MULTINATIONAL STRATEGIES, LOCAL HUMAN CAPITAL, AND GLOBAL INNOVATION NETWORKS IN THE AUTOMOTIVE INDUSTRY[•]

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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. This version of the paper is based on case studies from Germany and South Africa; we aim to add case material from Italy, India, and Brazil in the subsequent version.

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). A 2010 survey of 1215 companies in six European countries and in Brazil, China, India, and South Africa in three industries (agro-food, automotive, and ICT) revealed that 25 per cent offshored either production or R&D, and that, next to market access, the availability of specialized competences and qualified human capital 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 Appendix for more information in 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 of the dynamics underlying the transformation of GPNs into 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 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 mastered the hardly trivial process of moving from excellence in execution to more creative activities in which knowledge played an increasing role.

The present paper is an attempt to contribute to a better understanding of the micro determinants of GINs. 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 addresses these issues on the basis of a set of matched case studies from a European car producing economy (Germany), whose assemblers and suppliers have investments in important advanced developing countries (India and South Africa). It also includes Southern firms that invested in Europe to access knowledge from more advanced suppliers. The analysis focuses on specific instances of technical change, how they were supported by human capital upgrading, and what difference this made (or not) for the control of technological progress within each value chain.

The next section briefly reviews relevant literature on the relationship between human capital and MNE strategies. Then we present an overview of pertinent developments in the global automotive industry, followed by background on South Africa's education and skills system, as well as on FDI in the country. Afterwards we present data and methodology, and finally analyse the cases before concluding.

MNEs and human capital

MNEs embody certain capabilities while at the same time looking for new ones in a few advanced developing countries. In the South, education and training systems are an essential element of high absorptive capacities which in turn are a prerequisite for GINs. Hence there is a two-way relationship between FDI and local human capital. Two-way refers to the attraction educational achievements hold for inward direct investment (Noorbaksh, Paloni and Youssef 2001, Te Velde 2005, see also Dunning 1993) and to the influence MNEs exert 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 (see also Green et al 1999). 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.

Fourth, technological trajectories cannot be successful by relying exclusively on the mastery of operational know-how without deepening this to understand know-why, especially in the context of GINs as opposed to GPNs, where the exclusive pursuit of operational know-how may be a feasible strategy. 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 competences, 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.

Trends in the global automotive manufacturing industry

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; see Table 1). 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).

Table 1 – World car sales and production by sub-regions 2001-07 (million units)

	2001		**2004**		**2007**		**2001-2007 % change**	
	Sales	Prod.	Sales	Prod.	Sales	Prod.	Sales	Prod.
Europe, West	14.93	15.00	14.65	14.75	14.82	14.24	-0.7	-5.1
Europe, East	2.13	2.45	2.83	3.13	4.42	5.07	107.5	106.9
North America #)	19.03	13.70	18.51	14.32	17.88	13.10	-6.0	-4.4
Latin America #)	2.80	3.71	3.07	3.79	4.28	5.24	52.9	41.2
Asia-JO	4.90	8.40	5.46	9.06	5.14	10.24	4.9	21.9
Asia-DK	3.58	4.67	6.40	7.81	9.78	11.52	173.2	146.7
Middle East	1.00	-	1.85	-	2.18	-	118.0	-
Africa	0.66	0.23	0.77	0.24	1.08	0.28	63.6	21.7
Total	49.03	48.16	53.54	53.10	59.58	59.69	21.5	23.9

Source: Automotive Quarterly Review (2008), quoted in Wad, 2010).

Notes: Western Europe is the old EU-15 plus other Western countries. Eastern Europe is the new EU-12 + CIS and Turkey. North America is Canada and USA; Latin America is South America and Mexico. Asia-JO is Japan and Oceania (Australia and NewZealand). Asia-DK is Asia minus Japan and Oceania, i.e. Developing Asia (incl. Iran) and South Korea. #) Includes light trucks in both sales and production figures.

The onset of the world financial crisis in 2008 exacerbated 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 (JIT) 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).

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 turned the heat on OEMs and accelerated supplier consolidation. The number of first tier suppliers was predicted to fall globally from 8,000 in 2002 to around 2,000 by 2010, driven by a weak financial position of the industry, acrimonious relationships between OEMs and suppliers, as well as low capacity utilisation (Barnes and Morris, 2008, Osterman and Neal, 2009, Maxton and Womald, 2004, Ch. 7). 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).

Innovation and upgrading

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, K. and Jaruzelski, B. 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, further reducing the scope for innovation among smaller firms. The close collaboration between suppliers and assemblers leads to agglomerations of firms near the headquarters of assemblers and large tier 1 suppliers. The industry effect is a limit of 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 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, 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,????; Lorentzen, Møllgaard, and Rojec, 2003). Finally, lead local firms can work with highly specialised engineering and design houses and source from the world's top system integrators to achieve competitiveness first locally and later perhaps globally. For example, the Chinese OEM Chery, working with suppliers such as Pininfarina and Bosch, started production in 2001, only to become China's largest vehicle exporter by 2006 (Sturgeon and van Biesebroeck 2010).

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). The most straightforward channel is technology transfer from MNEs to their subsidiaries (e.g. Ivarsson and Alstram 2005). Learning can, but need not, take place in JVs (e.g. Nam, 2010; Sadoi, 2008). Upgrading can also take place when a Northern supplier transfers technology to a Southern assembly plant or when a Southern assembler acquires the competences 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 is guaranteed success in terms of transfer of especially the tacit knowledge that would allow the Southern firm to bridge existing technology gaps, certainly not in the short term.

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 assemblers and system integrators. 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.

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.
Conso-lidation	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.

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

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

Automotive foreign direct investment and absorptive capacity in South Africa

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. All except the German-owned MNCs had largely divested from the country, leaving their brands in local ownership. Following political changes in the country, the OEMs returned to South Africa and reacquired their assets. They were attracted by 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).

South Africa suffers from severe skill constraints. 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 (see Table 3), 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.

But these are average assessments. More important is how skills constraints affect automotive firms, how firms address them, and with what effect. Even while the industry increased investment, production, and exports from the second half of the 1990s, 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).

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 which in the early 1990s had been rather large. In 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 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.

Table 3 – Comparative human resources indicators

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	World Bank 2010; UNESCO 2010a
Public sector education expenditure as % of GDP 2007	5.34	5.21	3.18*	3.22**	n/a	World Bank 2010; UNESCO 2010a
Public sector education expenditure per capita (2007) USD	316.86	374.27	27.21*	231.35**	n/a	World Bank 2010; UNESCO 2010a
Gross tertiary enrolment as a % of the total 18-24 age cohort 2000	12.9#	16	10	7.8	n/a	World Bank 2010; # Department of Education, 2007
Gross tertiary enrolment as a % of the total 18-24 age cohort 2007	16.2#	30.01	13	22.05	n/a	World Bank 2010; # Department of Education, 2007
Brain drain ranking***A19	62	39	34	37	31	WEF Global Competitiveness Report 2010-2011
Quality of educational system****	130	103	39	53	18	WEF Global Competitiveness Report 2010-2011
Quality of math and science education****	137	126	38	33	39	WEF Global Competitiveness Report 2010-2011
Availability of scientists and engineers****	116	68	15	35	27	WEF Global Competitiveness Report 2010-2011
Quality of management schools****	21	73	23	63	31	WEF Global Competitiveness Report 2010-2011
Quality of scientific research institutions****	29	42	30	17	6	WEF Global Competitiveness Report 2010-2011
Internet access in schools****	100	72	70	22	39	WEF Global Competitiveness Report 2010-2011
Extent of staff training****	26	53	59	57	8	WEF Global Competitiveness Report 2010-2011
University-industry linkages****	24	34	58	25	9	WEF Global Competitiveness Report 2010-2011
Local availability of R&D services****	49	36	51	50	2	WEF Global Competitiveness Report 2010-2011
Top 200 ranked universities	1	0	1	9	10	QS World University Rankings 2010
% of tertiary graduates in science fields 2008	4	6.77	n/a	n/a	13	UNESCO 2010a
% of labour force with a tertiary education	13	8.6#	n/a	7##	24	UNESCO 2010a, # = 2006, ##http://english.peopledaily.com.cn/
Thompson Reuters' Science Citation Index publicationS % change 2002-2008	48.3	110.6	91.7	174.7	24.1#	UNESCO 2010b, #=EU total
Patent output 2007 per million of population	1.86	0.65	0.64	118.02	9713	UNESCO Science Report 2010

Notes: * = 2006, ** Source: People's Daily 2009, *** A lower ranking indicates greater brain drain., ****WEF rankings out of 139 countries

Methodology and data

In order to identify the joint effect of firm strategies and local absorptive capacities on the nature and quality of technical change, we selected German first-tier supplier MNEs with investments in one or more of South Africa, Brazil, and India. We did a similar exercise with Italian firms, including an OEM, which had investments in one or more of Brazil and 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 resulted in three lists of case studies. The first list contained matched firms where the teams interviewed both headquarters and subsidiary. The second list contained "like-with-like" matches where we interviewed different suppliers competing on the basis of similar product portfolios. The third list contained firms that were not matched but that nonetheless provided valuable illustrations of the research question. Firms on the first list allowed for triangulation and were the most interesting in that they occasionally revealed different viewpoints of managers of the same firm, depending on whether they were based in the South or the North. We compiled profiles for each firm, based largely on trade magazines and other specialist literature. The actual interview was semi-structured and focused on upgrading and location strategies, human capital, and the management of technological change. 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.

This version of the paper features five firms drawn from the first and the third lists (see Table 4).

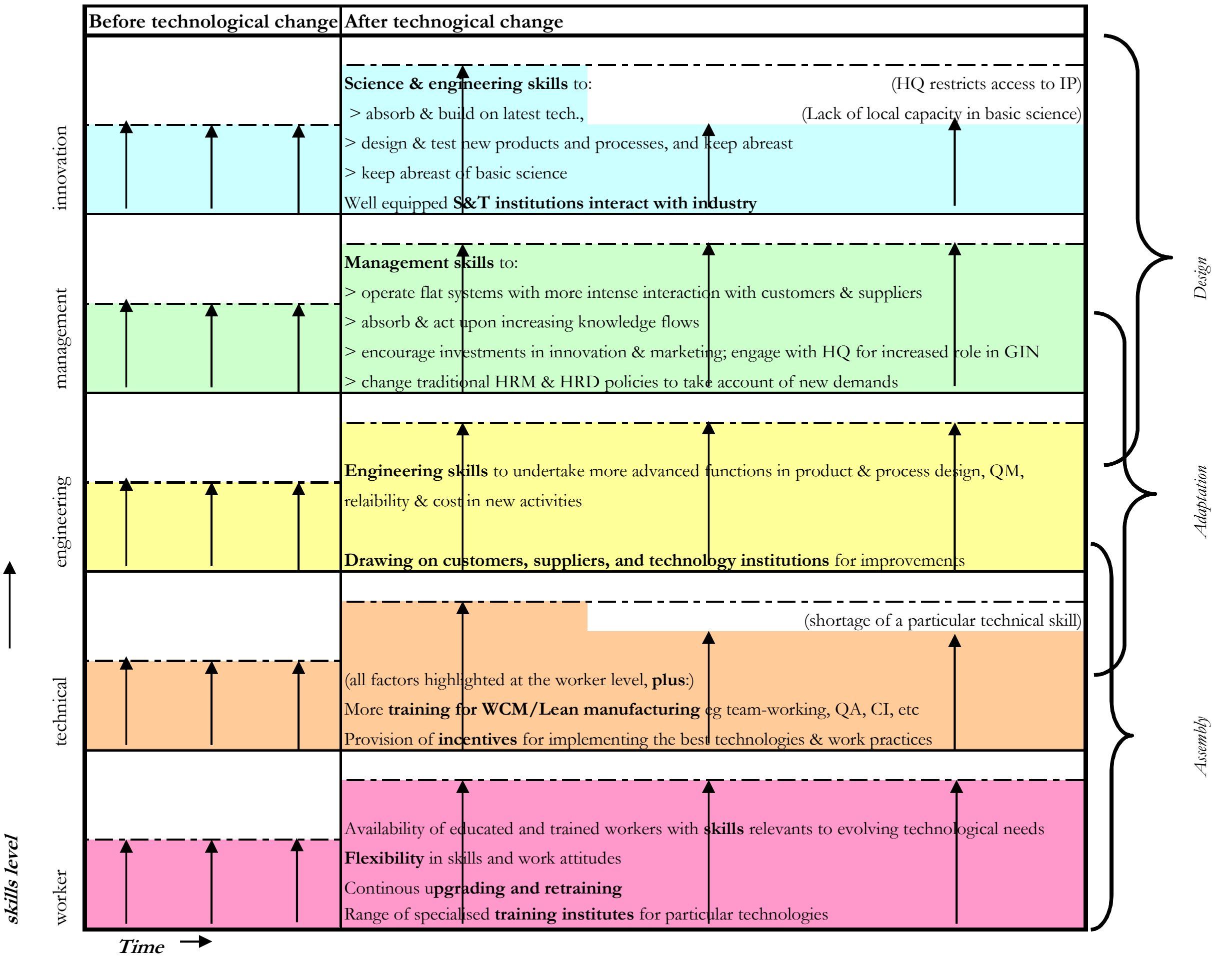
Table 4 – Case studies description

Firm	Turnover 2009	Locations	Product range	Interviews conducted
Drivetraincomp (list 3)	€5-10 bn	Global: 180 locations in 50 countries	clutches and bearings	South Africa
Exhaustcomp (list 1)	€1-5 bn	Global: locations in more than 20 countries	exhaust systems, heating systems	Germany, South Africa, India (planned)
Tempcomp (list 1)	€1-5 bn	Global: 22 production locations, 11 development centres, and two fully equipped R&D centres.	heating and cooling systems	Germany, South Africa (planned), India (planned)
Elecsys1 (list 3)	€0-1 bn	HQ and manufacturing in South Africa, sales and R&D centres in the UK and US	electronics	South Africa
Elecsys2 (list 3)	€0-1 bn	HQ in South Africa, subsidiaries in the UK and Australia	electronics	South Africa

Note: Turnover is given in ranges to protect anonymity.

The human capital dimension of the interview comprised all skill levels of the workforce, from shop floor workers to scientists. In 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 (see Figure 1).

Figure 1 – Dynamic human capital/technological upgrading analysis



This tool provides a framework for analyzing the skills that are required for a particular case of technological upgrading. Vertically, the table is divided into five areas, depicting skills strata from highest to lowest (from workers to scientists). In each area, the left side of the table represents skills requirements prior to a technical change, while the right side represents skills requirements ex post. Where the dotted line has been reached, the requisite skills were available or were developed during the course of upgrading. Where the dotted line was not reached (at the technical and innovation levels, in this example), a shortage of skills acted as a constraint on upgrading.

Analysis

Each instance of technological upgrading discussed in this section reflects both a strategic decision to undertake a process or product change in a specific location and the availability of the requisite human capital. 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 or India 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. Elecsys2 undertakes its R&D in South Africa. The German MNEs are more or less reluctant R&D offshorers. Elecsys1 undertakes its entire R&D abroad.

Reluctant offshorers

Drivetraincomp traditionally conducts basic R&D as well as pre- and product development at headquarters and centrally coordinates global innovation activity. It invested in a new R&D centre in the US in the early 2000s and more recently in. Its South African subsidiary only undertakes applied development. For example, Drivetraincomp SA designed a specific drivetrain component for a Japanese OEM. For this contract it interacted directly, not via the parent, with the customer. Its knowledge of local road surface and load conditions allowed it to develop an adaptation of an existing component to the much tougher requirements faced by commercial vehicles in developing countries. Its technology was subsequently passed on to the Brazilian subsidiary.

The South African subsidiary possesses most of the skills required for applied development. Where 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.

Similarly to Drivetraincomp, Exhaustcomp's and Tempcomp's principal R&D facilities are located in Germany. This reflects high local R&D capabilities and the need for proximity to OEM customers. Both companies have development centres in other countries where market size and characteristics warrant and demand adaptation of existing products; Exhaustcomp has four such centres and Tempcomp has 11 in different parts of the world. Driven by cost considerations, both companies opened R&D facilities in Pune, India. 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.

By contrast, Exhaustcomp's SA subsidiary is given little leeway in influencing process innovations although local managers claim that they have the necessary capabilities, reflected in significantly lower reject rates. For example, the South African plant reported a reject rate of 60 to 80 parts per million, compared to about 200 in the equivalent German plant. In their interpretation, the existing division of innovation labour is due to group internal hierarchies rather than a reflection of lack of capabilities on their part. The subsidiary is involved in product innovation only where OEM customers request components for vehicles that are marketed exclusively in South Africa.

Aggressive offshorers

Elecsys1 used to be a South African company that produced electronic components for OEMs. As a local company, it was in danger of being substituted by a follow-source supplier. In order to retain access to the OEM market in a longer-term perspective, it needed a development facility that was recognized for its capabilities, specifically to design the components required by the OEMs. Due to the structure of innovation in the automotive industry explained above, such a facility had to be located in a Triad economy. Thus, in the mid-noughties, the firm acquired an engineering services consultancy 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 some Chinese OEMs referred to above, the company thus bought assets that were technologically more advanced than its own. The division of labour is that the developed-country operations undertake R&D, whereas the South African operation focuses on manufacturing.

The company now supplies very advanced engine management systems for upmarket vehicles that it develops in-house. Hence it is engaged in R&D that leads to product innovation. This would not be possible without the acquisition. In combination with the advantages of flexibility that characterize the South African operation, the enlarged firm is carving out a niche as a non-Triad first tier supplier to global OEM customers.

Onkeepers (or whatever the opposite of offshorers is)

Elecsys2 manufactures electronic components. Although it exports to overseas markets, the firm develops almost all its products in South Africa. It does not do basic research but undertakes applied development on the basis of high-tech components that it sources globally. For example, the firm imported breathalysers from the UK and integrated the technology into an automotive application (an immobilizer). When the market for breathalysers grew and the UK company was not in a position to meet increasing quality standards and higher volumes, Elecsys2 re-engineered the product. At the assembly level, this required very little adaptation because it is essentially a standard process. Components may vary in size and so on, but operators familiar with electronics assembly can easily be trained to make a breathalyser instead. This is a capital-intensive process that minimises human error. Hence, changes in competences 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 and then proceed to designing the requisite process to produce it.

In addition to engineering new products for the automotive sector, the company aims to shift its electronics expertise to applications outside the automotive industry in order to escape the hierarchy and ever-diminishing margins in favour of sectors where it can extract higher rent, for example developing communications and tracking systems for surveillance use.

Upgrading or 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.

Both Drivetraincomp SA and Elecsys2 undertake knowledge-intensive activities, and Elecsys2 has significantly increased its research intensity over the past decade. Yet both companies engage essentially in applied development, recombining complex sources of knowledge to design components and systems. Neither engages in basic R&D, nor is it likely to do so in the future. Hence their technological trajectory merely confirms the larger story of upgraded supplier competences in the automotive industries of developing countries over the past two decades. Neither firm faces insurmountable skills constraints. For example, when Elecsys2 develops a new product, the primary skills requirement is at the engineering level. At the assembly level, new products require very little adaptation because the electronic components they produce essentially employ a standard, capital intensive assembly process that minimises human error as much as possible. Hence, skill is less important at the shop floor level, and more important at the engineering level, where the firm manages to find adequate skills. Another example is the development by Drivetraincomp of a clutch for a major Japanese assembler. The primary purpose of this development was to modify the existing design to cope with the rougher and more varied driving conditions in South Africa. In this instance Drivetraincomp had access to the necessary skills to develop the product and successfully bring it to market in South Africa; in addition, the South African designed product was also produced by the group's subsidiary Brazil.

By contrast, Elecsys1 and the two other German MNEs do 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 the South African manufacturer, R&D offshoring to Europe is the result of the local absence of the requisite capabilities. In the case of Tempcomp and Exhaustcomp, R&D offshoring to India is manifestly not the local absence of such capabilities in Germany, but their presence abroad at a much more competitive price. In both cases, human capital thus acts as a pull factor.

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 and different time zones.

The reluctant offshorers use cross-cultural communication and the migration of knowledge workers to address this problem (cf. Lehner and Warth 2010). When Exhaustcomp opened an R&D facility in India, the manager was appointed in India, then transferred to headquarters in Germany, where he remained 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. In India, he had to reconcile this experience with the way local processes. He therefore acts as a knowledge bridge between India and Germany. This organisation of learning is used across the group. At headquarters, there are engineers from several countries where the firm is present, some undergoing training before they return to their home countries, others permanently appointed in Germany to be the contact point for the related subsidiary abroad.

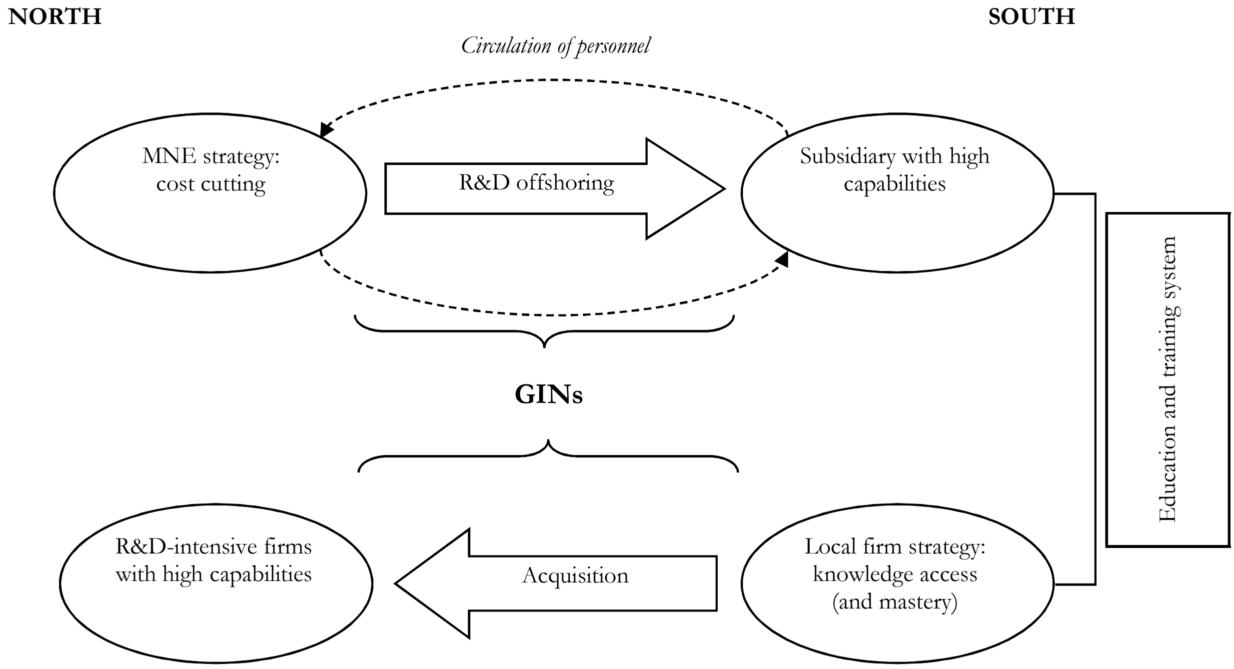
Tempcomp faced similar challenges of knowledge transfer between Germany and India, and in response commissioned a knowledge management expert from within the company to investigate possible responses. This formed part of an "action-oriented" PhD project. Their aim was to improve opportunities to relocate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

Conclusion

Based on the evidence presented above it is evident that the offshoring of knowledge-intensive activities is beginning to appear in an industry that is known more than others for centralizing most such activity close to headquarter locations, and always in developed economies. It is also evident that this phenomenon is not just based on Northern MNEs taking advantage of advanced capabilities in developing countries. Firms from the South, too, *in*shore the relevant knowledge through acquisitions of strategic assets in the North. As a result, GINs may evolve (see Figure 2).

The experience of the firms makes it clear that strategic intent and the stock of local capabilities are not a sufficient condition for the emergence of GINs. The tacit character of relevant knowledge in the industry, combined with different work practices that, in turn, are influenced by the respective cultural environment, necessitate dedicated knowledge management in the context of cross-cultural communication. The difficulties of such communication are related to the distance, cultural and otherwise, of firms from different backgrounds. For obvious reasons they are larger between a European and an Indian firms than between, say, a South African and an English firm.

Figure 2 – GINs in the automotive sector



The management of knowledge transfer is key because owning a knowledge asset is not equivalent to know-why, much like JVs do not guarantee knowledge transfer from the senior to the junior partner, as hoped for in policies incentivizing equity partnerships between foreign and local firms (Sadoi 2008). For example, although Elecsys1 now owns advanced engineering capabilities, it has not yet internalized these competences. Doing so takes time, and in this industry it is likely to require more time than in others where knowledge is more codified. The same applies to the Chinese and Indian OEMs that have acquired European or US carmakers.

The education and skills system obviously influences average capabilities and is thus an important indicator of the attractiveness of a region or a country for knowledge-intensive investments. But the more relevant finding is that firms in economies with severe human capital constraints at lower and medium levels can manage technical change, including new-to-the-world innovation, by exploiting high-level capabilities while adjusting to lower-level skill constraints through dedicated process engineering.

Finally, opportunities for GINs are larger in large-high-growth markets. Ceteris paribus, the evidence has shown that India is more likely to be part of automotive GINs than South Africa, despite the fact that its relevant competencies are currently not necessarily higher.

Bibliography

Archibugi, D. and Iammarino, S. 2002, "The globalization of technological innovation: definition and evidence", *Review of International Political Economy*, vol. 9, no. 1, pp. 98-122.

Automotive World Automotive Passenger Car OEM Quarterly Data Book, 2009

Barnes, J. and Kaplinsky, R. 2000, "Globalisation and the death of the local firm? The automobile components sector in South Africa", *Regional Studies,* vol. 34, no. 9, pp. 797-812.

Barnes, J. and Morris, M. 2008, "Staying alive in the global automotive industry: what can developing economies learn from South Africa about linking into global automotive value chains?", *The European Journal of Development Research,* vol. 20, no. 1, pp. 31-55.

Barnes, J. and Morris, M. 2004, "The German connection: shifting hegemony in the political economy of the South African automotive industry", *Industrial and Corporate Change,* vol. 13, no. 4, pp. 789-814.

Becker, H. 2006, *High noon in the automotive industry,* Helmut, Berlin.

Birchall, D.W., Tovstiga, G. and Chanaron, J.J. 2001, "Capabilities in strategic knowledge sourcing and assimilation: a new look at innovation in the automotive industry", *International Journal of Automotive Technology and Management,* vol. 1, no. 1, pp. 78-91.

Black, A. 2009, "Location, automotive policy, and multinational strategy: the position of South Africa in the global industry since 1995", *Growth and Change,* vol. 40, no. 3, pp. 483-512.

Blum, R. 2009, "The global crisis and restructuring in automotive and metalworking industries", *Metal World,* vol. 2, pp. 18-22.

Borensztein, E., De Gregorio, J. and Lee, J.W. 1998, 'How does foreign direct investment affect economic growth?', *Journal of International Economics*, vol. 45, pp. 115–135.

Brandt, L. and Van Biesebroeck, J. 2008, *Working report for Industry Canada: Capability building in China's auto supply chains*, Industry Canada, Ottowa.

Carrillo, J. 2004, "Transnational strategies and regional development: the case of GM and Delphi in Mexico', *Industry and Innovation*, vol. 11, no. 1/2, pp. 127–53.

Dehoff, K. and Jaruzelski, B. 2009, *The Global Innovation 1000*. Report for Booz and Company.

Chanaron, J.J. and Rennard, J.P. 2007, "The automotive industry: a challenge to Schumpeter's innovation theory" in *Re-discovering Schumpeter: creative destruction evolving into "mode 3"*, eds. Carayannis E. and Ziemnowicz, C. Sage, New York, pp. 320-343.

Chang, S.J. 2008, *Sony vs. Samsung*, John Wiley and Sons: Hoboken

Chuang, Y. 2000, "Human capital, exports, and economic growth: a causality analysis for Taiwan, 1952-1995", *Review of International Economics,* vol. 8, no. 4, pp. 712-720.

Coe, D.T., Helpman, E. and Hoffmaister, A.W. 2008, *International R&D spillovers and institutions, IMF working paper WP/08/104*, International Monetary Fund, Washington D.C.

Dilk, C., Gleich, R. and Wald, A. 2006, "State and development of innovation networks: evidence from the European vehicle sector", *Management Decision*, vol. 46, no. 5, pp. 691-701.

Dunning, J. 1993, *Multinational Enterprises and the Global Economy.* Addison-Wesley, New York.

Dutrénit, G. 2004, "Building technological capabilities in latecomer firms: a review essay", *Science Technology & Society,* vol. 9, no. 2, pp. 209-41.

Gastrow, M. and Gordon, A. 2010, "*Technological evolution in the South African and Argentine automotive manufacturing sectors: policy responses and results*", presentation at the 8th conference of the Global Network for Economics of Learning, Innovation, and Competence Building Systems, Kuala Lumpur.

Gereffi, G. 2005, "The global economy: organisation, governance and development" in *Handbook of Economic Sociology*, eds. S. Smelser and R. Swedberg, Princeton University Press and Russel Sage Foundation, Princeton, NJ, pp. 160-182.

Goldstein, A.E. 2003. "*Regional integration, FDI, and the competitiveness of SADC*", paper prepared for the OECD African Investment Roundtable.

Green, F., Ashton, D., James, D. and Sung, Johnny. 1999. The role of the state in skill formation: Evidence from the Republic of Korea, Singapore, and Taiwan. *Oxford Review of Economic Policy*, vol.15, no.1, pp. 82-96.

Grossman, G.M. and Helpman, E. 1991, *Innovation and Growth in the Global Economy*, MIT Press, Cambidge, Massachusetts.

Hobday, M., Rush, H. and Bessant, J. 2004, "Approaching the innovation frontier in Korea: The transition phase to leadership", *Research Policy,* vol. 33, no. 10, pp. 1433-1457

Humphrey, J., Mukherjee, A., Zilbovicius, M. and Arbix, G. 1998, "Globalization, foreign direct investment and the restructuring of supplier neworks: the motor industry in Brazil and India" in *Learning, liberalization and economic adjustment*, ed. M. Kagami, Institute of Developing Economies, Tokyo.

Humphrey, J. and Memedovic, O. 2003, *The global automotive industry value chain: what prospects for upgrading by developing countries?*, UNIDO Sectoral Studies Series paper, Vienna.

Ivarsson, I. and Alvstam, C.G. 2005, "Technology transfer from TNCs to local suppliers in developing countries: a study of AB Volvo's truck and bus plants in Brazil, China, India, and Mexico", *World Development,* vol. 33, no. 8, pp. 1325-1344.

Jung, M. and Lee, K. 2010, "Sectoral systems of innovation and productivity catch-up: determinants of the productivity gap between Korean and Japanese firms", *Industrial and Corporate Change,* vol. 19, no. 4, pp. 1037-1069.

Kim L. 1997, *Immitation to Innovation: The Dynamics of Korea's Technological Learning.* Harvard Business School Press, Cambridge, Massachusetts.

Lall, S. and Narula, R. 2004, "Foreign direct investment and its role in economic development: do we need a new agenda?", *The European Journal of Development Research,* vol. 16, no. 3, pp. 447-464.

Lehner, F. and Warth, C. 2010, Knowledge transfer processes in the automotive supplier industry – designing an integrated knowledge transfer model. Paper presented at the 11th European Conference on Knowledge Management, Universidade Lusíada de Vila Nova de Famalicão, Portugal.

Lorentzen, J. 2007. "MNCs in the periphery: DaimlerChrysler South Africa (DCSA), human capital upgrading and regional economic development" in *Multinationals on the periphery*, eds. Benito, G.R.G. and Narula, R. Palgrave Macmillan, New York.

Lorentzen, J. 2009, "Learning and innovation: what's different in the (sub)tropics and how do we explain it? A review essay", *Science, Technology & Society*, vol. 14, no. 1, pp. 177-205.

Lorentzen, J. and Barnes, J. 2004, "Learning, upgrading, and innovation in the South African automotive industry", *European Journal of Development Research*, vol. 16, no. 3, pp. 465-498.

Lorentzen, J., Møellgaard, P. and Rojec, M. 2003, "Host-country absorption of technology: evidence from automotive supply networks in Eastern Europe", *Industry and Innovation*, vol. 10, no. 4, pp. 415-32

Maxton, G.P. and Womald, J. 2004, *Time for a model change. Re-engineering the global automotive industry.* Cambridge University Press, Cambridge.

Moran, T.H. 1998, *Foreign direct investment and development.* Institute for International Economics, Washington, D.C

Nam, K. 2010. "Learning through the international joint venture: lessons from the experience of china's automotive sector", presentation at the 8th conference of the Global Network for Economics of Learning, Innovation, and Competence Building Systems, Kuala Lumpur.

Noorbakhsh, F., Paloni, A. and Youssef, A. 2001, "Human capital and FDI inflows to developing countries: new empirical evidence", *World Development*, vol. 29, no. 9, pp. 1593-1610.

OECD, 2007. *The internationalisation of business R&D: evidence, impacts and implications*. OECD, Paris.

Osterman, D. and Neal, B. 2009, *The global automotive industry crisis: a way ahead.* An IMVP position paper, IMVP, MIT, Cambridge, Massachusetts.

Rutherford, T. and Holmes, J. 2008, "'The flea on the tail of the dog': power in global production networks and the restructuring of Canadian automotive clusters", *Journal of Economic Geography,* vol. 8, no. 4, pp. 519-544.

Sadoi, Y. 2008, "Technology transfer in automotive parts firms in China", *Asia Pacific Business Review,* vol. 14, no. 1, pp. 147-163.

Spar, D. 1998, "Attracting high technology investment: Intel's Costa Rican plant", *FIAS Occasional Paper 11*, Foreign Investment Advisory Service, IFC and World Bank, Washington, D.C.

Sturgeon, T. and Van Biesebroeck, J. 2010, *Effects of the crisis on the automotive industry in developing countries: a global value chain perspective. Policy Research Working Paper 5330*, World Bank, Washington, DC.

Sturgeon, T.J., Memedovic, O., Van Biesebroeck, J. and Gereffi, G. 2009, "Globalisation of the automotive industry: main features and trends", *International Journal of Technological Learning, Innovation and Development,* vol. 2, no. 1/2, pp. 7-24.

Sturgeon, T., Van Biesebroeck, J. and Gereffi, G. 2008, "Value chains, networks and clusters: reframing the global automotive industry", *Journal of Economic Geography,* vol. 8, pp. 297-321.

Tan, H.W. and Batra, G. 1995, *Enterprise training in developing countries: incidence, productivity effects and policy implications*, World Bank, Washington, D.C.

te Velde, D.W. 2005*, "Globalisation and education: What do the trade, investment and migration literatures tell us?",* Working Paper 254, Overseas Development Institute, London.

te Velde, D.W. and Xenogiani, T. 2007, "Foreign direct investment and international skill inequality", *Oxford Development Studies*, vol. 35, no. 1, pp. 83-104.

UNCTAD, 2005, *World Investment Report*, UNCTAD, Geneva.

UNESCO 2010a. *United Nations Educational, Scientific, and Cultural Organization Institute for Statistics Data Centre.* [Online]. Available: http://stats.uis.unesco.org/unesco/TableViewer/document.aspx?ReportId=143andIF_Language=eng [5 December 2010].

UNESCO 2010b. *United Nations Educational, Scientific, and Cultural Organization Science Report 2010*. [Online]. Available: http://www.unesco.org/new/en/natural-sciences/science-technology/prospective-studies/unesco-science-report/ [5 January 2010].

World Bank 2010. *Data*. [Online]. Available: http://data.worldbank.org/ [4 December 2010].

WEF 2010a. *World Economic Forum: The Global Competitiveness Report 2010–2011*. [Online]. Available: http://www3.weforum.org/docs/WEF_GlobalCompetitivenessReport_2010-11.pdf [6 January 2011].

WEF 2010b. *World Economic Forum: The Global Gender Gap Report 2010*. [Online]. Available: http://www.weforum.org/issues/global-gender-gap [10 January 2011].

Wad, P. 2010, *Impact of the global economic and financial crisis over the automotive industry in developing countries*, United Nations Industrial Development Organisation (UNIDO) Working Paper 16/2009, Vienna.

Wooldridge, A. 2010, "The world turned upside down - Special report on innovation in emerging markets", *The Economist*, April 17th.

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

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

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

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

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