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## A TECHNOLOGY GAP ANALYSIS OF LEADING FIRMS IN CAPE TOWN



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**Abstract**

This paper addresses technological learning in Cape Town's principle economic activities. The relative role of demand, capabilities and created assets in technological learning is explored; and how such learning results (or not) in bridging existing technology gaps. Local firms were interviewed and eight sectors were compared. Results show that demand, capabilities and created assets have had large positive effects on narrowing the gap in different sectors; to the extent where firms in the agro-processing and financial sectors are developing frontier technologies. However, where the determinants of catch-up are lacking, technology gaps are evident. In particular, a lack of market demand and global competition in the construction and retail sectors has inhibited technological upgrading.

Keywords: Technological learning, technology gap, catch-up, global competitiveness, knowledge economy, Cape Town.

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## 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 do 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 the developing world as a whole, penetration rates of both new and old technologies remain rather low (Jung and Lee 2010). Within Africa, South Africa is a special case in so far as it is a highly unequal society, with both weak and highly developed firm capabilities. Under such circumstances it is not particularly meaningful to look at national averages, which is why this study addresses catch-up where firms are competing closer to the technological frontier, namely in one of the continent's most knowledge-intensive urban agglomerations. Cape Town is one of the two technologically most advanced metropoles in South Africa (OECD 2008). This paper focuses on leading firms in eight of Cape Town's principal economic activities, namely retail, agro-processing, finance, business process outsourcing, construction, oil and gas, the creative industries, and tourism.

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. 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 (Cohen and Levinthal 1990).

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. There are 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 (Silberglitt et al 2007), factors likely to hold back this process include inadequate infrastructure, insufficient technical literacy, and a lack of high-quality human capital.

### 1.1 Demand, capabilities and created assets

Without the demand for new products there is little incentive for firms to narrow the technology gap or innovate. Manufacturers often innovate in response to advanced or stringent market demand. Innovation by domestic manufacturers is also supported by links to innovating lead users (von Hippel 2005). Hence the catch-up is influenced by the level of global exposure and competition in the market. The global exposure of firms can also affect their absorption and diffusion of technologies by exposing them to the frontier technologies employed by competitors. Multinational enterprises can create cross-border knowledge flows through foreign direct investment, international technological and scientific collaborations, trade, licensing and cross-patenting activities. These mechanisms for cross-border knowledge flow are impaired in sectors where global exposure and competition is low (Fagerberg and Godinho 2005). Conversely, firms opening in markets with strong global competition have to adapt to global product innovations. The trend towards greater information flow for buyers gives consumers greater product information awareness, and creates a demand for world-class products. Global market exposure can therefore have a profound effect on consumer demand (Porter 1986).

Regulations and government policy can have both intended and unintended consequences for consumer demand and technology diffusion. In the United States for example, regulations permitted unlimited local land-line calling for a fixed monthly rate, whilst in Europe rates were proportional to usage. Unlimited monthly lower the cost-to-consumer of land-line internet access and promoted the early diffusion of internet usage, e-mail and instant messaging in the United States relative to other developed economies. Only with the later introduction of monthly charges for ISDN internet in Europe did internet usage begin to spread rapidly. On the other hand, text messaging and other mobile phone technologies diffused more rapidly in Europe and Japan where the relative costs over wireless networks were lower. Again these lower costs were due to the regulatory environment (Fagerberg et al. 2005).

Firm capabilities are central to reducing technology 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).

R&D investment plays a role in developing a country's technological capabilities. However 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).

Building technological capabilities cannot be achieved without the requisite skills within the labour market. Findlay (1978) identifies a higher educational level of the domestic labour force as a factor that can increase the rate of technology diffusion from foreign to domestic firms. Fagerberg and Godinho (2005) argue that created assets such as the educational system, physical infrastructure and legal system are important determinants of developing country catch-up. In fact only countries who have invested considerably in these areas have been able to catch up in the post World War II period. More specifically, technological capabilities and a specialisation in services were also found to be relevant to catch-up in the 1980 and 1990s Fagerberg and Godinho (2005).

The remainder of the paper is structured as follows. Section 2 explains the methodology. Section 3 discusses technology gaps in Cape Town's most important economic activities, and offers explanations for existing gaps. 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.

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 Figureido'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. In each of the eight sectors 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 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] However this study focuses on Cape Town's role 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

[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.

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 (see Table 1), 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. Table 1 lists the 16 frontier technologies under their respective sectors. The table outlines what the technology is and what it does under the 'function' heading. Drivers summarises what compels firms to use the technology. Drivers are important as an indication of the usefulness of the technology, and whether or not the motive to use it is profit driven. The last two table columns list leading firms using the technology globally and locally. The use of frontier technologies by leading companies reaffirms their worth. It is also essential to know which local firms are using the frontier technologies to analyse technology gaps between global and local industry leaders.

## 3 Table 1 – Selected technologies

| Sector | Technology | Function | Driver | Lead global firms | Lead local firms |
|---|---|---|---|---|---|
| AGRO- | 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. | Less energy used than with heat pasteurisation, increase of shelf life for milk, and health benefits from sulphur reduction in wine. | McCain Foods, Wal-Mart | Lombardi Foods, SteenbergVineyards, L'Ormarins, Alluvia, and Stellar Organics, SAB Miller |
| AGRO- | Controlled Atmosphere (CA) | CA is used to increase the storage life of perishables. It maintains the quality of post harvest perishables better than other methods. Used in pack houses and 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 |
| CONSRTUCTION | Green Building | Green building changes traditional construction techniques by altering designs, promoting the better use of materials, recycling resources, and using 'green' materials. | Green building techniques and practices reduce waste and minimise energy and resource consumption in the long term. | 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) |
| CONSRTUCTION | 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. | More concrete planning of buildings. 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 |
| CONSRTUCTION | 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' are assembled on site. | Standardisation and economies of scale. Greater speed of construction. Early returns on investments. Efficient factory production. Less waste. | Skanska, BoKlock, Ikea (Sweden) | South African construction companies have used factory-built construction methods on select projects. |
| OIL & GAS | 4D seismic reservoir monitoring. Repeated 3D seismic surveys creating time-lapse images of fluid and pressure fronts in reservoirs. | 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 allows technicians to optimise drilling. | Reduces the risk and cost associated with drilling. Optimising placement of new wells, locating undrained reservoir compartments etc. | Schlumberger and its specialist 4D seismic subsidiary, WesternGeco. Patented Q-marine high-definition scanning system. | Schlumberger subsidiary |

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

Source (construction): GBCSA (2010a) GBCSA (2010b) Watson (2009) CIOB (2008) Fox (2010) Group Five (2009) Conradi (2009) HOCHTIEF ViCon (2009) Atkins and Tekla (2010) Tekla (2009) Neelamkavil (2008) Rogan et al. (2000) BoKlok (2010) Skanska (2010)

Source(oil and gas): WesternGeoco (2010), Schlumberger (2002), Lumley (2004)

| | Technology | Function | Driver | Lead global firms | Lead local firms |
|---|---|---|---|---|---|
| CREATIVE | 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 code conversion into high-quality images. This speeds up the value chain. | Pixar Animation Studios | Triggerfish Animation |
| | Post-production software | Raw audio and visual footage are treated and refined and combined with digital content. This may include 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 |
| RETAIL | Radio Frequency Identification (RFID) | Microchips are programmed to store information about a product, shipment, or other tagged items. Multiple tags can be scanned simultaneously using radio waves. | 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 | The instantaneous processing and coordination of value chain activities. Tracking inventory, in real-time, from warehouses to the point-of-sale. | 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. |
| BPO | 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 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 staff and customers. | Teleperformance (F), Accenture | Teleperformance, Accenture |

Source (creative): E-Film (2010), Animation SA (2010a and 2010b), Millimeter (2010)

Source (retail): Mujtaba and Maxwell (2007), CXO (2010), Retail Technology Review (2009), SPAR (2010), Metro Group (2005), Chan (2007)

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

| | Technology | Function | Driver | Lead global firms | Lead local firms |
|---|---|---|---|---|---|
| FINANCE | Cloud Computing | Access IT services over networks such as the internet or a private intranet. Rent processing capabilities, storage capacity, networking, and software as a service (SaaS) from a third-party provider on a pay-as-you-go basis. | Costs of maintenance, upgrades or new installations are shared. Flexibility to upscale or downscale operations rapidly. Economies of scale achieved. | 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 |
| TOURISM | 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 (finance): Federal Financial Institutions Examination Council(2005), ABSA (2010), Standard Bank (2008), Sawas (2006), Deloitte Touche Tohmatsu (2010), MacSweeney (2009), James (2010), Crosman (2010), Enerprise Innovation (2009), Data Innovation (2010), Njenga (2009), Roettgers (2009)

Source (tourism): ICCA (2009).

## 4 Technology gap analysis

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.

Table 2 lists the eight focus sectors and any corresponding insufficiencies in demand, capabilities and or created assets. The fifth column shows that lead firms in all the sectors are aware of frontier technologies; this was revealed in firm interviews and is an important first step towards bridging technology gaps. If firms are conscious of activities at the global frontier then any existing technology gaps cannot be explained by unawareness. Then focus is then on demand, capabilities and created assets for possible explanations. The sixth column indicates the level of frontier technology use in each sector. Firms may use their sector's global frontier technologies only minimally. If firms make use of a number, but not all, frontier technologies, they are classified using them partially. There is no technology gap if firms are using all of the sector's frontier technologies. In agro-processing and financial services firms are moving the frontier themselves through innovation, as is indicated in the seventh column.

**Table 2 – Summary of explanations for technology gaps in the eight sectors**

| Sector | Capabilities | Demand | Created Assets | Aware of frontier technology? | Using frontier technology? | Developing frontier technology? |
|---|---|---|---|---|---|---|
| Agro-processing | Greater investments in R&D and innovation required | Excellent global exposure, but further regulatory reform required | Good | Yes | Partially | Yes |
| Construction | Good | Global competition low, regulatory reform required | Good | Yes | Minimally | No |
| Oil and gas | Good | Requires an offshore supply base | Good | Yes | Yes (in principle) | No |
| Creative Sector | Greater investments in highly specialised skills and hardware required | Good | Costly/insufficient bandwidth | Yes | Partially | No |
| Retail | Lacking learning and upgrading capabilities in select areas | Global competition low | Good | Yes | Minimally | No |
| BPO | Good | Good | Costly/insufficient bandwidth | Yes | Yes | No |
| Financial services | Good | Global competition low (in banking) | Good | Yes | Partially | Yes |
| Tourism | Good | Good | Costly/insufficient bandwidth | Yes | Yes | No |

## 4.1 Demand

Demand is shown to play a role in technological catch up and innovation, especially in sectors where global exposure is high. In the **oil and gas sector** the MNE Schlumberger has operations in Cape Town. Schlumberger is the world's largest oil services firms, with approximately 77 000 employees in more than 80 countries. A subsidiary of Schlumberger based in Cape Town has access to all technologies in the group, allowing oil services in Cape Town to operate at the global frontier. Another firm 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 (Westvik 2010). There is demand for Cape Town's oil services from operations in West African oil producing countries, although the creation of an offshore supply base is required to service this demand. Whether establishing an offshore supply is in the city's best interests is at this stage uncertain (Westvik 2010).

The Western Cape **agro-processing sector** has high global exposure. Almost 43% of Western Cape exports are from the agriculture, forestry, fishing, food, beverages and tobacco sectors (Quantec EasyData 2008). Global clients expose the sector to world standards and innovations by competitors. In addition firms have to meet strict regulatory approval at both the local and international level. However local regulatory authorities have demonstrated that they are not open to approving first-to-world innovations and prefer the approval by international authorities first. Local regulatory bodies could assist the innovative activities and lessen the technology gap by opening the local market to the possibility of first-to-world products and processes.

The regulatory framework in the South African and Western Cape **construction sector** does not encourage the use of frontier construction technologies or city densification. Combined with a lack of global exposure and competition, there is little demand and therefore little incentive for local firms to move away from traditional techniques. Lead global firms have replaced the traditional 'brick and mortar' techniques with green building and factory built construction methods. 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). Green building techniques do tie in with some factory built construction techniques but primarily aim to lessen the environmental impacts of construction. The World Green Building Council which is the coordinating body for national Green Building Councils.

The US is one of the leading countries in green building. 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 globally, as the trade-off between building costs and energy efficiency becomes more favourable.

City regulations can also have a large impact on the demand for green buildings. The city of Vancouver in Canada for example has initiated a major EcoDensity initiative to combat urban sprawl and advocate carbon neutrality in all new buildings by 2030. The EcoDensity initiative is complimented by a transportation plan to ease congestion and pollution. This has boosted demand for green building technologies in the city (City of Vancouver 2010). 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. Citizens and firms in Cape Town have a green building rating system, yet there are only four registered projects and no completed green buildings, to date, in the city (GBCSA 2010b).

All of South Africa’s major construction firms were founded locally, hence global exposure is minimal. International firms are used on specialised large-scale projects, for example in stadium construction, where local capabilities are lacking.  Many of the frontier technologies used by lead global firms are not used extensively by local firms. For example, 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. A local firm, Murray and Roberts, has shown the capability of using Finnish BIM (Tekla) software on several projects in Dubai (Tekla 2009 and WS Atkins ME and Tekla 2010), however BIM is not used on South African construction projects. One possible explanation for the lack of frontier technology use could be a lack of global competition and global exposure in the South African market.

Little global competition also explains the technology gap in the South African **retail sector** to some degree. In 2010 US retailer Walmart initiated the process of buying one of South Africa’s major retailers, Massmart, but up to this point there has been no major competition. South African retail companies have adopted a wait-and-see strategy for some of the frontier inventory management and goods distribution technologies utilised by lead companies such as Walmart. Two frontier inventory management technologies not used by South African retailers are radio frequency identification (RFID) and real-time-value chain management technologies.

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 (CXO 2010, Retail Technology Review 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. On the whole, retailers in Cape Town and South Africa, while aware of the benefits, have not adopted these technologies. There is perhaps little incentive to do so with a lack of global competition.

In the **financial sector** 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. Mobile phones are becoming more commonly used for many banking functions and 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. Services are tailored for mobile users but also interchangeable between mobile and internet banking. 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 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).

South Africa has extensive mobile phone infrastructure and the use of mobile phones for internet access and banking is growing (World Wide Worx 2010). Absa (a large local bank) has 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 (Absa 2010) displaying capabilities in this area. But 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 and global competition.

Fraud will pose serious costs to banks regardless of the level of competition and one would expect there to be strong demand for frontier anti-fraud technologies in Cape Town. 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 (Sawas 2006). In South Africa, Standard Bank (one of the largest local banks) also utilises 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. As expected the technology gap with anti-fraud measures is small, with examples of banks in Cape Town using frontier technologies.

### 4.2 Capabilities

There are numerous examples of successful R&D and innovation undertaken in the Western Cape **agro-processing sector** demonstrating high capabilities. Some of these innovations have positive impacts on the sector. Locally developed technologies show that the industry has considerable knowledge creation potential.

An example of a first-to-the-world technology developed locally is a UV purification system used to inactivate bacteria and viruses in liquids, as an alternative to heat pasteurisation. The technology was developed by Surepure, a company based in Cape Town and recently incorporated in Switzerland. Tests by universities in the US and Western Cape have 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 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). The local subsidiary of Canadian multinational McCain Foods and a leading South African fruit producer are already using the technology during processing. US retailer Walmart, South African Breweries and other companies are also experimenting with the technology for which Surepure holds a worldwide patent.

Private firms, such as Surepure, are highly organised and supported by active industry associations. The well developed network of local universities and research councils, industry associations, and individual firms with whom they interact, are clearly at the forefront of knowledge production. The regional innovation system in the Western Cape agro-processing sector is strong and has demonstrated a high absorptive capacity and the ability to innovate. South Africa is the third largest deciduous fruit producer in the Southern hemisphere, after Argentina and Chile (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 controlled atmosphere (CA) to slow produce ripening, for this performance (Dodd et al 2008).

The Western Cape agro-processing sector is at the forefront of technology in some areas 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. 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).

Cape Town's **creative sector** is another area of potential growth for the city. The same temperate climate and terrain that is ideal for fruit production is also popular with the film industry. Firms have developed facilities for the production and post-production of feature films. Compared to international competitors, services are offered on a smaller scale (Stead 2010). Technological change in the film industry has been massive, with the introduction of digital cinema, computer animation, and stereoscopic 3D techniques. Post-production software and render farms are at the core of frontier film technologies.

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 specialised 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.

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 software 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. Hence, they would require investment in highly specialised skills to reach the technology frontier, and are currently behind it.

A render farm is a computer cluster built to render computer-generated imagery (CGI). 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. A render farm can be small or large. A small render farm is simply a network consisting of a few high-powered servers. 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. However, the power of a render farm is proportionate to its size.

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. 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.

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.

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 only 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 (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. For example ING Americas, the US arm of Dutch bank ING, have moved many of their internal processes into external cloud computing. 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).

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 (Fairweather 2010). 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. A few firms in Cape Town have been quick to take advantage of the technology and are operating at the technology frontier.

Capabilities in the creative sector are only insufficient where investment highly specialised skills and hardware is required. The same can be said for the **retail sector**, Upfold and Liu (2010) suggest that South African firms may lack the specialised skills required for RFID (see previous section) adoption.

### 4.3 Created assets

Cape Town's telecommunications infrastructure falls short in the area of bandwidth provision. Expensive and insufficient bandwidth affects all eight sectors negatively to some degree although the **tourism, creative and BPO sectors** are the most restrained. The creative sector is constrained in the ability of firms to send large amounts of multi-media electronically to clients and other firms (both local and foreign). High speed bandwidth is imperative, especially for companies working in conjunction with other creative industry firms abroad. The creative industries are global in nature and the bandwidth technology gap is a serious obstacle for Cape Town's firms.

Convention centres in the business **tourism sector** use large amounts of bandwidth as part of the audio, visual and other communication requirements for hosting large meetings. Technological sophistication is part of a larger package, consisting of infrastructure and hospitality factors, that determines the competitiveness of a business conference venue. The Cape Town International Convention Centre (CTICC) has the necessary systems and software requirements needed to host a successful event in Cape Town, although bandwidth is CTICC's weakness. Despite this 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. 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.

The **BPO sector** also relies heavily on bandwidth in order to relay and collect information over distances to and from customers and clients. One of the major cost saving strategies of leading contact centres is to 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 (Yahoo Finance 2010). One third of Whirlpool contact centre agents work from home.

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.

Bandwidth is sufficient in Cape Town to implement multi-channel contact centres. This technology allows 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. 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. 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.

It is only where large volumes of data transfer are required that BPO activities run into bandwidth shortages. For example data collection, metrics and data analysis (data mining) is used by BPO companies to maximise profit from every consumer. 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 and bandwidth shortages will impede data mining activities.

## 5 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.

The analysis also suggests the key challenges for a narrowing of the technology gap (see Table 2). 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 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 (Narula and Dunning 2009).

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 and a problem that if rectified by the City would benefit almost all sectors.

In sum, the technology gap between local and leading global firms varies greatly between sectors in Cape Town. Demand, capabilities and created assets all play important roles in technological learning and can largely explain technology gaps. Capabilities are sufficient in most sectors and only lacking the creative industries and retail where investment in highly specialised skills and hardware are required. Created assets are adequate besides a serious need for less costly and improved bandwidth. Local leading firms are aware of frontier technologies, and most firms use some of these technologies. Two sectors (namely agro-processing and finance) are even developing new-to-the-world innovations. The largest gaps are evident in the construction and retail sectors, where a lack of market demand and global competition has inhibited technological upgrading.

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