Learning, Upgrading, and Innovation in the South African Automotive Industry

[this version November 2003, comments very welcome]

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Abstract

This paper addresses the innovation activities of automotive component manufacturers in South Africa. It looks at the technological trajectory of a handful of firms that stand out from the crowd and analyses the results of their endeavours in the context of their interaction with foreign capital, their internal upgrading and R&D agenda, and their interface with South Africa's national innovation system (NIS). The analysis makes use of eight case studies, and illustrates the conditions under which indigenous innovation in the automotive industries can happen in a developing country. This finding contradicts at least part of the conventional wisdom concerning the location of innovation activities in global car value chains. Results also point to a deficient NIS insofar as there appears to be a disjuncture between the demand for engineering competence in the manufacturing sector on the one hand and output from the tertiary education sector on the other. Open questions that need further attention include among others the overall functioning of the NIS, and changes over time in the perception of local innovation potential by car assemblers.

Keywords: automotive industry, developing countries, technology transfer, technology accumulation, innovation.
JEL Classification: L62, O31, O32.

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1 Introduction

Technological innovation is to development what a blue sky is to the Sunday picnic: essential to its success but in many parts of the world hard to count on. The conditions under which technological upgrading takes place are rather well understood in theory. In the context of developing countries, what matters is the availability of foreign capital and the presence of local capabilities to make good use of it. When foreign and local inputs match well, technology transfer and diffusion may take place and do the little trick of moving the developing country forward.

In practice, things are a lot messier. For a start, technological success stories are far and few between. Some firms, industries, and even entire countries have "made it" but their number is dwarfed by those who stagnate or seem to be moving backward, relatively or absolutely. In addition, technology transfer and diffusion are empirically hard to operationalise. Studies that overcome problems of intractability often conclude that multinational investments do not lead to spillovers in the host economies. Finally, in some industries the very structure of the value chain may militate against the technological upgrading of any firms that are not located in a core group of technology-leading countries.

This paper addresses the innovation activities of automotive component manufacturers in South Africa and, hence, in the context of a continent often associated with the absence of technological activity *tout court*. More specifically, it looks at the technological trajectory of a handful of firms that stand out from the crowd in the sense that they pursue activities aimed at technological upgrading *and* innovation. It analyses the results of their endeavours in the context of foreign capital (through the global supply chains to which they deliver), their internal agenda in terms of upgrading and R&D, and South Africa's national innovation system. Section 2 summarises the relevant literature. Section 3 introduces key performance indicators of the South African automotive industry post-liberalisation, both from a macro and a micro perspective. Section 4 discusses eight case studies and constitutes the principal analytical contribution of the paper. Section 5 concludes with suggestions for further research.

2 Indigenous technological activity in developing countries: determinants and problems

Most technological learning – namely the ability to make use of externally available knowledge – takes place in firms (Section 2.1). In addition, public investment in education and training feeds into technological accumulation. Especially scale-intensive sectors such as the automotive industry necessitate technical and graduate engineering skills. This is part of the business environment – or the national innovation system – in which firms operate (Section 2.2). Finally, the specific structure of the value chains within which firms find themselves influences the

* The managers of a number of automotive component manufacturers who chose to remain anonymous generously made time available to answer our many questions. Without their insights we would not have been able to write our case studies. Mike Morris and Imraan Valodia helped us clarify some of our ideas. Workshop participants in Copenhagen, Oslo, and Durban provided constructive comments. We are grateful to all of them, and to Raj Narula for encouraging us to write this paper in the first place. Any errors or omissions are our own.

location of and the scope for innovation activity in global supply networks (Section 2.3). Section 2.4 summarises what all this implies for the analysis at hand.

2.1 Local firms: productive capacity, technological capability, and the impact of foreign knowledge

Following the widespread liberalisation of trade and investment regimes in developing countries in the 1980s and 1990s, local firms are more exposed to competition from foreign firms and products. Hence indigenous technological activity interacts more than previously with imported knowledge, often in the form of foreign direct investment (FDI). This relationship is not straightforward. Inflows of superior foreign technology may enhance incentives for innovation because of the competitive climate they create. Alternatively, they may obviate the need for indigenous generation of technology through the creation of no-need-to-reinvent-the-wheel type generation of technology through the creation of no-need-to-reinvent-the-wheel type situations. Firms who learn and upgrade – and this is not limited to new know-how in a narrow sense but includes operational techniques and managerial processes – are likely to be affected differently by foreign knowledge over time. Thus, for a new kid on the bloc, licensed technology may be the best bet to grow its competences. By contrast, once technologically more mature, the same firm may be in a position to take on more advanced knowledge embodied in FDI. Therefore, transfer modes influence the incentives for innovation.

How all this plays out for the local firm and the host economy more generally depends, inter alia, on capabilities at both the micro and the national level. Relevant firm competences include the search for new knowledge, skill development, and internal knowledge diffusion. Investments in education, information provision, and infrastucture more generally are key among host country characteristics (Lall 1993, Pack and Saggi 1997; see also Narula and Dunning 2000 and Ozawa 1992 for stage arguments linking the relative development of the host economy to the kind and complexity of inward direct investment it attracts, or Birkinshaw and Morrison 1995 for the relation between the entrepreneurial ambition and capability of subsidiaries, and intra-firm technology flows).

In principle, technological spillovers may materialise because local firms manage to copy technology from a foreign subsidiary. This is significant insofar as the technologies brought by MNEs will typically not be available in the market. Also, interacting with subsidiaries that use advanced technology may facilitate diffusion to local firms and reduce the risk from go-it-alone innovation. In practice, spillovers often prove elusive. Unfortunately, empirical research regularly fails to turn up strong evidence as to the exact nature and magnitude of spillovers (see Blomström and Kokko (1998) for a general survey, and Görg and Greenaway (2002) for an analysis of transition economies). This is but one of the reasons why research on the conditions of indigenous innovation in developing countries is so important, independently of whether they do or do not attract FDI.

Whether diffusion – understood as the acquisition of technology by local firms who then engineer adaptations and modifications to suit local needs – leads to innovation depends on the quality of resources the acquiring firms control. At a more basic level firms produce industrial goods using known combinations of equipment, skills, specifications, and organisational systems. Yet while necessary, production

capacity is not a sufficient condition for upgrading. To make the latter happen, firms must additionally possess the competences to incorporate new technology into their production capacity. These competences are also critical for continuous access to foreign technology in the context of moving closer to the global technology frontier which is of course itself a moving target.

This underlines the importance of learning for technological capability. The more complex technologies are, the more trial and error play a role in their improvement. Therefore product design, process and product engineering are all important sources of technical change even in the absence of direct links with R&D. R&D labs, design offices, and production engineering must feed off of each other to facilitate learning by doing. In other words, innovation is rarely if ever a unidirectional step from R&D downwards to production (Bell and Pavitt 1993a; see also Bell 1997, Bell and Albu 1999, Tidd, Bessant, and Pavitt 1997). This is not to detract from the key role of R&D for learning (Cohen and Levinthal 1989), but merely suggests that R&D spending alone is not a sufficient indicator for actual or potential innovation activity.

2.2 National innovation systems: developing countries and South Africa

The concept of national innovation systems (NIS) suggests that while firms are the main agents of technological learning, they interact more or less successfully with a host of other organisations and institutions. This interaction, in turn, influences where technical change comes from and how it is disseminated. The concept also proposes that countries are a meaningful unit of analysis insofar as distinctive national characteristics at least in part describe the differentiation of innovation activities across the world. High-income countries have been subject to very sophisticated and comprehensive analyses both of the evolution and the operation of their respective NIS (for example, Edquist 1997, Nelson 1993; see also Freeman 1994). A large body of work also exists that tries to explain differential rates of technological accumulation across developing countries (for an overview, see Bell and Pavitt (1993b) or Lall and Pietrobelli (2002) for a treatment of Sub-Saharan countries). On the whole, however, the links between the different constituents of the system, especially between firms and the tertiary education sector, are much less drawn out in developing country contexts. South Africa is no exception.

From the beginning of apartheid in the late 1940s to the regime change in 1994, South Africa had no coherent NIS. What elements of a system existed were informed by the needs of a privileged minority with a distinct supremacist agenda. This obviously stood in the way of an integrated framework (Scerri 1998), but did not prevent the country from world-class performance in a number of technologies. Examples include coal-to-oil conversion, deep mining, clinical medicine and, prominently, IT and armaments. The latter in particular exemplified both the achievements of mission-driven research (for example, in the development of nuclear weapons as well biological and chemical warfare capabilities) and the ability to acquire, adopt, adapt, and extend foreign technologies.

In the face of international sanctions, the sort of imitation encouraged by import substitution only partially gave way to competitive innovation in select areas such as aerospace engineering where advanced technologies proved much harder to get on the open market. What the sanctions regime definitely did was to keep effectively rather indiscriminate import substitution alive beyond any sensible economic motivation. Except in the military sector, industry and universities did not collaborate much, but science was generously funded, replicating the dichotomy between pockets of excellence and severe deprivation that characterised the country at large (Kahn and Reddy 2001, see also Birdi, Dunne, and Saal 2000). For example, offerings in natural sciences and technology were traditionally discouraged in the ten black universities. Their remit consisted primarily of teaching; research programmes remained the exclusive domain of the eleven white-governed universities. It is not clear how long it will take to redress this imbalance which is clearly dysfunctional in an inclusive society. What is clear is that innovation in South Africa at present suffers from this heritage.

Attempts to exploit best practices from national innovation systems elsewhere for a new science and technology policy led to the tabling of the first White Paper on Science and Technology in 1996. The ideas behind this initiative were an emphasis on cooperation between government, industry, and research institutions, along with a stronger focus on applications-based research. The White Paper spawned a number of policy initiatives. Of relevance to the present analysis are the Innovation Fund which promoted initiatives aimed at increasing competitiveness and at pushing collaboration between public Science, Engineering, and Technology Institutions (SETIs), the private sector, tertiary education, and civil society. This included the development of human resources generally and postgraduate training in particular through programmes such as Technology for Human Resources Programme (THRIP). To date, there has been little systematic evaluation of the effectiveness of these initiatives (but see Human Science Research Council 2003, Kaplan 2001).

Critics charge that South African science and technology policy focuses too much on technology generation by the SETIs, and too little on technology diffusion (Kaplan 1999, 486). The situation is compounded by unemployment levels of over 40 per cent, low skill levels, and insufficient labour mobility that exacerbate the social costs of technological change *per se*. Moreover, the country's brain drain has affected the world-class aeronautical and IT industries (see Goldstein (2002) for a perceptive analysis of the difficulties of South Africa's aerospace industry in adapting to reduced government demand and increased international competition). At 1.2 per cent of GDP, spending on higher education may be too low to reverse this trend (Kahn and Reddy 2001). Even alleged high-tech hubs such as the Midrand area in the Gauteng are based on manufacture and functional services instead of R&D, except in defence-related firms. The retrenchment of the public sector as a major contractor and the absence of a deep venture capital market combine in a vicious dynamic that knocks firms off their feet without providing them with an opportunity to struggle back up again (Hodge 1998, Rogerson 1998). What remains is, as in the past, relatively isolated pockets of excellence (e.g. Versi 2001).

2.3 Dynamics of innovation in the automotive industry

Vehicle assemblers co-design new car models in cooperation with so-called 0.5 or 1 tier suppliers who deliver complete systems or modules, rather than individual components. Outsourcing and long-term cooperation – for components that require relationship-specific investments – have increasingly replaced the high degree of vertical integration and arm's length contracts that traditionally characterised the

industry. The car manufacturers' investment into the relationship with key suppliers culminates in the system sourcing concept pioneered among others by General Motors at its Gravatai plant in Brazil, where the entire plant lay-out was jointly developed with leading component manufacturers. However, the locus of R&D in the value chain has not really changed. Independent companies such as Delphi or Visteon, having been spun off by the car makers, have joined historically important component manufacturers such as Bosch or Allied Signals in delivering black-box parts to the specifications of the assemblers but based on their own design and technological solutions.

In other words, vertical disintegration has not affected the scope for innovation activities below the 1st tier. What has changed, apart from a certain dissipation of the technological core away from the exclusive control of the assemblers, is the degree of concentration in the component industry which was forced to consolidate in order to acquire the global reach and financial depth necessary to survive in a very competitive industry suffering from chronic overcapacity. Hence, automotive R&D is essentially performed by fewer and very large, powerful firms protected by considerable entry barriers. It is unsurprising then that the world's ten largest automotive component manufacturers each have annual sales in excess of US$8 billion.

In their attempts to reduce costs, car makers have begun to build a larger model variety onto fewer vehicle platforms. In addition, the idea of a "world car" aspires to compensate rising development costs and shorter model turnover cycles on the one hand with larger model runs on the other. This means that locally adapted versions of essentially the same model are available worldwide. It also means that, in conjunction with the widespread liberalisation of investment and trade regimes over the last two decades, select car plants in developing or transition economies deliver top-of-the-range models to high-income countries. In practice, this has led to the harmonisation of quality standards across the world. For example, while in the past VW could get away with producing a substandard (old) Beetle in Mexico because it was mainly away with producing a substandard (old) Beetle in Mexico because it was mainly aimed at the domestic market, the new Beetle is primarily exported and must meet the same standards of quality and delivery as its model cousins manufactured in one of VW's European plants. Therefore, except for the remnants of genuinely local vehicles manufactured mostly for local markets such as the Russian Lada or the Malaysian Proton, cars produced by the major vehicle assemblers anywhere in the world must meet the same exacting quality standards.

Organisationally, the system of relations between vehicle assemblers and component and part suppliers is among the most complex in any industry. Not only have assemblers devolved substantial responsibilities in product development to upper-tier suppliers, the latter are also expected to guarantee quality standards and delivery schedules of their own lower-tier suppliers whose parts and components feed into their modules and systems. Lean production methods (just-in-time inventory systems, decentralised total quality management, bottom-up suggestions for process improvements) affect the entire value chain; for example, even a 3rd-tier supplier must in principle be in a position to accommodate engineering changes to be implemented in ongoing manufacturing processes (MacDuffie and Helper 1997).

Car makers have responded to the devolution of control over detailed design and production processes by tightening overall control of the production cycle. The two

key strategic tenets are "follow design" (several countries share the same vehicle design) and "follow sourcing" (the same manufacturer supplies parts in different locations). This guarantees the standardisation of vehicles and components within and across regions in the context of "world car" designs. Follow source decreases monitoring costs for the car makers while guaranteeing homologation.

The structure and organisational configuration of the car industry and the strategic orientation of its key players militate against the involvement of upper-tier manufacturers from developing countries in design and of independent suppliers in global supply chains more generally. Currently it makes most sense for a vehicle manufacturer with an investment in a developing country to rely on the tested and trusted relationships with preferred suppliers that set up production close to wherever their customer goes. Consequently, a number of observers have concluded that developing country firms are likely to lose design and engineering capabilities, and that the auto industry will contribute little to the hoped for technological capability within manufacturing at large. Humphrey (2000) makes this argument for Brazil and India, Barnes and Kaplinsky (2000a, 2000b) for South Africa, and Rutherford (2000) comes to a similar conclusion with respect to Canada. At the same time there is emerging evidence that these downbeat assessments may overstate their case (for a contrasting analysis concerning Japanese automotive investments in the US, see Craig and de Gregory (2000), Humphrey and Memedovic (2003, 34-5) on product development capabilities in Mexico, Lung (2003, 18) on the new design pole in the Barcelona metropolitan area, or Lorentzen, Møllgaard, and Rojec (2003) on the experience in Eastern Europe). The present analysis is an attempt to shed light on this controversy.

2.4 Summary: theoretical expectations on automotive innovation in South Africa

The review of the literature makes clear that local automotive component manufacturers intent on engaging in innovation activities have the cards stacked against them. First, the presence of sophisticated local competences is no guarantee that technological spillovers will be forthcoming. Hence the role of foreign technology is ambiguous. Furthermore, there is a long way from improving production capacity to developing technological capability and, finally, to engaging in innovation true and proper. Second, although the mechanisms of the post-apartheid national innovation system are not well understood at present, it is uncontroversial that the system suffers from its apartheid-era legacy and also exhibits dysfunctionalities of more recent vintage. Third, innovation and design in global automotive production puts a premium on core localities and traditional suppliers with global remits. This tends to jeopardise these activities in liberalised emerging markets such as South Africa both directly and indirectly.

Yet as the case studies below show, some firms do in fact engage in innovation activities. Before analysing how they defy the odds, it is important to understand the development of the South African automotive industry pre- and post-liberalisation.

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3 Macro and micro perspectives on innovation in South Africa's automotive industry

Although marginal by the standards of emerging markets with significant regional or global roles such as Mexico or Brazil, automotive production is an important industry in South Africa. It comprises eight producers of light vehicles, a number of specialist medium and heavy commercial vehicle makers, and some 250 dedicated component manufacturers, many of whom are subsidiaries of multinational firms. The industry employs over 100,000 people who are paid above-average wages. 2002 turnover was close to ZAR 100 bn. In 2001, total automotive production was worth 5.7 per cent of GDP and accounted for 12 per cent of exports. The industry's relative share in manufacturing employment, sales, and production has increased over the 1990s and in 2001 reached 6, 13, and 9 per cent, respectively.

3.1 The industry before 1995

Historically South African industry was heavily protected from outside competition. The car sector was no exception (see Black (2001) for a historical review). Nominal imports tariffs of up to 115 per cent ensured that domestic producers could profitably produce a broad portfolio of essentially outdated vehicles of questionable quality almost exclusively for the local market of, in the early 1990s, some 300,000-350,000 units annual sales. In contrast to the East Asian experience, where temporary infant industry protection against import competition was granted in parallel with enforcing tough competition among domestic producers, vehicle assemblers and component manufacturers in South Africa enjoyed the privilege of passing on the inefficiencies nurtured in an ossified import substitution model to the consumers. This obviously affected the scope for learning in automotive firms. For example, until 1989 the basic reference parameter of almost three decades of local content programmes had been weight rather than value. Thus firms received a premium for designing and producing heavy rather than light – or lean – products.

3.2 The industry from 1995

In line with its broader macroeconomic liberalisation strategy, the new government launched the Motor Industry Development Programme (MIDP) in 1995, originally expected to run until 2002. The MIDP aimed at increasing the international competitiveness of firms in the industry (for a detailed description, see Barnes and Black (2003), and Black (2001)). It consisted of a package combining a series of incentives with substantial import liberalisation – for example immediately cutting the import tariff on completely built up vehicles (CBUs) from 115 per cent to 65 per cent. Two reviews, in 1999 and in 2002, extended the programme to 2007 and 2012, respectively. Import tariffs are scheduled to reach 25 per cent for CBUs and 20 per cent for completely knocked down components (CKD) by 2012.

Next to gradual tariff reductions and the abolition of local content provisions, the most important feature of the MIDP is the Import-Export Complementation Scheme (IEC). Under this scheme vehicle assemblers and component suppliers can earn Import Rebate Credit Certificates (IRCCs) from exporting. Based on the value of local raw materials and value added in the exported product, these duty credits are tradable and can be used to offset import duties on vehicles or components. In turn, this allows vehicle manufacturers to buy credits from component exporters to finance the import of completely assembled vehicles not produced locally, or of components they prefer to source abroad. In addition, car manufacturers can also draw on a duty-free allowance on component imports of 27 per cent of the wholesale value of the vehicle. Taken together, on the one hand this creates incentives for foreign assemblers to invest in production in South Africa for both the local and the export markets. It also makes sense for them to work with suppliers based in South Africa – though these need not be domestically owned. On the other hand the MIDP allows the car makers to retain their global supply networks.

The flip side of this arrangement is that domestic firms no longer have the luxury of domestic go-it-alone strategies and must confront the challenge of export success. This means that they either manage to join global supply chains or resign to bidding the automotive industry farewell.

The MIDP appears to have been successful in providing a framework conducive to the development of the industry though concerns persist how the gradual phasing out of export incentives will affect the sustainability of export expansion. For example, in 2002 total passenger vehicle production was 288,000 units, nearly 50 per cent more than the 193,000 vehicles produced in 1998. Almost a fifth of these were essentially outdated models, some of which with a slow phase-out period of up to three years. Over 40 per cent of total production was for export markets, up from 4 per cent in 1995 and 9 per cent in 1998. By contrast, sales of light commercial vehicles (LCVs) were 17 per cent lower in 2002 than in 1995, with only 8 per cent going abroad. Further, yearly real turnover of the components industry grew 7 per cent in 1997-2000. Exports prominently contributed to this, growing more than 20 per cent annually since 1995. This performance was based on increased levels of capital investment and manifested itself in higher profitability, especially from the late 1990s, for both assemblers and component manufacturers.

The automotive industry's trade balance continued to be negative through 2002. This is due to the reduction in effective protection and the use of IRCCs which increased the share of fully imported CBUs to 24 per cent of the domestic market, from 5.5 per cent in 1995, and reduced local content in locally assembled vehicles from 58 per cent to 50 per cent in 1997-2001. In 2000, only 5 per cent of component imports by value actually faced a duty (Black and Mitchell 2002, 6). Hence, South African based operations are progressively being integrated into global sourcing networks both upstream and downstream. This implies that they are much more subject to international competition than only a few years ago.

A number of competitiveness indicators for the industry improved. Labour productivity in 2001 was roughly a third higher than in 1998, and above the manufacturing average. Firm level data confirm that operationally much has been happening since the late 1990s (see Table 1). The information below is taken from a benchmarking club database that comprises competitiveness and financial benchmarking club database that comprises competitiveness and financial performance data from over 40 automotive component manufacturers located in South Africa. These firms belong to one of three regional benchmarking clubs in KwaZulu-Natal, Eastern Cape and Gauteng provinces. They represent roughly 25% of the national automotive components industry by value. Each member is benchmarked

against an international competitor based in either Western or Eastern Europe, Malaysia or Australia. Thus the database includes information from a set of international firms that broadly match the product profile of their South African counterparts.

[Table 1 about here]

How this compares to competitors in other developing, transition, and developed countries is evident from Table 2. South African based firms generally lag behind their competitors. Only the top performers generally match their international peers. How they manage to do that is discussed in detail in Section 4.

[Table 2 about here]

Also, the architecture of globalised automotive value chains has militated at least in part against domestic firms. A number of large, independent component manufacturers have had to leave their 1st-tier position for the 2nd tier, for example the Metair companies, Murray and Roberts, and the various subsidiaries of Dorbyl Automotive Technologies, all with turnover in excess of US$150m. Others were forced to abandon the industry altogether. Table 3 shows a clear preference on the part of the South African based car makers to source their components from wholly owned subsidiaries of multinational component suppliers rather than from domestic companies with proprietary or licensed technologies.

[Table 3 about here]

Although local technology has thus come under pressure, a quarter of the firms in the Benchmarking Club database in 2002 invested only 17 per cent less, in relative terms, in R&D than the international firms (see Figure 1). Of course, the data do not show if this is residual expenditure left over from the previous era of localisation and local design for the local market, or if it indicates, on the part of these firms, a search for more high value adding and innovative roles in the new global environment. The empirical evidence from the Benchmarking Club database is inconclusive insofar as it shows no positive relationship between R&D expenditure on the one hand and the age profile of products or operational competitiveness on the other. The former is due in part to the significant presence of foreign-owned subsidiaries who do not invest in R&D at all but do produce the latest products. The latter is probably affected by the manner in which most firms fail to measure R&D aimed at process innovation. At this level of aggregation, then, it appears difficult to investigate upgrading and innovation. It seems clear, however, that in line with theoretical predictions independent product innovation is not a prerequisite for upgrading. To unpack the nexus between upgrading and innovation and gain a more robust understanding of how firm activities in either are linked to the dynamics of global value chains and the national innovation system, our attention now turns to the case studies.

[Figure 1 about here]

4 Case studies

4.1 Data and methodology

Managers of five firms contained in the database discussed in Section 3 plus of three firms from without the Benchmarking Club agreed to participate in a series of in-depth interviews with both authors. The interviewees held positions of managing director (7), CEO (1), and technical director (1). They received the questionnaire (see Appendix 1) prior to the meeting, and subsequently a written protocol for review. Due to the in part highly confidential nature of the data, anonymity was agreed. The interview explored questions derived from the theoretical discussion in Section 2. Thus it conceptualised three levels of analysis, namely the firm, the supply chain, and the national innovation system.

The firms span the entire range of possible ownership constellations (see Table 4). Four are domestically owned (two privately and two by a large holding company), one is a domestic company owned by an international investor, and three are foreign-owned subsidiaries of European MNCs. We also interviewed a joint venture that is not fully reported here to protect confidentiality but that does inform the findings. Principal customers include the aftermarket (3), assemblers (5), and 1st-tier suppliers (1) on both the local and the global market. In terms of size, the firms ranged from 100 to 800 employees and $4 to $120 million turnover. Their export-to-sales ratio in 2002 was 0-80 per cent. The product portfolio includes relatively simple parts such as u-bolts, components such as alarm devices as well as complete fuel, exhaust and air conditioning systems.

[Table 4 about here]

4.2 Findings

The discussion of the case studies follows the structure of the literature review. The focus is first on how firms learn, upgrade, and innovate. We then discuss the innovation activities of the firms in conjunction with the national innovation system. Finally, we draw out the implications of the innovation activities for the firms' strategic positioning in the global automotive supply chain.

4.2.1 Learning

Learning is present in all firms. It covers production techniques, where the source of new insights was either the respective foreign partners (D1, D2, F1, F2), independent search activities (D1, D3, F3), or both; specifications of more complex finished products through re-engineering of existing designs (D4); design (D2, F2, F4), where in one instance a foreign customer involved a local firm in finding technical solutions to their specifications (D2) and where, in another, an OEM set up a joint laboratory with a local firm (F4); and strategy (D1, D2, F1, F4), where the competitive environment or changing regulatory requirements in important markets challenged the local firms to respond to new situations. In an example of strategic alertness, D2 tried to abide by EU Regulation 34 on gas permeability even though at present only very few vehicles with D2's components are actually exported to OECD countries.

Five firms regularly send staff abroad to pick up best practices or receive on-site input from their foreign partners. The purpose of these missions can be both learning (D1, D2, F1) and upgrading (F2, F3). One (F3) supports further studies of select staff. Another (F2) absorbs the innovation activity of the parent company over the life cycle of the product to be able to re-engineer variants of the original equipment when it matures into the aftermarket. Finally, some firms purposefully monitor industry dynamics so as to build competences before market demand for new or modified products actually manifests itself.

4.2.2 Upgrading

All firms upgrade what they make (D1, D2, D3, D4, F1, F4) and how they make it

(D1, D2, D3, D4, F2, F3), or both. F1 alluded to the quality revolution that accompanied the arrival of global sourcing. In the past, reject rates below 3 per cent were tolerated and rates around 0.5 per cent considered eminently acceptable. Until a few years ago "ppm" was an unknown concept yet for the new Toyota Corolla export project F1 managed to meet the required target of no more than 50 ppm. R&D and solid engineering capabilities are behind the improvement in product profiles. Most R&D spending is targeted at new product development. In another case (D4), technical change is managed mostly through technology transfer from two licensors in Germany and Japan, respectively. For F3, the major challenge consists of translating the parent's innovations into its extended production system, ranging from material sourcing to the optimisation of its production layout.

R&D affects process improvements, too, along with a more broadly based technological and organisational facility to integrate individual parts and components into more complex products. D2 moved up the value chain by offering complete fuel systems instead of just fuel tanks. This implies accepting warranty obligations for parts and components, such as pumps or valves, that are sourced from abroad and that are thus more difficult to control. There are knock-on effects upstream and downstream in that the dynamics of the value chain pull up the quality at each tier (D2, F2). At D2 for example, rotational moulding benefited on the input side from the R&D activities of the polymer and fluorination producers whose product, because of their link with D2, assumed safety critical features. Upgrading may thus be both supplier- and customer-driven, as well as domestically and internationally linked, much as it presupposes a positive disposition for learning in the first place.

4.2.3 Innovation

Only two firms (F1, F3) categorically exclude self-driven product innovation activities. In the first case, research in acoustics control and noise reduction is so expensive and thus geographically concentrated that scope for decentralised activity does not really exist (F1). In the second, the design of OEM exhaust systems requires proximity to the vehicle assemblers which is why the foreign parent has R&D centres in both Europe and the US.

Two firms (D2 and D3) have come up with innovative processes where they employ radically new techniques, different input combinations, or specific tooling arrangements primarily to obtain cost advantages. In one case (D2) it is tougher regulatory requirements that drives the search for a new production technique. Also

on the process side, D4 and F3 substituted processes developed in house for much on the process side, D4 and F5 substituted processes developed in-house for much more capital-intensive toolings that would have been uneconomic for the much smaller production runs typical for South Africa. In one case (F3), the result was qualitatively so impressive – in terms of guaranteeing lower reject rates – that the US sister operation preferred it to the equipment used by the German parent. In acknowledgement of the local process engineering capabilities, the parent dropped the process support fee previously charged and granted complete process autonomy.

Three other firms (D1, F2, F4) have produced entirely new products for which they own the intellectual property. In one case (D1) this has taken the form of diversification sideways which aims at new markets, namely away from automotive products. In another (F2), downwards re-engineering (whereby fewer different components with wider applicability substitute a higher number of more specific components) aims at developing cost-effective components for the aftermarket, while diversification upwards tries to circumvent the strictures of follow design in marginal markets both locally and abroad. By contrast, F4 holds multiple international patents and in 1997 won the European Environmental Award for its innovations. It licenses its products to a major OEM assembler and a 1st-tier supplier.

F2 shows the limits to blue-sky developments compared to the past. The world car concept increasingly means that all capital-intensive R&D is centralised in Western Europe and North America, thus leaving little or no space for players that in terms of their innovation activities are marginal. By contrast, in the early 1990s the predecessor of the affiliate had 4-5 professional staff working on a leading materials technology it had developed. After the arrival of its new owner this was immediately discontinued in South Africa and for cost reasons moved to a more central location. Of course, the location for R&D need not remain in the home country of the MNC but to the extent that it does get relocated it is much more likely to move to another place in the Triad, as happened when the new parent set up a technology centre in the US in proximity to the Big-3.

This trend appears to be growing stronger as design and manufacturing for car makers are separated. For example, a MNC competitor is developing a system that the group to which this firm belongs will eventually make, meaning that even among 1 tier suppliers core competences are more and more narrowly defined. In a global context, the local subsidiary does not occupy a position from which it could single-handedly promote ambitious innovation activities nor offer itself to customers who would like to outsource certain development tasks. This sort of subsidiary mandate could emerge only if the affiliate were assigned centre-of-excellence status because of a fortuitous combination of low labour costs and sophisticated engineering skills. In sum, with expensive, highly centralised R&D, technical agreements are important for the local firm to keep up to date. But when R&D is centralised purely for organisational reasons, then TAs are instrumental only to guarantee follow-source contracts. Over time, the latter may be subject to change.

Ownership and market focus may have a bearing on how easily firms can exploit technological opportunities. Independent firms on the whole have obviously fewer resources than multinational groups. But they do not face the trade-off between access to resources and R&D concentration that characterises MNCs. For example, D2 engages in expensive innovation activities that it would not likely be allowed to undertake if it were a subsidiary in a larger group.

The example of F2 and F4 also shows that the aftermarket and the local OEM market are more permissive in terms of accepting solutions that deviate from the norm. But although F2 as a member of a group is kept on a much shorter leash than F4, they share a commitment to retaining technical competence, along with the ability to design and test solutions that in essence can be either minor adaptations of existing solutions or more radical departures from existing products or processes. Either way, this involves innovation, thus requiring staff (or at least to have access to service providers) who can design, test, create the necessary tooling , and so on.

These findings, albeit not representative, suggest some insights into the relationship between production capacity and technological capability on the one hand, and innovation activity on the other. The going wisdom in technology accumulation, namely the principles of a certain hierarchy of competences and linearity implied in the idea of a progression from process to product innovation, does shed light on select trajectories but is only part of the whole story. For example, prodded on by its parent, F2 has made significant improvements in stock control. Although inventory management is not a sufficient condition for innovation, it is necessary – firms that do not possess a world-class manufacturing competence are unlikely to get involved in successful innovation. This is because the knowledge accumulation associated with the former provides the ground for building technological capability. The gains for F2 from the relationship with the parent company imply that, in the absence of the foreign direct investment, F2 would have been relegated to the niche aftermarket.

But the problem with generalising this view is that it simply reverses the hierarchy of simpler and more complex competencies and the linearity of assimilation compared to innovation that emanates in top-down fashion from R&D proper. The cases show that exposure to the exacting requirements of lean production need have no bearing on the scope for R&D and design. For some components, R&D is geographically so concentrated that opportunities and incentives for technological learning are objectively limited so that lab activity bypasses all but the leading units or manufacturers and hence not just those in emerging markets. Industry or (sub-)sector characteristics therefore matter. Perhaps more importantly, sometimes technological capability informs production capacity rather than the other way round (e.g. D1, D2). And there is also learning-without-doing (D2). Hence the other part of the story is less intuitive. What seems clear is that when a firm's knowledge system is superior to its production system, the real bottleneck to bringing innovative ideas on stream lies on the shopfloor and not in the absence of cutting edge activities *per se*, nor for that matter in the logic of the supply chain as such.

4.2.4 Path dependency and the national innovation system

Import-substituting industrialisation and, later, sanctions turned South African manufacturing into a jack-of-all-trades. The former meant that there was a premium on local content. The latter necessitated designing technical solutions even when they were available on the open market simply because South Africa under apartheid was not an accepted customer. The principal challenge for innovation was to realise low volumes at acceptable cost. Drawbacks of this system included, as elsewhere,

inefficiency and substandard quality except in areas deemed essential to the regime's survival.

What happened subsequent to the liberalisation of the economy was that increased competition disciplined manufacturers to reduce their product portfolio. The new focus on core competence, in connection with cheap, high-skilled labour and the knack of engineers for "making do", meant that niche opportunities in global automotive supply became within reach. For example, through rearranging toolings produced in-house and through decreasing capital-labour ratios, local firms were able profitably to organise production runs of 60,000 units for phase-out vehicle models that producers in high-cost countries could only make at volumes of at least 300,000 units. At the extreme, F4 occasionally produces a dozen catalytic converters to order. Hence compared to the past, where in the absence of effective competition firms could get away with the inefficiencies that resulted from doing too many things themselves, including in-house tooling, tooling now deepens the firms' focus and no longer contributes to horizontal efficiency losses. It helps local firms to compensate for perhaps less-than-optimal production runs by designing alternative solutions at low engineering costs. This is a positive example of path dependency

A negative example is the uncertain future of human capital in engineering. It appears in short that competences embedded in South Africa's old military industry have more successfully adapted to global market demands than the country's new education system. In the past, engineering competence was created for and absorbed by the military sector from where it fertilised other manufacturing sectors. A substantial part of R&D personnel and also many production engineers in the case firms had a military background. Most were middle-aged or older. With the retrenchment of the military complex, it is important that the tertiary education system produce technical specialists and engineering graduates to fill the thinning ranks of