A TECHNOLOGY GAP ANALYSIS OF LEADING FIRMS IN CAPE TOWN•

Background paper for the study on Cape Town's future competitiveness and the global knowledge economy

2nd DRAFT: 15 October 2010

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• We are grateful to the many individuals from the private sector, industry associations, research institutes as well as universities who agreed to be interviewed for this study and helped us with useful information, to Simon Bittmann for research assistance, and to Gordon Pirie and Shirley Robinson for helpful suggestions on an earlier version. The usual disclaimer applies.

Executive summary

1 Developing countries must narrow the technology gap with more advanced countries in order to catch up and achieve long-run growth. Since lead technologies and even industries change over time, catch-up is a dynamic process without a fixed target. This means that technology gaps cannot simply be bridged by substituting a new for an old technology.

2 In general, what matters for growth in developing countries is not so much radical innovations but incremental innovations. What also matters is the efficiency with which developing country firms imitate because successful imitation in lagging countries tends to erode technological differences, much like innovation in leading countries exacerbates them. When latecomer countries advance technologically and narrow the technology gap, imitation tends to lose relevance relative to innovation because closer to the frontier imitation becomes less and less possible – not only getting to but also being at the frontier is tough.

3 On average, technological gaps in the world have narrowed but this hides very significant inter-country differences. Catch-up competition has become much more intense; some countries and regions are rather successful whereas others are not. In fact, in the developing world as a whole, penetration rates of both new and old technologies remain rather low. But upper-middle-income countries do better than the rest; the expectation is therefore that Cape Town should also do relatively well.

4 Absorptive capacity has not improved as quickly as technology exposure, especially as far as business climate and governance indicators are concerned. This explains why countries at similar income levels have different levels of technological achievement. As a group, there are indications that the level of technological sophistication of middle-income countries will continue to converge to that of advanced economies.

5 This paper focuses on technology gaps between leading firms in Cape Town and the global frontier. In each sector we establish frontier technologies through a review of the literature, as well as examples of global firms that make use of them. Although knowledge evidently exists "behind the frontier", the increasing importance of innovation for competitiveness underlines the importance of local knowledge being linked to knowledge at the frontier. This is why this paper is not an assessment of the average technological competence of any sector. Although average capabilities are important in this context as well, without advanced capabilities of at least some players, global competitiveness is likely to remain an elusive goal.

6 Selected **agro-processing activities** in the Western Cape operate close to the global technological frontier. Indirect evidence to this effect consists of export performance, comparative industry evaluations of technical efficiency, the competitiveness of user firms, and the existence of global clients. The diffusion and development of these technologies depends on a highly organized private sector supported by active industry associations, as well as linkages between scientists in local universities and research councils, industry associations, and individual firms,

and is conditioned by local and international regulatory systems. These linkages make for a regional agro innovation system in the Western Cape.

7 In **oil and gas**, the subsidiary of Schlumberger based in Cape Town has access to all technologies in the group. In principle it therefore operates at the global frontier. Other oil and gas firms similarly benefit from technology transfer from their parents. One firm in particular claimed to have designed world-class valve technology. But this does not apply to the entire sector. Substantial gaps exist, for example, in the market for subsea technologies.

8 Frontier **construction** technologies are not household technologies in South Africa or Cape Town. This is mostly because the regulatory environment does not as yet provide incentives for green building design, and there is no or little demand for other advanced construction technologies. A few South African firms, including some based in Cape Town, have made use of such technologies in overseas projects. Hence they aware of activities at the frontier and some are able to use them as well. But until users demand innovation away from traditional techniques and the regulatory environment changes accordingly (or vice versa), construction firms in Cape Town are likely to continue to operate at a considerable distance from the frontier.

9 In the **film industry**, although Cape Town has render farms (i.e. computer clusters built to render computer-generated imagery), they are internal to film companies and not stand-alone entities. Specialised render farms in world film centres that are technology leaders have much larger and more powerful facilities. Firms in Cape Town are therefore behind the frontier in terms of the scale of computing power employed which constrains what is technologically feasible. In post-production software, local firms similarly operate at a much smaller scale. Perhaps more importantly, although they master the use of the relevant software, they do not (yet) have the capability to customize it. Hence, they are behind the frontier.

10 South African **retailers** do not use all the available frontier technologies in inventory management, distribution, and e- or m-commerce. The use of selected technologies is not as extensive as practiced by global leaders in the US and Europe. South African retailers are therefore behind the frontier.

11 Key frontier technologies are available to **BPO firms** in Cape Town and there are examples of contact centres within Cape Town adopting them. Technology gaps do however exist, especially in home-based agent strategies. The high cost and poor speed of bandwidth in Cape Town is a hindrance to adopting home based agent strategies. Data collection, metrics and data analysis face similar problems.

12 The global **financial services sector** has undergone rapid technological changes in recent years. The advent of cloud computing (i.e. outsourced IT services over external networks) is one example. A few firms in Cape Town have been quick to take advantage of the technology and are operating at the technology frontier. In addition skills in Cape Town have been used by one of the leading providers of cloud computing to pioneer new products for a multinational firm. Mobile banking is another technology that is expected to grow in popularity. Local banks have

developed mobile banking services for customers. However, many of their services are not as comprehensive as those offered by Safaricom and Zain in Kenya or by Citibank in the Philippines and India. There are also services that are not available at all, such as mobile phone credit card payments, although they exist elsewhere. These are large and important technology gaps, especially for banks considering further expansion into developing countries. Technology gaps in anti-fraud measures are smaller, with examples of banks in Cape Town using frontier technologies such as multi-factor authentication.

13 In **business tourism**, in the technological package that distinguishes convention centres, bandwidth is CTICC's weakness. But otherwise there is no indication of a technological gap between the leading convention centres and CTICC. The systems and software requirements that are needed to host a successful event exist in Cape Town. This is reflected in rising market share.

14 Frontier technologies exist in Cape Town and both local and foreign firms use them. This means that some firms in their respective sectors use close-to-frontier technologies, not that the entire sector does. Conversely, no sector emerged in which frontier technologies were completely absent.

15 Since technological learning and upgrading is a dynamic process, what matters is whether firms are aware of activities at the frontier and are in a position to select those which are necessary for their competitiveness, and absorb and utilize them. Lead local firms are indeed aware of frontier technologies, regardless of whether or not they make use of them.

16 There are important differences across lead firms in the various sectors in terms of how they access technology, whether and how much they make use of it, and whether they contribute to developing it. Also, some technological gaps or achievements are specific to the Western Cape and Cape Town, while others describe the entire industry.

17 Key challenges for a narrowing of the technology gap also differ and include technology transfer, firm capabilities, learning, investment in innovation and R&D, insufficient infrastructure, and the regulatory environment.

1 Introduction

The concern with technology gaps dates back at least half a century. After World War II, levels of US productivity exceeded those reached in Europe. Productivity increases were seen as the key to unlock Europe's economic recovery. Productivity differences were due to a host of managerial and social factors, but prominently also to technological advances pioneered by US firms. It was in this context that science and technology started getting more systematic attention in policy circles and that the "productivity gap" became the "technology gap" (Godin 2002). In the early 1960s, the OECD started undertaking international R&D surveys in order to examine R&D efforts in its member countries and to benchmark them against each other and against the US. These surveys produced the kind of cross-country data that made it possible to discuss the existence and size of alleged technology gaps among the developed countries. Thus, in 1968 the OECD produced *Gaps in Technology* which among other things argued that the more innovative behaviour and performance of US firms accounted for the difference with firms in Europe. The debate about gaps also led to the creation of statistical series such as *Science and Technology Indicators* that exist to this day and are used to rank or benchmark countries (Godin 2002).

Technological differences evidently did not just characterize the advanced industrial economies but even more so rich and poor countries. The idea of catch-up is premised on narrowing the technology gap by less developed countries in their pursuit of long-run growth. Since lead technologies and even industries change over time, catch-up is a dynamic process without a fixed target. This means that technology gaps cannot simply be bridged by substituting an old with a new technology. Instead, firms and more aggregate entities like cities or countries engaged in catch-up must continuously transform their technological and other relevant structures (Fagerberg and Verspagen 2002). When successful, this leads to convergence in economic growth and, thus, income levels. But it need not, and history has examples of periods both of convergence and divergence.

In general, what matters for growth in developing countries is not so much radical innovations but incremental innovations. The latter include the diffusion of radical innovations throughout the economy. In plain language, a developing country is unlikely to produce a radical innovation such as a microchip but what it can do is exploit the efficiency-generating effects of information technology as widely as possible. What also matters is the efficiency with which developing country firms imitate because successful imitation at home tends to erode technological differences, much like innovation elsewhere exacerbates them (Fagerberg and Verspagen 2002). When latecomer countries advance technologically and narrow the technology gap, imitation tends to lose relevance relative to innovation. As explained in more depth in the accompanying literature review (Lorentzen 2010), imitation and diffusion must not be misunderstood as something that is somehow "easy"; in fact, with accelerated technological change, the diffusion of technology tends to become more demanding.

Although the discussion of technology gaps is of a certain vintage, it is of no less relevance today. Levels of total factor productivity (TFP) -- output changes not due to increases in inputs -- still vary widely in the global economy. For example, in 2005 Sub-Saharan Africa's TFP was under six per cent of that in the US, and in the previous 15 years it only grew by 0.2 per cent annually (Burns 2009, Table 8.1). But on the whole the developing world has become much more exposed to foreign technologies, with imported capital and intermediate

goods playing a much bigger role than they used to before the 1990s. Likewise, imports and exports of high-technology goods have also grown. In fact, longitudinal data shows that currently technology tends to diffuse much faster than it used to (Comin and Hobijn 2004).

On average, technology gaps have narrowed but this hides very significant inter-country differences. While the narrowing of the gap is in many ways good news for developing countries, it also suggests that catch-up competition has become much more intense. In fact, in the developing world as a whole, penetration rates of both new and old technologies remain rather low. Upper-middle-income countries do better than the rest which is why one can expect that Cape Town should be doing better as well. Also, while penetration rates tend to be high for lead firms in lead cities, the same is not necessarily true for areas outside of urban agglomerations which is likely to exacerbate inequality. There are also differences across sectors, depending on the character of knowledge relevant for technological advance. In Korea, TFP catch-up with Japanese firms was faster in sectors where technologies were more explicit and embodied in capital equipment imported from abroad. This explains why the Korean electronics industry is world-class, while its car industry where tacit knowledge plays a bigger role is still somewhat behind the frontier. Monopolistic markets with exposure to global competition and short technology cycle times also helped (Jung and Lee 2010).

Absorptive capacity has not improved as quickly as technology exposure, especially as far as business climate and governance indicators are concerned (Burns 2009; for a discussion in the OECD context, see Kneller 2005). This explains why countries at similar income levels have different levels of technological achievement. As a group, there are indications that the level of technological sophistication of middle-income countries will continue to converge to that of advanced economies. According to a report by the Rand Corporation (Silverglitt et al 2007), factors likely to hold back this process include inadequate infrastructure, insufficient technical literacy, and a lack of high-quality human capital (see Box 1).

Although technology gaps are not only determined by the activities of firms but are dependent on several factors, firm capabilities are central to reducing these gaps. It is therefore unfortunate that the academic literature offers relatively little insight on how firms in advanced developing countries approach the frontier (Dutrénit 2004), perhaps because until not so long ago such firms were the exception rather than the rule and their existence was limited to a dozen or so countries. International business scholars tended to focus on firms at the frontier – how they renew core competences they already possess through effective knowledge management – without paying much attention to how they ever got there in the first place. By contrast, academics interested in the capabilities of developing country firms concentrated on the cumulative creation of minimum essential knowledge bases, for example allowing for the meeting of world quality standards and the like, without considering how such embryonic strategic capabilities could evolve to fully fledged capabilities through which firms might approach frontier activities.

What happens in between these two perspectives is that firms that have successfully built up their capabilities make use of increasingly diverse and complex knowledge bases. In this transition phase, firms develop incipient core competencies that help them to create distinctive competitive advantage. They face technological and organizational problems that are different from the two categories of firms described above. In short, their knowledge base is more uneven across domains and units; they are probably constrained by

underdeveloped networks between firms and other relevant actors; as well as markets, incentives, and institutions that may not be conducive to learning (Dutrénit 2004).

The innovation activities in this transition phase are unlikely to be primarily, let alone exclusively, based on R&D. Firms can also innovate through investments in new capital equipment, process improvements to increase productivity, and the re-combination of existing knowledge. In fact, especially small firms without highly educated staff and little export exposure are more likely to innovate *not* doing R&D. Schumpeter's (1950) insight on the role of large firms in technological progress by and large tends to apply today as well (Huang, Arundel, and Hollanders 2010). Likewise, process innovation tends to involve R&D less than product innovation. Also, technological opportunities differ from sector to sector – and possibly within sectors that are characterized by diverse markets – and depending on what they consist of, firms are likely to use different ways to exploit them. By implication, patents may be a misleading indicator of the innovative prowess of firms, simply because not all technological progress is R&D-intensive or science-based. This is particularly relevant for developing countries, but not only – innovation survey results in Europe show that half of firms engaged in product or process innovation do not undertake R&D in-house (Huang, Arundel, and Hollanders 2010).

Section 2 explains the methodology employed in this paper. Section 3 discusses technology gaps in Cape Town's most important economic activities, and provides an overview table for each technology discussed, covering function, drivers, and examples of lead global and local firms. Section 4 discusses the meaning of the findings for Cape Town's future competitiveness in the global knowledge economy.

2 Methodology

Technological achievements or gaps can be measured in different ways, mostly indirectly, none of which is perfect. The most common way to measure technological progress is by looking at the change in TFP. This can estimate the impact of technology on growth but it pretty much treats technology as a black box in the sense that it ignores some of the most interesting questions such as the nature of the technology employed or the way it was absorbed. However, a recent extension paid attention to sectoral variables such as whether the relevant knowledge was explicit or tacit and the degree to which technology was embodied in capital goods (Jung and Lee 2010). The technology gap model (Fagerberg 1988) explains growth as a function of innovation (measured through the growth of patents), the potential for diffusion (proxied by the level of productivity), and a number of complementary factors that describe absorptive capacity.

Box 1 -- Technology in 2020

A recent report by the Rand Corporation (Silberglitt *et al.,* 2007) examines some 56 emerging technologies expected to be real products by 2020 and evaluates in detail the 16 judged to be most important on the basis of technical feasibility, marketability and societal impact. These applications include, among others, improvements in health services (targeted drug delivery, improved diagnostic and surgical methods), in access to information (rural wireless communications, quantum cryptography), and in the environmental sustainability of products and services (improved water purification, green manufacturing and hybrid vehicles). It then examines in detail the technical base required by a country to make effective use of each technology and the likelihood that each of 80 representative economies, including high-income and developing countries from every region in the world, will be able to exploit these technologies by 2020.

	Technology application	Most of Africa, Middle East, Oceania	Latin America, South Africa, Turkey, Indonesia	China, India, Russia, Eastern Europe	Industrial countries
	Technologies likely to be mastered by 2020 (x)				
Requires increased technological sophistication	Cheap solar energy	**x**	**x**	**x**	**x**
	Rural wireless communication	**x**	**x**	**x**	**x**
	Genetically modified crops	**x**	**x**	**x**	**x**
	Filters and Catalysts	**x**	**x**	**x**	**x**
	Cheap autonomous housing	**x**	**x**	**x**	**x**
	Rapid bioassays		**x**	**x**	**x**
	Green manufacturing		**x**	**x**	**x**
	Ubiquitous RFID tagging		**x**	**x**	**x**
	Hybrid vehicles		**x**	**x**	**x**
	Targeted drug delivery			**x**	**x**
	Improved diagnostic and surgical methods			**x**	**x**
	Quantum cryptography			**x**	**x**
	Ubiquitous information access				**x**
	Tissue engineering				**x**
	Pervasive sensors				**x**
	Wearable computers				**x**

Source: Silberglitt *et al.* (2007).

While many countries are expected to be able to take advantage of some of the simpler-to-use technologies, a wide range of countries are not expected to be able to do so, because they lack the required technological infrastructure, because their population is not sufficiently technically literate, or because a critical mass of scientists and engineers is not present to exploit the technology (see table). The report finds that most high-income countries will be able to adopt and exploit all of the technologies effectively. A second group of countries – China, India, Russia and the countries of Eastern Europe – has a considerable level of scientific and technological proficiency in specific applications, but barriers to technology adaptation are likely to limit their ability to take advantage of the most sophisticated network applications. A third group of middle-income countries – several Latin American countries, South Africa, Turkey and Indonesia – lack more prerequisites and are thus expected to exploit fewer of these technologies. A final group, comprising most of the world's poorest countries – most of the countries of Africa, the Middle East, and Oceania – are projected to make use of only the simplest of the new technologies. This analysis provides a useful snapshot of the prospects for technological progress based on current data. However, it does not incorporate the potential for dynamic improvements in technological progress (for example, through the rapid dissemination of existing new technologies), which could rapidly improve developing countries' ability to absorb new technologies.

Source: Burns (2009, Box 8.4)

Historical case studies of individual firms or industries have produced rich accounts of the change in the level of technological differences over time. Examples include Kim's (1997) work on a variety of Korean industries, Chang's (2008) account of Samsung's catch-up with Sony, or Figueiredo's (2001) study of steel mills in Brazil. Lorentzen (2005) analysed technology gaps through case studies of firms in the South African automotive supply industry.

Composite indices capturing technological differences include UNCTAD's Index of Innovation Capability (which is a mixture of R&D investment and high-level human capital), UNDP's Technology Achievement Index (which includes information on diffusion such as internet connectivity), and UNIDO's Index of Competitive Industrial Performance (which looks at the relative importance of high-tech activities in manufacturing(UNDP 2001, UNCTAD 2005, UNIDO 2009).

This paper focuses on technology gaps between leading firms in Cape Town and the global frontier. It does not assess the consequences of technology gaps in terms of differential growth rates between Cape Town and other cities, but attempts to establish the size of the gap plus an explanation of its causes. It covers the same sectors as the other background papers to this study (Harrison and Boulle 2010, Lorentzen et al 2010, Turok 2010) with the exception of higher education. In each sector we establish frontier technologies through a review of the literature, as well as examples of global firms that make use of them. Based on fieldwork we then describe whether or not lead local firms use such technologies or not, and why. This gives rise to a matrix which relates local to global technological achievement and examines the reasons for the gap, if any, between the two.

In explaining the gap, the paper looks specifically at firm capabilities and the role of demand and of created assets. These are key determinants – by definition, weak capabilities, the absence of demand for new technologies, and inexistent or underdeveloped created assets make it impossible to reduce technology gaps. These factors are related: a firm with high capabilities which faces demand for its products might be hampered by weak created assets, much like an ideal business environment does little good if firm capabilities are weak.

In so far the paper focuses on lead firms, it has a bias in favour of activities closer to the frontier. This is intended. Firms in Cape Town can in principle be globally competitive at a distance to the frontier, provided the gap does not increase over time.[1] But this study is mandated to assess the city's future competitiveness in the global *knowledge* economy. Although knowledge evidently exists "behind the frontier", the increasing importance of innovation for competitiveness underlines the importance of local knowledge being linked to knowledge at the frontier. This is why this paper is not an assessment of the average technological competence of any sector. Average capabilities are important in this context as well, but without advanced capabilities of at least some players, global competitiveness is likely to remain an elusive goal.

The paper necessarily focuses on selected technologies in each sector, rather than on all technologies used. The choice of technology was primarily determined by what industry insiders and the relevant literature considered a key technology for future competitiveness, likely to have a lasting impact on firm strategy and performance.

[1] In theory, firms could be globally competitive even with rising technological gaps. But this would take the form of the infamous race to the bottom, or immiserising growth, which in practice is not an option.

3 Technology gaps in individual sectors

3.1 Agro-processing

This section focuses on post-harvest technologies in deciduous fruit and on a novel UV purification system. For an overview, see Table 2.

3.1.1 Post-harvest technologies in deciduous fruit

Although fruit is a relatively low-technology product, the fruit value chain is technologically very sophisticated. From the design of new cultivars to cold chain and packaging techniques, fruit production is a highly knowledge-intensive activity. Technological advances have aimed at the reduction of delivery time, the maintenance of product quality, and the cutting of shipping costs. To this end, shippers use satellite systems to track cargo and (remote) electronic systems to monitor quality (Economic Research Service/USDA 2005). Especially fruit destined for exports must be handled so as to arrive at destination in premium condition. The market for fruit is global and highly competitive.

Modern fruit inspection and monitoring systems, along with handling, cooling, and storage techniques have been around in the Western Cape since the late 1950s, the main production area for deciduous fruit in South Africa. Cold stores have been in existence in fruit production areas since the 1960s. From the 1990s, the industry had a dedicated research arm (Unifruco Research Services (Pty) Ltd), funded by an industry-wide levy, which after deregulation morphed into Deciduous Fruit Producers' Trust (DFPT) Research. DFPT Research funds research at universities, science councils, and other centres. The monitoring of compliance with quality standards is undertaken through the Fresh Produce Exporters Forum. The Perishable Products Export Control Board (PPECB) inspects and certifies fruit for export to be in compliance with international quality standards on behalf of the Department of Agriculture (Deciduous Fruit Producers' Trust 2005).

Most deciduous fruit has an optimum handling temperature of -0.5^0 C. Cold chain management aims to ensure that fruit is handled, transported, and marketed so that it reaches the final customer in top quality condition. Regulations are in place to ensure that fruit destined for export has been through an unbroken cold chain. Upstream from the cold chain, techniques known as maturity indexing see to it that fruit is harvested at the optimum stage. This varies among cultivars, among other things depending on whether the fruit continues to ripen after picking or not. After harvesting, deciduous fruit must be pre-cooled within a few hours (grapes) or up to two days (apples and pears) and kept in well ventilated, high-humidity storage. Temperature, high ethylene concentrations, and low humidity accelerate the ripening process and must be avoided in so far as this has a direct impact on the shelf life of fruit.

Table 2 – Core technologies in Agro Processing

Technology	Function	Driver	Lead global firms	Lead local firms
		Post-harvest technologies		
Controlled Atmosphere (CA)	CA is a process to increase the storage life of perishables. It maintains the quality of post harvest perishables better than any other known methods and is used in pack houses as well as during shipment.	Out of season demand for high-quality fresh fruit by customers in overseas markets.	Dole Chile and Chiquita, the largest exporters of fruit in the Southern Hemisphere.	Many pack houses, Capespan, many other fruit exporters
Packaging	To protect the fruit from mechanical damage and to maintain fruit quality while allowing sufficient ventilation for proper cooling and temperature maintenance.	As above, plus more recently the need to reduce carbon footprint through compostable or re-usable packaging.	Dole, Chiquita	ExperiCo, a division of Capespan
SmartFresh™	To protect against the effects of naturally produced ethylene which speeds up the ripening of fruit.	Extension of shelf life.	AgroFresh, a subsidiary of Dow Chemicals	Experico. a division of Capespan
		UV purification		
Surepure Ultra Violet Purification System	An internationally patented cold-purification system that kills harmful micro-organisms in liquids by damaging their DNA and disabling their growth with no residual effect.	Decrease in energy consumption relative to heat pasteurization, increase of shelf life for milk, and health benefits from sulfur reduction in wine production.	McCain Foods, Wal-Mart	Lombardi Foods, SteenbergVineyards, L'Ormarins, Alluvia, and Stellar Organics, SAB Miller

Source: Food and Beverage (2009), Dodd et al. (2008), Regmi and Gelhar (2005), Thompson (2009).

The storage life of apples and pears can be extended through a technique known as controlled atmosphere (CA). CA storage reduces oxygen and increases carbon dioxide and nitrogen levels which can double storage life up to ten months. CA storage has been used in South Africa since the late 1970s. Prior to deregulation, the relevant industry body -- the South African Apple and Pear Producers' Association -- was responsible for CA quality assurance and to this effect issued a CA label to compliant members. Since the late 1990s the Agricultural Research Council and consultants conduct inspections of CA stores upon request (Deciduous Fruit Producers' Trust 2005). The world's largest producer, exporter, and marketer of fresh fruit and vegetables, Dole, uses CA extensively for exports from the Southern hemisphere to North America and Europe. Firms based in the Western Cape that use CA include Capespan and TransFresh Africa (Pty) Ltd.

CA can be administered as a static or a flow-through system. Closed (static) systems re-circulate gases from the storage chamber and are the most common system used commercially. It is prevalent in South African pack houses. Open (flow through) systems do not re-circulate the gases, but have a continual supply of gases of the required composition flowing through the storage chamber (Smith et al 1997).

It is not possible to measure the technology gap between deciduous fruit exporters from the Western Cape and their competitors directly. This is because too many factors impact on the quality of the fruit when it arrives at its destination. Physiological or microbiological post-harvest disorders can affect the quality of the fruit. Even if such disorders originate in the orchard, they may only present in the cold store or during post-storage ripening. The cold storage regime itself can also initiate disorders. With fruit that successfully passes all inspections before being shipped out and then again at its destination port, things can go wrong in the period before it reaches retail shelves, that is when it is no longer in the possession and under the control of the exporter. To mitigate this, the Fresh Produce Exporters Forum has integrated temperature and humidity measuring devices into pallets. Rejected consignments, in sum, can have many causes that would have to be determined on a case-by-case basis in order to detect where in the value chain problems appeared, and whether technological differences played any role.

In the absence of unambiguous indicators, circumstantial evidence must be used to assess the technology gap. South Africa is the third largest deciduous fruit producer in the Southern hemisphere, after Argentina and Chile. In 2008, it was the eighth largest exporter, amounting to six per cent of the top-ten apple and seven percent of the top-ten pear exporters (FAO 2009). The volume of deciduous fruit production more than tripled between 2003 and 2008 to reach some 95m cartons. Industry insiders credit technological improvements in post-harvest handling, such as CA, for this performance (Dodd et al 2008). However, the efficiency of cold storage facilities in South Africa lies behind that found in Chile and New Zealand. The industry in New Zealand performs well in education and IT deployment. Chile, with weak human capital, enjoys modern cold storage facilities. But in an evaluation of their relative competitiveness, South Africa was given maximum points on the use of controlled atmosphere (South African Fresh Fruit Exports 2009). Hence, deciduous fruit producers based in the Western Cape are close to the technological frontier in post-harvest technology.

Further, in a comparison of production efficiency as well as infrastructure and inputs in 29 major apple producing countries, the World Apple Review (2009) ranked South Africa -- and, thus, primarily the Western Cape -- ninth worldwide. Overall, the country came in fourteenth place, due to a weak ranking of financial and market -- and hence non-

technological -- factors. Similarly, the World Pear Review (2009) ranked South Africa second worldwide for production efficiency, eighth in terms of infrastructure and inputs, and twelfth overall, again due a weak performance in financial and market factors.

A benchmarking study covering South Africa, Chile, and New Zealand found that South Africa's fresh fruit export logistics did not compare favourably. Technology-relevant weaknesses included the use of technology in transport systems and the structuring of information technology. South Africa is behind its competitors in the electronic processing of all documentation. Also, all aspects of packaging need modernization (Post-Harvest Innovation Programme II n.d., 79-80).

In addition, the industry has considerable knowledge creation potential. AgroFresh, a division of US based Dow Chemicals, recently developed a technology called SmartFresh. SmartFresh is an ethylene management system that slows down the ripening process and can be used in conjunction with CA or on its own. Experico, a research firm owned by Capespan based in Stellenbosch, collaborated on research with AgroFresh and was contracted to do the commercial applications of the technology. It also conducted registration trials for certain fruit kinds, giving local growers an opportunity to use the technology.

Experico is also involved in research on packaging. Packaging is key to the maintenance of quality. For example, insufficient ventilation to fruit increases the cooling cycles and energy consumption. An important consideration for improving packaging concerns the effects of packaging on the environment. Experico researches packaging material that can be recycled, reduced, and reused. For example, preliminary studies indicate opportunities to replace the current packaging bags for more environmentally friendly biodegradable bags.

Experico's research is part of a larger post-harvest innovation programme, steered by the Fresh Produce Exporters' Forum in conjunction with the Department of Agriculture, Forestry and Fisheries (DAFF) and the Agricultural Research Council (ARC), funded by the Department of Science and Technology. In the first three years of its existence, the programme funded projects in the areas of integrated packaging solutions, container technology, temperature and humidity control of products, irradiation technology, non-destructive fruit quality assessment techniques, the development of an information hub, post-harvest physiology, pre-harvest disposition of post-harvest disorders, post-harvest disease control, food safety, technology transfer, mitigation technology for sanitary and phytosanitary compliance, entomology, and carbon footprint (Post-Harvest Innovation Programme n.d., Post-Harvest Innovation Programme II n.d.).

The post-harvest innovation programme is an attempt to design novel solutions to practical problems the industry is facing and that are affecting its future competitiveness. This is a knowledge-intensive process. In 2008/09, DFPT Research had 98 ongoing research projects, funded ten researchers at Stellenbosch University and three at its codling moth SIR facility, plus 48 postgraduate students. It also supported the local integration into global knowledge flows by funding the attendance of local researchers at international conferences, and the of international experts to South Africa (Hortgro 2009).

3.1.2 Ultra-violet (UV) purification

UV radiation has been used for some 80 years to inactivate bacteria and viruses, including in clear liquids such as water. In the food industry, UV radiation has a number of advantages over other preservation methods such as heat-based pasteurization. It can kill microorganisms that are not susceptible to heat treatment. Because it is non-thermic, it does not negatively affect food whose properties are sensitive to heat. Finally, it uses much less energy than heat treatment. In principle, UV treatment can therefore improve food quality and safety, while reducing the carbon footprint of producers, for example in the dairy and fruit juice industries. Regulatory bodies such as the US Food and Drug Administration have given market approval to use UV radiation for the treatment of water and food under certain conditions (Reinemann et al 2006).

However, the practical application of this technology faces a number of challenges. In the dairy industry, for example, the solids present in milk limit the penetration of UV radiation, thereby limiting its efficacy. Also, inappropriate exposure to UV can cause oxidization and sensory defects in the product (Reinemann et al 2006).

Surepure, a company based in Cape Town and recently incorporated in Switzerland, has developed a UV purification system that addresses these shortcomings. Its system increases the penetration of UV throughout the liquid being treated and thus ensures a maximum coverage of individual microorganisms. The mechanism of the system is that it guides the liquid to be treated in a turbulent flow past a germicidal UV lamp housed in a quartz sleeve.

A number of universities both in the Western Cape and the US tested the technology. In dairy, the results showed a high efficacy of bacteria reduction with no noticeable effect on the taste of milk, except when UV was applied excessively. The researchers concluded that Surepure's technology could be used for the cold treatment of raw milk, reduction of bacteria not susceptible to heat treatment, psychotrophic reduction in milk refrigerated for prolonged periods of time, and in parts of the world where unreliable or costly energy supply make on-farm refrigeration unviable (Reinemann et al 2006). The Innovation Center for US Dairy (2009) confirmed the relevance of UV in reducing the carbon footprint of the industry by launching a series of laboratory trials aimed at demonstrating the feasibility of substituting UV for heat pasteurization in the near future and for ultra-high-temperature (UHT) processing in the longer term, and at securing regulatory approval.

The technology has also shown good results in the treatment of fruit juices against bacteria, viruses, yeasts, and moulds, where in comparison to heat treatment it did not alter taste or colour profiles. It was recommended as a substitute for thermal treatment or antimicrobial compounds, giving consumers a preservative-free but safe product. The researchers also commented on the low energy intensity and low maintenance costs of the technology (Keyser et al 2007).

Related research (Davaux n.d., Fredericks et al n.d. a,b) suggests that the new UV technology can be used to reduce the sulfur dioxide content of wine. Its effectiveness depends on both the turbidity and the colour intensity of the wine, which means that the treatment must still be optimized. In addition, the sensory impact of the treatment is still to be evaluated comprehensively. Likewise, although hops in known to react to UV radiation by developing an "off-flavour", preliminary research shows that this effect can be contained which suggests

that the technology could possibly be applied in the brewing of less light-sensitive beers (Mezui n.d.)

The feasibility of a technology is not synonymous with its demand. The fact that Surepure holds a worldwide patent on its technology does not demonstrate in and of itself that the new system is a frontier technology -- if nobody is interested in it, the technology will not have an impact and be relevant for technological upgrading. But Surepure is working with a number of global and local customers that either operate the technology already or are experimenting with it. Examples includes US retail group Wal-Mart which wants to increase the shelf life of its milk and reduce the frequency of delivery to retail outlets in order to cut costs. The local subsidiary of Canadian multinational McCain Foods, one of the largest producers of potato chips, uses the technology to disinfect starch-laden water used for rinsing potatoes.

A leading South African fruit juice producer based in the Western Cape, Lombardi, has been using Surepure's technology since 2007. Lombardi's main customer is Woolworth who market UV-treated juices as a greener product, due to their much lower use of energy compared to heat-treated juices. The South African operation of SAB is also experimenting with the technology. Prestigious estates such as L'Ormarins, based in Franschhoek, in 2008 produced a small batch of Chardonnay whose sulfur content was merely 20 parts per million, some six to seven times below the industry average (No mess, no fuss 2009).

In sum, this innovation is based on a process patented by a local firm that taps into research both locally and internationally to test its system, develop it further, and prepare it for regulatory approval, mainly in the dairy industry. The firm interacts intensely with the Food Microbiology Research Group at the Department of Biotechnology of the University of the Western Cape, Department of Biochemistry and Institute for Wine Biotechnology, Department of Viticulture and Oenology, both at Stellenbosch University, Elsenburg Dairy Research Facility at the Agricultural Research Council, and Department of Food Technology, Cape Peninsula University of Technology as well as Birmingham University, California Polytechnic State University, and Milking Research and Instruction Lab, Center for Dairy Research, University of Wisconsin.

The assessment has shown that there is global interest in UV technology and that Surepure's systems are among the first to being used in practice. By definition, this implies that there is no technology gap between the relevant knowledge system in the Western Cape and its international counterparts.

3.1.3 Summary

This section showed on the basis of two technologies -- one proven and widely established, another emerging -- that selected agro-processing activities in the Western Cape operate close to the global technological frontier. Indirect evidence to this effect consists of export performance, comparative industry evaluations of technical efficiency, the competitiveness of user firms, and the existence of global clients. The diffusion and development of these technologies depends on a highly organized private sector supported by active industry associations, as well as linkages between scientists in local universities and research councils, industry associations, and individual firms, and is conditioned by local and international regulatory systems. These linkages make for a regional agro innovation system in the Western Cape.

3.2 Oil and gas

3.2.1 4D seismic reservoir monitoring

When drilling in challenging environments such as offshore or in complex geological structures, the measurement and information systems supporting the drill bit can be just as important as the hardware itself. The main purposes of such information systems are to transfer data about underground conditions to the surface, to allow technicians to guide and position the drill correctly. Frontier technologies in this area are developed and owned by large multinational firms. They include technologies that can monitor conditions inside the borehole and surrounding strata in real time, feed this information to the surface, process it, bounce it off a satellite, and send it in real-time anywhere in the world for monitoring purposes. This allows experts to analyse the information and send real-time instructions back to the drillers. For example, such a process allows to analyze micro-seismic data to avoid faults or to keep a horizontal well inside a reservoir path (Seismic Applications Throughout the Life of the Reservoir 2002, see Table 3).

A key technology in this area is 4D seismic reservoir monitoring, which consists of repeating 3D seismic surveys in order to make time-lapse images of the fluid and pressure fronts as they move in a subsurface reservoir during hydrocarbon production (http://www.westerngeco.com/technology/4d.aspx). When successful, 4D seismic images can locate areas of bypassed oil for new drilling opportunities, map out water-flooded areas to avoid the costly mistake of drilling new wells into swept zones, and identify the geometry and nature of reservoir flow compartments that are key to optimizing hydrocarbon recovery. This is particularly relevant in the context of carbon exploration maturity, which is driving oil companies to develop production strategies that will result in the extraction of more hydrocarbons from existing assets.

Industry analysts have assessed the economic impact of 4D seismic in the North Sea and concluded that since 1996 4D surveys have resulted in added value of more than $4bn; greater than six per cent reduction in drilling costs; significant improvements in production forecasting; and additional reserves averaging five per cent per field.

Table 3 – Core technology in the oil and gas sector

Technology	Function	Driver	Lead global firms	Lead local firms
		4D Seismic scanning		
4D seismic reservoir monitoring ➔ repeated 3D seismic surveys in order to make time-lapse images of fluid and pressure fronts as they move in a subsurface reservoir during hydrocarbon production	4D seismic can locate areas of bypassed oil for new drilling opportunities, map out water-flooded areas, and identify the geometry and nature of reservoir flow compartments. Data about underground conditions is then transferred to the surface to allow technicians to optimize drilling.	Reduces the risk and cost associated with drilling. Specific benefits include: optimizing placement of new wells, locating undrained reservoir compartments, identifying drained areas/fluid fronts, and reducing uncertainty in reservoir models.	Schlumberger and its specialist 4D seismic subsidiary, WesternGeco. Schlumberger's frontier technology is its patented Q-marine high-definition scanning system, which allows it to conduct high-definition 4D scanning from the sea surface.	Schlumberger subsidiary

Source: http://www.westerngeco.com/; http://www.westerngeco.com/technology/4d.aspx; "Seismic Applications Throughout the Life of the Reservoir," Oilfield Review, Summer 2002; http://tle.geoscienceworld.org/cgi/content/extract/23/11/1166; http://oilgasexploration.energy-business-review.com/news/acorn_energy_invests_in_4d_seismic_technology_for_oilfield_monitoring_100225/

In general, field economics can be improved by accelerating production, increasing or extending plateau production rates, reducing the rate of decline after plateau, or extending field life to delay abandonment. A new well, properly placed, can achieve all of these benefits, although the plateau production rate is often limited by external constraints and is thus not changeable. If poorly placed, the well may encounter high water saturation immediately, or it may water out rapidly, for example. Given the resulting range of possible economic outcomes, information such as 4D measurements that help to guide well placement can have a significant and quantifiable value.

Although other firms, for example Acorn Energy, also have capabilities in this area (http://oilgasexploration.energy-business-review.com/news/acorn energy invests in 4d seismic_technology_for_oilfield_monitoring_100225/), the French multinational Schlumberger is the global leader in 4D technology. Schlumberger is the world's largest oil services firm, with approximately 77 000 employees in more than 80 countries. It operates research centres in Cambridge (England), Moscow, Norway, and Saudi Arabia and has a long history of contributing to the development of new technologies in the area of drilling information systems. Its specialist 4D seismic subsidiary is called WesternGeco, which is the acknowledged industry leader (Welling & Company 2004). The company's research and internal training are based in Stavanger, Norway, at a dedicated 4D Centre of Excellence (http://www.westerngeco.com). Schlumberger's particular edge is its patented Q-marine high-definition scanning system, which allows it to conduct high-definition 4D scanning from the sea surface.

3.2.2 Summary

The subsidiary of Schlumberger based in Cape Town has access to all technologies in the group. In principle it therefore operates at the global frontier. The background paper on leading firms in Cape Town (Lorentzen et al 2010) reported that other oil and gas firms similarly benefit from technology transfer from their parents. One firm in particular claimed to have designed world-class valve technology. But this does not apply to the entire sector. Substantial gaps exist, for example, in the market for subsea technologies (Marintek 2010).

Table 4 – Core technologies in construction

Technology	Function	Driver	Lead global firms	Lead local firms
Green Building	Green building changes traditional construction techniques by altering designs, promoting the better use of materials, recycling resources, and using new 'green' materials.	Green building techniques and practices reduce waste and minimise energy and resource consumption, therefore cutting construction costs and improving sustainability..	Leadership in Energy and Environmental Design (LEED) (US)	Group Five Building, Green by Design (a division of the multinational engineering group WSP Consulting Engineers SA)
Building Information Modelling (BIM)	Four-dimensional, data rich, real-time construction planning software. The software allows for the interchange of information between all parties involved in the construction planning process. The virtual building can aid conceptualisation, and prevent conflicts in technical systems.	BIM allows for the more concrete planning of buildings and can therefore save time by lowering the incidence of costly conflicts, errors and changes.	ViCon, HOCHTIEF (D), Turner and Flatiron (US), Leighton and Thiess (AUS)	Murray & Roberts
Factory-built construction (modular, precast, and prefab building)	Pre-engineered building products and components are mass produced off site in factories. Concrete structures are precast in transportable panels or parts. The 'building blocks' making up the structure are transported to the site for installation and assembly.	Standardisation and economies of scale lower construction costs. The greater speed of construction also lowers costs and allows for early returns on investments. Waste is drastically reduced because of efficient factory production.	Skanska, BoKlock, Ikea (Sweden)	South African construction companies have used factory-built construction methods on select projects.
Tilt-up	This construction method uses mobile cranes to assemble concrete panels which are cast on-site in a horizontal position and titled vertically. A chemical bond-breaker is used to prevent the wall panel bonding with the floor or casting slab.	On-site casting reduces transportation costs. Large panel sizes can speed up construction time, and panels can be easily arranged and assembled giving design flexibility.	Several firms in U.S., Australia, and parts of the Middle East.	Tilt Up Systems cc
Lean Construction	Lean construction makes use of techniques such as last planner, just-in-time, 5S, and value stream mapping to maximise value and minimise waste. The method is based on the principles of lean manufacturing.	Lean construction speeds up building and increases labour productivity.	Skanska (Sweden)	A South African construction company implements the 5S, value stream mapping and just-in-time lean construction techniques; however, the last planner system is not used in South Africa.

Source: GBCSA (2010a) GBCSA (2010b) Watson (2009) CIOB (2008) Fox (2010) Group Five (2009) Conradi (2009) HOCTIEF ViCon (2009) Atkins and Tekla (2010) Tekla (2009) Neelamkavil (2008) Rogan et al. (2000) BoKlok (2010) Skanska (2010) Ebisch (2009) CNCI (2010) Forbes et al. (2002) Elfving (2009) Salem et al. (2005)

3.3 Construction

This section considers four sets of technologies that are relevant in the construction industry. They all concern process innovations; one in particular is inspired by the need to reduce the industry's carbon footprint (see Table 4).

3.3.1 Green building techniques

Green building techniques primarily aim to lessen the environmental impacts of construction. Such techniques are certified by among others the World Green Building Council which is the coordinating body for national Green Building Councils. The Green Building Council of South Africa (GBCSA) became the thirteenth full member Council of the World GBC in September 2008. It bases its rating tool, the Green Star SA, on Australia's Green Star system. GBCSA rates buildings according to management, indoor environment quality, energy usage, users' transport, water usage, materials, environmentally and ecologically sensitive land use, and emissions.

Another internationally recognised green building certification system, Leadership in Energy and Environmental Design (LEED), was developed by the US Green Building Council and launched in 2000. In 2009 LEED registered and certified floor space grew by 40% from 2008 to over 7 billion square feet worldwide. LEED buildings have been shown to save on costs over the lifetime of the building, especially on lower energy and water consumption. Healthy and pleasant interior environments can also improve returns on personnel, raising retention, improving productivity, reducing illness and even increasing recruitment options. Other benefits include reduced stormwater runoff, increased groundwater recharge and the use of sustainable transportation systems (Fox 2010, Watson 2009, GBCSA 2010c). Rising energy prices and pressures associated with climate change mitigation have boosted the demand for green buildings as the trade-off between building costs and energy efficiency becomes more favourable.

South Africa is behind first-world green building leaders, such as the US, UK and Germany. At present there is only one completed Green Star certified project in South Africa, the Nedbank Phase II building in Sandton, Johannesburg. The project was completed by Group Five Building and Green by Design (a division of WSP Consulting Engineers SA) and achieved a four star rating out of a possible six. There are currently a further eleven registered green star projects in South Africa, including the City of Cape Town Electricity Head Office (GBCSA 2010b). Energy price hikes in South Africa may encourage green building in the future. However, presently construction companies are not experiencing significant demand for green building techniques in Cape Town or South Africa. Although the industry is aware of these techniques, it has hardly any experience in using them; there is therefore a relatively large technology gap between construction firms based in Cape Town and their competitors from countries where these new techniques are more in demand.

3.3.2 Building information modelling (BIM)

Computer aided design has been a key area of technological progress in the construction industry over the past few decades. More recently Building Information Modelling (BIM) has been introduced into the construction industry. The introduction reflects a growing trend towards developing buildings digitally before beginning construction, and a movement from

computer-aided design to BIM software (Conradi 2009). BIM allows for a more integrated planning of buildings and can therefore lower the incidence of costly errors or changes. For example, whereas previously technical systems (such as refrigeration or ventilation) were installed one after the other with little coordination, managers can now plan the combined installation of technical systems without creating conflicts.

BIM, previously used predominantly in the aircraft and automobile industries, has been adopted by many construction companies in the US and Europe, especially for large, complex buildings. HOCHTIEF, for example, is currently using BIM software to design and construct the Elbe Philharmonic Hall in Hamburg. Each section of the building was tested for system conflicts prior to physical construction, and 8000 conflicting situations were identified in advance. The BIM software needs to be understood and used by all subcontractors in order to work together successfully (HOCHTIEF ViCon 2009). Murray and Roberts have used Finnish BIM (Tekla) software on several projects in Dubai, such as the Trump Hotel and Tower development and the Dubai International Airport (Tekla 2009 and WS Atkins ME and Tekla 2010). In 2009, Murray and Roberts won the Tekla Award for the best BIM project in the Gulf region for the Sorbonne University project.

3.3.3 Factory-built construction

Precast concrete is often used in conjunction with other factory-built construction methods, such as modular, prefabricated and panelised building. Factory production has many advantages over on-site construction. Outside climatic conditions do not affect production, and there is more scope for automation, integration and optimisation. Large savings can also be gained from economies of scale and standardisation (Neelamkavil 2008). Modular construction is most widely used in Japan, Scandinavia and the US where light steel framing is the primary structural medium (Rogan et al 2000). In South Africa companies have used factory-built construction methods on select projects. A larger scale shift towards factory-built construction would require a major shift in building design, materials, production, assembly, and a shift from unskilled to upskilled labour. This would require greater investment, more human resources and an overall shift in the industry's mindset. It is for these reasons that the building and construction industry is likely predominantly to continue to use traditional 'bricks and mortar' in the foreseeable future and change is likely to be slow (CIOB 2008).

3.3.4 Tilt-up

The mobile crane tilt-up method is gaining popularity and makes use of reinforced concrete panels. Although known since the 1940s, the technique has become more widely used since the 1980s due to improvements in mobile crane technology. Tilt-up is mainly used on one to three story buildings, but can also be applied to multi-story office and warehouse buildings. Innovations in tilt-up allow for wider use of the method. For example, panels can be insulated for use in cold rooms. Globally, tilt-up is most prominent in the US, South Africa, Australia, and parts of the Middle East. Examples of South African projects where Tilt-Up Systems cc have been involved are the Weltevreden Shopping Centre in Mitchells Plain (1990 by Murray and Roberts), the Hillfox Power Centre in Johannesburg (1995 by Murray and Roberts), the Mr Price Distribution Centre in Durban (2005 by Stocks and Stocks), and the Maponya Mall in Soweto (2007 by Grinaker-LTA). Although tilt-up is practiced in Europe, European companies largely prefer using precast concrete. Compared to precast

concrete panels, tilt-up has the advantage of fewer, larger panels, and no need for panels to be transported from other locations. Disadvantages include that tilt-up panels require time to set; and can require large and costly cranes (Ebisch n.d., CNCI 2010).

3.3.5 Lean construction

Lean construction techniques encompass a series of processes aimed at improving workflow and reducing waste, like in the automotive industry that pioneered lean manufacturing. It includes personnel performance planning and monitoring ("Last Planner"), the so-called 5S system of organising building sites, value stream mapping, and just-in-time construction. A full deployment of lean construction methods requires the coordinated involvement of owners or users, architects, engineers, contractors, and suppliers. The process encourages the open sharing of information between all the parties involved in the production process. Most techniques (such as just-in-time production and last planner) require seamless communication between involved parties. Lean construction techniques have been shown to reduce supply chain losses, lower construction costs and speed up project delivery (Forbes et al. 2002). One construction firm, based in Johannesburg with offices in Cape Town, makes use of all the above techniques, with the exception of Last Planner.

3.3.6 Summary

With the exception of tilt-up, none of the technologies reviewed in this section are household technologies in South Africa or Cape Town. This is mostly because the regulatory environment does not as yet provide incentives for green building design, and there is no or little demand for other advanced construction technologies. A few South African firms, including some based in Cape Town, have made use of such technologies in overseas projects. Hence they aware of activities at the frontier and some are able to use them as well. But until users demand innovation away from traditional techniques and the regulatory environment changes accordingly, or vice versa, construction firms in Cape Town are likely to continue to operate at a considerable distance from the frontier.

3.4 Creative and design

This section focuses on two technologies in the film industry, namely render farms and post-production software (see Table 5). Technological change in the film industry has been massive, with the introduction of digital cinema, computer animation, and stereoscopic 3D techniques. In general, both Cape Town and Johannesburg host facilities for the production and post-production of feature films. This includes Kodak-approved film laboratories as well as film transfer and grading equipment that can handle processes along the entire film value chain. Compared to international competitors, services are however offered on a smaller scale (Stead 2010).

Table 5 – Core technologies in the creative industries

Technology	Function	Driver	Lead global firms	Lead local firms
Render farm	Computer cluster built to render computer-generated imagery (CGI), usually for film and television visual effects, using off-line batch processing.	Reduction of lead times for complex converting code into high-quality images. This speeds up the value chain in an intense data exchange environment.	Pixar Animation Studios	Triggerfish Animation
Post-production software	Raw audio and visual footage are inputs into a post-production process that treats and refines raw footage, and combines it with sources of digital content. In addition, post-production includes editing functions and the creation of computer generated imagery (CGI).	Innovation in post-production software improves quality, saves time, reduces costs, and offers customised services.	E-Film (Hollywood), Moving Picture Company	Triggerfish Animation

Source: http://www.fiercemobilecontent.com/story/the-hyperfactory-drives-toyota-mobile-campaign/2007-02-05; http://www.moving-picture.com/index.php/r-a-d.html#id=album-27047&num=3; http://www.efilm.com/cinemascan/launch.html; http://www.efilm.com/companyinfo/; http://www.animationsa.org/article/sunrise-productions-uses-qube-render-pipeline; http://www.animationsa.org/article/us-studio-chooses-cape-town-animated-tv-series; http://digitalcontentproducer.com/news/video_pixar_builds_massive/

3.4.1 Render farms

A render farm is a computer cluster built to render computer-generated imagery (CGI), usually for film and television visual effects, using off-line batch processing. The rendering of images requires very large amounts of processing power, as the codes describing three-dimensional objects for each animated frame need to be converted into visual outputs and matched with audio outputs. This is a highly parallelizable activity, as each frame can usually be calculated independently of the others, with the main communication between processors being the upload of the initial source material, such as models and textures, and the download of the finished images.

A render farm can be small or large. A small render farm is simply a network consisting of a few high-powered servers. This can be set up inside even a small firm. However, the power of a render farm is proportionate to its size. Film productions with sophisticated data processing demands will therefore benefit from large farms. In sum, a render farm greatly reduces the lead time for converting complex code into high-quality images. In an industry predicated on deadlines and the massive exchange of data, a render farm is essential for competitiveness.

Leading film studios, online media firms, advertising firms, television producers, and 3G animators utilize large and advanced render farms, sometimes internally, and sometimes through outsourced service providers. Some of the most high-volume rendering is performed for CGI animated movies. For example, Pixar Animation Studios created one of the most powerful computer installations ever used for digital animation. In 2004 its farm was geared to the production of "The Incredibles", and at that stage consisted of 1024 Intel Xeon processors inside of eight supercomputing clusters, each containing 66 dual-processing servers, and running on Pixar's internally developed RenderMan software. Pixar worked closely with Intel on the design of the systems.

Creative firms in Cape Town currently perform rendering processes only internally. Hence there are no commercial render farms in the city. This makes local firms less competitive as their small-scale internal rendering capabilities fall behind the capabilities of large-scale specialist render-farms or the capabilities of large international competitors. In addition, a leading Cape-Town based animation firm reported that internal render farms are expensive to set up, and that their limited internal rendering capacity acts as a constraint on their productivity.

In principle, it would be possible to calculate the processing power of different render farms, which would allow a quantitative comparison and thus a precise estimation of the technology gap. In practice, however, it is difficult to obtain detailed information. A leading Cape Town based animation firm, Triggerfish, indicated that its internal render farm, one of the largest in the country, consists of 80 ‘nodes’ or processors, compared to thousands of nodes included in the render farms of their large global competitors. Since more nodes allow for the making of more sophisticated products, this highlights a large gap.

3.4.2 Post-production software

Post-production software encompasses the tools required to produce digital outputs such as audiovisual advertisements, animated video for online content, or flash-driven online content, including high-end software to create and manage digital outputs. This is a very dynamic field

and firms must continuously update and improve the quality, efficiency, and specialized offerings of their post-production software to remain competitive. The technological frontier is held by large firms based in film centres such as London and Los Angeles, primarily serving the European and American markets. Two examples follow.

E-Film is a post-production house in Hollywood that specializes in the digital intermediate process and other digital motion picture technologies. It claims to operate the most advanced 'digital laboratory' in the world. Clients include the major film studios, independent filmmakers, advertisers, animators, and visual effects companies. The firm develops its own software for use in the post-production process. Its R&D capacity is central to the firm's competitiveness. Over the last two decades, it developed a proprietary tape-to-film transfer process that created the highest possible quality film recordings at the time (1989); customised high-definition scanning systems (1994); upgraded earlier versions of digital laboratory software covering the entire workflow including scanning, tape-to-film, film recording and video and digital cinema deliverables (1996); created digital colour correction software (1996) as well as capabilities in the 3D format (2003); and designed more advanced colour correction and workflow management software (2006).

Each of these aids competitiveness in different ways. For example, internally developed workflow software manages digital content throughout the post-production process. Raw data is retained, and meta-data like scene, take, and colour adjustments can be stored, searched and retrieved at any point in the process, for example for dailies, marketing, preview screening, and visual effects. This is claimed to improve quality, save time, reduce costs, and thus confers a competitive advantage.

The Moving Picture Company is a post production facility creating digital visual effects and computer animation for feature films, commercials, music videos and television. They are world leaders in the field, consistently winning awards for their work. The firm also develops its own software for use in the post-production process. Examples include Alice, an in-house system for generating crowds; PAPI, which facilitates the creation of scenes involving falling, colliding and constrained rigid bodies; Furtility, a surface dressing tool, primarily used for creating photo realistic fur and hair for CG characters; and ISIS, a full suite of software for digital set reconstruction.

Cape Town based firms are behind the global frontier, but not massively. Triggerfish Animation is a local leader and has produced animated material for the US market. The company reports that its core technology, the 'Nuke' compositing software, is the global industry standard for medium sized and large post-production firms. However, it faces constraints in terms of scale; Triggerfish owns eight Nuke licences, compared to about 100 owned by large global competitors. Compositing software is a core technology because it brings together many streams of audio-visual input, such as various sources of CGI, film, animation, sound, and other programmed content, and produces the final output. The competitive advantage of animation firms lies in customisation which takes place in specialised softwares that deal specifically with one or other aspect of these inputs, for example computer-generated imagery or colour management.

Triggerfish currently does not have the capability to customize its post-production software. In sum, local leaders face constraints in terms of scale, but they use world class post-production technology without yet having the capability to design it.

3.4.3 Summary

Although Cape Town has render farms, they are internal to film companies and not stand-alone entities. Commercial render farms in world film centres that are technology leaders have much larger and more powerful facilities. Firms in Cape Town are therefore behind the frontier in terms of the scale of computing power employed which constrains what is technologically feasible. In post-production software, local firms similarly operate at a much smaller scale. Perhaps more importantly, although they master the use of the relevant software, they do not (yet) have the capability to customize it. Hence, they are behind the frontier.

3.5 Retail

This section focuses on a series of technologies that can be grouped under three categories, namely inventory management, distribution, and e- or m-commerce (see Table 6).

3.5.1 Inventory management

Many frontier technologies in the retail sector focus on the optimisation of inventory management and customer satisfaction. They include integrated multi-channel retailing (IMCR), vendor managed inventory (VMI), and electronic data interchange (EDI). IMCR allows customers to purchase and return items through any number of available channels (e.g. physical stores or online stores) and can also involve co-ordinating inventories and marketing drives between channels. International retailers that pioneered ICMR include Wal-Mart and Circuit City in the US. In South Africa, Pick 'n Pay allows customers to return online purchases to any Pick n Pay store within the Delivery Area or have it collected by the Delivery Team.

VMI shifts the responsibility of maintaining inventory levels at a distributor's or retailer's site onto the supplier. For the retailer, this creates a more efficient supply chain and reduces inventory costs. Wal-Mart and Procter and Gamble pioneered this technology in the late 1980s. Wal-Mart transmits point-of-sale (POS) and inventory level data electronically to the supplier who then uses it to prepare shipments accordingly. In South Africa, Shoprite is the first retailer to make suppliers monitor stockholding down to the branch level. The company plans to move to a complete VMI model in the near future.

Effective management of inventory requires communication between parties in the supply chain. Advanced information and electronic data interchange (EDI) systems make it possible to share sales and inventory information between suppliers, distributors and retailers. Wal-Mart pioneered a private satellite network in the 1980s, and has since set up other EDIs. Since 2002, the company has been using web-based EDIs to send point-of-sale (POS) data and communicate with suppliers (Kenny 2002). All major South African retailers use EDI systems to some degree. However, information is often confined to networks between retailers and distributers/wholesalers, and is not shared with suppliers. This can create supply problems and is a barrier to vendor-managed inventory. Most major South African retailers work on a model where the stores manage their own inventory and purchase from wholesalers or distribution centres, managing the entire value chain.

Table 6 – Core technologies in retail

Technology	Function	Driver	Lead global firms	Lead local firms
		Inventory management		
Integrated Multi-Channel Retailing (IMCR)	IMCR allows customers to purchase and return items through any of the available retail channels. It can also involve co-ordinating inventories and marketing drives between channels.	IMCR gives customers greater access to goods and services, gives retailers wider access to customers, can boost sales and increase customer satisfaction.	Wal-Mart (US), Circuit City (US)	Pick 'n Pay
Vendor Managed Inventory (VMI)	VMI (also known as continuous replenishment or supplier managed inventory) partnerships give the supplier the responsibility of maintaining inventory levels at a distributor's or retailer's site.	VMI creates a more efficient supply chain, and lowers the risk of holding stock for retailers.	Wal-Mart (US), Procter & Gamble (US)	Shoprite
Electronic Data Interchange (EDI)	EDI is a standardised electronic data transfer system over a dedicated private network or the internet, involving two or more organisations. It can include all the retailers, distributors and suppliers that make up the supply chain.	EDI increases the ease of communication and transactions between all parties within the value chain.	Wal-Mart (US)	Shoprite
Radio Frequency Identification (RFID)	RFID uses microchips attached to a radio antenna that can be programmed to store information about a product, shipment, or other tagged items. Multiple tags can be scanned simultaneously using a reader in the vicinity. The reader emits radio waves and receives data signals back from the microchips.	RFID increases the speed and accuracy of inventory tracking and identification.	Wal-Mart (US), Metro Group (DE), Tesco (UK)	RFID is used by a major South African retailer with a presence in Cape Town, but only in its distribution centre.
Real-Time Value Chain Management	Real-time value chain management involves the instantaneous processing and coordination of value chain activities. Tracking inventory in real-time at the point-of-sale, in transit, in warehouses, between warehouses, at distribution centres, and at customer locations.	Real-time value chain management enables organisations to respond quickly to changes in demand and supply, better utilise capacities and avoid bottlenecks.	Wal-Mart (US)	This technology is not used throughout the value chain by the major retailers in South Africa.

Technology	Function	Driver	Lead global firms	Lead local firms
		Distribution		
Consolidation Centres	Centres in close proximity to a number of smaller suppliers, used to combine the shipments of these suppliers into larger deliveries.	Consolidation centres lower delivery transportation costs and by increasing delivery frequency, lower storage costs and stockouts.	Carrefour (F), Wal-Mart (US)	None
Cross-Docking	Cross-docking uses warehouses as inventory coordination points rather than for storage. After goods arrive from the manufacturers/ suppliers they are transferred to delivery vehicles (for retailers) as soon as possible (usually in less than 12 hours).	Cross docking lowers or eliminates inventory storage costs and lowers the cost of inventory delivery.	Carrefour (F), Wal-Mart (US)	Cross docking is implemented by a major local retailer at distribution centres.
		E- and m-commerce		
E-Commerce	E-commerce is the buying and selling of goods and services over computer networks, such as the internet. The most common forms of e-commerce are business-to-business (b-to-b) and business-to-customer (b-to-c), respectively.	E-commerce can lower procurement costs, reach new customers, and offer customers a wider range of goods, services, and product information.	Wal-Mart (US), Carrefour (F), Metro (D), Tesco (UK), and Schwarz Unternehmens Treuhand KG (D)	Pick n Pay, Woolworths and Makro, Shoprite
M-Commerce, Mobile Marketing, and Mobile Retail Applications	M-commerce is the buying and selling of goods and services over mobile networks, mainly mobile phones. Mobile phones can also be used to provide customers with information, for marketing, and other retail applications.	M-commerce can lower procurement costs, reach new customers, and offer customers a wider range of goods, services, and product information.	Nestlé (CH), Kraft (US), Johnson&Johnson (US), Wal-Mart (US), Metro (D), Carrefour (F)	None in retail

Source: Chu & Pike (2002), Pick 'n Pay (2010), Waller et al. (1999), Shoprite (2010), Mujtaba and Maxwell (2007), CXO (2010), Retail Technology Review (2009), SPAR (2010), Metro Group (2005), Chan (2007), Simchi-Levi et al. (2003), Kenny (2002), Banker (2010), Dalton (2006), Deloitte Touche Tohmatsu and STORES Media (2010), U.S. Census Bureau (2010), Internet World Stats (2010), EIU (2010), Birchall (2010), Shoprite (2010), GoMo News (2009), Retail Technology Review (2010), GS1 MobileCom (2009)

Radio frequency identification (RFID) uses microchips attached to a radio antenna that can be programmed to store information about a product, shipment, or other tagged items. Multiple tags can be scanned simultaneously using a reader in the vicinity. The reader emits radio waves and receives data signals back from the microchips. RFID increases the speed and accuracy of inventory tracking and identification. Tags can be used for automated product recognition, inventory control, quality assurance, and theft control in stores. For instance, products can be automatically monitored for when they are reaching best before dates. Many international retailers make extensive use of RFID tags. SPAR uses RFID to track products and manage warehouse inventories. Metro Group has also been testing the use of RFID technology in-store but does not believe that the new technology will completely replace bar-code technology for a number of years (Mujtaba & Maxwell 2007, CXO 2010, Retail Technology Review 2009, SPAR 2010).

On the whole, retailers in Cape Town and South Africa, while aware of RFID benefits, have not widely adopted the technology. Upfold and Liu (2010) identify a number of barriers to RFID adoption by South African retailers, including RFID skills shortage, a lack of standardization, high costs of RFID devices, the difficulty of integrating with current legacy systems, and a lack of familiarity with RFID systems. These barriers are however diminishing with the technology increasingly being adopted by global companies. An electronic product coding test centre (EPCglobal South Africa) has been set up to test RFID technologies. Procter & Gamble SA, Unilever SA, Pick n Pay and Shoprite Checkers are some of the members of EPCglobal South Africa (Krooman 2009).

Real-time value chain management is a more comprehensive form of inventory management. It involves the instantaneous processing and coordination of all value chain activities, from tracking inventory in real-time at the point-of-sale, in transit, in warehouses, between warehouses, at distribution centres, and at customer locations. It enables organisations to respond quickly to changes in demand and supply, utilise capacities better and avoid bottlenecks. Wal-Mart uses this technology; no South African retailer does.

3.5.2 Distribution

Innovations in distribution include consolidation centres and cross-docking. Consolidation centres are set up in close proximity to a number of smaller suppliers. This facilitates the consolidation of smaller shipments into larger deliveries and thus lowers transportation costs and, through a higher delivery frequency, storage costs. The French retailer Carrefour currently has eight consolidation centres operating in France and is in the process of developing twelve more. The company is also looking at supplier networks throughout Europe to determine the possible location of more consolidation centres.

In the Carrefour model the manufacturers use EDIs for communication with the retailers, orders, and invoices. They are responsible for transport costs to the consolidation centre. A third party logistics company runs the consolidation centre and Carrefour is responsible for transportation costs to the Distribution Centre (DC) and retailers. If the process is well synchronised goods can be cross-docked at the DC without need for storage (Banker 2010). In South Africa retailers do not make use of consolidation centres, and goods are either taken directly from suppliers to retailers, or to distribution centres. A change from the current system to using consolidation centres would require that suppliers share information and work more closely together.

In cross-docking, warehouses become inventory coordination points rather than storage places. After goods arrive from the manufacturers or suppliers, they are transferred to delivery vehicles (for retailers) as soon as possible, often in less than 12 hours. This eliminates storage and lowers delivery costs. Carrefour has implemented such a system in Poland. Wal-Mart delivers 85 per cent of its goods this way. One Cape Town based retailer uses cross-docking.

3.5.3 E- and m-commerce

E-commerce refers to the buying and selling of goods and services over computer networks, such as the internet. E-commerce can lower procurement costs, reach new customers, and offer customers a wider range of goods, services, and product information. All of the top five major global retailers (Wal-Mart, Carrefour, Metro, Tesco, and Schwarz Unternehmens Treuhand KG) have relatively well developed business-to-customer (b2c) e-commerce channels. For example, Wal-Mart operates large e-commerce sites in the US, UK and Brazil and has singled out e-commerce as one of its priority growth areas. In addition, it is creating a larger presence in online social networking sites. New and larger headquarters for its online operations are being set up in San Francisco (EIU 2010, Birchall 2010). Of the top 100 retail companies, 69 had e-commerce channels in 2008. E-commerce accounted for 6.6 per cent of their total sales.

In South Africa, Pick n Pay, Woolworths and Makro have developed online retailing sites. Shoprite has an online business-to-business (b2b) website used for purchases and orders between the company and suppliers. E-commerce is growing relatively quickly in South Africa, albeit from a low level. In 2009 internet users made up only 10.8 per cent of the South African population. This is well below the world average of 26.6 per cent or 76.3 per cent in the US. The Economist Intelligence Unit's e-readiness rankings for 2009 rank South Africa 41st out of 70 countries worldwide. The U.S. Census Bureau estimates that 92% of e-commerce in the US is b2b e-commerce. B2c e-commerce transactions were estimated to be 3.7 per cent of overall 2009 retail sales (EIU 2010, U.S. Census Bureau 2010, Internet World Stats 2010). In South Africa the full potential of online retailing is additionally hampered by a relatively weak postal system and the high cost of broadband (Internet World Statistics 2010).

Mobile-commerce (m-commerce) is the buying and selling of goods and services over mobile networks, for the most part over mobile phones. Mobile phones can also be used to provide customers with information for marketing and other retail applications. Over one hundred global companies, including Wal-Mart, Metro, and Carrefour, are involved in an initiative to promote engagement with consumers via their mobile phones. The initiative (GS1 MobileCom) includes manufacturers, retailers, mobile industry companies, and solution providers. The GS1 MobileCom initiative focuses on using mobile phones for coupons, payment methods, advertising, promotions, creating shopping lists, mapping store locations and providing further product information. Open standards are to be adopted by stakeholders to create cost-effective, scalable and interoperable applications. Wal-Mart has also publically announced its intentions to expand its mobile commerce platforms, seeing this as an important channel through which Wal-Mart can reach new customers (GS1 MobileCom 2009).

South African companies have started to use m-commerce, but not in food retailing, although a market opportunity exists. World Wide Worx estimates that South Africa has 5.3 million internet users and that a further 5.26 million South Africans could potentially access the internet via their mobile phones. These mobile phone users currently have the mobile technology required but do not use their phones for this function. Mobile internet is an important form of internet access since less than 30 per cent of regular mobile web users has access to other internet channels. South Africa had 37 million cell phone users in 2009 (a 77% population penetration), and there is huge potential for mobile internet applications with a growing proliferation of phones capable of internet access. On the mobile marketing side some South African firms are already pioneers (GoMo News 2009).

3.5.4 Summary

South African retailers do not use all the available frontier technologies in inventory management, distribution, and e- or m-commerce. The use of selected technologies is not as extensive as practiced by global leaders in the US and Europe. South African retailers are therefore behind the frontier.

3.6 Business process outsourcing

Key technologies in the contact centre business process outsourcing (BPO) sector are associated with home-based agent strategies, multi-channel contact centres, data collection, metrics, and data analysis (see Table 7). Software is at the core of these technologies; the successful use of such software relies on suitable information technology infrastructure and requisite skills. Some suppliers have invested in skills training to encourage BPO companies to use their products, services and technologies. Huawei, for example, is a niche player in contact centre infrastructure and provides both infrastructure and skills training for contact centres. It has set up a training initiative with the University of Cape Town, training telecoms engineers and providing the necessary equipment for the facility (Kraus et al. 2010, Huawei 2010).

3.6.1 The home-based agent strategy

Contact centres can implement the home-based agent strategy by routing calls, data and customer information to agents in their homes or in remote locations. Employees in remote locations can work collaboratively with employees in offices or other remote locations. The strategy increases staff retention, flexibility and productivity. Office overheads can also be reduced with fewer employees using office space and facilities.

Technologies that allow contact centre agents to operate from home have been available for a number of years from vendors such as Avaya and Mitel. Whirlpool Corporation, the world's leading manufacturer of home appliances, with current annual revenues of over $18bn and 67 000 employees, has used Avaya technologies extensively. It markets and distributes laundry appliances, refrigerators, cooking appliances, dishwashers, mixers, and other small household appliances under various brand names (Yahoo Finance 2010). Whirlpool Corporation operates four contact centres (customer excellence centres) in North America.

Table 7 – Core technologies in BPO

Technology	Function	Driver	Lead global firms	Lead local firms
Home-based agent strategy	Allows contact centre agents to telecommute.	Increased staff retention, flexibility and productivity.	Whirlpool Corporation (US)	Spescom Datafusion, dental treatment firm
Multi-channel contact centres	Customers can seamlessly switch between a number of different contact channels, such as traditional voice calls and e-mail, instant messaging, short message services or self service applications.	Reduced agent handling time and increased customer satisfaction.	Whirlpool Corporation (US)	Spescom Datafusion
Data collection, Metrics and Data analysis (Data Mining)	Electronically monitor every interaction with customers to improve productivity and client satisfaction through data collection and data mining.	Gains more comprehensive customer profiles across markets and reduces the need for direct interaction between (esp. senior) staff and customers.	Teleperformance (F), Accenture	Teleperformance, Accenture

Source: Accenture (2009), Avaya (2010, 2010b), Teleperformance (2008, 2010)

One third of Whirlpool contact centre agents work from home. Only agents with six to twelve months experience are given this option. Experience shows that this increases agent retention and increases productivity. Furthermore, the home based agent strategy can be extended to allow agents to conduct business from any remote location. This flexibility allows companies to maintain business continuity, even in emergency situations. The Whirlpool Customer eXperience Centre in Canada won the best use of technology award from the International Quality and Productivity Centre (IQPC) (Avaya 2010 and Avaya 2010b).

BPO firms in Cape Town are behind leader firms in home-based agent strategies. Avaya and Mitel home-worker technologies are both available locally, yet high costs for high-speed bandwidth to home users is a major hindrance to adoption. Only one dental treatment company in Cape Town has implemented the Mitel Teleworker technologies and this company has an in-house contact centre. None of Cape Town's contact centres dealing with outsourced business processes have implemented the technology.

3.6.2 Multi-channel contact centres

Multi-channel contact centres allow customers to switch seamlessly between a number of different information and data channels. For example, customers and agents communicate through traditional voice calls, e-mail, instant messaging, or short message services. Information collected through any channel is also shared between channels. Giving customers a choice of multiple channels allows them to relay and receive information more efficiently, accurately and at a time that suits them. For example, data or information requests can be sent to customers via e-mail or short message service for retrieval at any time, whilst instant messaging or phone calls may be better suited for attending to certain enquiries. Multiple channels reduce agent handling time by requiring less phone calls and using more automation. Customer satisfaction is also increased with more communication options and reduced handling time.

Whirlpool Corporation operate multi-channel contact centres on an Avaya platform. Whirlpool was an early adopter of multi-channel contact centre technology, and Avaya is rated as a global leader in contact centre infrastructure (Kraus et al. 2010). Avaya software allows agents to receive communications from customers through a variety of channels. Notifications, responses and other information can also be sent to customers through a channel of their preference. Phone calls to live agents, interactive voice response (IVR), e-mail, web applications and short message services are commonly used by Whirlpool's contact centres (Avaya 2007, 2010).

Many contact centres within Cape Town use multiple channels to share information and data with customers. Mindpearl, for example, is a Cape Town based multinational company that uses a multi-channel contact centre to handle Delta Airline general sales and the SkyMiles frequent flyer program (Mindpearl 2010). Spescom Datafusion, a division of Spescom Ltd with offices in Johannesburg, Cape Town, Durban and London, provides multi-channel contact centre services to many medium and large contact centres in Cape Town. It supplies business process solutions from Avaya, with whom it has Platinum Certification (Spescom 2010). There is no indication of a technology gap in multi-channel contact centre technology between Cape Town's firms and foreign leader firms such as Whirlpool Corporation. There are a number of vendors offering world class multi-channel technologies to local firms.

3.6.3 Data collection, metrics and data analysis (data mining)

Companies can use every interaction with a costumer as a potential source for data collection, thus increasing actual knowledge on client expectations (*ex ante*), the quality of the interaction *per se*, and the satisfaction regarding the outcome (*ex post*) of the communication. Hence, the collection, transfer and analysis of data are becoming more important for BPO activities. Utilisation of this model helps maximise profit from every consumer, not just according to a cross-section aggregate profit but also taking into consideration the overall profit earned from repeat business every time a customer returns. Data is at the core of this model because it enables firms to take advantage of every interaction with a customer to increase future productivity, enhancing a learning-by-doing process at the firm level. Through the categorisation of customers one can improve automatic electronic monitoring, which assists marketing and can improve client satisfaction. Moreover, experienced senior staff can be released from channelling customers upstream (purpose of electronic monitoring) and therefore focus on management activities such as training or coaching. Data collection also has a business effect, enabling up-selling and cross-selling as well as long term loyalty and future consumption for each customer. The relevant question is therefore the choice of the right metrics, that is which questions to ask and which indicators to report.

Accenture, which has offices in Cape Town, dedicates part of its research to this subject. Typical indicators include average call-length as a proxy for productivity levels. However this may introduce moral hazard, as an employee could seek to end the communication more rapidly regardless of the quality of the service provided. Other indicators are therefore often resorted to. They include first call resolution rate or overall fix rate, which capture broader efficiency measures. Teleperformance, a French MNE, one of the leading technical and IT support outsourcing companies in Sub-Saharan Africa and it operating over 300 workstations and 235 employees in Cape Town, is using advanced statistical techniques and data mining software to analyse the data at hand more precisely and turn it into business relevant material. These new technologies require efficient telecommunication technologies and appropriate bandwidth due to the large volume of data that is collected and transferred, including for the quality and speed of electronic monitoring.

3.6.4 Summary

All of the examined frontier technologies are available to firms in Cape Town and there are examples of contact centres within Cape Town adopting them. Technology gaps do however exist, especially in home-based agent strategies. The high cost and poor speed of bandwidth in Cape Town is a hindrance to adopting home based agent strategies. Data collection, metrics and data analysis face similar problems.

3.7 Financial services

Computing power has changed the way financial sector has conducted business over the past few decades, and information technology continues to drive innovation in the financial sector. Although software is behind many changes in the industry, new forms of hardware play an important role in giving people greater access to software innovations and financial services as well. The internet and smartphones are two important means of access to financial services. With new forms of access, new problems arise and need to be addressed with new solutions, such as novel anti-fraud measures. This section focuses on frontier technologies in cloud computing, mobile banking, and anti-fraud measures (see Table 8).

3.7.1 Cloud Computing

Cloud computing is a rapidly growing technology in the financial sector. It allows companies to access IT services over networks such as the internet or a private intranet. Firms rent processing capabilities, storage capacity, networking, and software as a service (SaaS) from a third-party provider. IT infrastructure is maintained off-site by third-party personnel. Firms only pay the third-party provider for the services they use, and are thus able to benefit from economies of scale. They can save on maintenance, upgrades or new installation costs that are shared and no longer in-house. Cloud computing gives companies the flexibility to implement changes in their computing capacity quickly and allows for limitless up scaling. Instead of spending capital on whole solutions, firms can take advantage of only the appropriate components. In addition firms no longer run the risk of investing capital in excess IT infrastructure, skills, and software that will sit idle at times. Solutions and applications can be rented by the hour and rapidly tweaked to meet changing business imperatives. New applications can be introduced in a number of days, thus reducing the time to market for new applications (Deloitte Touche Tohmatsu 2010, James 2010, MacSweeney 2009).

Many multinational financial sector firms have identified the advantages of cloud computing and have adopted the technology. ING Americas, the US arm of Dutch bank ING, have moved many of their internal processes into external cloud computing. The degree to which cloud computing is utilised depends on the business unit. ING estimates that costs and processing time will be drastically cut using cloud services. The three companies providing services for ING are Rackspace, Amazon, and Salesforce.com. Other big service providers include IBM, Microsoft, Google, and Hewlett Packard (Crosman 2010). Merrill Lynch which uses IBM's Blue Cloud servers to build and evaluate new risk analysis programmes, estimates that the cloud computing market will reach $160bn by 2011. Morgan Stanley uses Salesforce's Force.com cloud service for recruiting applications. Nasdaq stores Nasdaq, NYSE and Amex data in Amazon's storage cloud (Crosman 2009). AIG Edison, a life insurer in Japan, uses a number of Salesforce.com's cloud computing services for sales, contract management, and insurance payments. Cloud computing reduces AIG Edison's hardware, software and IT system costs and speeds up service delivery (Enterprise Innovation 2009).

Cloud computing is also present in Cape Town. In fact, the software for Amazon's Web Services (AWS) was largely developed in Cape Town using local skills. Since its inception in 2006, AWS has grown into a highly successful business with revenues of over $0.5bn (Fairweather 2010). However, the quality of bandwidth connecting customers to cloud facilities is an issue (Deloitte Touche Tohmatsu 2010). For example, an application requiring large amounts of data to be sent to or from a cloud in the US relies heavily on local bandwidth. Dedicated internet connections to the US can overcome this problem but are costly. There is a cloud computing group in Cape Town and approximately 50 firms in the city use the technology (David Hislop: personal communication, see also http://www.korwe.com/). A lead firm in cloud computing in the financial sector is Thought Express (www.thoughtexpress.com). Based in Cape Town, the firm uses semantic cloud computing to offer online financial modelling and dynamic enterprise optimisation services. Semantic cloud computing technology allows computers to perform tasks normally undertaken by humans, such as tedious work involving searching for, combining and acting on data.

Table 8 – Core technologies in financial services

Technology	Function	Driver	Lead global firms	Lead local firms
Cloud Computing	Cloud computing allows companies to access IT services over networks such as the internet or a private intranet. Firms rent processing capabilities, storage capacity, networking, and software as a service (SaaS) from a third-party provider on a pay-as-you-go basis. IT infrastructure is maintained off-site, by a third-party.	Companies can share the costs of maintenance, upgrades or new installations and achieve economies of scale. Large start-up costs are avoided and companies. Cloud computing affords the flexibility to upscale or downscale operations rapidly.	ING Americas (banking), AIG Edison (life insurance), Merrill Lynch (financial management and advisory)	Thought Express (financial modelling and dynamic enterprise optimisation)
Mobile Banking	Using mobile phones to make payments, check account balances, check posted transactions, receive account alerts, make account transfers, pay bills, and access stock market data.	Access a larger customer base and increase customer satisfaction.	Safaricom, Zain (Kenya), Citibank (US)	Absa
Multifactor Authentication	Allows an increase in sector growth through a combination of decrease in actual losses due to fraud and enhanced participation in new types of transactions.	Improvement in the security of online or mobile banking and financial transactions through different layers of authentication.	HSBC (UK)	Standard Bank, ABSA

Source: Federal Financial Institutions Examination Council(2005), ABSA (2010), Standard Bank (2008), Sawas (2006), Deloitte Touche Tohmatsu (2010), MacSweeney (2009), James (2010), Crosman (2010), Crosman (2009), Enerprise Innovation (2009), Data Innovation (2010), Njenga (2009), Roettgers (2009)

3.7.2 Mobile banking

One of the growing uses of mobile phones in banking is to pay people, businesses or bills. The mobile payment industry experienced strong growth according to figures released by Gartner Research, up from 43.1 million worldwide users in 2008 to 73.4 million worldwide users in 2009 (Shen 2009). Gartner predicts that this number will grow to 190 million by 2012, or three per cent of mobile phone users worldwide. Aside from making payments, mobile phones are becoming more commonly used for many banking functions. A survey in the US by Data Innovation found that the most popular services were checking account balances or posted transactions, account alerts, account transfers, and bill payments, respectively. The most desired mobile applications in the survey were mobile wallets, account alerts, bill payments, peer-to-peer services, mobile remittances, and accessing stock market data (Data Innovation 2010).

Citibank is a lead global firm in mobile banking and payment services in several countries. Clients with smartphones can check balances, pay bills and transfer balances (Citibank 2010). In the Philippines, where Citibank is the largest foreign bank, customers are offered similar services via their mobile phones. In addition, deliveries from limited vendors can be charged to one's bank card. Services are tailored for mobile users but also interchangeable between mobile and internet banking. No financial information is stored on the mobile device and dual authentication and encrypted transactions are used as security measures. Citibank has more than one million mobile banking customers in the Philippines (E-commerce Journal 2010). In Bangalore, Citibank, in partnership with MasterCard, Nokia, Vodafone and ViVOtech, has launched a contactless mobile payment service. The "Tap and Pay" service allows users to make credit card payments via their mobile phones (E-commerce Journal 2009).

Developing country firms have also produced innovations and grown in a short period of time. In Kenya, Safaricom launched its M-PESA service in 2007 allowing customers to make peer-to-peer mobile payments and draw cash from ATMs using their mobile phones (Njenga 2009 and Roettgers 2009). What started as a service to allow minute-sharing for prepaid cell phone plans, was adopted as a surrogate currency by many Kenyans. Safaricom subsequently launched M-PESA and a year later became the biggest bank in East Africa (Roettgers 2009). M-PESA now has more than 10 million users, providing many poor and rural Kenyans with financial services, almost half of whom did not previously have bank accounts. Safaricom has now teamed up with Equity Bank, one of Kenya's largest financial institutions, and launched M-KESHO. This will allow customers to deposit money in interest bearing accounts, and have access to microcredit and short term loans (Onyiego 2010 and Njenga 2009). Mobile banking in South Africa has not delivered financial services to poorer and more rural South Africans on a similar scale as in Kenya. It seems unlikely that this is due to a lack of capabilities, and more because of a lack of incentives.

South Africa has extensive mobile phone infrastructure and the use of mobile phones for internet access and banking is growing (World Wide Worx 2010). A number of banks, notably Absa, have developed mobile banking technology. Absa have pioneered a system that allows customers to transfer cash from their own cheque or savings accounts to anyone with a cell phone number around the country. A reference number and access code are sent to the receiver by SMS. Cash can then be withdrawn at any of Absa's ATMs with the number and code, without the need for a bank account or bank card. Customers can send

cash "peer-to-peer", using mobile banking, internet banking, or via an ATM (Absa 2010). The Absa Cash-Send service won the company the 'most promising new product' and 'outstanding innovation' awards at the 2009 *Financial World* innovation awards, and the 'most innovative use of IT' award at the 2009 *Banking Technology* awards (Banking Technology 2009).

3.7.3 Multifactor authentication

Multifactor authentication technology is seen as a standard requirement since the Federal Financial Institutions Examination Council issued a guidance report in 2005. The report recommends the use of at least two different types of authentication channels in securing online banking transactions. These requirements are more and more stringent due to the frequency of fraud such as phishing, pharming, or spoofing associated with Internet banking.

Authentication strategies are usually divided into three types: shared secrets ("what you know"), such as passwords, PINs, personal questions or selection within a pool of images. Security tokens ("what you have") concern physical devices such as smart cards, USB tokens (Public Key Infrastructure) or password-generating tokens (or confirmation codes sent by email or SMS) and are also commonly provided by online banking services. Finally, biometrics ("what you are"), although still costly and limited to major transactions, is starting to spread as the most secure technology. Biometrics includes physiological recognition (fingerprints, face, voice, finger and hand geometry, retinal and iris scan) and practical recognition (like keystroke or handwriting). The key trade-off is to minimize the probability of fraud while maximizing the incentive for customers to resort to online banking, despite the somewhat unappealing complexity and length of the security procedures.

Leading international banks such as HSBC have handed free one-time password (OPT) generating devices to all their online banking customers since 2006. In South Africa, Standard Bank also utilisesg these types of tokens in addition to the usual shared secrets authentication (passwords or PINs). Absa has also implemented two-factor authentication but has not yet introduced security tokens. Absa has suffered major security breaches since 2003, and one of the reasons emphasised for this is that confirmation codes are still sent to mobile phones. Codes sent in this way are more vulnerable to phishing than other physical devices such as smart cards or USB tokens. Indeed, hackers usually send fake messages asking the costumer to transmit his or her secret information to a third party, therefore taking advantage of consumers' unawareness. Such scams are made more difficult to carry out with an automatic password generating device.

3.7.4 Summary

The global financial sector has undergone rapid technological changes in recent years. The advent of cloud computing is one example. A few firms in Cape Town have been quick to take advantage of the technology and are operating at the technology frontier. In addition skills in Cape Town have been used by one of the leading providers of cloud computing to pioneer new products for a multinational firm. Mobile banking is another technology that is expected to grow in popularity. Local banks have developed mobile banking services for customers. However, many of their services are not as comprehensive as those offered by Safaricom and Zain in Kenya or by Citibank in the Philippines and India. There are also services that are not available at all, such as mobile phone credit card payments, although

they exist elsewhere. These are large and important technology gaps, especially for banks considering further expansion into developing countries. Technology gaps in anti-fraud measures are smaller, with examples of banks in Cape Town using frontier technologies such as multi-factor authentication.

The use of these technologies requires advanced skills. Stellenbosch University is one of two universities in the country to offer an undergraduate programme that covers at least 70 per cent of the CFA Programme Candidate Body of Knowledge. But only the University of Pretoria offers a ratified CFA postgraduate program.

3.8 Business tourism

To host a successful event and gain market share, a convention centre must integrate a number of technology solutions to meet the audio, visual and other communication requirements of delegates. Among others, this includes the availability of fibre optic cables, broadband access, and wireless connections. Technological sophistication is part of a larger package, consisting of infrastructure and hospitality factors, that determines the competitiveness of a business conference venue (see Table 9).

For example, Paris Porte de Versailles is a leading international convention centre and the seventh largest in Europe. In 2008, the centre hosted 139 meetings (ICCA Statistics report, 2009). The venue can accommodate over 4000 people and has 32 separate reception rooms. Its in-house technology includes telephone connectivity, wireless internet access, and state-of-the-art audiovisual technology. Delegates inside the facility can travel between halls on a moving sidewalk, while arriving to the facility itself is easy thanks to nearby Metro, bus and train stops. Over 8,300 hotel rooms are also within walking distance. The venue has in the past hosted world leading conferences such as the World Federation of Anesthesiologists and the International Congress of Actuaries.

Despite the fact that CTICC has been operational for only a few years, it has managed to attract major conferences such as the International Congress of Actuaries. CTICC competes with long haul destinations both in the Northern and Southern hemispheres, such as Melbourne, Vancouver, and Rio de Janeiro. Although a relative newcomer on the international event circuit, South Africa is considered the premier African business tourism destination, and Cape Town plays a particularly important role (see Tables 10 and 11).

Table 9 – Core technologies in business tourism

Technology	Function	Driver	Lead global firms	Lead local firms
Convention centre	To attract international conferences by providing world class infrastructure and customer service.	Gain market share in business tourism and become a destination of choice for international business meetings.	Paris Convention and Exhibition Centre, Vancouver Convention Centre, Melbourne Convention and Exhibition Centre, Barcelona	Cape Town International Convention Centre

Source: ICCA (2009).

Table 10 -- World ranking of business tourism destinations, by country, 2004-2008

Rank	Country	2004	2005	2006	2007	2008
1	USA	610	603	612	564	507
2	Germany	409	89	428	484	402
7	Brazil	156	171	230	213	254
14	Australia	186	187	204	199	182
34	South Africa	63	77	72	75	82
41	New Zealand	38	31	34	33	38
55	Egypt	15	18	24	24	20

Source: ICCA (2009)

Table 11 -- World ranking of business tourism destinations, by city, 2004-2008

Rank	City	2004	2005	2006	2007	2008
1	Paris	133	121	162	135	139
3	Barcelona	137	133	110	112	136
29	Vancouver	40	37	45	43	54
35	Cape Town	40	41	45	43	42
36	Rio de Janeiro	40	44	54	37	41
39	Melbourne	40	54	56	34	38
120	Johannesburg	14	4	5	13	13
128	Durban	9	1	7	10	12

Source: ICCA (2009)

South Africa is experiencing an absolute and relative increase in global business tourism events hosted (Table 10), and CTICC accounts for the lion share of this business (Table 11). In fact, Cape Town hosts over 10 per cent of all business tourism events in Africa (SA Tourism 2010). Between 2000 and 2009, although Cape Town attracted only between a fifth and one half of the events organized in Barcelona, 87 per cent of its business was global, compared to 38 per cent in Barcelona which was generated half of its events in Europe. Put differently, the share of international organizations from Europe and North America in Cape Town's event portfolio (81%) is similar to Vancouver's (89%). Although Cape Town specializes in events with up to 500 delegates, in 2009 it hosted relatively more events with more than 3,000 delegates than Vancouver, Barcelona, or Perth. The total number of business tourist delegates in Cape Town in 2009 was a fourth of that in Barcelona, but two to six and a half times as high as in Vancouver, Durban, or Perth (International Congress and Convention Association 2010).

CTICC has proven somewhat more resilient to the recession than other (long-haul) destinations. Business tourism events differ in complexity. CTICC has been able to attract some of the most complex and leading congresses in the world (see Table 12).

Table 12 -- Host cities of leading world congresses

Congress	Host cities				Capacity
World Congress of Anaesthesiologists	Sydney (1996)	Paris (2004)	**Cape Town (2008)**	Rio de Janeiro (2012)	10,000
World Congress of Gynaecology	Chile(2003)	Kuala Lumpur(2006)	**Cape Town (2009)**	Rome (2012)	5,000
World IAS HIV Pathogenesis Treatment and Prevention	Sydney (2007)	**Cape Town (2009)**	Rome (2011)		5,000
World Congress of Medical Informatics	San Francisco (2004)	Brisbane(2007)	**Cape Town(2010)**		4,000
International Congress of Actuaries	Paris(2006)	**Cape Town(2010**)	Washington (2014)		5,000

Source: CTICC (2010)

In the technological package that distinguishes convention centres, bandwidth is CTICC's weakness. But otherwise there is no indication of a technological gap between the leading convention centres and CTICC. The systems and software requirements that are needed to host a successful event exist in Cape Town. This is reflected in rising market share. CTICC has secured business as far ahead as 2013 when it will host the World Critical Care Conference and the International Federation of Dental Hygiene.

4 Conclusion

This study has found that frontier technologies exist in Cape Town and that both local and foreign firms use them. This is not a trivial finding -- the introduction argued why catch-up and competitiveness in the global knowledge economy are difficult to conceive of in the presence of a large distance between technologies used locally and globally. It bears reiterating that -- with the exception of agro-processing where the assessment covered a number of organizations involved in a regional innovation network -- the study focused on individual, leading firms. The findings therefore only mean that some firms in their respective sectors use close-to-frontier technologies, not that the entire sector does. Conversely, no sector emerged in which frontier technologies were completely absent.

Since technological learning and upgrading is a dynamic process, what matters is not so much whether local firms are at the frontier -- because by definition only a few ever will be -- but whether they are aware of activities at the frontier and are in a position to select which are necessary for their competitiveness, and absorb and utilize them. So the key strategic

challenge is not the mastery of some theoretical endpoint of frontier activity, but through which trajectories firms get there. The fieldwork in combination with the research on core technologies in the various sectors confirmed that lead local firms are indeed aware of frontier technologies, regardless of whether or not they make use of them. To borrow from Plato's parable of the cave, the selected firms do not sit in the dark, caught in some suboptimal equilibrium where their technological trajectory is determined more by incomplete information or sheer ignorance rather than their strategic competences.

There are important differences across lead firms in the various sectors. The Schlumberger subsidiary has in-principle access to frontier technologies through its parent company but does not currently operate it because it is not involved in the kind of drilling support that necessitates this technology. A few construction firms and most retailers use frontier technology not at all or minimally. The former currently have little incentive to upgrade their processes, while retailers gradually implement changes pioneered by global firms in the US and Europe. In agro-processing and the creative and financial sectors, frontier technologies are used in some ways but are lacking in others. Only in BPO and business tourism do frontier technologies seem to be part and parcel of the capabilities of local firms.

By contrast, only in agro-processing and finance are local firms involved in developing such technologies themselves. In all other activities, core technologies are knowledge external to local firms who need to access them through technology transfer, embodied in capital goods, or mobile knowledge workers.

Only in a few examples does the technology gap identified reflect a reality specific to Cape Town. For example, in construction, retail, BPO, and finance, technology gaps are essentially sector-specific and affect local firms as much as those in Johannesburg or elsewhere. In the creative sector, some industry insiders claim that Cape Town as a location is becoming more important than the other film centre in Johannesburg. Due to the scale effects mentioned in Section 3.4, this might imply that the technology gap in the Western Cape film industry will shrink compared to the one in Gauteng. Similarly, the gaps in oil and gas and also in agro-processing are specific to the Western Cape because a major part of these industries is located in and around Cape Town. For example, of the 25 projects currently being researched in the context in the Post-Harvest Innovation Programme (Post-Harvest Innovation Programme n.d., 101-102), only one is located in KwaZulu-Natal and three in Gauteng; all others are in the Western Cape. In some activities it therefore appears easier to exploit technological opportunities in Cape Town rather than in Gauteng.

The analysis also suggests the key challenges for a narrowing of the technology gap and what role policy might play (see Table 13). The critical factors are firm capabilities, the role of demand, and created assets. Not surprisingly, firm capabilities are a key constraint in many sectors. This does not mean that firms have weak capabilities. But they struggle with increasingly complex knowledge bases whose combination and integration is required to approach the frontier. This is especially evident in agro-processing and also in the film industry. In agro-processing, the public good character of the linkages between the main actors in the regional innovation system means that public policy could reinforce especially the linkages between industry and universities and other research organizations. In film, firms are not yet in a position to design the requisite software, which is where the frontier lies and where competitive advantages are generated but the City cannot possible influence the supply of such highly specialized human capital. In sectors where the core technology is

known and in principle available, such as in retail, local firms must learn about its relative advantages and to what extent they would benefit from it.

In sectors where the parent company holds the critical technology -- oil and gas, BPO, and finance -- it is important that technology transfer takes place and contributes to technological upgrading. The literature review for this project (Lorentzen 2010) underlined that the technological sophistication of foreign direct investment very much depends on local absorptive capacities; if the latter is not commensurate with external knowledge, such knowledge is unlikely to yield lasting (productivity) benefits and to contribute to a narrowing of the gap.

In oil and gas and in construction, the major constraint is the lack of demand. Growth in the demand for oil and gas services from West Africa and elsewhere hinges largely on the creation of an offshore supply base whose future is currently uncertain. In construction, the technology gap could be narrowed by changing building legislation to reflect a more carbon-conscious urban design footprint. The City has a role to play in this respect because it can certainly influence demand for new technologies through its own buildings that need to be refurbished or through new ones that need to be built.

Another key constraint in the creative sector and also in BPO and tourism is the lack of bandwidth. This is a created asset where the City could relatively easily make a big difference.

In sum, the technology gap between local and leading global firms does not seem to be the biggest constraint to future competitiveness in the global knowledge economy for the business environment in Cape Town. In areas where the gap is low, the key challenge is diffusion. Where it is high, local government can influence technological trajectories in some sectors through demand-driven innovation (e.g. public procurement or changes in the regulatory regime), also because this reduces the uncertainty that might otherwise stifle innovation. Where science is an important input to technological advance, as in agroprocessing, local government can help foster linkages between knowledge producers (i.e. local universities and research institutes) and users, especially if those users have traditionally innovated through technology adoption and never undertaken R&D themselves (cf. Huang, Arundel, and Hollanders 2010).

The purpose of this study was to assess whether leading firms in Cape Town develop, use, or are at least aware of frontier technologies. The answer is yes. This is good news. But the really important question is how much of advanced technology is diffused more broadly in the local economy. In turn, this depends on the upgrading modes of the firms that are not in the lead, but rather adopt or adapt or re-engineer technology. This is worth finding out about and crucial for an evidence-based economic development policy.

Table 13 -- Frontier technologies and technology gaps in Cape Town

	Aware of frontier technology?	Using frontier technology?	Developing frontier technology?	Gap/achievement specific to WC/CT?	Key issues for narrowing the gap	Role for policy
Agro-processing	Yes	Partially	Yes	Yes	(1) Firm capabilities: investments in R&D and innovation. (2) Demand: regulatory environment	(1) Champion agro-fo incentivize networks. Influence national standards
Oil and gas	Yes	Yes (in principle)	No	Yes	Demand: creation of an offshore supply base	Clarify future role o oil&gas
Construction	Yes	Minimally	No	No	Demand: regulatory framework	Introduce green build standards
Creative sector (film)	Yes	Partially	No	Partially	(1) Firm capabilities: investments in highly specialized skills and hardware. (2) Created assets: broadband	(2) Create more bandv
Retail	Yes	Minimally	No	No	Firm capabilities: learning and upgrading	None
BPO	Yes	Yes	No	No	(1) Firm capabilities: technology transfer. (2) Created assets: broadband	Create more bandwi
Financial services	Yes	Partially	Yes	No	Firm capabilities: technology transfer, investment in R&D and innovation	None
Tourism	Yes	Yes	No	Partially	Created assets: broadband	Create more bandwi

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