor, for introducing qualified production of new products. Building up such capabilities is mainly the task of the personnel department requiring new organisational forms in model development for copying processes in different departments and subsidiaries. This will be discussed in chapter 3.3.

While all companies attempt to keep the first stages of an innovation process, i.e. the search for and picking up of "impulses", the assessment of these and the conversion of ideas into feasible products at home, they increasingly introduce a new spatial division of labour in a globalising network internal to the company concerning the process of "realizing" the innovation in terms of concrete product development. Chap. 3.4 will discuss these attempts in more detail.

3.3 Improving the learning capacities of global subsidiaries

Producing quality goods, introducing new products into production and implementing improved processes require a highly qualified labour force always willing to learn. It is in these capacities that the companies see their core competence at home. As said earlier, the companies form part of the sophisticated dual VET system in Germany which offers highly qualified technicians at the shop floor and supervisor's level (masters). The case companies have continuously followed their policy of young blood acquisition and appointed apprentices even during the recent crisis. As a response to the perception of Auto1 concerning both the ageing of society and the growing lack of interest of young people in technical professions, the company has for a long time been "going to school" and, among other things, offers short-term internships to schoolboys and schoolgirls in order to stimulate them to apply for an apprenticeship in the company. These policies are local or regional in

Germany, and many of the family-based "*Mittelstand*" companies follow them. At present, however, none of the case companies see a bottleneck in qualified labour force in production. They believe that, even after the crisis, the ongoing consolidation of manufacturing in general and the automotive industry in particular in Germany offers the opportunity to appoint an experienced and qualified labour force from other companies or sectors.

One way to maintain and strengthen the long-term quality of the labour force is to introduce new tools in the labour organisation and to develop human resources. As Dankbaar and Vissers (2009) say, this is about the upskilling of the labour force, not knowledge development. Some companies have explicitly started to introduce "competence management" in the personnel business in recent years. Take Auto8 as an example of a company which aims at making available "the necessary [technical] competence [of the employees] just in time and just at place" (Auto8, document). Here, competence management is a task and tool for managers. This is about defining target competences for each workplace, measuring the deviances from the actual competences and developing new instruments for the building of competences. For a global company, this means developing standards of workplace competences across all plants wherever they may be. Competence management is seen as the task of a team organised vertically (across production planning and production) and horizontally (across all business fields of the company).

We may understand the implementation of this new management tool as a diffusion process from the core of the company to its (global) periphery. To govern this diffusion, the companies have implemented a system of primary plants at home where competence management has been implemented first. These primary plants act as best practice locations and models for subsidiaries abroad. They are responsible for the implementation of competence management in other countries. It comes as no surprise that primary plants are generally located in Germany and nearby the headquarters. As the case companies have often established subsidiaries in emerging economies due to capacity extension and a follow-the-client strategy, they have mostly built quasi-similar plants to the production plants in Germany. However, even where new products are first introduced at a subsidiary abroad, support is given from a European primary plant (in that technology) as European – and sometimes US-American – plants get new tools first (even if they are not formally a "primary" plant).

Thus, a geographical core-periphery relationship evolves in the globalising company, where German or European primary plants form the knowledge core for developing skills at plants in other continents. Primary plants support learning abroad at different occasions, e.g.

- when a new plant in an emerging economy is established. Host country technical staff will be trained at home, in Germany, while technical staff from Germany will train personnel abroad for a certain while. This is not new but it will be professionalized through forms of competence management. Production in primary plants is generally highly automated, which means that fewer but more highly qualified operators and a sophisticated support infrastructure are required. Although new plants in emerging countries are generally more labour intensive, and require a larger number of operators, they place fewer requirements on their qualifications and on the support infrastructure, primary plants still govern the processes of personnel development.

- when a new production line is introduced into a foreign subsidiary, either for relocation due to cost reduction strategies or market extension. The same amount and kind of travelling from and to the host country apply as when a plant is established.

- when processes are standardised globally. Global standards in work processes are increasingly seen by the companies as a major means to efficiently achieve production of quality products abroad. As has been said before, the companies often follow the client (the OEM) into their markets, where they have to deliver similar quality to that at home. Auto2 has currently established training centres in different world regions and is developing curricula for basic courses to be used by instructors at the plants abroad in the training of the shop floor labour force. Training centres are virtual; they are an organisational tool for teaching instructors in different regions of the world used by teachers from the headquarters' personnel departments. Intercultural barriers to skill transfer across the global company should also be overcome with the help of these organisational forms of teaching, but the main target is the acquisition of technical capabilities. Auto8 prefers to train managers in so-called competence management in similarly organised virtual learning centres and by using "local" trainers in the regions of the world, both internal and external to the company.

Auto2 organises learning processes at the supervisory level in two ways. On the one hand, employees of the personnel department at the headquarters act as teachers in short-time courses abroad. The company puts much effort into crossing cultural barriers, and so the trainers themselves have completed courses in intercultural training by experts from the host countries. On the other hand, this is supplemented by meetings and by training employees of foreign subsidiaries in Germany, at the site of the headquarters.

Additionally, companies such as Auto1 have established global support teams, who travel around the world to give support in the introduction of new equipment or new product lines. To summarize this section, companies appear to becoming increasingly aware that upskilling of the labour force together with standardising processes abroad enhance their capabilities in production and competitiveness in different world regions. The organisational measures may not be new but companies attempt to learn more standardised and professionalised ways all over the globe.

3.4 Learning in internal and external innovation networks

Learning in global innovation networks can be considered on two levels, first on the level of the organisational structure of networks internal and external to the company, and, second, on the level of knowledge flows in collaborative activities within these structures. In the following, we first will discuss current changes in the organisational structure of R&D within the companies. We will then describe the ways how companies attempt to improve the likelihood for collaborative work in fragmented processes in development across geographical and cultural barriers.

As said before, the three companies belong to Kinkel/Zanker's (2007) type of home-based player, who is so typical for the German automotive supplier industry. They spend considerable means in R&D in order to maintain their position as first-tier suppliers and market leaders (tab. 3.1). The companies have established a hierarchical international division of labour in R&D processes which defines the opportunities and the legitimisation of external networking of each R&D lab. This hierarchy corresponds to the phases in the innovation process the companies have set beforehand.

3.4.1 The companies' spatial R&D system and its embeddedness

In early internationalisation of R&D all companies have first established another R&D centre in the US, as a clear strategy to conquer this huge market. These labs are capable of carrying out the complete product development for the regional market. They generally have a location of their own, although in proximity to one of the major subsidiaries for production. It appears, however, that in times of crisis the companies shift development tasks more easily to low- cost countries from the US than from Germany. This was the case in Auto2 (Lehner/Warth 2010a) when relocating engineering tasks from the US development centre to India the company got the chance to learn about how to govern collaborative work across state boundaries. We assume at least two reasons for the relocation of engineering tasks from the US, not Germany. First, labour market regulation in the US allows much easier for lay-offs than in Germany. Second, the US R&D centre is not involved in the first phase of the company's innovation process which is about collecting impulses and making strategic decision on more or less radically new products.

R&D labs in other continents are different. They often are allocated to production sites, have fewer employees and different tasks. The reason is that their tasks belong to the later phases of the innovation process, i.e. product adjustment to the customer's requirements and the "local" market. Additionally, companies have opened R&D offices in some world regions for observation of the market and acquisition of contacts to "local" customers (OEMs). These are small listening posts which are, however, very important for the further growth strategy of the companies. For example, Auto1 has established a 2-person R&D office in Tokyo for getting into contact with Japanese customers. Such an allocation policy is similar to what many suppliers do in Germany: to establish an office in close proximity to the central R&D lab of an OEM.

The companies' R&D centres are variously entitled to establish external relationships according to their position in the phases of the innovation process. The principal R&D centres get impulses on new technologies from everywhere in the (global) company but also look for them externally. In cooperation with a university chair, the company can combine collaborative innovation processes with further education of highly qualified academic staff. Companies are currently co-developing a "dual" academic education for young engineers and managers together with institutions of higher education. This can be organised in different ways. It is not new for companies to appoint individuals who get the chance to study at a university during working hours. Advanced studies are of particular interest for the company, where employees get the opportunity to develop their PhD dissertations on a company's problem under the supervision of a professor. Auto2, for example, currently employs a PhD student, who is looking into the problem of how to overcome cultural barriers in collaborative work processes of German and Indian engineers working in development. Because the capability of the professor matters, geographical distance (or proximity) to the university is not an issue.

Auto1 prefers to foster higher education. A new type of higher education institution has emerged in Germany in recent times, the so-called "dual university". Their curricula combine the theoretical education at the university with practical learning and practice at the company. Auto1 signed a contract with a dual university nearby for regularly sending a couple of employees to full two or three-year studies, both in technical and commercial fields. Through practice-oriented diploma dissertations the students can contribute to expanding knowledge in the company. However, this refers more to knowledge in production than in products. Auto8 has a much greater power in resources, and so it has recently sponsored professorships at a nearby university, in those technical fields which are considered as "technologies of the future" by the company. These professorships are simultaneously engaged in education and collaborative research with the company's R&D centre.

There may be further ways of interaction between a company and universities for R&D. Such a close industry-university nexus exists only among German companies in Germany. To a lesser degree, the global Auto8 reports similar relationships in the US. There is no such policy of the companies in emerging economies. Local managers may have contacts to nearby universities – and they are sometimes encouraged to look for them – but the purpose of these predominantly is access to qualified young people. Occasionally, these contacts may lead to improvement innovations, mostly in production processes.

As a result, the increasing meaning of knowledge management and the search for "talent" particularly strengthen the home place of the companies in Germany. At the same time, however, increasing competitive squeeze (from the OEMs) urges the companies to look for cost reductions, even in personnel-intensive and knowledge-intensive R&D activities. The fragmentation of the product design process appears necessary if the company wishes to organise collaborative work in a spatial division of labour. OEMs have demonstrated outsourcing in model development and its new organisation in simultaneous processes (simultaneous engineering) to the suppliers (Schamp et al. 2004). The companies see a major problem in controlling these fragmented collaborative processes and look for various solutions to divide R&D processes and reduce costs. One of the first steps seems to lie in standardisation of parts of the engineer's work load. For example, new products are usually designed in 3D at the R&D centre, while production sites need 2D drawings. German engineers call this a laborious task. Auto1 has relocated ("offshored") the translation of 3D design into 2D drawings to India in outsourcing to a joint venture while Auto2 has created its own R&D engineering service centre in India. Again, the larger Auto8 has established a global development and engineering service centre in India for all of its different business areas.

3.4.2 Learning how to overcome international communication barriers in globally dispersed engineering work

The organisational fragmentation of work at different locations requires the definition of new interfaces and new forms of interaction to become efficient in the collaborative process. Offshoring and outsourcing are not problematic when standards of the characteristics of the deliverables, goods or services, are clearly defined. Product design of automotive suppliers, however, is largely based on experiential knowledge of the engineers. This makes it difficult to relocate development tasks over large distances and different societal cultures. Our companies have answered to the problem, first, in an incremental and traditional way. They send expatriates to the subsidiaries abroad and get employees from the subsidiaries for long-term training (sometimes of several years) to the headquarters. By this they hope to overcome tensions between company culture and the "local" culture of the host countries in order to produce efficiently.

Concerning production, the companies made clear that the way how they try to overcome cultural barriers differs by country. For example, Auto8 attempts to appoint Russian immigrants with a German background ("*Russland-Deutsche*") as expatriates for its subsidiaries in Russia as the company perceives a lack in education in Russia. Qualification levels in China are considered high, and so the company appoints young Chinese having graduated in Germany in German plants before sending them to China in order to foster their corporate identity. This is due to the fact that, unlike in Germany, company loyalty is low in most emerging economies.

The companies realize, however, that they need an improved management of these intercultural barriers if they wish to offshore their collaborative knowledge intensive activities. Auto2 provides a good example of how to cope with the problem. Rather recently, Auto2 established an engineering services company at Pune/India as a joint venture. Auto2 has had a long experience with production for the local market in India since the 1960s. The small R&D department at this location has mostly worked for local clients. Auto2 learnt rather late to use their capacities for some R&D processes in Germany. When the company realized the increasing time pressure on R&D processes from growing demand by OEMs, in the 1990s, it outsourced some R&D activities to a German engineering service provider. A number of large engineering services and consultancy firms have emerged in the "lean production revolution" of the early 1990s in Germany, which still offer their services to OEMs and suppliers. But increasing cost pressure both for internal and external R&D personnel and the fear for losing too much internal experiential knowledge has led the company to investing in a joint venture for engineering services in a country where engineers are qualified but wages low. Auto2 has used its own experience in India and allocated the new engineering services company near to the older production and R&D site. The new engineering service company now has 170 engineers, among them 166 Indian and 3 German and one American. The recent crisis has pushed the decision to relocate further R&D activities on product development to India while basic research and pre-development, i.e. the strategically relevant fields of R&D activities, still remain at the German headquarters. The main problem then – in the eyes of the company's management – is how Indian engineers can catch up with the experience of more than 100 years of product development, which is allocated at the German R&D centre? In another context, that is the relocation of R&D activities from the US R&D centre of a German company to India, Lehner/Warth (2010b, 592) had stated that Indian engineers "lack internal company know-how and product-specific experience," while they are rather familiar with technical systems like CAD and Catia software. Thus, the main problem was how Indian engineers within the company could learn from their German counterparts.

Auto2 used its policy for close collaboration with universities in Germany both in higher education and research by collaborating with a chair on management sciences from the university of Passau, appointing a PhD student and implementing a new knowledge transfer tool which measures the performance of knowledge processes in six dimensions and was developed by that chair (together with a German OEM). This was used to improve processes within the Indian subsidiary, but also as a starting point for overcoming barriers in international and intercultural communication with the German R&D centre. This was not an easy task, as both German older aged (average: 40s) and highly experienced engineers and Indian young aged (medium: 20s) inexperienced engineers spoke different languages. With the assistance of the PhD student, and partly financed by public funds being awarded during the recent crisis, Auto2 looked in-house for a boundary spanner who would be able to translate specific technical requirements from the German R&D centre and teach engineers in cross-cultural communication. Among their nearly 15,000 employees, they found only one Indian engineer who established an intercultural training course specific to the requirements of the company. In order to minimize resistance among the German engineers for fear of being laid-off, Auto2 called this course "training in collaboration".

This had been added to a host of other measures which try to improve the capacity of the Indian engineering services. In order to train Indian engineers in "basics" of technical knowledge on product design and transmit tacit knowledge of the German engineers, Auto2 established IT-based guidelines, checklists and procedure manuals on experiences made in technical problem solving and obliged Indian engineers to use this database. Auto2 was driven to standardize procedures in design processes in India which are not (yet) standardised in Germany, as German engineers still largely refuse to standardise, claiming that this would affect their creative work and self-conception of engineers. In order to teach Indian engineers the complexity of technical solutions Auto2 established short term assignments of Indians to Germany and visiting programmes to suppliers and production plants. And, last but not least, Auto2 implemented a boundary spanner model transferring three Indian engineers to the German headquarters and having three Germans/Americans at the Indian location in order to comprehend the tasks, inform their colleagues (in India) and check the quality of the deliverable (see also Lehner/Warth 2010b). Recently, Harvey et al. (2000) have discussed the increasing need for replacing expatriates by "inpatriates" in global multinationals with "true multicultural competences". Inpatriates are "third country nationals transferred or hired locally into the parent organization on a semi-permanent or permanent basis" (386). Obviously, Auto2 has not yet reached this stage of internationalisation. "Inpatriates" have specific tasks of acting as boundary spanners but are simultaneously counter-balanced by expatriates.

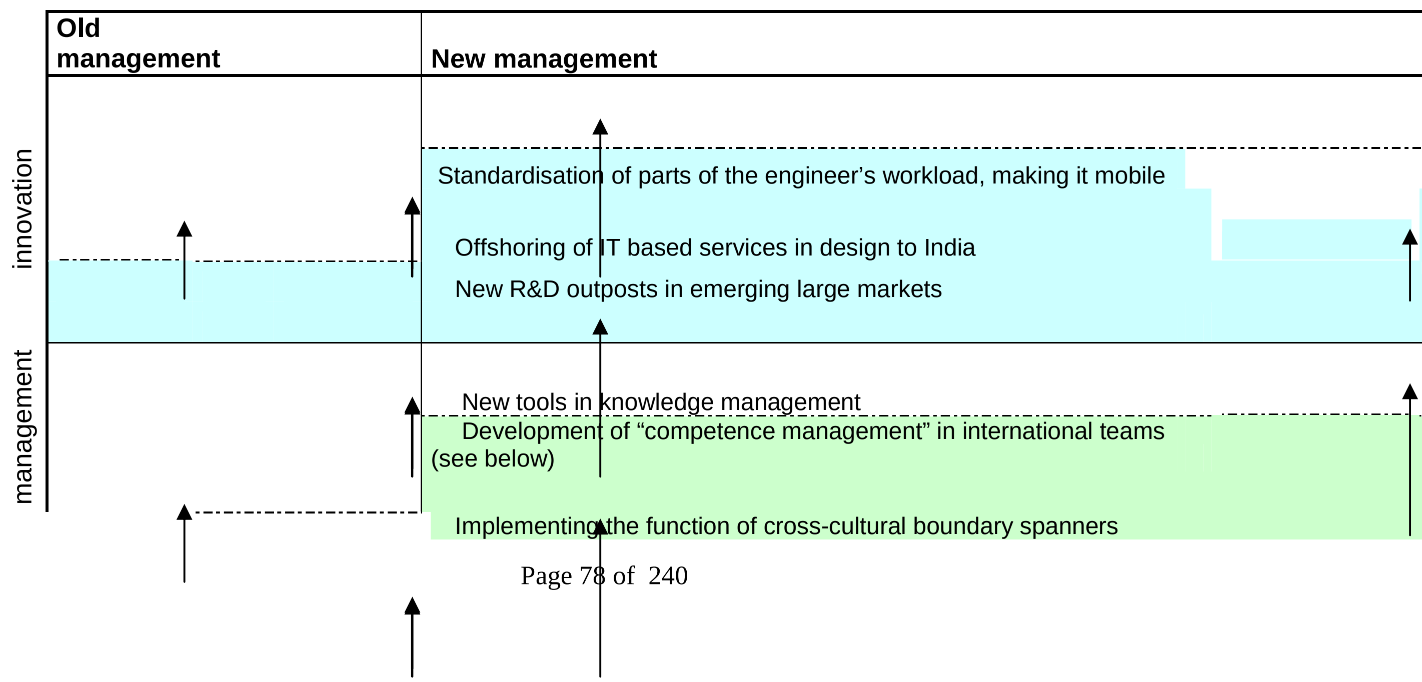
Another problem is to find a balance between safeguarding engineering work at home and relocating abroad, to India. Auto2 currently is involved in an EU-financed project on lean development. One of the topics is international knowledge management by expats. However, there is decreasing preparedness of Germans to go abroad as an expat. Auto2 has some difficulties in appointing German engineers who are willing to go abroad (not in sufficient numbers and sometimes not with the required technical capabilities). At the same time, however, the company does not want to invite Indian engineers in great numbers to the German R&D centre, in part in order not to raise fears among the German engineers of being replaced shortly.

As a consequence, automotive suppliers face certain difficulties in organising efficient collaborative R&D work across large distances but invest in the development of tools for international knowledge transfer and knowledge generation. Again, we state that these problems mainly arise in fields of synthetic knowledge exchange. Where companies are able to define clear-cut interfaces in knowledge products, outsourcing and offshoring seems to have become easier and more likely. That seems to be true in the case of Auto8, which has offshored all its development in software to the Indian engineering service centre.

4. In what sense GINs?

This paper has attempted to elaborate on the emergence and management of global knowledge networks based on the example of three companies from the automotive industry. Although different in size (tab. 3.1), all companies act as "home-based players", are active in broadly the same field of combustion engine technology and share similar clients, the premium car OEMs.

Fig.2: Summary of measures taken in upgrading global capabilities of 3 German companies



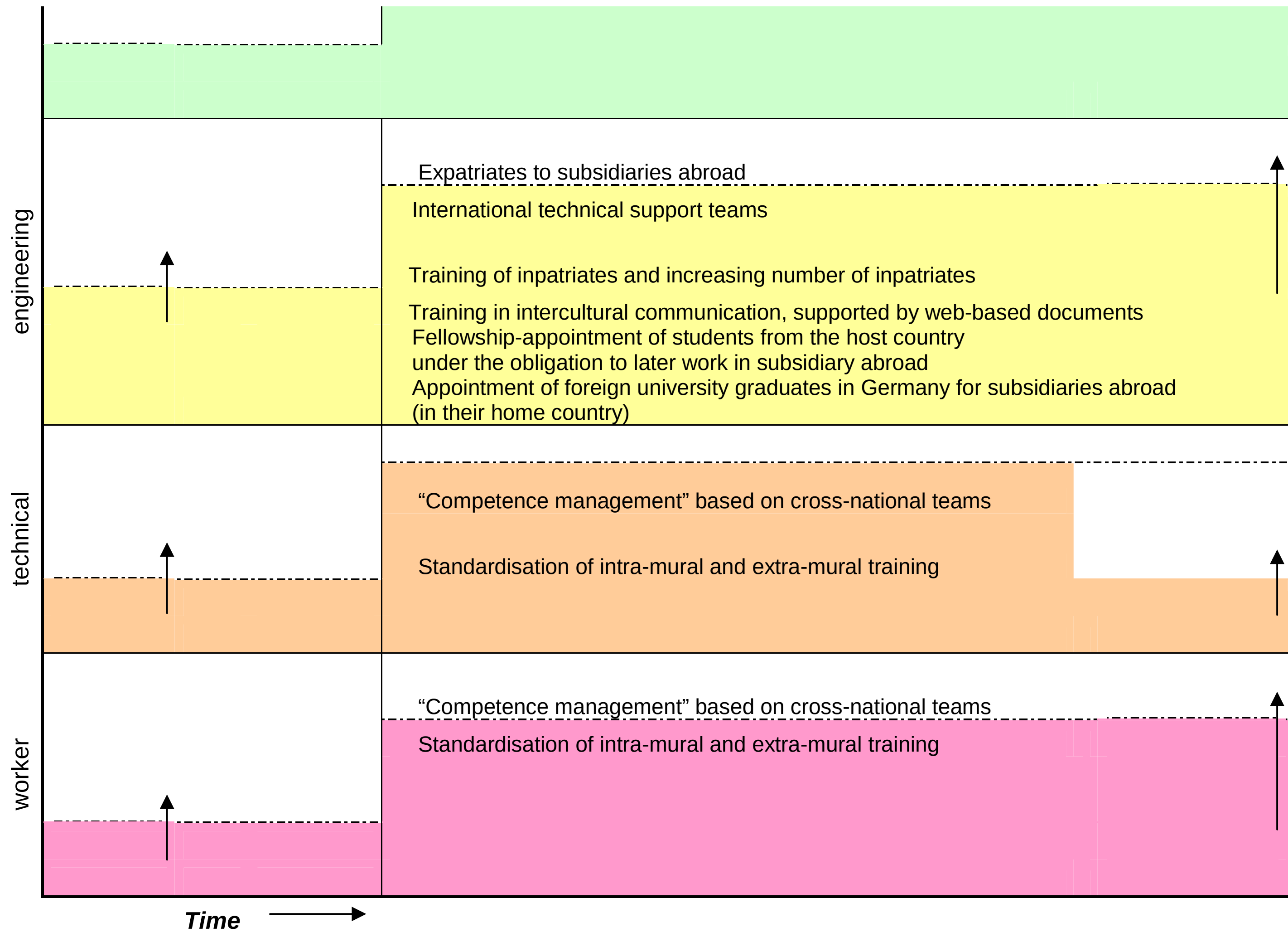


Fig. 2 presents a summary of measures taken by the German multinationals to enhance the capabilities of their global labourforce and to increasingly enable management to offshore more sophisticated tasks. These measures affect all levels of the labour force and include reorganisation of business activities.

To conclude, we will first discuss again the motivation of the companies for implementing new measures in upskilling and acquiring higher qualified human capital abroad. Then the ways how the companies try to learn in the context of a global division of labour are recapitulated. Finally we discuss how far global innovation networks have emerged.

4.1 Push-pull factors in the motivation to upskilling abroad and offshoring R&D

Current literature claims that there are two major causes for going global in knowledge management (Manning et al. 2008, Lewin et al. 2009, among others); first, a shortage in "talent" in the home country due to an "increasing speed to market", second, cost cutting in innovation activities due to increasing global competition. The first argument is on push factors for internationalisation and the building of global innovation networks, seeing the main human resources of the companies in danger in the long-run. The second is on pull factors in the emergence of global innovation networks concerning both availability of "talent" and comparatively low costs of talent at new locations in the world economy and particularly in those regions which currently become fast growing markets for automobiles. Obviously, this applies most to China and India, nowadays.

In discussing the first argument, the case companies do not see any serious problems in finding young staff at home. If they need highly qualified experienced engineers they are confident in the mobility of specialists among companies and sectors in Germany. They believe that there is a pool of experienced labour force in Germany in their own sector and related sectors available, not least because of the decline in manufacturing employment. This is particularly true for the German automotive industry, where consolidation and, partly, lay-offs of experienced labour force are currently taking place. In looking for highly qualified young people, the companies increasingly cooperate with universities (of applied science) in some kind of "dual" education. This dual education combines the accumulation of analytical knowledge at university with the accumulation of experiential knowledge at the company, at the same time. This perception of the three companies on the quasi non-existence of a shortage in qualified labour force – or, at least, of shortage as a minor problem – is partly shared in the current academic and political debate in Germany.

So, the first argument does not seem to be valid, at least in the case of the German automotive industry. This does not mean, however, that the companies are not looking for new "talent" abroad, in emerging economies. The reason is competitive squeeze, so the second argument applies. Automotive markets are not global in its proper sense, but regional. Because of stagnating markets at home, in Europe, the US or Japan, the OEMs have started to conquer new regional markets in Latin America, China and India by investing in own production sites. If automotive supplier companies wish to grow they simply have to follow the OEM client abroad. Imminent market saturation at home and cost competition in the new markets in low income countries cause automotive suppliers to look for new ways of cost reduction even in the development of products. As a result, the building of a global knowledge management is market driven.

4.2 How companies learn to build pipelines in global knowledge management

In general, companies behave tentatively in the appropriation of technical skills at lower costs globally, as they do not wish to threaten their strong competence at home. For the home-based capabilities of the labour force currently are substantially fortified by the close cooperation with institutions of vocational training and higher education. Companies have the opportunity at home to exert influence on changes in the training and education system in terms of new contents and new curricula, via associations, chambers of commerce, and individual cooperation.

By contrast, the companies do not attempt to influence the educational system in their host countries, at least directly. Rather, they react to national education systems by taking measures internally. The way they do this depends on the particularities of the education and training system in the host country. A case in point is Russia, where vocational training in technical fields is non-existent. As a consequence, Auto2 sometimes appoints academically educated engineers even at the shop floor level. In other countries, where the German development assistance has introduced the German system of dual vocational training – which was a major target in development aid during the 1970s and 1980s – the companies took advantage of this. This diversity results in a huge heterogeneity of technical capabilities at the subsidiaries abroad. The companies see their first task, therefore, in achieving an internal company standardisation of skills at the different plants abroad in order to become able to follow the requirements of costumers by quality of products and productivity of the plants. Although this policy does not directly relate to global innovation, it is obvious that global innovativeness of the companies will not be possible without a well trained global labour force in markets which are regional and not truly global.

A second task in learning refers to an improved exploitation of “talent” in engineering for the development of new products in low wage countries. Again, standardisation in parts of the work flow is necessary to enable offshoring. Standardisation reduces barriers in understanding among engineers from different contexts, whether in technical disciplines, language or country-specific cultures. However, barriers in the exchange of experiential knowledge are not reduced by standardisation. The companies, therefore, make use of various ways to simultaneously reduce communication barriers among engineers, such as “inpatriates” for intercultural exchanges, face-to-face training abroad or new concepts for web-based documents. All of these procedures apply internally to the company when the company establishes an offshore R&D centre in an emerging economy. It has to said, however, that most outsourced development processes are software-based activities and software is highly standardised. India is the preferred location for these activities.

A third task is the most difficult as it relies on downgrading in the design of products and production, which is seen as a major future challenge in emerging markets. This seems to be in clear contrast to the two first tasks of learning, which are the (internal) upgrading of the human capabilities. It means, however, a totally different philosophy of innovation as new products are expected to achieve fewer functions, less “comfort” and sometimes less quality but higher cost reductions. The companies see this kind of downgrading as a further activity, in addition to their high-quality activities, extending their access to low-cost markets, creating new capabilities of the company in emerging economies, or, to be more precise, in India. Obviously, the case companies see India as the new base for learning how to develop low-cost products. They claim that high wages for engineers and the traditional philosophy of product architecture trained in education makes low-cost product development impossible at home and requires learning how to develop low-cost products to be allocated in a low-cost country. All the companies make efforts to learn how to develop low-cost products. It seems, however, that Auto8 has made major progress in its Indian R&D centre in this direction. A good indicator for the performance of this strategy is the contribution of German automotive suppliers to the production of the Indian Nano model. Wells (2010, 447) lists several large and well-known German automotive suppliers for the Tata Nano model, such as Bosch, Behr, Continental, Mahle and Freudenberg.

4.3 Which kind of global innovation network?

Global innovation networks have been defined as “a globally organized network of interconnected and integrated functions and operations by firms and non-firm organisations engaged in the development or diffusion of innovations” (Chaminade 2009). Our case study has shown very sector and country-specific forms of going global with innovation activities. Among the cases, we do not see fundamental differences in strategy but differences in the degree of internationalisation, mostly dependent on the size of the company and the variety of product lines. The main message is that the companies stick to a hierarchical model of R&D organisation, maintaining or even increasing the strategic role of the focal R&D centre at home. Paradoxically, innovation activities make different use of internal or external and local or global networking in the different stages of the innovation processes that have been defined by the companies. Thus, the most remote stage of obtaining impulses and generating new ideas is both fixed to the headquarters as well as being the most global in networking to internal and external sources for knowledge. A new division of labour is emerging in providing “services” for engineering at home, mostly based on IT processes. This is mainly located in India. The companies differ in their organisational form as they either have established a world centre for engineering services for all business activities of the company or empower a local R&D site, which is generally only responsible for applications. This offshoring needs a serious standardisation of certain steps in work flows. Finally, the cases have established so-called R&D centres in the different world regions (or regional markets) mostly for access to the region’s OEMs and adjustment innovation. As a matter of fact, global innovation networks in the strong sense as defined above hardly emerge in the German automotive industry.

We believe that these results reflect the behaviour of most of the large automotive suppliers in Germany. The media are increasingly reporting on newly established R&D centres, preferably in China, of large and well-known automotive suppliers. But which type of centre and for which kind of innovation? We would assume that the results of Kinkel and Zanker’s study (2007) apply, namely that most of the (innovative) German automotive suppliers are home- based players and wish to stay with this strategy as long as possible.

4.4 Prospects in the automotive GINs

Another point is how long German automotive suppliers will be able to follow this home- based strategy. There are at least two caveats, one based on the current technology of products and the other based on the current technology of processes. Concerning product technology, it has to be said that the cases are active in (traditional) combustion engine technology for premium cars and commercial vehicles. Both the combustion engine and the premium segment of car markets are increasingly contested, however. During the recent crisis, public debate about new drive propulsion systems has come to the fore. Many OEMs offer or promise to offer soon vehicles with hybrid engines or electrical engines. Then, traditional technologies in gasoline systems (Auto8), exhaust systems and related heating systems (Auto1) and management of thermal processes (“thermo-management”, Auto2) seem to become obsolete. While a radical shift in drive propulsion systems is not to be expected in the near future, the cases have started to prepare for this shift by buying small specialist companies and developing new products based on these technologies. Without any exception, this is done at home, in Germany.

The second caveat concerns production technologies or low-cost production. Wells (2010) has recently sketched the dilemma for European OEMs of being driven to combine a strategy to develop new technologies for environmental reasons and a strategy to reduce production costs substantially, at the same time. For the moment, the premium car segment still is of major importance to most of the automotive suppliers in Germany and so are new “high” technology products. As has been said before, cases begin, however, to learn how to offshore standardised engineering processes and learn about low-cost products and production abroad. Against the claims for a third revolution in the automotive industry, cases claim to have – and get – time for learning. Maybe at the end of a long-term process of a shift of markets to Asia and low- cost products, European production sites (and employment) may suffer but not the companies.

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Multinational strategies, local human capital, and global innovation networks in the automotive industry: case studies from Germany and South Africa

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1. Executive summary

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.

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2. 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.

3. 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 instutions, 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 creatitivity.

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.

4. 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**
Auto9	€5-10 bn	Global: 180 locations in 50 countries	clutches and bearings	South Africa
Auto1	€1-5 bn	Global: locations in more than 20 countries	exhaust systems, heating systems	Germany, South Africa
Auto2	€1-5 bn	Global: 22 production locations, 11 development centres, and two fully equipped R&D centres.	heating and cooling systems	Germany, South Africa
Auto10	€0-1 bn	HQ and manufacturing in South Africa, sales and R&D centres in the UK and US	electronic components	South Africa
Auto11	€0-1 bn	HQ in South Africa, subsidiaries in the UK and Australia	Electronic security systems	South Africa

Note: Turnover is given in ranges to protect anonymity.

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

5.1. 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).

5.2. 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).

5.3. 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.

5.4. 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.

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.

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.

6. 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.

7. 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. Auto1 and Auto2 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.

Auto9 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. Auto11 undertakes its R&D in South Africa, and channels this knowledge to its subsidiaries in Europe and Australia. Conversely, Auto10 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.

7.1. 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. Auto9, 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. Auto1 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. Auto2 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 Auto9'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, Auto9 SA designed a specific 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, Auto9'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 Auto9, Auto1's and Auto2'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. Auto1 has four such centres and Auto2 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 Auto9's South African subsidiary undertakes some product development for the local market, the Auto1 and Auto2 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 Auto1 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.

Auto1 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.

7.2. South African firms

Auto10 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, Auto10 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.

Auto11 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, Auto11 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.

7.3. 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 Auto9 and Auto11 undertake knowledge-intensive activities, and Auto11 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 Auto11 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 Auto9 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 Auto9 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, Auto10 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 Auto10, R&D offshoring to Europe is the result of the local absence of the requisite capabilities. In the case of Auto2 and Auto1, 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 Auto9. 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.

7.4. 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 Auto1 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.

Auto2 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 an Auto2 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 Auto2'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.

8. Conclusions

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. Auto2 and Auto1 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. Auto9 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). Auto9 manages to find sufficient skills to undertake this product development.

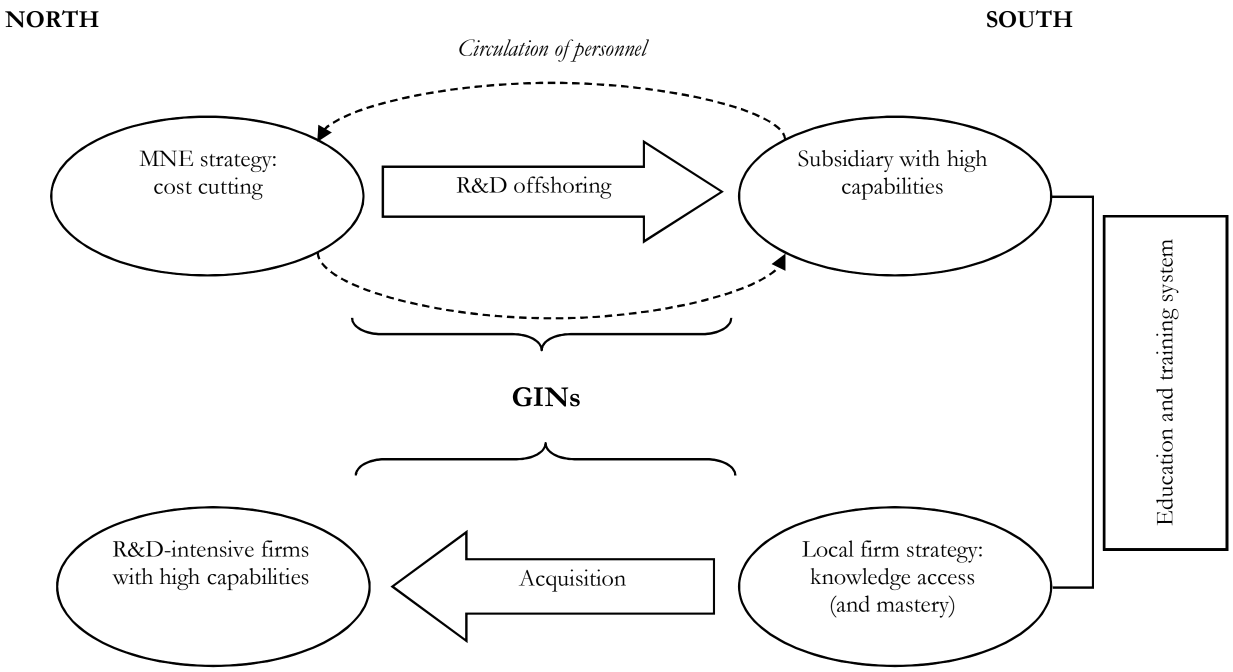
All three German MNE subsidiaries undertake an array of measures to access or internally build up required competencies and capabilities, including staff exchange within the group, internal group knowledge networks (for example, access to specialists in other countries through the intranet), and relationships 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. Auto10 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.

Auto11 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 Auto11 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

[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

Sources: 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

The role of competence-building in firms in the emergence and evolution of GINs in Brazil

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Table of contents

1. Executive summary

The objective of this report is to provide inputs to deliverable A6.1 of Work Package number 6, coordinated by HSRC, South Africa. Within the broader aims of the deliverable, the research carried out by the research team at Cedeplar/Fundep aimed to investigate the correspondence of activities in the GIN and demand of skills by the way of case studies of one large European automotive manufacturer and four automotive systems suppliers.

The most important result from the case studies confirm the studies general hypothesis, i.e., that demand for higher-level competences, in particular of engineering positions, is closely tied to the configuration of the local GIN. In the case Brazil, the GIN under investigation is found in the automotive sector, which has been subject to important qualitative changes in terms of innovative activities in the last decade. From mere processes of adaptation of products developed elsewhere to local markets, local branches have gaining increasing degrees of autonomy to develop new products to the local market, which can eventually be selected by the headquarters to serve other countries.

This broad trend has a few peculiar characteristics. First, the degree of autonomy is, somewhat paradoxically, related to a higher degree of integration of Auto3's local branch to the corporation's global activities. In this sense, for reasons which are intrinsic to this sector, it seems that emergence of GINs is associated with improvements in the configuration of Auto3's GPN. Secondly, the position of the local branch in Auto3's global division of innovative labour is highly path dependent. Local capabilities have been built progressively during the past two decades, having been accelerated in the past 10 years. Thirdly, the degree of autonomy of the local branch to carry out development projects with increasing degrees of independence is inextricably tied to growth and investments cycles of the local market. Changes (consistent increase) of local demand has greatly contributed to foster changes in the supply side, such as the adoption of process innovation, as will be seen in more detail later.

Following the Term of Reference, the report is divided in three sections, apart from this introduction. Section two brings key background information needed to situate the case studies carried out specifically to assess the relationship between GIN activities and demand of skills. This section is further divided in two parts. The first brings information of MNCs R&D strategies in recent years. This information is also based on case studies carried out in the INGINEUS project and considers largely the same companies interviewed for this report. The second sub-section brings information on GIN formation and dynamics in the Brazilian Southeast region. The analysis presented was based on data from the local CIS, the INGINEUS survey and on all case studies carried out for the project. Section three is composed by background information on recent trends in terms of FDI and on local Education training systems. Section three brings the case studies, followed by conclusions and final remarks

2. MNCs, recent R&D trends and GIN formation in the automotive sector

2.1 Recent trends in R&D

Analysing the characteristics of the automotive industry based on the interviews, allows us to argue that the MNCs' strategies have, in general terms, led to a growing process of internationalisation and decentralisation of the innovation activities during the current decade, contributing to the formation of a local GIN. However, the process of internationalisation of R&D activities of the automotive sector is very heterogeneous. It depends on the specific characteristics of the different strategies adopted by each company, both local and MCSs.

The MNCs' strategy for the international expansion of their R&D activities, originally aiming only at product adaptations, has been greatly modified. The interviews carried out for the case studies, with a manufacturer of the sector and its suppliers, allows for some considerations about the changes occurring to the internationalisation strategy for these activities.

The adoption of the global platforms strategy was conducive to the headquarters becoming responsible for formulating or conceiving a new vehicle, while the branches would be responsible for its derivatives. This is due to the fact that the creation of a new vehicle platform involves much more refined innovative activities, which produce an overarching impact on the company's global strategy of product platforms. These activities, in the initial phases of development of global product, are still largely restricted to manufacturer's headquarters, for they capture a higher strategic and decision-making value and demand a greater degree of consolidation of technological competences.

Nevertheless, the R&D works at the branches has been improved in order to allow for a higher degree of specialisation and sophistication. This process increases the responsibilities of the branch, leading to a stronger influence in the definition of the companies' global vehicle platforms.

The hierarchical supply structure, in spite of the growth and concentration of the suppliers, made the latter responsible for adaptations to local market conditions, as well as innovations in the systems produced. It is necessary to bear in mind that there are specific roles for Auto3 and the supplier, which, different as they may be, interact with one another. The supplier is responsible for conducting a careful study on the components and/or systems, proposing new solutions. Auto3, in its turn, is responsible for understanding the integration of the system as a whole, its behaviour in the vehicle's environmental and utilisation conditions and its interaction with the other systems, as well as providing feedback to the process based on the perception of the clients regarding the complete automotive system.

A good example of the changing nature of local R&D is the case of the Computer-Assisted Transmission (CAT). In this case, it is the supplier who was in charge of overcoming technical and production hurdles of this system's elements, but it is Auto3 1HQ and Suplier 2 that defined the installation conditions, the requirements for integration with the vehicle's electronic system and the advanced user configurations. Manufacturer 1 was involved with advances in design activities as well as in vehicle tests, but not in research. As mentioned above, the basic research activities were carried out at the HQ research center in Europe.

It can be said, however, that there has been an increase in the capacity of Auto3's branch influencing the conception of new platforms. Manufacturer 1 has a local development facility that performs numerous activities which were exclusively carried out at HQ ten years ago. This facility can suggest modifications to a platform, and, even though there is currently no demand for it, it is able to independently develop a new platform.

Suppliers also play a key role in the innovation of certain systems such as flex-fuel, differential block system (DBS) and CAT. Be that as it may, it is important to bear in mind that the branches follow different strategies for the internationalisation of innovation activities. The contribution of the Brazilian branch is evident in the flex-fuel case, even though the product was developed together with the headquarters. The company's long experience and accumulation of local technological capacities, due to the development of the ethanol motor, were decisive in this process. Regarding CAT, the innovation was originally proposed abroad, but local competences exerted important influence in the development of the product, which was carried out by the branches of both Auto3 and the supplier. Finally, the supplier's branch was the centre of the development of the DBS system, but the integration to the vehicles was coordinated by Auto3's branch.

An important point is that the increase in some of the suppliers' branches innovation activities was based on the knowledge accumulated along the years and on the capacities of Brazilian companies (systems suppliers) acquired by MNCs. The existence of more consolidated capabilities in the branches of certain MNCs has allowed for a more intense decentralisation of development activities.

The global platform is, therefore, the prevalent strategy. It is induced by the growing importance of the local and of others similar markets, as well as by the capture and control of the growth of the local branches' technological capacities according to specific paths. This has happened in a contradictory manner that sometimes creates conflicts with the headquarters.

A central point is that the strategic decisions still lie with the headquarters. The most important question is the location of the decision-making power, and no changes whatsoever can be noticed. Nonetheless, the changes in the flow of knowledge cause significant investments in more noble activities to be constantly redirected to the branches. On that account, the MNCs' strategy of internationalising the R&D activities signal to the formation of a global innovation network. This network is marked, though, by a strong hierarchical character, regarding both the responsibilities of each part and its decision-making structure.

2.2 GIN formation and dynamics in Brazil

The combination of ICS data with case studies and the INGINEUS survey allowed us to identify the inner workings of a GIN in the automotive sector in Brazil. The GIN studied is centered on one of the local market leaders. The company coordinates innovative projects across both across its own productive chain and with outside partners such as universities and research institutes.

The case study provided evidence of increasing levels of independence of the MNC in relation to its headquarters in the last decade. From pure product adaptation mandates the company's capabilities have been progressively upgraded towards new product development. This process includes the constitution of independent R&D department in one of the group's companies as well as the appointment of a director of innovation to each internal department,

However, R&D is still restricted to product development under strict oversight of the HQ. Basic research is still virtually absent from the network for a variety of reasons, chief amongst them are the dynamics of innovation in the sector (kept closely to the HQ) as well as depth of the local market which only allows for incremental innovations stemming from the more usual processes of product adaptation. Hence, it can be said that the formation of a GIN does not present a significant challenge to the hierarchical structure of the sector.

Within this broader landscape, new initiatives that divert from the sector's norm could be observed. The case studies have revealed a couple of successful projects which have originated locally and, when the financial viability was verified by the HQ, sprung out to involve different parts of the corporation as well as outside partners to bring the project to fruition.

During theses projects, the types of innovations and connections between several distinct partners, which involved the movement of local engineers to the company's HQ, can be said to fit the "true" configuration of a GIN as described by the literature. However, such projects are still not the norm in the industry and are commonly associated with the personal effort of some professionals which have moved faster than the institution itself in terms of the pursuit of innovations.

Based on all available data, we argue that that a GIN could be clearly identified in the auto sector. However, contrary to what has been described in the literature, the local GIN's structure is, at one time, incomplete (immature) and intermittent.

The GIN is incomplete for three main reasons. First and foremost, the vast majority of innovation projects are of product development usually to adapt new products to the local market. Secondly, the connections between companies that are part of the proactive chain such as universities and other RIs is still in its infancy. There are only but a handful of on-going formal collaboration projects involving URIs. However, the case studies have shown that the companies are actively searching new forms of collaborations and partnerships. Finally, the companies interviewed are still in the process of institutionalizing innovation management routines.

The intermittent character of the GIN comes from the close relationship found between the degrees of freedom to innovate and economic performance of the local branches. Economic success is still not seen as emanating from the local innovative effort. However, this scenario tends to change in the short run given the rates of growth of the local market observed in the past few years which has led to increasing competitive pressure within the sector.

3. FDI and Education Systems

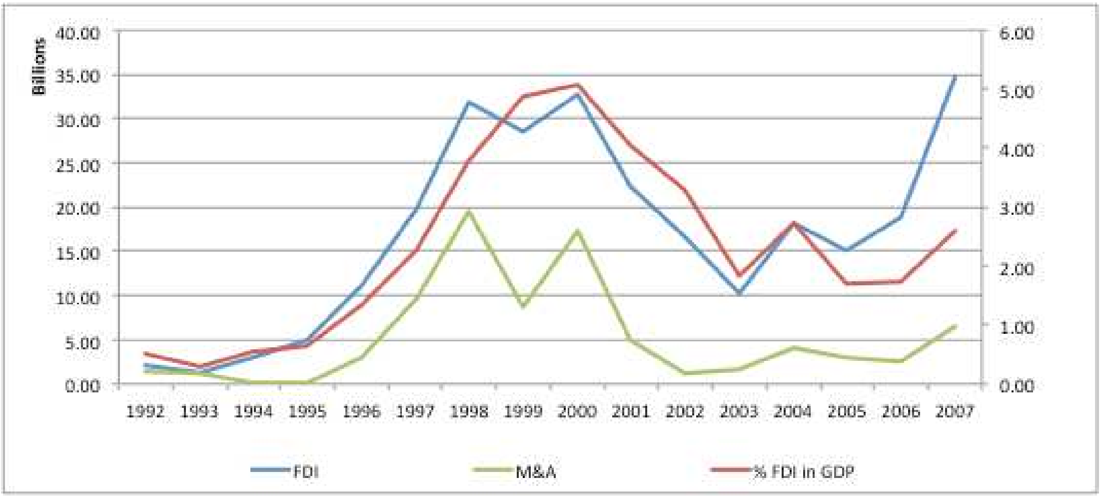
3.1 Foreign Direct Investments in Brazil

After a long period of low capital inflows, the Brazilian economy was subject of a series of market-oriented reforms. Chief amongst of the objectives of the policies adopted, was the attraction of foreign of foreign direct investments (FDI). That strategy was closely related to the proposals of the Washington Consensus, which advocated the importance of: (i) price stability to improve investment; (ii) trade and financial liberalization in order to enhance competitiveness and productivity; (iii) foreign direct investment and privatization to investment and infrastructure. In that view, foreign capital would be not only responsible to finance transitory balance of payment disequilibria, but also to induce a process of industrial modernization, increasing the productive capacity and transferring technology to the local economy.

Figure 1 shows the results of the FDI attracting policies. The economic liberalization, started in 1990 and reinforced after 1994, was responsible for a sharp increase in FDI. The increase can be partially explained by the search for new markets in face of the stagnation of the developed economies, and the excess liquidity due to low interest rates level. In addition, the rise in FDI inflows were also due to the policy of privatization of state owned enterprises. This type of FDI inflows is represented by Mergers and Acquisitions (M&A), which increased noticeably between 1995 and 2002.

According to Cano (2003), between 1986 and 1992 thirty-eight state companies were privatized (eighteen among metallurgy, fertilizing and petro chemistry), another twenty-six between 1995 and 1997 (mostly industrial ones), and another thirty six only in 1997. In the year 2000, eleven companies were privatized, bringing to an end the privatizing cycle. During the whole period, around US$ 100 billion in state owned enterprises were transferred to the private sector (US$ 82 billion in effective payments and US$ 18 billion in debt transfers). Besides the overall privatization, there was also, as mentioned, an internationalization of the production through a series of M&A, which resulted in a closer correlation of the domestic and international investment cycles.

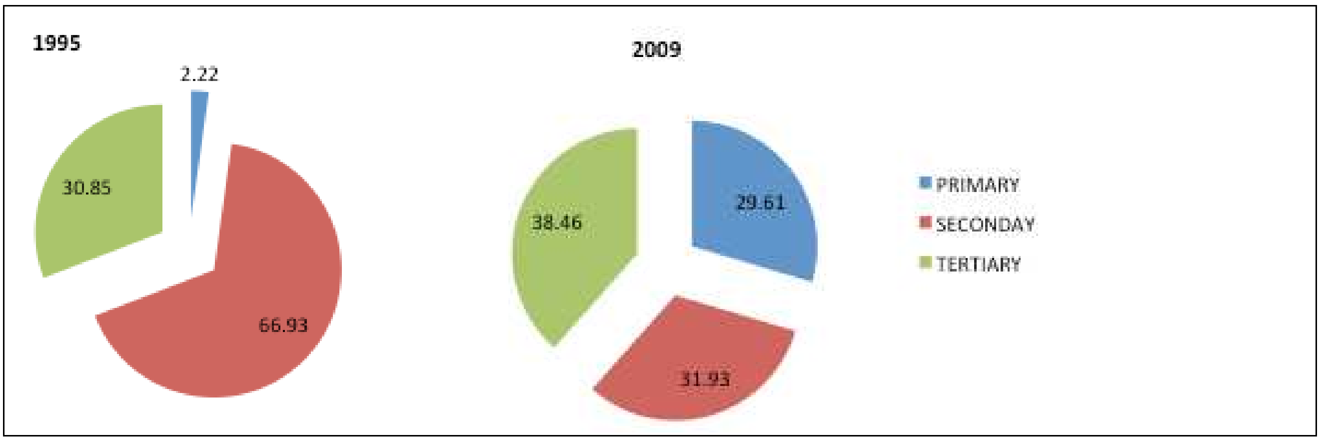
Figure 1: Total FDI inflows, Brazil (1992 – 2007)



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

Together with an overall increase in values, a sectoral change in distribution FDI inflows could also be observed, as shown in Figure 2 below. For instance, in 1995, two-thirds the FDI in Brazil was focused on the manufacturing industry. In 2009, that share falls under a third, in parallel with increases in services (fro over 30% to 38%) and primary sectors (from around 2% to almost 30%).

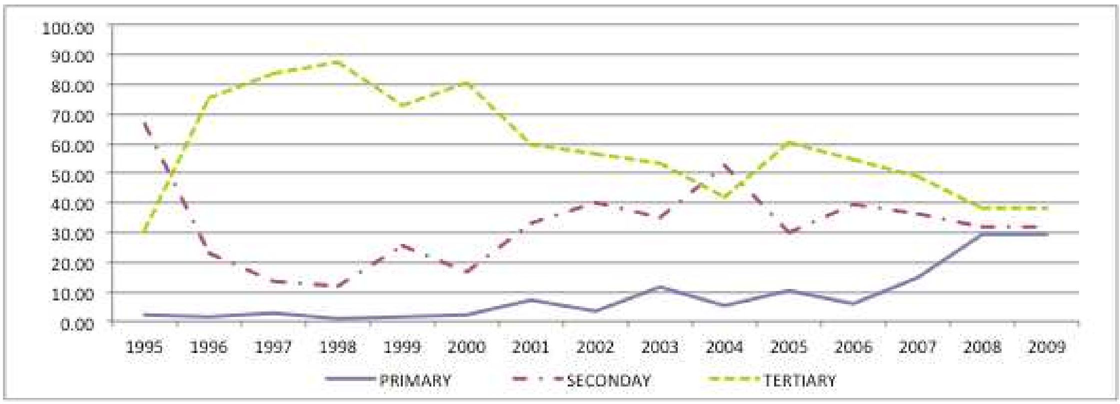
Figure 2: Sectoral share of FDI



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

By looking at the evolution of the sectoral share of FDI (Figure 3), it can be seen that during the boom of FDI (1995 to 2002), the main destination of investments was the services sector. In particular, financial services and telecommunications received the bulk of the resources as a result of privatizations of state owned banks and telecommunication service providers. During this period there was a significant relative decline in industrial FDI, which would only recover from the year 2000 onwards. The primary sector FDI remained at low levels until 2006. The recent growth can be attributed to mining, due to the constant increase of its demand, motivated by the Chinese growth. However, despite of the recent shifts, the services sector remains the main focus of the FDI in Brazil.

Figure 3: Evolution of the sectoral share of FDI, Brazil (1995-2009)



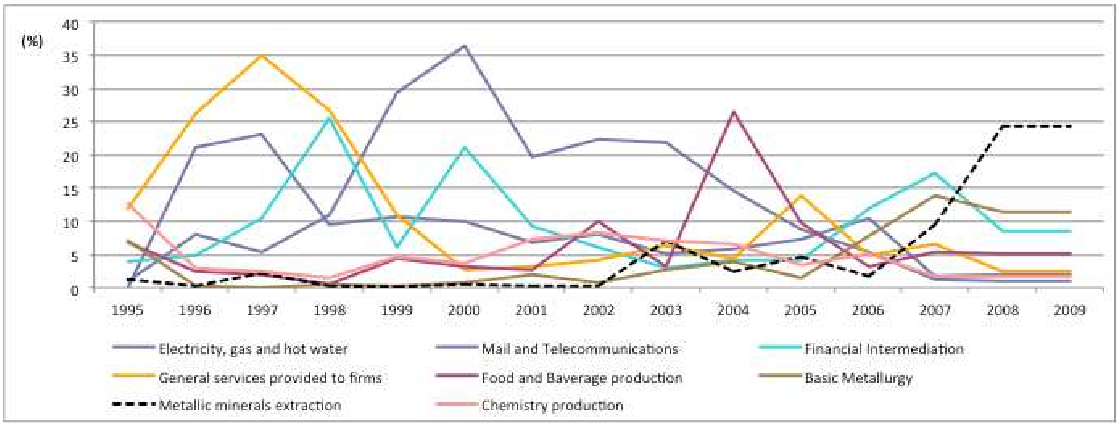
Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

Within these broad trends, it is also important to evaluate the sectoral composition of FDI composition in a more disaggregated basis. As can be seen in Table 1, from 1995 to 2009, the average participation of the primary sector on the total FDI was only of 8,57%, in comparison with 32,5% on industry, and 58,9% on services. Here becomes clear how predominant was and still are the focus of FDI in the services sector. In this sector, the highest average shares of FDI are observed in the areas of Electricity, gas and hot water (8,3%), Mail and Telecommunications (12,5%), Financial Intermediation (9,7%), and General services provided to firms (10,8%). Once more, the data show the importance of the privatizations. Other important areas were the wholesale and retail trade sectors (respectively with 3,6 and 3,7% average FDI share).

Regarding the primary sector FDI, the main focus was the Metallic minerals extraction (5,29%). The industry FDI, on the other hand, was mostly focused on the Food and Beverage production (6,03%), Chemistry production (4,76%), Basic Metallurgy (4,31%) and Automotive vehicles production and assembling (4,81%).

The recent trends follow the increasing Chinese demand, which produced a rise in the Metallic metals extraction, Metallurgy, and Food and Beverage production. All the other relevant sectors mentioned received higher amounts of FDI due to privatizations. It is worthy to mention the fall on the General services provided to firms, which escapes those two lines of analysis (Figure 4).

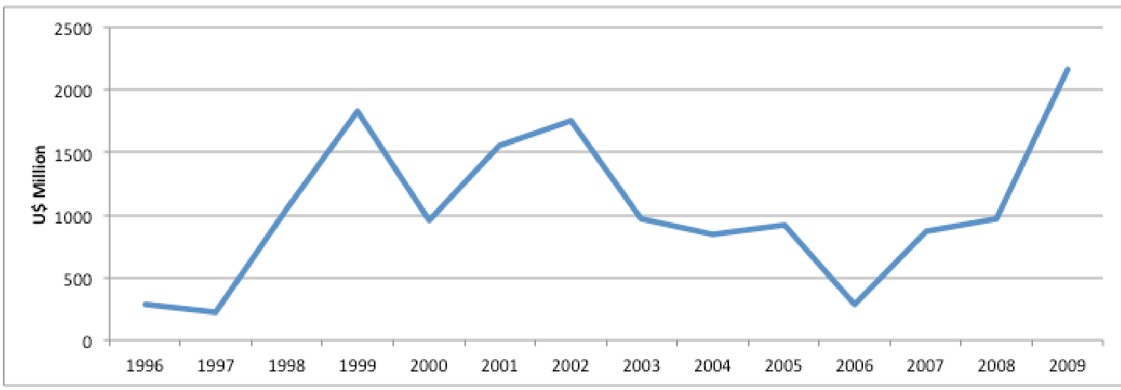
Figure 4: Sectors' share on total FDI in the services sector



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

As for the automotive sector, two distinct phases can be seen in Figure 5. The first phase includes three processes. The first is represents a cycle of investment in modernization and capacity expansion of existent automakers, mainly from 1996 to 1999. The end of this cycle coincided with the second process, which includes greenfield investments of new entrants. The third process involves M&A and capacity expansion of autoparts and components companies. The second phase has a clear start in 2006 and corresponds to the need to increase production capacity in face of the sharp increase in sales occurred in the 2000s, and from 2005 in particular. The boom in sales was a result from the increase in the local market due to consistent income growth as well as the expansion of credit mechanisms.

Figure 5: Evolution of the sectoral share of FDI, Brazil (1995-2009)



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

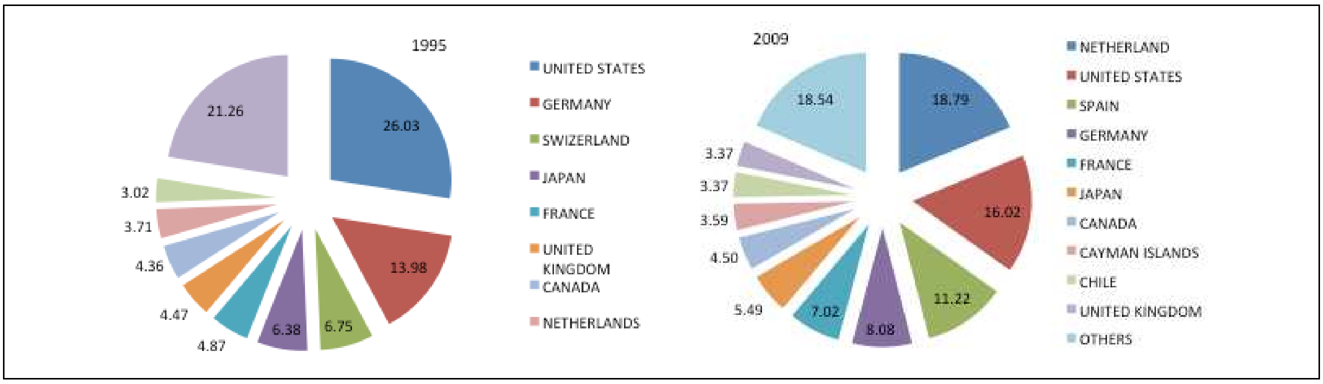
Table 1: Sectoral FDI distribution, Brazil (selected years)

	1995*		2000		2005		2006		2007		2008		2009	
SECTORS	**Stock**	**%**	**Flow**	**%**	**Flow**	**%**	**Flow**	**%**	**Flow**	**%**	**Flow**	**%**	**Flow**	**%**
AGRICULTURE, ANIMAL HUSBANDRY AND MINERAL EXTRACTION	924.99	2.22	649.4421	2.17	2194.371	10.20	1363.121	6.13	4982.067	14.78	12995.57	29.61	4474.27	29.61
Agriculture, animal husbandry and related services	207.23	0.50	0	0.00	210.176	0.98	176.1144	0.79	316.9124	0.94	498.1131	1.14	255.0155	1.14
Forest production	30.49	0.07	0	0.00	36.45934	0.17	34.91064	0.16	473.1188	1.40	117.8117	0.27	164.7641	0.27
Fishing	7.88	0.02	0	0.00	6.36284	0.03	2.616358	0.01	5.9744	0.02	3.281218	0.01	1.59218	0.01
Coal extraction	0.00	0.00	0	0.00	0.295	0.00	0.768188	0.00	0	0.00	0	0.00	0	0.00
Oil extraction and related services	72.01	0.17	480.9051	1.61	896.9005	4.17	734.0528	3.30	650.3749	1.93	1338.971	3.05	2533.233	3.05
Metallic minerals extraction	566.71	1.36	133.357	0.45	995.6867	4.63	392.8617	1.77	3223.018	9.56	10644.69	24.26	1303.235	24.26
Non-metallic minerals extraction	40.68	0.10	35.18	0.12	48.49106	0.23	21.79643	0.10	40.58438	0.12	161.6563	0.37	7.241606	0.37
INDUSTRY	27907.09	66.93	5070.18	16.97	6402.811	29.75	8743.779	39.33	12166.08	36.10	14012.97	31.93	11924.74	31.93
Food and Baverage production	2827.52	6.78	975.0295	3.26	2074.827	9.64	739.3257	3.33	1816.744	5.39	2238.233	5.10	542.3208	5.10
Tabacco production	715.41	1.72	0	0.00	20.04534	0.09	114.2713	0.51	7.062739	0.02	7.161025	0.02	8.811625	0.02
Textile production	529.78	1.27	35.7	0.12	126.6326	0.59	649.0195	2.92	52.63781	0.16	51.04983	0.12	66.10606	0.12
Clothing and accessories production	78.08	0.19	14.9	0.05	12.90919	0.06	21.74208	0.10	30.12014	0.09	18.36978	0.04	15.73453	0.04
Leather and related goods production	428.40	1.03	0	0.00	9.471364	0.04	13.64943	0.06	50.66209	0.15	3.797879	0.01	18.05018	0.01
Wood goods production	28.99	0.07	31.67197	0.11	123.7949	0.58	67.46621	0.30	34.60915	0.10	103.8372	0.24	211.2362	0.24
Cellulose, paper and related goods production	1633.66	3.92	10.30505	0.03	158.6202	0.74	1797.381	8.08	262.5238	0.78	204.8483	0.47	771.845	0.47
Printing and edition	137.97	0.33	15.6207	0.05	25.83181	0.12	278.7187	1.25	10.27851	0.03	12.5301	0.03	8.24239	0.03
Coke, oil refine and fuel production	0.00	0.00	0	0.00	8.065138	0.04	259.9825	1.17	1618.712	4.80	1637.929	3.73	1144.474	3.73
Chemistry production	5331.12	12.79	1100.715	3.68	763.6577	3.55	1133.877	5.10	587.615	1.74	789.326	1.80	753.3403	1.80
Rubber and Plastic goods production	1538.66	3.69	58	0.19	481.4295	2.24	223.2381	1.00	465.4339	1.38	670.5105	1.53	437.4556	1.53
Non-metalic metal goods production	853.84	2.05	67.02484	0.22	16.57935	0.08	151.8048	0.68	307.4487	0.91	650.5261	1.48	224.4371	1.48
Basic Metallurgy	3004.90	7.21	245.5836	0.82	310.2987	1.44	1712.515	7.70	4699.746	13.94	4984.255	11.36	3768.641	11.36
Metal goods production	572.76	1.37	26.11705	0.09	94.20504	0.44	96.99117	0.44	56.76887	0.17	143.7432	0.33	128.3292	0.33
Machinery production	2345.29	5.62	578.891	1.94	254.9656	1.18	429.7264	1.93	431.3097	1.28	506.0481	1.15	390.4225	1.15
Office and computer machinery	457.86	1.10	23	0.08	59.31131	0.28	18.22162	0.08	159.0503	0.47	145.1694	0.33	326.6684	0.33
Eletric materals and machines production	1100.58	2.64	65.8317	0.22	163.9396	0.76	206.1915	0.93	371.4738	1.10	335.4626	0.76	357.1042	0.76
Eletronic material and telecomunication equipment production	785.42	1.88	655.32	2.19	395.9787	1.84	325.1083	1.46	0	0.00	0	0.00	0	0.00
Hospital equipament production	168.43	0.40	19.5	0.07	69.67481	0.32	100.5569	0.45	0	0.00	0	0.00	0	0.00
Automotive vehicles production and assembling	4837.70	11.60	960.6709	3.22	924.8647	4.30	287.6031	1.29	871.7079	2.59	964.1301	2.20	2163.458	2.20
Other transportation equipaments production	223.00	0.53	186.2992	0.62	208.992	0.97	108.3916	0.49	13.21029	0.04	55.38286	0.13	73.38865	0.13
Furniture and other industries production	294.41	0.71	0	0.00	80.55364	0.37	7.615195	0.03	124.8333	0.37	120.9575	0.28	125.6564	0.28
Recicling	13.32	0.03	0	0.00	18.1633	0.08	0.382106	0.00	0	0.00	0	0.00	0	0.00
SERVICES	12863.54	30.85	24156.75	80.86	12924.38	60.05	12124.4	54.54	16556.44	49.12	16877.75	38.46	14044.96	38.46
Electricity, gas and hot water	0.29	0.00	2972.191	9.95	1570.891	7.30	2331.808	10.49	618.2213	1.83	909.1761	2.07	970.0686	2.07
Water distribution, captation and treatment	1.80	0.00	73.52799	0.25	5.473894	0.03	19.09253	0.09	7.517439	0.02	148.2482	0.34	28.73463	0.34
Construction	202.68	0.49	12.00699	0.04	203.4481	0.95	320.93	1.44	1716.611	5.09	1746.181	3.98	1164.535	3.98
Trade and repair of automotive vehicles	84.39	0.20	88.2935	0.30	62.42277	0.29	24.32417	0.11	70.13835	0.21	96.02005	0.22	64.16705	0.22
Wholesale trade	2132.20	5.11	886.3477	2.97	680.7549	3.16	914.4018	4.11	666.3572	1.98	1640.383	3.74	1474.926	3.74
Retail trade and personal objects repair	669.11	1.60	660.0881	2.21	2099.62	9.76	546.7695	2.46	2099.454	6.23	923.2636	2.10	1292.67	2.10
Home renting and food	364.31	0.87	0	0.00	127.8807	0.59	349.5013	1.57	170.2007	0.50	167.2682	0.38	275.9716	0.38
Land transportation	6.43	0.02	44.12038	0.15	27.91003	0.13	10.17165	0.05	36.11383	0.11	346.8297	0.79	132.5321	0.79
Water transportation	90.49	0.22	0	0.00	23.44328	0.11	19.51129	0.09	166.5547	0.49	117.5325	0.27	158.2698	0.27
AirtTransportation	24.72	0.06	0	0.00	0	0.00	133.2512	0.60	32.9084	0.10	188.0287	0.43	220.059	0.43
Complementary transport activities	71.42	0.17	38.3	0.13	161.4137	0.75	153.7181	0.69	911.1035	2.70	418.7818	0.95	324.3849	0.95
Mail and Telecommunications	398.74	0.96	10914.05	36.53	1899.657	8.83	1215.534	5.47	402.2742	1.19	463.3728	1.06	584.9333	1.06
Financial Intermediation - excluding insurance and private pension funds	1638.38	3.93	6352.214	21.26	888.6138	4.13	2647.349	11.91	5828.189	17.29	3802.568	8.66	2503.176	8.66
Insurance and Private pension funds	149.61	0.36	13.86531	0.05	860.9886	4.00	252.17	1.13	369.3891	1.10	473.8671	1.08	1314.844	1.08
Complementary activities of financial intermediation	390.43	0.94	32.16	0.11	404.8717	1.88	345.1723	1.55	126.4637	0.38	1911	4.35	1130.267	4.35
Housing activities	1109.24	2.66	20.87605	0.07	296.9512	1.38	1405.013	6.32	721.8494	2.14	1721.397	3.92	596.1226	3.92
Non-tripulated vehicles and machines rent	363.31	0.87	0	0.00	47.77664	0.22	67.99717	0.31	60.87874	0.18	79.07333	0.18	83.95593	0.18
Computer suport activities	115.11	0.28	1121.483	3.75	144.2915	0.67	192.3208	0.87	193.2091	0.57	392.9123	0.90	858.9416	0.90
Research and development	5.54	0.01	0	0.00	11.65006	0.05	4.804086	0.02	21.99785	0.07	19.09673	0.04	19.86145	0.04
General services provided to firms	4952.70	11.88	814.7213	2.73	2978.102	13.84	1067.005	4.80	2243.478	6.66	1072.998	2.44	737.1814	2.44
Education	1.08	0.00	0	0.00	50.65904	0.24	36.99666	0.17	49.75131	0.15	178.5912	0.41	56.88771	0.41
Health and social services	17.84	0.04	0	0.00	3.004708	0.01	3.534498	0.02	7.091282	0.02	5.128937	0.01	3.58611	0.01
Urban cleaning and sewage activities	2.19	0.01	34	0.11	0.202739	0.00	17.4447	0.08	0	0.00	0	0.00	0	0.00
Associative activities	54.42	0.13	24.04112	0.08	0	0.00	0.262846	0.00	0.100349	0.00	0.057571	0.00	0.013382	0.00
Recreative, cultural and sports activities	15.21	0.04	54.46969	0.18	372.7731	1.73	34.67858	0.16	32.93495	0.10	53.85601	0.12	46.74286	0.12
Personal services	1.92	0.00	0	0.00	1.583975	0.01	10.63966	0.05	3.650283	0.01	2.040938	0.00	2.128761	0.00
TOTAL	41695.62	100.00	29876.37	100.00	21521.57	100.00	22231.3	100.00	33704.58	100.00	43886.3	100.00	30443.97	100.00

Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

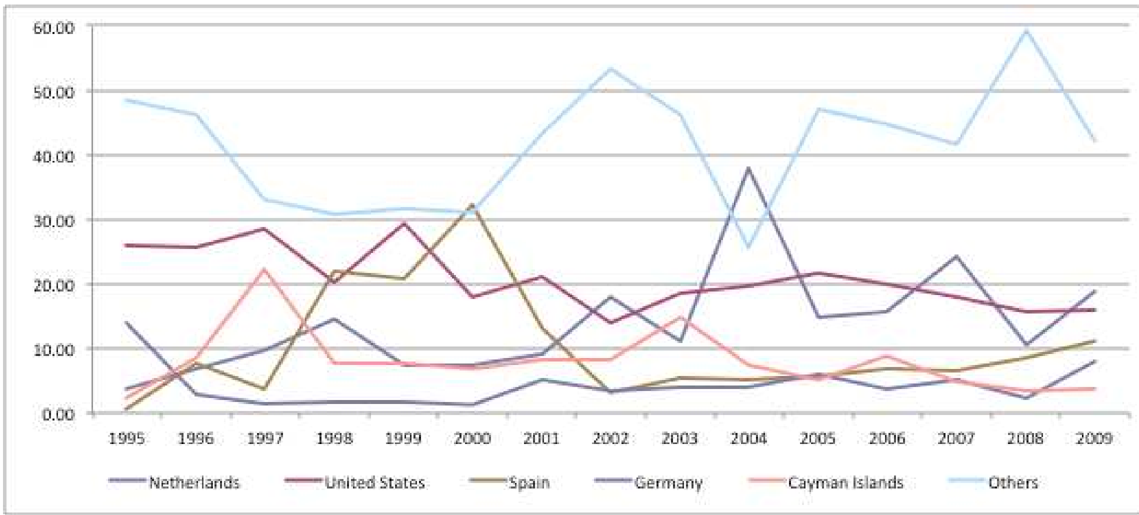
Examining the source of the FDI, a considerable change of pattern can also be seen. From a predominance of US (26,03%) and Germany (13,98) FDI, sector shares shift to a higher percentage of FDI from the Netherlands (18,79%), with US coming in second (16,02%), followed by Spain (11,22%), and then Germany (8,08%).

Figure 6: FDI share by source, Brazil (1995, 2009)



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

Figure7: Evolution of FDI share by source



Source: based on data from the Brazilian Central Bank (www.bcb.gov.br)

By looking at the evolution of the share(Figure 7), one can observe that most of FDI from Spain was concentrated between 1997 and 2002, associated with the process of privatization of telecommunications and financial institutions (it is interesting to highlight that Portugal's FDI in Brazil followed the same trend). The share of investments from the US presents a persistent downward trend, while Germany's share shows a slight rise. The most impressive feature is still the rise of Netherlands' share.

As argued by Silva (2004), while national companies were involved in privatization in the industrial sector, foreign capital was mostly focused in the services sector. US and Germany's FDI in Brazil was mostly directed to the manufacturing industry, while the Netherlands' FDI focused services (mainly in telecommunications and financial intermediation).

In that sense, it can be argued that the contribution of the FDI to the Brazilian growth was modest, both due to its low share on total GDP, and to its bias towards the services sector. Laplane and Sarti (2003) stress this argument by showing that the investment rate in Brazil did not presented considerable variations during the 1990s, staying always around 20%. In terms of exports performance, Brazil's share in international trade in 1980 was 1%, growing to 1,4% in 1984-5, and then going down to an average of 0,9% during the 1990's (Silva, 2004). In general, the impact of FDI growth in 1990's did not resulted in a positive long-term impact on the trade balance. Laplane and Sarti (2003) also show that in 2000 the share of foreign companies in the biggest five hundred companies operating in Brazil was of 56% in terms of profit, 49% of exports, and 67% of imports. The data suggests a higher propensity to import by the foreign firms. In this sense, the increased FDI presented a higher pressure on the balance of payments deficit.

3.2. Education and training system in Brazil

The Brazilian education system is characterized by a mix of public and private institutions. In primary and secondary education, the vast majority of students are enrolled in public schools. These provide, with rare exceptions, lower quality education, in comparison with private schools. This characteristic tends to reinforce the effects of income inequalities in the country, given that only the richer families can afford private schools.

In terms of higher education, the opposite can be observed. Public universities and public research institutes are most often the best, and provide usually a broader range of courses. However, public institutions do not account for the majority of higher education enrolment. More than half of students in higher education students are enrolled in private universities and faculties, which present considerable variations in terms of quality of education (Schwartzman, 2005). This pattern is true for undergraduate and postgraduate education alike. The latter, in its turn, offers a relatively low number of places.

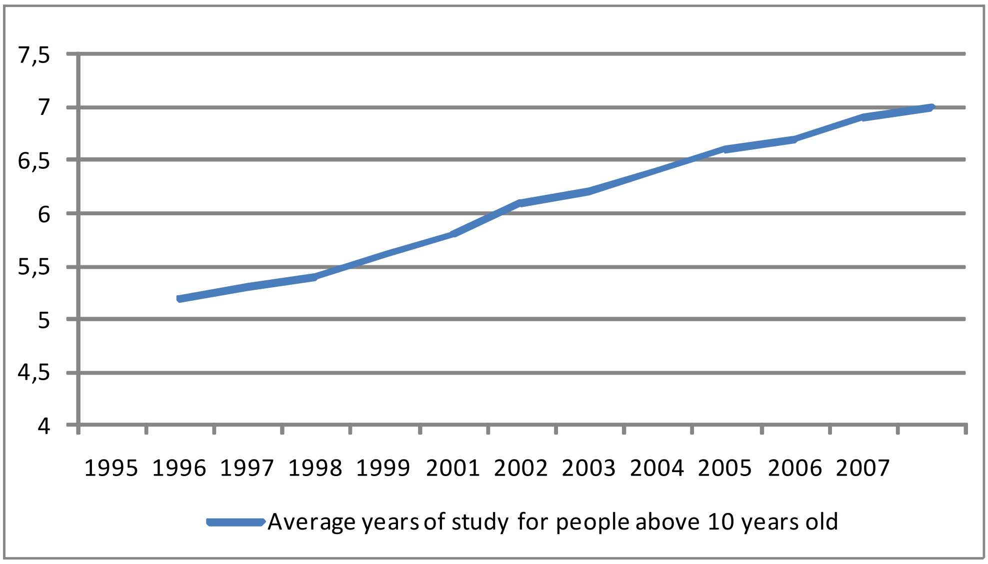
The structure of higher education also reinforces the effects of income inequalities. Given that enrolment in public universities depends on merit, the vast majority of students that are granted a place in public institutions attended secondary education in private schools. Hence, the asymmetric quality of education is tied to an historical asymmetry in opportunities. Education policies have focused on the improvement of infrastructure in general, and on the improvement of participation ration in primary and basic education. More recently, more effort has been directed to the increase of higher education places in public institutions outside the main urban centers, in a process often described as 'interiorization' of higher education.

Given the gap existing gap in terms of participation rates between secondary and higher education, professional education has historically been important to prepare large number of students to the labour market. However, this modality does not solve the inequality issue, once university education usually presents higher prestige and result in better job allocations (Schwartzman, 2005).

It is also important to notice that there is also a regional disparity of quality education in Brazil. In richer states, located in the Southeast and South regions, are home of the best schools and universities. In this regard, however, public universities fulfil an important gap. All states have public, federal universities that guarantee higher education even in the more remote areas of the country.

From 1995 to 2002, several policies were introduced by the National Institute of Pedagogic Studies (INEP) in order to improve the education system. During this period, tests were created to evaluate the quality of basic education (SAEB – evaluation system of the basic school), high school education (ENEM – national exam of the high school), and superior education. This apparatus provided better tools enable better policy formulation and evaluation. Together with these mechanisms, the federal government was also responsible for the creation of the Bolsa-Escola (replaced during Lula's presidency by the Bolsa-Família), a program that provides a small income to poor families that keep their children in school. This and other efforts have shown positive results (Figures 8 and 9).

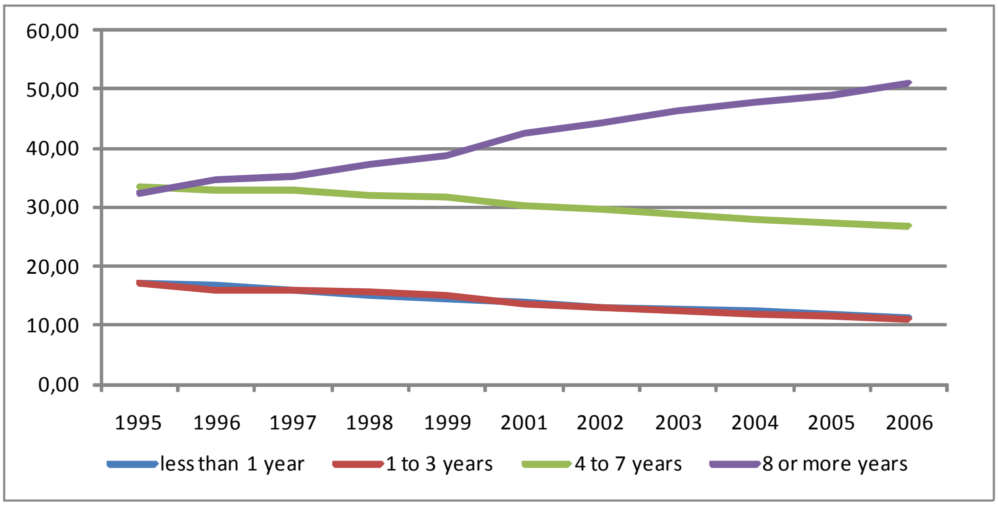
Figure 8: Evolution of years of schooling in Brazil



Source: own elaboration

Source: based on data from Undata, UNESCO Institute for Statistics (UNESCO UIS), www.data.un.org

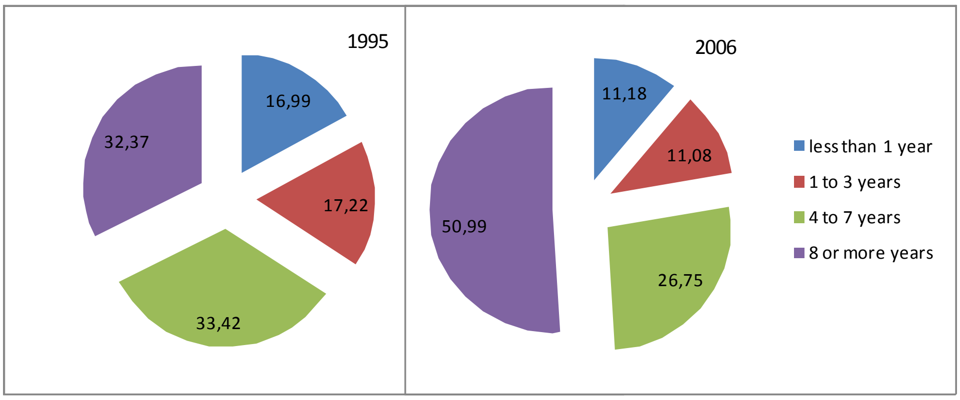
Figure 9: Evolution of years of schooling of people above 15 years old (%)



Source: Own elaboration

Source: based on data from Undata, UNESCO Institute for Statistics (UNESCO UIS), www.data.un.org

Figure10: Years of schooling of people above 15 years old (%) – 1995 and 2006

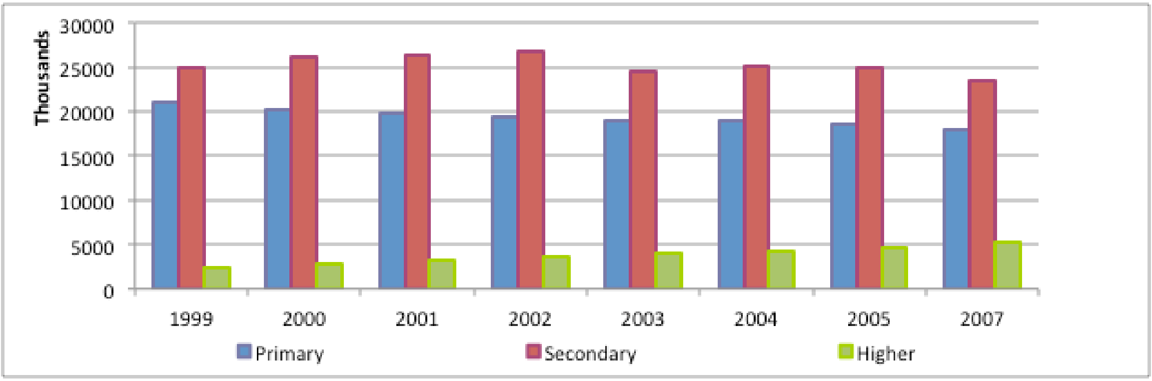


Source: own elaboration

Source: based on data from Undata, UNESCO Institute for Statistics (UNESCO UIS), www.data.un.org

As one can see by the Figures 8, 9 and 10, while the total average years of schooling has been rising consistently, the share of people with less than 7 years of school (green, red and blue lines in Figure 2) has been falling, and share of people with more than 8 years of schooling has been grown considerably (purple area in Figure 10). Figure 11 shows that while primary and secondary enrolment present a slight decrease over the last years, mostly due to changes in demographics, higher education presents a clear rising trend.

Figure 11: Education enrolment evolution in Brazil



Source: based on data from Undata, UNESCO Institute for Statistics (UNESCO UIS), www.data.un.org

In order to guarantee the allocation of resources to education, the National Constitution of 1988 created the Fund for Maintenance of Fundamental School (Fundef). From 2002, another fund was created, with the objective of channelling resources to primary education (FUNDEB). This resource was directed to the improvement of education quality as well as to the increase of participation rates.

It is important to stress that, until 2004, the resources allocated education have reached already a relatively high level (more than 5% of the GDP – Schwartzman, 2005). Most of that budget, however, was directed to higher education. To increase the budget destined to primary and secondary education, a new policy was implemented in 2006 with the Education Evaluation Index (IDEB) and the establishment of a national minimum wage to primary school teachers, with the purpose of enhancing the basic education quality. Another two important policies were implemented in the past years was aimed at the reduction of the disparities in terms of access to higher education. The first is a new programme that provides funding for the studies of poor students in private universities was created (PROUNI). The second is a program that facilitates the access of students from public secondary schools to public universities.

Further analysis of the Brazilian educational system is carried by comparing the number of students of each study level as a percentage of the population, sorted by age level.

Table 2: Percentage of students by age group, by each level of study

Year	Age Group	Primary	Secondary	Tertiary	Out of school
1991	5 to 15	62,75	1,19	0,00	36,06
	16 to 19	23,83	16,24	1,74	58,20
	20 to 24	15,47	5,28	4,76	74,48
	25 to 29	5,63	1,41	2,31	90,65
	30 or more	0,52	0,26	0,42	98,80
2006	5 to 15	85,50	4,42	0,00	10,08
	16 to 19	13,60	32,26	4,40	49,73
	20 to 24	3,66	8,24	13,63	74,47
	25 to 29	2,37	3,30	7,30	87,04
	30 or more	1,64	0,90	1,80	95,67

Source: Censo 1991 and PNAD.

Obs.: in 2006, data available is cuted differently: 5 to 14, 15 tp 19.

As can be seen in Table 2, school evasion in the lower age level (5 to 15 and 16 to 19) has fallen sharply from 1991 to 2006, although the evasion at the level 16 to 19 is still very high. There are two possible explanations for this fact: (i) at that age the income incentives (provided by Bolsa-Família) to children to stay at school is lower; (ii) continuous school failure can provide incentives for students to drop out. Nevertheless, the data also shows that the second explanation is becoming less relevant, given that the share of students between 16 and 19 (and also between 20 and 24) years old that are still in primary education has decreased from 23% to 13% and from 15% to 3%, respectively, while the number of students of that age in the secondary education has risen from 16 to 32%. In line with previous data presented, higher education figures presented a considerable improvement in all age levels.

The conclusion is that the education enrolment in Brazil has presented an improvement during the last decades, while the quality of the education is still matter of discussion, and is in the present, the main focus of policy in the country.

Tables 3 and 4 summarize the profile of higher education openings, candidates, enrolments and graduates, in Brazil, for the years of 2001 and 2009. There is, during this period, an increase in the number of openings, candidates, enrolments and graduates. The largest expansion of openings, in public and private institutions, was for engineering courses, followed by the courses of the Health area. The greatest increase in the number of candidates and enrolments was, likewise, in engineering courses. It is noticeable, however, that although there was a significant rise in the number of openings for courses in the areas of Sciences, Mathematics and Computer Science, it was not accompanied by an increase of candidates – these areas do not seem attractive for the candidates. A possible explanation for this is that Brazilian companies do not incorporate large numbers of Sciences and Mathematics graduates, and so the labour market for these areas unattractive. The profile of the graduates follows this pattern, revealing that only 8% are of the Sciences, Mathematics and Computer Science areas. This proportion was stable during the period. Similarly, just 7% are concluding Engineering courses. The greater part of the higher education graduates in Brazil belong to Social Sciences, Business and Law, followed by the Health and Education areas. Finally, it is relevant mentioning that there seems to exist a dropout problem in Brazilian higher education, since the number of enrolled students is much higher than the number of graduates.

Table 3: The profile of Brazilian higher education, openings and candidates

Field	Education openings					Candidates				
	2001		2009		Change %	2001		2009		Change %
	Total	%	Total	%		Total	%	Total	%	
Total	1,408	100	3,165	100	125	4,260	100	6,223	100	46
Education	304	22	523	17	72	656	15	733	12	12
Humanities and Arts	49	3	121	4	146	152	4	265	4	75
Social Sciences, Business, Law	592	42	1,289	41	118	1,624	38	2,282	37	40
Sciences, Math, IT	135	10	314	10	133	435	10	679	11	56
Engineering)	106	8	322	10	204	367	9	777	12	112
Agriculture, Veterinary	24	2	54	2	127	115	3	155	2	35
Health and Social Care	151	11	431	14	185	818	19	1,180	19	44
Services	47	3	112	4	137	89	2	153	2	72

Source: based on data from the National Institute of Pedagogic Studies (INEP, www.portal.inep.gov.br)

Table 4: The profile of Brazilian higher education, enrolment and graduates

Field	Enrolment					Graduates				
	2001		2009		Change %	2001		2009		Change %
	Total	%	Total	%		Total	%	Total	%	
Total	3,031	100	5,116	100	69	352	100	827	100	135
Education	654	22	743	15	14	91	26	149	18	63
Humanities and Arts	100	3	179	3	79	11	3	30	4	160
Social Sciences, Business, Law	1,266	42	2,180	43	72	140	40	350	42	150
Sciences, Math, IT	262	9	435	8	66	29	8	64	8	123
Engineering	254	8	538	11	111	24	7	55	7	129
Agriculture, Veterinary	68	2	131	3	94	7	2	19	2	161
Health and Social Care	363	12	809	16	123	46	13	138	17	200
Services	62	2	101	2	64	4	1	22	3	506

Source: based on data from the National Institute of Pedagogic Studies (INEP, www.portal.inep.gov.br)

4. Competence building and skills in the automotive sector in Brazil

The automotive industry was established in Brazil during the second half of the 1950s, having experienced continuous growth until the late 1970s. During this period, there were two growth cycles with diverging characteristics. The first, ranged from 1957 to 1967, and the second from 1968 to 1980. The former comprehended the establishment of vehicle production proper, while the latter completed the process of installing the automotive industry as a whole, with the arrival of important multinational corporations. The 1980s was marked by a strong contraction of the automotive industry's activities, due to the economic imbalances that the Brazilian face during the whole decade.

Auto3s and the auto-parts companies established and developed themselves via two different processes. Both have got their particularities, which led to distinct, albeit interrelated, market structures. Auto3s sector was characterised by larger multinational companies, with a concentrated structure. The auto-parts sector, on the other hand, was marked by the prevalence of small enterprises of national capital.

In the 1990s, following the process of trade liberalization, (particularly from 1993 onwards) the production of vehicles experienced a marked recovery. Pushed by competition from foreign markets and the growth of the local market, a strong investment cycle takes place. From 1991 to 2001, manufacturers invested U$ 17.5 billion, while the auto-parts companies invested U$ 11.9 billion (Anuário Estatístico/Anfavea, 2009).

The investment cycle can be divided into two distinct phases. The first, which extended from 1990 to 1994, aimed essentially at the rationalisation and technological modernisation of the industrial park. Its main consequences were the introduction of automatized production processes and, most commonly, of lean production principles in production. The second cycle, ranging from 1995 to 2001, encompassed investments both from established manufacturers and from entrants. Those that were already established invested to increase their installed capacity, to increase specialisation in light vehicles and to obtain larger and more efficient production scales. On the other hand, the smaller investments made by the entrants were compatible with an entry strategy based on producing smaller quantities.

The investments brought along innovations in the production process. The new plants followed lean production flexibility criteria, adopting multi-tier or hierarchical supply chains for components and parts. This means that it was possible for Auto3s to reduce the initial investment requirements and share risks with the first-tier suppliers.

In relation to the auto-parts industry, the investments, although high, were smaller than those observed for manufacturers. This difference is due to the high growth of auto parts imports during the whole period. Another characteristic of the investments in these activities was the intense process of M&A. This process led to the denationalisation and concentration of the Brazilian auto-parts industry, as shown in Table 5, in tandem with the movement of capital concentration and centralisation the industry experienced internationally.

Table 5: Capital ownership, auto-parts sales, and investments, Brazil (1994, 2001)

	1994		2001	
	Local capital	**Foreign capital**	**Local capital**	**Foreign capital**
Capital ownership	51,9%	48,1%	22,8%	77,2%
Autoparts sales	52,4%	47,6%	26,7%	73,3%
Investments	52,0%	48,0%	15,6%	84,4%

Source: Anfavea (2009)

With the beginning of the Asiatic Crisis, in 1998, the Brazilian automotive industry experienced a period of contraction and instability that lasted until 2003. From this year onwards its production and sales once more presented strong growth, with the production capacity nearly reaching its limit. During this time, a recovery of investments could also be observed (from 2006/2007), having been only momentarily slowed down by the international financial crisis. The current perspectives, however, point to an increase of the production and to new investments. The projections indicate that the production capacity, which went from 2.0 to 3.5 million vehicles with the investments of the 1995/2001 period, will reach 6 million in 2013.

It is, therefore, a mature and important sector, with Auto3s responding, by themselves, almost a fifth of the country's industrial GDP (Anuário Estatístico/ANFAVEA, 2010). There is a striking presence of MNCs in the sector, including in local competence-building.

During the 1990s, it is important to notice that the process of production restructuring experienced by the entire sector. MNCs branches and local suppliers replicated practices based on the Toyota Production System, which had been adopted at the their headquarters. This process modified the profile of the workforce, especially of the operational, technical and supervisory workers. From the 2000s onwards, the existent Brazilian branches were inserted differently in the strategies of the headquarters, leading to the configuration of new Global Production Networks (Fleury, 1999).

The new strategies of the MNCs included the possibility of a new international division of knowledge-intensive activities. In this division, the Brazilian branches would be responsible for the development of certain products or technologies, directed to local markets (which is more common) or to global markets, such as alternative fuel engines, robust suspension systems and light, low cost vehicles, leading to a selective decentralisation of engineering activities towards Brazil (Dias; Salerno, 2004).

Innovation, or, more specifically, engineering activities in the Brazilian automotive industry, as whole, have evolved according to a path that begins with the adaptation of products developed abroad to the conditions of the local market, after the installation of the MNCs. The next step is the development of local products based on those produced at the headquarters. Finally, in some cases, there is the possibility of developing products for other markets (other developing countries, or, more rarely, developed countries). For companies in Brazil, for more than thirty years, this evolution presented, during the 1990s, a reduction of the installed capacity of engineering activities (following the initial concepts of what a "global product" should be). This trend was reverted during the 2000s, with the reintegration of the Brazilian branches into the global strategies of their headquarters (FLEURY, 1999).

As a consequence, GINs have emerged, albeit incipiently. Nevertheless, it is important to highlight that the Brazilian branches are usually responsible for the development of technologies related to specificities of the local market (such as alternative fuels for internal combustion motors or more robust suspension systems). Significant innovation activities related to more advanced technologies (e.g., electrical motors or new materials), have not been observed. It can be said that, in the Brazilian automotive sector, basic research is almost inexistent – applied research and product development are the most frequent.

4.1. Description of the studied companies

Five companies were chosen for the WP6 Brazilian case studies, one of them a manufacturer and the other four auto parts companies. Auto3 is a branch of an MNC of European capital. It is ranked amongst the ten largest manufacturers of the world and the five largest of Europe, and it is one of the market leaders in Brazil. The auto parts companies are all direct suppliers of this manufacturer, and are also branches of MNCs. Three of them have got their headquarters in the same country of Auto3. Table 5 summarizes the characteristics of the examined companies.

Table 5: Case studies

Company	Main product	Capital origin	Time in Brazil	Notes
Auto3	Cars	Europe	More than 30 years	
Auto4	Powertrain systems	Europe (same as Manufacturer)	10 years as an independent company	It is a spin-off from Auto3
Auto5	Stamped parts and bodies	Europe (same as Manufacturer)	11 years	
Auto6	Suspension systems	Europe (same as Manufacturer)	More than 50 years	Once a Brazilian company, it was acquired by an MNC in the 1990s
Auto7	Transmissions/ engine parts	USA	More than 50 years	

Source: Author's elaboration

4.2 Case 1: Auto3

Auto3 is a subsidiary of a European TNC which has been operating in Brazil for more than 30 years. It is the largest subsidiary outside its home country (in terms of production volumes and sales), and it is considered a strategic branch inside the corporation. The building of local competences is a consequence of the trajectory of the subsidiary, which is typical of the Brazilian automotive industry: innovation related activities have evolved from adaptation or "tropicalization" to product development. No significant basic research activities exist in this subsidiary, only applied research – more specifically, product development. The Brazilian unit is formally responsible for adapting products which were developed in the headquarters to emergent markets, in particular Brazil, as well as for developing new products on centrally designed platforms.

In Auto3, 12% of shop floor workers have college degrees or are enrolled in college. Currently, the lowest admission requirement is a high school degree. The workers who do not meet the standard are stimulated to qualify themselves, either through partnerships the company has established or by means of an internal incentive for minimal qualification (e.g., general education development courses). The company has established partnerships with educational institutions, consultancies and training institutes associated with Auto3. Partnerships with public institutions for operational level qualification were not mentioned.

The company also mentioned the importance of training in management tools, especially World Class Manufacturing (WCM), a production system similar to the Toyota Production System. It is worth mentioning that WCM is a corporate policy and all firms of the group (Manufacturer, Auto4 among others) must implement it. The company also trains its workers to allow for a broader comprehension of how the production processes work. The immediate supervisors are the ones responsible for giving task-training courses to the operators. Workers are thus being trained in the WCM techniques as well as in methodologies and other tools specific to the daily routine of their tasks. These competences are related to continuous improvement and to methods of analysing and solving problems, and their purpose is to eliminate waste. There is no evidence of other particular technologies in which the operational level workers are being trained. Most of the time, training is provided on demand.

Auto3 also has a programme which gives financial benefit to workers who propose innovative ideas to improve products or processes, even for operational level workers. The programme can foster the search of new knowledge by the workers and by the company as a whole.

The profile of the supervisors in Auto3 has changed since the production restructuring the sector underwent during the 1990s, which introduced aspects of the Toyota Production System to shop floor management. The presence of the WCM management system is currently accelerating this process. The most important changes imply a move towards a supervision model which requires higher formal education levels, advanced knowledge of management tools related to WCM, and knowledge of HR management tools.

In Auto3, above the operators there are two supervisory levels, followed by a direction level. Alongside the operators there is a special professional category of operators capable of using more sophisticated machinery (automated machinery). These special operators have a status equivalent to production technicians. There are also technologists responsible for specific aspects of each manufacturing cell (maintenance and quality). Supervisory level workers must have higher education (Engineering or Business) as a minimum qualification level. For the technical level, a technical school degree is necessary. Production technicians are required to have technical school degrees, or secondary education and complementary courses regarding specific technical aspects.

The supervisory and technical levels are offered training programmes in behaviour, quality tools (TQM), continuous improvement, metrology and others (mainly WCM techniques). For instance, when the research was being conducted there was a course being offered specifically for automated machinery operators, in partnership with SENAI (National Service of Industrial Learning);the course dealt with Industrial Processes Technologies (including management methods). CAM programmes are offered to the engineering department, but not to the production department. Supervisors and production technicians can have a CAM background to follow the implementations of new processes, but most of the training is focused on engineers.

The case studies demonstrated, in all companies investigated, a growth trend for the local engineering sectors and the workers' competences. Auto3, whose engineering evolution follows closely the pattern described in the introduction of Section 2, possesses no on-going local basic research projects, only applied research. Basic research occurs fundamentally at the headquarters, and collaboration is more intense with the latter's laboratories.

Nevertheless, in the last seven years the company has set up new local laboratories that made local development projects possible. This trend became stronger with tax incentives, but is also due to the fact that Auto3 presents important competences related to the development of products aiming at emerging countries – low cost, medium performance products. These competences were built along the trajectory of the company, from local adaptation to local development.

For instance, in the 1980s, when the Brazilian federal government consolidated its research program on ethanol as a biofuel (the *Pro-Álcool* program), the company developed and launched the first ethanol engine in the Brazilian market. In the 1990s it was the first company to introduce a vehicle equipped with a 1000 cc engine, in accordance with the public policy of decreasing federal taxes over small vehicles (locally known as popular vehicles), in order to stimulate sales and rescue the Brazilian automotive industry from a general crisis. In the end of the 1990s the Brazilian unit was part of the global team which developed a car destined to emerging markets (Dias; Salerno, 2004).

The engineering department grew from 400 employees in 2005 to approximately 850 in 2010. This increase is due mainly to hiring new engineers. The profile of these workers is, therefore, mostly of young. With the growth of innovation activities, the respondent stated that there is a shortage of engineers relatively to the company's current needs. The product development sector is structured as in the headquarters; this makes the relationship with the headquarters easier, as each Brazilian engineer has a "correspondent" within the European engineering. Whenever a technical matter emerges, they are able to meet in order to discuss it, thus enhancing an international network.

The department has engineers responsible for the project development management of each set of new products (chassis, bodies, electrical and electronic engineering, etc.), as well as specialists in the components of each of these sets (wheels, suspension, etc.). These specialists are considered scarce in the local market (there were, in August 2010, approximately 40 vacant posts in the engineering department).According to the company, the employed engineers still lack some background in technical areas. Once in the company, they must undergo training programmes in product development management (amongst others, quality and reliability), as well as technical training (in automotive engineering). The company also has formal incentive programs for specialisation, Master's and PhD courses. Training programmes in a research centre at the headquarters are also frequent.

Following sector standards, Auto3's interaction with research institutes and local laboratories is not very intense. This company is also negotiating new cooperation projects with the state. Finally, a new educational programme that aims at attracting individuals with Masters and PhD degrees from local universities to research projects within Auto3 has just started.

The relationships between Auto3 and suppliers, and between the Suppliers and the clients, are of extreme relevance in the Brazilian automotive sector – which is also a pattern observed worldwide. Co-design is a common practise in the sector, and differences between companies regard the level and strength of the partnerships established for the development of the project. Auto3 is in charge of directing co-design activities in the studied network. Interaction with suppliers and subcontractors exists and is reportedly very strong. It is important to remark that this type of interaction is part of the company's history. There are four types of suppliers: suppliers that co-develop the products;

suppliers that develop the product given the specifications from the client; suppliers that only manufacture the product according to the specifications; and the more simple "commodities" suppliers. There is also a more sporadic on-demand relationship with project offices.

4.3 Case 2: Auto4

Auto4, which was previously a power train department inside the organizational structure of a European car assembler, was created in the beginning of the 2000s. Its headquarters are located in the same European country as the car assembler. Although the car assembler still is the main client of Auto5 at present, the strategy is to decrease its participation while broadening the market by selling power train systems to other car assemblers or any other company which needs internal combustion engines (truck, buses, boats etc) – "non-captive" customers. At present the company is carrying out an internal program in order to promote innovation in its products and processes (a strategy to conquer new, non-captive customers).

Due to its trajectory, even if it has existed as an independent company for less than 10 years, it profited from the 30-year Brazilian experience of the car assembler from which it has split. This means that many of its workers have previously been workers of the car assembler; its organizational structure and procedures are still very similar to the car assembler ones. Some of its workers were responsible for the development of important local innovations such as the small engines and the ethanol fuelled engines that were mentioned in the previous sub-section. These competences, which arose from the path followed by Auto3, are being consolidating at present, for instance, with the development of flex fuel technologies. Indeed, the company faces ongoing changes, towards greater local technological competence regarding new local and global products (alternative fuels), as well as competences related to large production, due to WCM. It is thus necessary for the employees – operators, technicians and engineers as well – to be constantly upgrading their skills.

At worker level Auto4 requires a minimum of secondary education for shop floor workers. As Auto3, Auto4 has implemented World Class Manufacturing principles in its production lines, and workers have been trained in WCM tools – especially quality control, problem solving methods, autonomous maintenance and continuous improvement. The matter of the autonomy/flexibility of the operational level worker is present in the discourse of the interviewees of all the studied companies, including Auto4. There is, however, a confusion regarding what flexibility actually means. By saying that "The worker must do more and better", one of the interviewees states that flexibility is related to productivity. By making it explicit that the worker must be familiar with many quality tools, for example, it becomes clear that the demands presented to the worker can require more capacities. Moreover, the worker must know when to use his capacities (he must know how to solve problems). This can be seen as an increase of competences and as multitasking, but it does not always involve flexibility and autonomy.

On the other hand, Auto4 recognises the importance of the worker "knowing his role", and "having a notion of innovation". This is related to the company's current context, marked by the development of an innovation programme. Besides this, like Auto3, Auto4 has got benefit programs for workers who propose innovation and improvement ideas.

The demand in terms of formation and qualification is also increasing to a higher education degree in the technical and supervisory levels. With this increase the company mainly expects the technical employee to arrive with a larger market experience and with a smaller need of routine training. The training programmes for specific technologies in supervisory level are given, in most cases, through partnerships with the suppliers. In order to handle more complex processes, a specific training programme is required of the worker. Internally, a competence centre belonging to Auto4 and Auto3's corporation gives these programmes. It consists of a training centre that also offers training in behavioural and other skills development. There are partnerships with other institutions that offer this kind of programme, such as universities and consultancy firms, amongst others, but the main source is the competence centre.

The impact of being inserted in a global chain (or network) is evident in the case of development of competences in the engineering and innovation levels. In particular the relationship with the headquarters is very important, as can be seen in the slogan "one product, one engineering". The practice of sending Brazilian engineers to the headquarters for them to do specific training programmes is quite common in Auto4. In this company, the branch also hosts engineers from abroad, for them to, for example, familiarise themselves with the flex-fuel engine technology – a case of local developed technology that may be exported to other markets. For the engineering area, there are innovation and manufacturing ideas and knowledge generation programmes. The company is studying the implementation of a prize for engineers who publish academic papers on innovation ideas. The company's engineers possess specialised knowledge, but they develop flexible abilities in multidisciplinary teams. The very organisational structure of the engineering department stimulates this – it is a matrix structure with product development cells comprising workers of the functional areas of Product Engineering, Manufacturing Engineering and Production. In the Auto4 engineering department there are about 300 employees, 56% of which are engineers. In this sector, ten employees possess Master's degrees and only one is a PhD.

Co-design is also present in Auto4. Besides carrying out the development of its product with Auto3, some of the main locally developed products involved a decisive participation of the suppliers. For example, recently a new device aimed at enhancing the performance of flex fuel and ethanol engines was developed in Auto4 together with a company which belongs to the same group as Auto6. This device was granted in 2010 a Brazilian and a European patent. The development of this device is strongly related to the competences already possessed by the engineers of Auto4, which were developed for over 20 years, due to the ethanol Brazilian programme (therefore these competences at first were not developed because of GINs, albeit they might be enhanced within a GIN at present).

Another example concerns an important local innovation introduced in a transmission system which was developed along with Auto7.This new transmission system was developed due to a demand of Auto3, which asked Auto4 for a system that could improve the performance of its small off-road vehicle (developed in Brazil). Auto4 started a conceptual research on technologies available on traction, presented by the headquarters as well as by other suppliers. Since final product price could not be increased, given the characteristics of the Brazilian emerging market, it was necessary to think up a low cost solution. Finally an idea concerning a device which could enhance the performance of the small vehicle in low adherence road conditions was borrowed from agricultural machinery market and seemed to present the best cost-benefit-viability scenario. However, a specialist supplier which could implement this in a first prototype was needed, as integrating the new mechanism in a small front transversal transmission represented a new-to-the-world challenge. So, after dealing with some potential suppliers in a more focused stage of definitions, Auto7, which presented the application of an electro-mechanical locker differential system, was finally chosen.

Just after the selection occurred, contracts, quantified technical targets, specific budget constraints, formal product development team and other main issues were then formalized. A product development team was created with manufacturing engineers, production engineers, purchasing engineers, testing engineers and technicians as well as engineers from Auto7, in Brazil and in the USA.

The new product called for new productive processes, because the new transmission would aggregate fragile electric components (Bagno et al., 2008) – something challenging for a traditional gearbox assembly line. Shop floor workers were trained in the new process. Finally, the service kits and maintenance procedures were agreed among specialists of the development team. The car user’s manual specially warns about correct using of locker mechanism and a help desk (hot-line) strategy was built to give quick support in case of early field problems. Special training was offered to sale and service people.

This case illustrates how engineering worked through transversal processes with other departments as process and manufacturing engineering, service, legislative council, client and others. Concerning the external relation, it is important to emphasize the managing of complementary competencies among Auto4 internal teams, Manufacturer and Auto7. It can thus be said that an innovation network emerged, and that the overall competence level of the network (or, of the actors involved in the network) was increased. Since some of the competences needed to develop the new device were not present in the Brazilian subsidiary of Auto7, engineers from the USA development center were integrated in the team. Therefore, this case presented a good example of the insertion of Brazilian subsidiaries in GINs.

4.4 Case 3: Auto5

Auto5 is a subsidiary of a European TNC company which has been operating in Brazil for less than 10 years, following a demand posed by its main client, Auto3. Therefore, its very presence in Brazil is a consequence of being inserted in a global network which operates with “follow sourcing” policies, since Auto5 is a main supplier of Auto3 in Europe. It produces stamped parts and car bodies and its whole production is destined to Auto3.

The company is also adopting WCM techniques in its production lines. This is so due to an exigency of Auto3. Indeed, in the automotive industry, the car assemblers drive the value chain and it is not uncommon that they compel their suppliers to adopt specific production methods and techniques. In Auto5, with the introduction of WCM, the company realised that it was necessary to require an elementary school degree for shop floor workers – it is paramount that they understand the production process, have a better control over the production and know how to use WCM management tools (e.g., interpreting simple graphs).

Auto5 formally assesses a set of skills (for instance, concentration, logical thought) and practises at the moment of staff recruitment, which are also informally assessed by the supervisors immediately after the worker is hired. Given the requirements placed mainly by the growth of the industry (especially in 2009/2010) and the introduction of WCM, an increase in the qualifications of the technical and supervisory positions can be noticed as well. For supervisory levels, a high school degree is required, preferably in technical courses, and a college degree is desired. For the technical level, a high school degree in a technical course is demanded. Such requirements have expanded over time, and the incentive for an increase in skills is primarily due to the internal recruitment policy. The company gives priority to internal recruitment and, even though there is not a formal and explicit competence-building system, the respondent says the employees seek the company's HR for advice on which courses to take, so that they can apply for the higher positions inside the company. The formal assessment of supervisory jobs takes into account leadership, the ability to work under stress, planning and decision-making, and communication skills.

There is no systematic requalification process for technicians and supervisors. There is a requalification programme, but it is only sporadically offered according to the company demands. There was, for example, leadership training for supervisors in 2010 (there is, though, a yearly requalification process for operators). According to the respondent, there are difficulties (budget and motivation of the supervisors) to conduct this requalification process. The respondent also considers that the fact of the company being certified by the ISO 16949:2004 norm, which requires regular and systematic recycling processes for the operational level, is a factor behind the greater attention given to operational level recycling in lieu of the supervisory and technical levels.

There is CAM training for specific jobs, namely tool technicians and automated machinery operators. Such training processes have increased over time. Additionally, technicians and supervisors receive training in management tools, especially those related to quality and WCM. As an example, supervisors and technicians recently received training in the Value Stream Mapping (VSM) tool. Other training programmes offered to technicians are: Problem Solution Methods (PSM), Statistic process control (SPC), and Failure mode and effect analysis (FMEA).

The role of the HR department is to support the managers. In spite of this, the subordinate employees are evaluated in an unstructured manner by the managers themselves, who also evaluate the training needs in their areas. However, there are no incentives for the innovation practises in HR by the managers to their subordinates. For example: operational level workers are only submitted to systematic requalification programmes, and the immediate supervisor at the operational level is supposed to facilitate the requalification program to their subordinates. However, this aspect does not reflect in the higher hierarchical levels beyond supervision. In other words, it is not demanded of the other managers and supervisors that they continuously stimulate their subordinates. In the case of the management and HR professionals, in spite of the incentive the discourse on innovation and insertion in global networks gives to flexibility, the latter is not as of yet present in the analysed companies.

Auto5, as Auto3 and Auto4, also presents a kaizen program, in order to enhance continuous improvement. The Engineering department of Auto5 formally evaluates the kaizen suggested by the supervisory and operational levels, and then decides whether the proposed modifications are viable or not. Those who propose the best improvement suggestions are entitled prizes.

According to the respondents, in Auto5 the link between production supervisors/technicians and the engineering department has greatly increased during the last year. In the words of the interviewed engineer, nowadays the manufacturing department goes after the engineering department with product improvement proposals: “production ‘discovered’ engineering”. The company has also promoted meetings and regular training programmes involving engineering and manufacturing managers, which can, in the respondent's point of view, contribute to such an approach. Another reason for the greater communication between the departments is possibly WCM itself. The engineering staff currently evaluates the improvement suggestions and cost-reduction processes developed by the manufacturing department. However, the respondent stated that, even though the relation between manufacturing and engineering has improved, it is still restricted to specific issues.

The engineering department of Auto5 presents a significantly higher proportion of technicians in relation to engineers. The area comprises approximately 120 persons, 30% of them engineers and 70% technicians (basically CAD operators). The engineering works are arranged according to the automobile parts being projected, in a functional structure very similar to Auto3, which is its main client. When a project involves more than one area, a multidisciplinary team is formed including engineers and technicians of all relevant areas.

There are few members of the staff with post-graduation (one with a Master's degree, one of the area's managers is doing a Master's in Engineering and another is doing an MBA). Most CAD operators are taking engineering courses. The engineers have got no background in production process management. There is no internal development, so the engineers and technicians acquire some background in business or cost engineering, for example. The training programmes that were offered in this area are: FMEA, CAD, an automotive engineering short-term course and foreign language courses (offered by external institutions). Recently, the company has been investing in internal courses, given by their own staff – e.g., sheet metal forming lessons for engineering technicians.

The company has got no partnerships with research institutes or local universities. The respondent from the engineering department said the company is not engaged in many market driven innovations, as most of their products and project services are the property of the client. Another obstacle to local innovation is that the engineering work hours are dedicated to the ongoing production projects, and the innovations would have to be carried out simultaneously to these projects (the former are not remunerated). It is also important to mention the relationship between the company and its European headquarters – the latter has got the engineering competences the Brazilian branch relies on, especially regarding projects of vehicle bodies. On the other hand, the headquarters does not possess the structural calculation competence, carried out only by the Brazilian branch, which supports the company worldwide. Innovation projects in the company tend to be internal and process-related, but even in these cases Auto5 does not use research results or research institutes for the improvement of its processes.

The interaction of Auto5 with its subcontracted staff is expressive, as some of the CAD operators are subcontracted. Such interaction does not lead to innovations for the company. On the other hand, the company has been pursuing partnerships with suppliers to start innovation projects for the company (not the client). As an example, there is a North-American supplier that performed structural calculations for a bus body, a product for which the studied company did not possess know-how. The contract with the supplier from the USA was signed determining the transfer of structural calculation technologies to the Brazilian company. Regarding physical component suppliers for manufacturing, it is important to clarify that Auto3 chooses most of the suppliers of Auto5. Some of them participate in the product development, in a co-design involving Auto3 and Auto5; in these cases, Auto3 formally establishes the interaction between Auto5 and its suppliers by contract.

4.5 Case 4: Auto6

Auto6 is a case of a former Brazilian company which was acquired by a multinational group in the 1990s, during the period of restructuring of the Brazilian automotive industry that followed the opening of the market (as discussed in the introduction of this section). This company was one of the largest Brazilian autoparts firms and, before being incorporated by the European group, it had followed a path of technological development in Brazil. When the acquisition occurred, many questions were raised concerning the risk of reduction of engineering and innovation activities in the company. Indeed, to a certain extent some of the engineering activities the firm carried out in Brazil were centralised in the European headquarters, but others, more related to local products, were kept in the country. It was the case of technologies related to suspension systems, since, due to local conditions (bad road conditions), vehicle suspensions in Brazil must be much more robust than European ones. Competences linked to the development and testing of these robust, low cost suspensions were developed in the company since it was a Brazilian-capital firm.

The company demands a minimum of secondary education for shop floor workers. Currently, the lowest admission requirement is a high school degree. There is increasing demand in terms of education and labor skills. The workers who do not meet the standard are stimulated to qualify themselves, either through partnerships the company establishes or by means of an internal incentive for minimal qualification (e.g., general education development courses). The company has incentive programs for the minimum qualification (suppletive programs for production workers) and development (encouraging technical courses). There are partnerships with training bodies, of which SENAI is a reference, including the training focused on specific technologies such as training in management tools, especially WCM. They also offer training for understanding how the production processes work.

Increasing the minimum requirement for qualification for production workers (high school) is related to the trajectory of technology and innovation of the company, as well as the characteristic transformation of the company's history over the past year. In 1990, when the acquisition by the multinational group was accomplished, it began to incorporate more complex technologies and new ways of managing processes such as quality and cost reduction programmes. The profile of the shop floor workers was also changed.

As regards flexible teams, attitudes and skills at the operational level, there is a formalization of the attitudes and skills. There are no structured programs to assess performance in terms of skills and attitudes. Nor are there any programs that foster certain skills that could favor flexibility in the implementation of tasks. Production workers must be prepared for the correct interpretation and use of quality tools in place, as the WCM, for example. There is a rapid training concerning WCM tools, but there is not a structured programme of skill development for new ways of performing work. There is a process of operational training, workers are continuously trained in their activities and tools of quality, but without a defined periodicity. It can be said that the flexibility of the workers has increased, but not necessarily their autonomy. Indeed, as in Auto4, the discourse of flexibility is again present in the interviewees of Auto6, even if this flexibility does not mean more autonomy.

At the technical level and supervision, there is also evidence in the improvement of education and qualification. This improvement is also enhanced by increasing the required level of qualification in the recruitment and selection. In the specific case of the level of supervision, this qualification is increasingly being required in the selection process, which is not true at the operational level, where training is still very encouraged after hiring the employee. There are also incentives for the development of professional and technical supervision, through courses offered by the organization in partnerships, or through the incentive for others courses.

The level of skill and attitude flexibility in the tasks of technicians and supervisors is fostered by the assessment of behavioural competences, related to the workers' performance and leadership profiles. Technicians or supervisors are valued for a proactive and team leadership profile. There are assessment tools, but no preparation programme. As in the operational level, in the technical level the workers are continuously trained in their tasks and rules, and, then again, there is no defined frequency. For management methodologies (quality management, continuous improvement etc.) the main training programmes are, amongst others, FMEA, TS, ISO9000 and WCM.

The interaction of technicians and supervisors from manufacturing with the engineering and product development department is also present in Auto6. There are periodic meetings and teleconferences within the staff. Besides this, there is also constant incentive to promote the application of better practices, through a programme of suggesting innovation and improvement ideas. With this programme, any worker can give a suggestion and should direct its application together with a team defined by the company.

Concerning innovation activities, after the acquisition in the 1990s, the MNC made use of the local competences the national company had developed, basically concerning low cost solutions for more robust suspension systems. Nowadays, there are engineers with specialised knowledge, as well as the organisation of multidisciplinary teams conjugating flexible abilities related to product and process design, quality management, reliability engineering and cost engineering. These teams are mainly in the product development centre, located in its own premises, which are equipped with laboratories for testing new products.

The other cases also report the existence of co-design involving clients and suppliers. Engineers of Auto6 directly interact with the suppliers and subcontracted companies, in co-design activities as well as in qualification and training programmes.

Marketing and Purchasing managers have specific qualification and training programmes aiming at managing more interactive systems related to clients (Marketing) and suppliers (Purchasing). It seems as though competence-building, at the management level, is a more balanced effort between individual pursuit and stimulus by the company. In general, managers are encouraged to invest in innovation and marketing. However, there are no systematic skill development programmes for these managers to manage global networks.

Concerning HR policies, they are usually corporative, and there is no incentive for the development of new tools. The professionals and departments of this area are stimulated to adequately use the existing tools developed by the corporative HR. In this perspective, HR managers are encouraged to provide training and continuous learning to their subordinates. This occurs trough evaluation tools, where the training and formation needs are indicated.

4.6 Case 5: Auto7

Auto7 is a subsidiary of a USA multinational group, which has been operating in Brazil since the 1950s. It produces transmissions and engine parts to cars, trucks and buses manufacturers. Most of its production is sold to manufacturers and around 25% is destined to aftermarket. During the 1970s the company started a policy of local adaptation of its products, which evolved to local development in the 1980s, thus consolidating its local engineering, which is specialised in transmissions and clutches components to small pickup vehicles (a type of vehicle which is not present in USA); other competences are centralised in the headquarters.

Auto7 provided further evidence for the tendency of greater qualification and instruction amongst technicians and supervisors. It stated that most of its supervisors currently posses higher education, while its technicians posses secondary education and technical degrees. The interviewee pointed, as the main reason for the increase in the qualification of these levels, the greater scope of abilities demanded of the direct workers, and, consequently, of supervisors and technicians as well. Requalification training is a routine activity, although greater emphasis is given to the new employees or when there are changes in the production process. Once more, it can be seen that continuous training is more common in the operational levels when compared to the supervisory and technical levels. The company does not significantly invest in training for technologies specific to supervisors and technicians – the professionals with such competences are hired.

Improvement suggestion systems (kaizen) extensive to all employees were also verified in Auto7. In this company, multi-functional groups design the improvement projects. They hold regular meetings in order to accompany the evolution of the project, observing the methodologies of the Toyota Production System.

At the technical level and supervision, the minimum instruction required is high school with most employees having superior degree in several areas. There is evidence that the education / qualification has been expanded over the years. This requirement can be justified by the demand for professionals with more flexible and broad skills and attitudes, who are ready to perform various tasks. Trainings are ongoing, related to routine procedures, only for new employees. For existing employees, the trainings occur only when a process or procedure is changed. On the other hand, and following what was verified in the other Suppliers and in Auto3, technicians and supervisors are constantly provided training in management methodologies, especially those dealing with Quality Management. Internal symposia are held in the company for this purpose, as well as external training in local institutions (consultancy agencies and universities).

There is no training for technicians and supervisors concerning specific technologies on the shop floor workers; instead, competences related to these technologies are achieved by hiring people with formal qualifications. Technicians and supervisors interact with employees of manufacturing and engineering in every project from its beginning, through multi-functional teams.

The engineering department follows the same pattern, making use of multidisciplinary teams for the development of products for local or world markets (the headquarters consider Auto7 a competence centre for certain products). This company has been present in Brazil for more than 50 years, notwithstanding the fact that is has always been a branch of an MNC, and during this period it has accumulated engineering competences. The engineers of Auto7 are currently presented with goals regarding innovation and submission of patent proposals. There are incentives for innovators, via internal prizes. The company also possesses a centre for the development of new products, equipped with a laboratory for testing materials (chemical, physical and resistance analyses) and for mechanical tests (dynamometers, coupling durability, lubrication, impact...). The tests the company cannot internally perform are carried out at the USA headquarters, at the facilities of the clients, at research institutes or at universities.

Concerning the levels of management and marketing, Auto7 maintains professional-level formal qualification. Managers of Marketing and Purchasing have specific training and qualification in order to manage systems more engaging for customers and suppliers. There are systematic programs to develop management capacity of global networks for these managers. The company also conducts programs for retraining and continuing training, internal and external, and through the annual plan for career development. The managers of these areas and other areas are guided and encouraged to seek new policies for HR management and HR development, but it is still characterized as corporate.

5. Conclusions

The evolution of competences, knowledge and abilities displayed by the workers of the Brazilian automotive sector is closely related to the sector's trajectory in the past twenty years. Competences related to engineering and to technological development have grown in pace with the increase of innovation-related activities, especially the development of local products, which occurred largely during the 2000s. The shop floor workers' competences have likewise increased as the production processes are modified, particularly due to the adoption of TPS/lean production principles. The relationship between the increase of competences and the greater responsibility of the firms is bidirectional. There is, on the one hand, an effort to increase local competences due to changes in the technological profile of the unit (which leads to offering qualification and training programmes inside the companies, through partnerships with local institutions or by the local governments). At the same time, such an increase enables the Brazilian branches to demand from their headquarters that they perform activities of greater technological content, configuring a virtuous cycle. The Brazilian professionals are trying to obtain greater qualification and experience, while the companies are also in a process of acquiring autonomy in R&D. The transfer of competences and of knowledge for product development activities occurs, between local branches, in an informal and contextual manner. This is an obvious hindrance to the process, for in the global context the relationships are formal, hierarchical and dominated by the MNCs.

In this sense, a "global network" or “global chain” configuration can be identified in the competence-building process of local units of multinational corporations. This process involves the unit, the headquarters and its suppliers and clients (multinational and local), universities and local training or qualification institutions. Knowledge and technology transfers thus occur locally and globally. No relationship for competence-building could be seen between the local investigated units and global education or qualification institutions, in whichever levels (operational, technical/supervisory, engineering or management).

The main force in the internal dynamics of this network is the car manufacturer (the headquarters and the branch company). It is the (bidirectional) relationship between the headquarters and the branch that determines which competences must be locally developed, in the operational as well as in the management and engineering levels. The local development necessities of Auto3 determine the partnerships with the education institutions and the universities. They also determine the competence development necessities of the suppliers, especially those participating in co-design (joint development of products or processes by Auto3 and the suppliers), which are usually systems providers. Co-design practises themselves create an engineering network in which there is a daily exchange of experiences and knowledge, increasing the competences of the network as a whole.

This cooperation is bound by contractual relations, i.e., there is a hierarchy, a power structure, organising these exchanges. Also worthy of notice are the communications and exchanges made via ICT tools. They were reinforced by the restructuring of the relationships between Auto3s and their suppliers, which led to more intense links between the chain's companies. The partnerships with other agents outside the chain, as universities and research institutes, are not significant, although they do exist. No robust programme in this sense was verified, and such partnerships, informal or incipient though they may be, are more common in the chain's leader companies.

At the global scale, the transfers occur mainly between the headquarters and the branch – therefore, maybe the GIN is not really “global”. In the studied companies there could be seen an emerging movement for autonomy in relation to the headquarters, in order to develop technologies and produce knowledge (adaptations, tropicalisation etc.). As an example, engineers are frequently trained in specific technologies at the headquarters, but there already is a movement of transferring certain pieces of knowledge from Brazil to the headquarters (flex fuel, for instance).This means that if at present the cases of new-to-the-world local developed technologies are quite rare, there is a possibility that in the future the number of local major innovations will be increased.

In the studied companies, the local process of transmitting and spreading knowledge many times occurs through informal and unplanned relationships. This is a contextual and historical characteristic, and it is related to the "manner of doing things" that is disseminated in the studied companies.

The analyses revealed that the sector's labour demand faces a shortage of qualified professionals (regarding the required minimal education, technical knowledge and experience), given the global demands, the technological complexity and the emergence of programmes and departments dealing with research and development.

An attempt to standardise the production management models between the headquarters manufacturer, the branch manufacturer and the suppliers was detected, led by the headquarters manufacturer. The production management model chosen is based on the TPS, and presents characteristics such as: adoption of quality tools (statistical process control, PDCA, structured problem-solving methods...), continuous improvement (kaizen) performed in a structured manner, multifunctional capabilities and an increase in the demand for holistic knowledge (comprehending the whole production, being able to deal with eventualities, amongst others). Hence, there have been efforts to improve the qualifications of shop floor workers (mainly by Auto3s and systems provider auto parts companies), materialised, fundamentally, in (internal and external) trainings in the management tools adopted by the model. The important external institutions in this process are SENAI, consultancy agencies and training institutes associated to Auto3. Partnerships with public institutions were not mentioned for operational level qualification programmes. Internally, the companies have got incentive programmes for minimal qualification (e.g., general education development courses for production workers), besides training in management tools related to the TPS. It is important to stress once more that the changes in the qualification of shop floor workers in the Brazilian automotive industry are much more related to the introduction of lean production principles than to technological changes in production process.

In the staff departments and in the technical and engineering levels, there is a movement of professionals preoccupied with acquiring the competences necessary for a career in innovation in the automotive sector. This movement is still timid in Brazil, and it can be seen by the growth of professionals with technical level qualification (with knowledge of software specific for product development, especially CAD and simulation or laboratorial ones, though there are others as well) and higher education (business and engineering courses). However, the market still is short of qualified and experienced professionals (specialists), particularly in the technical and engineering areas. This can be explained by the still recent character of the research in the sector, which was intensified only beginning in the 2000s. The studied companies declared that, for these departments, they select the professional the market presents, offering basic and routine training. Qualification is mainly the responsibility of the employee, but the companies stimulate partnerships with training institutions.

In the engineering areas, contrary to the operational level, there is more interaction between the companies and local research institutes or universities, both public and private. This interaction occurs primordially through the investment in specialisation, Master's or PhD courses – although there are relatively few PhDs in the sector. There are incipient partnerships being attempted with local universities, aimed at technological development. These initiatives are mostly present in Auto3.

A second and equally important way of developing engineering competences is the transference of local engineers to training programmes at the headquarters of MNCs. There are cases in which local branches send engineers abroad with the explicit purpose of performing training in the headquarters' Research Centres, plants or training centres. Finally, it is of relevance the fact that the branch manufacturer trains engineers, technicians and managers of the suppliers.

Taking all these factors into consideration, it can be argued that the participation in a global network, albeit a incomplete one, has helped to an increase of the local competences of the automotive sector. This occurs via internal development (internal training, knowledge transfer between the headquarters and the branch or between the client and the supplier) as well as via the development of competences through the establishment of partnerships with local supplier, clients and education and research institutions.

However, it is important to notice that, with the exception of the technologies related to ethanol fuelled engines, local competences have been developed by the Brazilian units along the years in an informal way, i.e., without formal partnerships with local universities or research centres. These competences are related to local market characteristics, such as conditions of usage and customers' preferences and lower income levels. To the extent that some of these characteristics are also present in similar, important developing markets (such as Latin America, South Africa, Western Europe or India) these competences started being recognised by the headquarters, local engineering infrastructure was enhanced and its procedures and local competence development were formalised in the last decade. This is the case of Auto3, Auto4 and Auto6, for instance.

For all that, the participation of staff workers, technicians and, to a smaller extent, engineers, in the concept of global work/product/company seems to be a rather informal process. Especially for the administrative workers (marketing and purchasing managers), there are no systematic programmes for the development of global network management competences (for example, the capacity of buying globally or prospecting and interacting globally with clients).

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