UNITED NATIONS UNIVERSITY

UNU-WIDER

World Institute for Development Economics Research

Research Paper No. 2008/92

Economic Proximity and Technology Flows

South Africa's Influence and the Role of Technological Interaction in Botswana's Diversification Effort

Alexis Habi Yaremye*

October 2008

Abstract

In less than a decade after the end of the apartheid, South Africa has intensified its economic ties with its African neighbours to become one of the top-ten investors and trading partners of many African countries, displacing companies from the former colonial powers in Europe. Among such South Africa's closest trade partners, Botswana has enjoyed one of the highest growth rates in the world for several decades, thanks to its rich mineral reserves, but its diamonds-dominated export structure has barely changed over this growth period. In a national endeavour to reduce its dependence on diamond exports, Botswana recognizes the importance of adopting foreign technologies and deploys sustained efforts to move to high value-added activities in other industries. Since the successful adoption of new technologies requires active technological learning, this paper takes the national innovation systems (NIS) approach and uses industry level panel data to analyse the role played by the proximity and interactions

…/.

Keywords: innovation systems, technological learning, diversification

JEL classification: O19, O32, O33

* UNU-MERIT, Maastricht, email: habiyaremye@merit.unu.edu

This study has been prepared within the UNU-WIDER project on the Southern Engines of Global Growth, co-directed by Amelia U. Santos-Paulino and Guanghua Wan.

UNU-WIDER acknowledges the financial contributions to the research programme by the governments of Denmark (Royal Ministry of Foreign Affairs), Finland (Ministry for Foreign Affairs), Norway (Royal Ministry of Foreign Affairs), Sweden (Swedish International Development Cooperation Agency—Sida) and the United Kingdom (Department for International Development).

ISSN 1810-2611 ISBN 978-92-9230-146-0

between the economies of South Africa and Botswana in the process of technological learning within Botswana's manufacturing sector. Our analysis of the learning attributes based on three categories of technology flows reveals that Botswana's technological learning process has been an increasing function of the extent of trade and investment linkages to the SA economy and the intensity of their interactions.

Acknowledgements

I wish to thank Denis de Crombrugghe and Vladimir Raymond for insightful discussions during the drafting of this paper. I am also grateful to Daniel Chitsulo, Leah Ogtakazi and Seema Boitumile for their precious help in the access and compilation of the data. My special thanks are further owed to Mrs Mien Vink of the Dutch General Consulate in Gaborone as well as to Ms Leonie, Chargée d'Affaires of the Royal Dutch Embassy in Harare for their excellent consular assistance during my stay in Gaborone (July-September 2006). Financial support of UNU-MERIT is gratefully acknowledged.

Acronyms

Acronyms given at the end of the paper.

UNU World Institute for Development Economics Research (UNU-WIDER)
Katajanokanlaituri 6 B, 00160 Helsinki, Finland

Typescript prepared by Liisa Roponen at UNU-WIDER

1 Introduction

Sound management of its large diamond revenues has allowed Botswana to achieve remarkable growth rates over several decades and the country seems thus a potential candidate for technological catch-up with industrialized countries. However, in spite of consistent efforts aimed at economic diversification, the country's economy is still heavily dependent on raw diamond exports and faces many challenges in its efforts to move to high value-added activities in other industries. In contrast, its neighbour, South Africa, is the economic and technological engine of Africa, with world-class academic institutions as well as cutting-edge technological leadership in some domains. By mastering foreign technologies through interactions with South Africa and adopting them in domestic production, Botswana has the potential to secure a source of long-term growth and converge to the productivity of industrialized nations. Botswana's geographic and economic proximity with South Africa is thus perhaps its most important trump for a successful technological catch-up and long term-growth.

The tacit nature of technological knowledge often renders face-to-face contact a necessity for technology to diffuse because knowledge circulates best locally (Kesidou and Szirmai 2007). This explains why geographic proximity is important for technological learning by facilitating direct interactions and knowledge diffusion. Our argument that Botswana can derive many productivity and growth advantages from its interactions with South Africa is also rooted in the various theories of international knowledge flows and their implications for economic performance of the recipient. These theories stress the importance of knowledge as a weightless production factor that can diffuse across national borders through various channels, such as trade and investment flows that embody technological knowledge as well as management knowhow and practices.

These theories emerge from the endogenous growth literature which emphasizes two mechanisms of international technological knowledge transfer: transmission of ideas that can be traded independently from goods and the trade in intermediate inputs and capital goods that incorporate new ideas, known as 'the lab-equipment model' (Rivera-Batiz and Romer 1991). Barba Navaretti and Tarr (2000) provide a detailed review of the various theoretical models dealing with trade and knowledge diffusion. These theoretical insights are confirmed by substantial empirical evidence such as Coe and Helpman (1995); and Keller (1997, 2002).

However, the amount and degree of sophistication of technology that developing countries can adopt and efficiently utilize, depend among other factors, on their supply of technical and managerial skills and their interactions with technologically more advanced countries. For many, if not most developing countries, catching up technologically depends on the extent to which they are able to learn and position their systems of innovation to best take advantage of knowledge flows from developed as well as from other developing countries. Economically successful countries are those that have been able to transform scientific knowledge and technical innovation into profitable economic productivity. Such economies have succeeded technologically because they possess a complex, integrated system of human capital, infrastructures, and institutions for translating new knowledge and innovation into economically viable new products and processes (Feinson 2003). Such systems, now known as 'national innovation systems (NIS) or national systems of innovation (NSI)', have increasingly been recognized both as a supplement and as an alternative analytical framework to standard macroeconomic perspective on development

This paper takes the NSI approach to analyse how economic proximity with South Africa affects knowledge flows to neighbouring Botswana and facilitates its effort to reduce dependence on diamond exports. We analyse the knowledge flows between the economies of South Africa and Botswana by examining three transmission mechanisms, namely import of capital goods, cross-border equity investments, and technology licensing. By relating the intensity of interactions to the measures of technological learning achieved by the various manufacturing industries in Botswana, we are able to evaluate their ability to adopt, internalize, and diffuse new technologies, and thereby contribute to the country's diversification effort. The remainder of the paper is organized as follows: the next section delineates the NSI functions as they explain the interactions and knowledge flows between various actors in these two neighbouring countries, and explains how it can serve as a framework to analyse technological learning. Then section 3 presents the existing interactions and outlines a theoretical model linking three categories of business interactions and knowledge flows on the one side to the manufacturing productivity and skills upgrading on the other. The findings are discussed in section 4 while the final section summarizes and concludes the paper.

2 NIS as analytical framework for knowledge flows

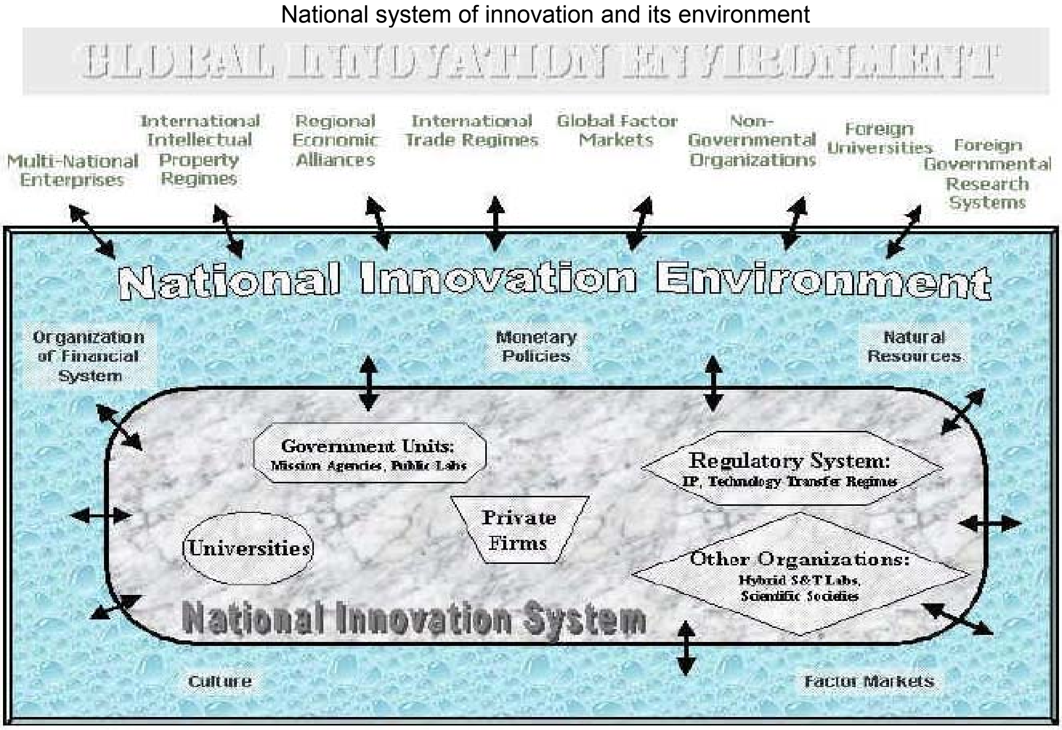
2.1 Actors, institutions and linkages in a national system of innovation

According to Lundvall (1992), the concept of national systems of innovation can be traced back to Friedrich List (1841), who took into account a wide set of national institutions (such as those engaged in education and training) as well as infrastructures (like networks of transportation of people and commodities) as crucial to the development process of productive forces. The modern revival of this concept has emerged some 20 years ago under various approaches including the Aalborg University approach (Lundvall 1985) and the US approach (Nelson 1988). This notion of NSI was introduced into contemporary debate by Freeman (1987: 1) who defines it as 'the network of institutions in the public and private sectors whose activities and interaction initiate, import modify and diffuse new technologies'. As a prominent actor in NSI, the government has the responsibility to contribute to the formation of the human and social capital needed to evaluate, choose, implement, and modify foreign technologies.

Various attempts have been made to schematize the flow of information and resources between environment and national systems of innovation, and to map the actors and linkages that make them function. An analytical distinction has been made between a narrow innovation system concept, which includes the institutions and policies directly involved in scientific and technological innovation and a broad NSI perspective which takes into account the cultural, social, and political environment of the country being examined. The narrow version is an integrated system of economic and institutional agents directly linked to the promotion of the generation and use of innovation in the national economy (Adeoti 2002), whereas the broad version includes, in addition to the components of the narrow system, all economic, political, and social institutions affecting learning, research and innovation activities.

Schematically, NSI can thus be represented as a systemic structure of people, organizations, and institutions interacting to fulfil various interconnected functions that are essential to effecting technological change (Figure 1). Alternatively, it can be represented as a set of actors, institutions, and linkages that together implement the innovation strategy. To understand the functioning of innovation systems, it is indispensable to conceptualize the knowledge flows and linkages among its actors.

Figure 1
National system of innovation and its environment

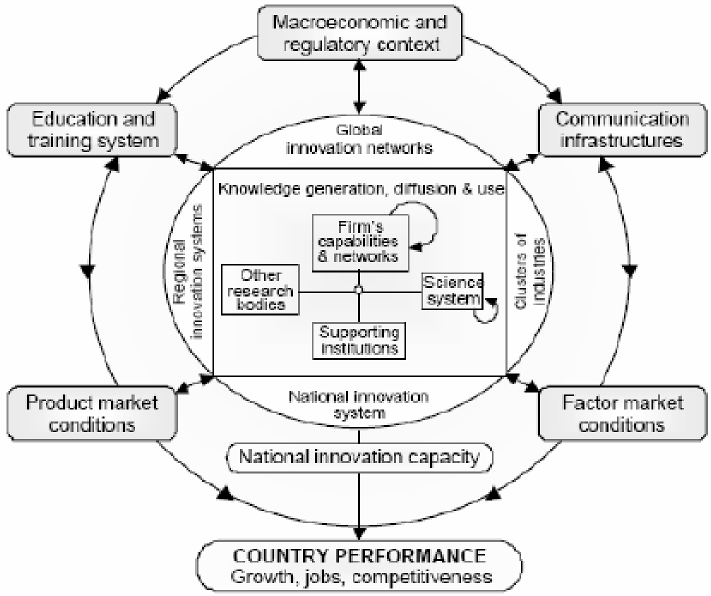


Source: Bozeman et al. (2003).

The broad definitions of NSI include, in addition to the above components, all the institutions affecting learning and research in a country, e.g., the financial system, monetary policy, internal organization of private firms, the pre-university educational system, labour markets regulatory policies, and institutions. Conceptually, the narrow system is embedded within the broad system as depicted in an OECD schematic representation of Figure 2.

The NSI linkages which reflect the absorptive capacity of the entire system are determined by the flow of knowledge and resources between the narrow and the broad levels and amongst the institutions and organizations via the formal and the informal channels. The individual institutions that make up both the broad and the narrow innovation system are important, but the intensity and variability of knowledge flows among constituents of a national system are the critical determinant of its functioning (Feinson 2003). For this reason, it has been suggested that policymakers should shift their interest from steady structures and absolute measures of innovative activities to the different types of interaction among actors within and beyond the boundaries of a national system of innovation.

Figure 2
Actors and linkages in the innovation system



Source: OECD, Managing National Innovation Systems, 1999

While a great variety can be found in national economies and tremendous complexities exist within the systems themselves, it is possible to identify the key actors and main functions of innovation systems. According to the OECD (1999), innovation systems' institutions and actors, defined in the narrow context, can be divided into five main categories:

- Governments (local, regional, national and international with different weights by countries) that play a key role in setting broad policy direction;
- Bridging institutions such as research councils and research associations which act as intermediaries between government and the performers of the research;
- Private enterprises and research institutes they finance;
- Universities and related institutions that provide key knowledge and skills;
- Other public and private organizations that play a role in the national innovation systems (public laboratories, technology transfer organizations, joint research institutes patent offices training organizations, etc.).

The production of technological knowledge is not sufficient to generate technological innovation. The critical role of NSI is the circulation of knowledge and resources between enterprises and other actors involved in the implementation technological progress. For innovation systems to be a catalyst of sustainable technical change, they must fulfil the following functions, as stressed by Johnson (2001):[1]

[1] Alternative lists of NSI functions have been suggested by Rickne (2000); Johnson and Jacobson (2001); Liu and White (2001); Jacobson, Sanden and Bangens (2004) and Hekkert et al. (2005), but all share the same core functions and attributes.

- Supply of incentives for firms to engage in innovative activities;
- Supply resources (capital and competences);
- Guide the direction in which actors deploy resources;
- Recognize the potential for growth;
- Facilitate the exchange of information and knowledge;
- Stimulate/create markets;
- Reduce social uncertainty about how others will act and react; and
- Provide legitimacy for the innovation.

Hekkert et al. (2005) propose a set of indicators that may be used to assess the fulfilment of these functions in a system of innovation. As a result of interactions among the various functions, they may have reinforcing features, as the fulfilment of a given function might have a positive effect on the other and vice versa. Thus, the overall performance of the system is to be assessed on the basis of the overall diffusion of technology over time.

2.2 Distinguishing between developed and developing countries' NSI

The application of NSI as a framework of analysis must be articulated around the various functions that national innovation systems perform. This means that countries, industrial sectors and firms assess their success in effecting technological change by evaluating the overall performance of the functions of their innovation systems. However, as a consequence of contextual and institutional differences between the innovation system of the developed and developing countries, it has been argued that developing countries need their own specific approach to NSI (Juma et al. 2001). One of the arguments in favour of specific approach to NSI in developing countries is that NSI are more at odds with neoclassical theories of growth in developing countries as indicated by Lundvall (1997). This has led Edquist (2001) to propose the concept of systems of innovation for development (SID), which has a number of key differences with the NIS approach taken in developed countries:

- Product innovations are more important than process innovations because of the effect on product structure;
- Small, incremental innovations are more important and more attainable than radical ones;
- Absorption (diffusion) of existing technologies is more important than the development of innovations that are new to the world;
- Innovations in low- and medium-technologies are more attainable than those in high-technology systems or technology frontier.

Under this approach, the most important attribute of NSI is to stimulate technological learning. Though not sufficient alone, active learning is a necessary condition to achieve long-term sustainable development. This explains why development scholars have put emphasis on the building of absorptive capacity by developing nations or their ability to acquire, learn, and implement the technologies and associated practices already in use in developed countries (Dahlman and Nelson 1995). The promotion of learning and national absorptive capacity through various NSI components is thus indispensable for long-term industrial and economic development. We now turn to some of the elements of the systems of innovations in both South Africa and Botswana in order to examine how these stimulate interactions and technology flows between the two countries.

3 South Africa and Botswana's NSI, economic proximity and interactions

3.1 Technological capabilities and potential for knowledge flows

According to the OECD (1987), economic growth arises over the longer term from the interplay of incentives and technological capabilities within an institutional framework. Lall (1992) groups technological capabilities at the national level under three broad headings: *physical investment, human capital, and technological effort*. Incentives comprise three broad categories: macroeconomic stability, competition, and factor markets conditions**.** Finally, institutions reflect the rules of the game that emerge from the functioning of the market and facilitate transactions, interactions, and learning. Institutions act to alter capabilities and change incentives and they can modify behaviour by changing expectations and attitudes. Following Lall (1992), we use this three pronged approach involving the interplay of incentives, capabilities and institutions to analyse numerous factors influencing technological learning that takes place as a result of the interaction between South Africa and Botswana. A brief overview of the South African and Botswana's NIS capabilities, incentives and institutions is provided in Appendixes A (South Africa) and B (Botswana) to allow for an assessment of the potential for knowledge flows between the two countries.

South Africa's innovation system is characterized by relatively strong capabilities, a comprehensive incentive system and innovation friendly institutions. With a PPP-adjusted gross domestic product (GDP) estimated at US$576.4 billion for 2006 (US$13,000 per capita), which is 25 per cent of the entire continent's GDP, South Africa is the economic and technological powerhouse of Africa and represents a great opportunity for its neighbours as a source of much needed technological knowledge. The country leads the continent in industrial output (40 per cent of total output) and mineral production (45 per cent). Its major strengths include its physical and economic infrastructure, natural mineral and metal resources, a growing manufacturing sector, and strong growth potential in tourism, higher value-added manufacturing, and service industries. Being one of the lowest-cost energy producers in the world, it supplies two-thirds of Africa's energy requirements and many of its 23 universities are world-class academic institutions, with leading technological capabilities in some domains of research such as liquid fuels and atomic energy.

Like other industrializing nations, Botswana has increasingly recognized that successful economic development is tightly linked to the capacity to acquire, absorb, apply, and disseminate modern technologies within its economy. However, since most of technological innovation takes place through deliberate research and development (R&D), and world R&D activities are highly concentrated in a small number of industrialized countries, Botswana will have to depend on technological knowledge developed outside its borders. Even among advanced countries, empirical evidence shows that the major source of knowledge progress leading to productivity growth in these countries is not domestic but rather international (Coe and Helpman 1995; Eaton and Kortum 2001; Keller 2001, 2004). Since most developing countries like Botswana lack the needed facilities and technological requirements to efficiently produce capital equipment embodying the needed technology, importing them is typically an important channel for acquiring the corresponding technology.

Thanks to its impressive diamond deposits and its geographical proximity with the South African economy, Botswana is thus well poised to benefit from mastering and applying technologies that already exist in its southern neighbour. However, the engineering and management skills required in acquiring the capacity to optimize resources and assimilate the acquired technology are not trivial. Various kinds of high quality training are needed to embody in the personnel of the recipient firms the skills, knowledge, and expertise applicable to particular products and processes. Botswana's capabilities, incentive system, and institutions being relatively less strong than their South African counterparts, such resources are still insufficiently available and need to be further developed.

Notwithstanding these limitations, the economic and technological leadership of South Africa represents a huge growth opportunity for its neighbours and its potential is far bigger than any aggregated statistics can suggest. Indeed, South Africa can best be described as two countries: it consists of an urbanized industrial first-world component (56 per cent of the total population) at the one extreme and a deep rural, mostly black African, developing third-world component (44 per cent of the population) at the other extreme (NACI 2006). It is precisely this industrial South Africa that represents a potential source of economic diversification for Botswana and an opportunity for the reduction of its dependence on diamond exports.

The existing interactions between the two economies and the knowledge flows they represent are already indicative of the growth and diversification advantages of this proximity. Interaction with South Africa accounts for more than 60 per cent of total foreign direct investment stock in Botswana and more than 70 per cent of the needed capital equipment imports (Grobbelaar and Sotetsi 2005). Regional cooperation programs play a non-negligible role in facilitating these interactions. The most important is the Southern African Customs Union (SACU), in which free and unimpeded trade takes place among members. SACU consists of Botswana, Lesotho, Namibia, South Africa and Swaziland. Botswana sources the lion's share of its imports from its SACU partners, thus mainly from South Africa.

In line with the SADC[2] Regional Indicative Strategic Plan, which recognizes the importance of science and technology in stimulating economic development and regional economic integration, the African Cooperation Unit within the Department of Science and Technology (DST) is also responsible for engaging with SADC partners to develop and strengthen national systems of innovation so as to provide scientific and technological solutions for sustainable socioeconomic development. Over the past few years, the DST has engaged in a number of projects in policy and capacity development

2 Southern African Development Community (SADC) members are Angola, Botswana, Democratic Republic of Congo, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Seychelles, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe.

to achieve these objectives. Such interactions, although they undeniably contribute to facilitating or speeding up technological knowledge flows, fall beyond the scope of the current analysis.

Capital goods imports embodying technological knowledge contribute to knowledge flows, productivity growth and technological rent spillovers into the importing country as has been demonstrated among others by Keller (1995), Hakura and Jaumotte (1999), Mazumdar (1999), and Eaton and Kortum (2001). Cross-border equity investments contribute to technological knowledge flows by bringing capital, proprietary technology, technical skills training and advanced management practices to the host country, thereby increasing productivity and competitiveness of domestic firms (Djankov and Hoekman 1998; Aitken and Harrison 1992). Finally, licensing transfers disembodied technology in form of blueprints, designs, and production processes that enhance existing production methods and techniques in the host country. In addition to these market-transaction knowledge flows, various technological spillovers arise from demonstration effects (Akamatsu 1962), linkages (Gachino 2006), or allocative efficiency (Caves 1974).

Applying the above argument on Botswana's manufacturing sector, we can thus argue that manufacturing productivity growth is positively affected by the volumes of imports of capital goods, equity investments and the value of licensing agreements with technologically advanced countries in general and South Africa in particular. For the analysis of the effects of these knowledge flows, we use a panel of ten manufacturing industries, for which we relate the intensity of the above three indicators of interaction to the productivity growth and technical skills upgrading. Moreover, with the industrial sector in Botswana being narrower than that of industrial ones, we argue that the primary mechanism through which the acquisition of foreign technologies contributes to productivity growth is by widening the range of productive activities, especially by spurring new activities that can increase the diversity of export. In order to support this line of thinking, we extend the technological sophistication framework used by Hunt and Tybout (1999) by adding to it features borrowed from the capital goods trade framework developed by Mutz and Ziesemer (2005) and use it to investigate how Botswana has used imported embodied technologies to expand its industrial basis or upgrade its existing production techniques.

3.2 Trade, investments, productivity and technical skills upgrading

Mutz and Ziesemer base their model on a modified version of a two-gap growth model with imported inputs as introduced by Bardhan and Lewis (1970). That model emphasizes the insight that for developing countries, imported inputs paid for by export are the major mechanism of growth in the relation between export and growth in the short run, as advanced by Khan and Knight (1988). They go a step further than Bardhan and Lewis to develop a full fledged growth model in which:

i) Imported capital goods are the only source of investment in developing countries;

ii) All capital goods are paid for by the revenue from export;

iii) Export revenue is not used to import luxury consumption goods; and

iv) There is no debt and trade is balanced.

In this model the importation of capital goods and the elasticity of export demand contribute to explaining the growth behaviour of developing countries. The simplifying assumption made of no domestic production of capital goods is a fair approximation for many least developed countries and is thus suitable to analyse the case of Botswana. The growth of capital goods is thus constrained by the export revenue and can be written as:

$$\hat{K} = \frac{\dot{K}}{K} = p\frac{X}{K} - \delta, \hat{\hat{K}} = \hat{p} + \hat{X} - \hat{K} \tag{1}$$

where K denotes the capital stock, X represents the exports and p represents the terms of trade, defined as the price of domestic goods in terms of imported capital goods. A hat on a variable means a proportional growth rate while a dot on a variable represents change with respect to time.

Investments need to be paid for by domestic savings measured in terms of imported capital goods. The savings rate s is assumed to be a constant proportion of output and depreciation δK is a constant portion of the existing capital stock:

$$\hat{K} = \frac{\dot{K}}{K} = sp\frac{Y}{K} - \delta \tag{2}$$

Exports X are in turn assumed to depend on the trade partners' income, Z, and on the terms of trade p. For the sake of simplicity, a log-linear export function with a constant B and a stochastic term V is used:

$$X = BZ^{\rho} p^{\eta} V, \rho > 0, \eta < 0 \tag{3}$$

where ρ denotes the income elasticity and η represents the (negative) price elasticity of export demand.

By the relation between capital, output, import, and export:

$$\ln(\hat{K} + \delta) = \ln B + \rho \ln Z + (1+\eta)\ln p + \ln V - \ln K \tag{4}$$

In Hunt and Tybout (1999), product technological sophistication model starts from what they call the Lucas/Krugman/Stokey/Young (LKSY) view that growth is accomplished by concentrating resources in those goods whose production processes induce learning and knowledge spillovers. It was developed to relate firm- and plant-level technological sophistication of the manufactured products and the productivity growth rate associated with each product to the knowledge flow accruing to the analysed industries. For so doing, they distinguish between two mechanisms through which increasing sophistication can take place, namely the continual shifting of resources towards high-end products as predicted by the LKSY product spectrum models and a general increase in the intensity of skilled input use among all types of products. The latter is the kind of human capital deepening that provides an engine for growth in models that do not distinguish a spectrum of products in terms of their potential to generate learning.

In order to distinguish these two types of increases in the sophistication of production, the model decomposes the growth rate of manufacturing-wide technological sophistication, e, between two subsequent periods, t-1 and t as the sum of two components:

$$\frac{\Delta e_{jt}}{e_{jt}} = \frac{\sum_{j=1}^{J} \Delta e_{jt}\overline{\theta}_j}{e_{jt}} + \frac{\sum_{j=1}^{J} \Delta \theta_{jt}\overline{e}_j}{e_{jt}} \tag{5}$$

Here, e is the total number of technicians in manufacturing, expressed as a share of total manufacturing employment. Subscripts j and t indicate the industry and time period, respectively, θ_j is the jth industry's share in manufacturing-wide employment, an overbar indicates the simple average over two time periods, and Δ is the difference operator for the period t-1 to t. The same expression can be used, *mutatis mutandis*, to decompose changes in manufacturing-wide technician wages as a share of some manufacturing-wide normalizing variable (total wages, expenditures, or production).

The first term on the right-hand side captures the change in manufacturing-wide technological sophistication due to within-industry deepening of technical intensity, and the second term represents the reallocation of technically skilled workers across industries. If the second term is positive, then the technician-intensive industries are growing relatively rapidly, indicating the type of resource reallocation consistent with LKSY-type productivity growth. In contrast, if all of the change in aggregate technical intensity comes from intra-industry deepening, there is no evidence of this type of broad resource reallocation. Nonetheless, it may still be the case that within particular 3-digit or 4-digit industries, resources are being shifted toward high-end products, in which case further disaggregation is needed to detect the LKSY growth mechanism.

4 Estimating manufacturing productivity growth, sectoral expansion and skills upgrading in Botswana

4.1 Estimation model

We begin the analysis of manufacturing productivity growth by considering the relationship between manufacturing value-added (MVA) to the monetary value of investment in imported machineries used in the manufacturing sector over the period 1985 to 2005 for which data are available. To estimate this relationship we first assume a Cobb-Douglass production function with constant return to scale to labour and capital input factors. At this stage, the human capital factor in the form of skilled labour is ignored. We will deal with the intensity of skilled labour when we analyse the industry technical intensity. For each time period the output (MVA) is given by:

$$Y_t = A_t K_t^{\alpha} L_t^{\beta} \xi_t \tag{6}$$

where K_t represents the capital stock used in the manufacturing sector at time t and L_t the labour input in efficiency units, while A_t is the level of productivity or the technology factor at the same period and ξ_t a stochastic factor that captures measurement and observation errors. α and β are the usual input factor shares. Taking natural logarithms on both sides, we obtain:

$$\ln Y_t = \ln A_t + \alpha \ln K_t + \beta \ln L_t + \varepsilon_t \quad (7)$$

If we now subtract the expression at t-1 from Equation (7), we obtain the first difference equation between the two periods:

$$\ln(Y_t / Y_{t-1}) = \ln(A_t / A_{t-1}) + \alpha \ln(K_t / K_{t-1}) + \beta \ln(L_t / L_{t-1}) + \varepsilon_t - \varepsilon_{t-1} \quad (8)$$

The productivity growth can be derived from the previous expression by subtracting from the output growth the input-shares weighted growth in capital and labour, respectively:

$$\ln(A_t / A_{t-1}) = \ln(Y_t / Y_{t-1}) - (\alpha \ln(K_t / K_{t-1}) + \beta \ln(L_t / L_{t-1})) \quad (9)$$

From the so constructed values of manufacturing productivity growth, and the collected data on sectoral labour input, capital stock and foreign equity ownership and technology licenses, we can now use multivariate timeseries regressions to estimate the contribution of capital goods import, investment and disembodied technology purchase to the productivity increase for the whole manufacturing sector. To that end, we express the productivity growth ln(*At/At*-1) as a function of the logs of capital import (*CAPIMP*), foreign equity investments (*INV*), technology acquisition by licensing (*LIC*), the share of skilled labour in manufacturing and their lagged values (*SKILL*):

$$\begin{aligned} \ln(A_t / A_{t-1}) &= b_0 + b_1 \ln(CAPIMP_t) + b_2 \ln(INV_t) + b_3 \ln(LIC_t) + b_4 \ln(SKILL_t) \\ &+ b_5 \ln(CAPIMP_{t-1}) + b_6 \ln(INV_{t-1}) + b_7 \ln(LIC_{t-1}) + b_8 \ln(SKIL_{t-1}) \\ &+ b_9 \ln CAPIMP_{t-2}) + b_{10} \ln(INV_{t-2}) + b_{11} \ln(LIC_{t-2}) + b_{12} \ln(SKIL_{t-2}) + \varepsilon_t \end{aligned} \quad (10)$$

Skilled labour is defined here as labour input of employees with at least completed secondary or technical vocational education or other formal or informal training leading to comparable qualifications (see also Hunt and Tybout 1999). Foreign equity investment variable represents the share of South African controlled firms in each industry in Botswana, where management practices and organization structure can be significantly influenced by the South African investors. Joint ventures are arbitrarily treated here as foreign-owned firms. In order to gain further insights into these effects, we consider a panel of ten manufacturing industries for which trade data are separately available (see Table 1) and disaggregate the manufacturing sector in a panel data analysis.[3] We therefore write Equation (10) for each industry *j*, to obtain:

---

3 The matching between industries and capital equipment is partly based on the one used by Barba Navaretti and Soloaga (2001) and is reported in Table 5. Barba Navaretti and Soloaga base their matching on the correspondence in description between harmonized commodity description and coding system codes of imported machines and the 3-digit ISIC codes (revision 2) of the manufacturing industries using these machines to produce the described product in the importing countries.

$$\ln(A_{jt} / A_{jt-1}) = b_0 + b_1 \ln(CAPIMP_{jt}) + b_2 \ln(INV_{jt}) + b_3 \ln(LIC_{j\,t}) + b_4 \ln(SKILL_{j_t}) + b_5 \ln(CAPIMP_{jt-1}) + b_6 \ln(INV_{jt-1}) + b_7 \ln(LIC_{jt-1}) + b_8 \ln(SKIL_{jt-1}) + b_9 \ln CAPIMP_{jt-2}) + b_{10} \ln(INV_{jt-2}) + b_{11} \ln(LIC_{jt-2}) + b_{12} \ln(SKIL_{jt-2}) + \varepsilon_t \quad (11)$$

In the same way, we can also estimate the sectoral expansion effects of the three types of knowledge flows by replacing the productivity A in the left-hand side of Equation (11) by the value of sales or total assets of new firms entering each industry. As our equation contains lagged independent variables, this regression displays the characteristics of the so-called Beck-Katz de facto standard, which uses lagged dependent and independent variables. This model can be consistently and efficiently estimated using the panel corrected standard error (PCSE) method. The pros and cons of using of this estimation with panel corrected standard errors are extensively discussed by Beck and Katz (1995), who stress the higher accuracy and efficiency of error corrected OLS over the feasible generalized least squares (FGLS). However, Plümper, Troeger and Manow (2005) warn that while the Beck-Katz de facto standard has the advantage of eliminating serial correlation, it brings drawbacks as well: cross sectional variance may be absorbed by unit dummies while the lag structure could also be mis-specified. We nonetheless use it because it is most suited to our data given the time span and the relatively small number of units.[4]

Table 1
Matching of imported capital equipment with industries using them
(Based on Botswana trade data)

Industry (ISIC Revision 3)	Machines (SITC Revision 3)
Dairy (1520)	Dairy equipment (7123)
Beverages (155)	Food machinery, non domestic (727)
Spinning, weaving and finishing of textiles (171)	Textile machinery (7244/5/6/7)
Wearing apparel, except fur apparel (1810)	Sewing machines (7243)
Paper and paper products (210)	Paper & papermill machinery (725)
Basic chemicals (241)	Machine tools specialized for particular industries (chemical); parts and accessories thereof (728)
Rubber products (251)	Rubber and plastic working machines (72842)
Glass and glass products (2610)	Glass working machinery (72841)
Basic iron and steel (2710)	Metal working machinery (737)
Furniture (3610)	Machine tools for working wood and wood treating machines (331+332)

4 Beck and Katz (1995) Monte Carlo results indicate that for timespans from two times larger than the number of units, PCSE model performs much better that the FGLS. Beck (2001) recommends it when the number of timepoints is larger than 15. Plümper and Tröger (2006) suggest the use of a 3-stage fixed-effects vector decomposition as an even more efficient estimation method in the presence of rarely changing or time-invariant variables or when the within-variance is small.

4.2 Data

The industry-level data used in this analysis are based on the data files compiled by the author from the records of the Enterprises and Establishments Register (EER) and Botswana Exporters Association as until the end of September 2005 and the survey conducted among manufacturing firms between July and September 2006. The EER is a computerized database of enterprises and establishments in Botswana. It is mainly used as a sampling frame for economic surveys and contains relevant information on all business activities in the country. At the end of September 2004, there were 55,033 establishments listed in the EER compared to 54,875 at the end of September 2005. Out of these 55,033 listed establishments, 16,683 were known to be operating. In terms of number of firms, according to these records the manufacturing sector represents only 7.8 per cent of all registered economic entities in Botswana and accounts for only 4 per cent of the total value added in 2005 as illustrated in Table 2, but employs 8.6 per cent of the active labourforce.

Botswana's capital import data are compiled from the records of the Botswana Central Statistics Office (CSO), a governmental department in the ministry of finance and development planning, and from the UN Comtrade database. The CSO records the current as well as the 1993 constant dollar value of capital imports from customs declaration documents. Goods declared at ports of entry/exit are classified according to the harmonized commodity description and coding system of Botswana, which is an adapted version of the internationally recognized harmonized commodity description and coding system. The official currency used in customs declaration documents as from the introduction of the Single Administration Document (SAD) in May 2002 is the Pula (local currency). Although goods can originally be declared in different foreign currencies, an exchange rate is given for any particular currency and this is used to finally convert that currency to the Pula. Equipment import volumes in from South Africa amounted to US$1,078,196,097.

Table 2
GDP by economic activity in selected years

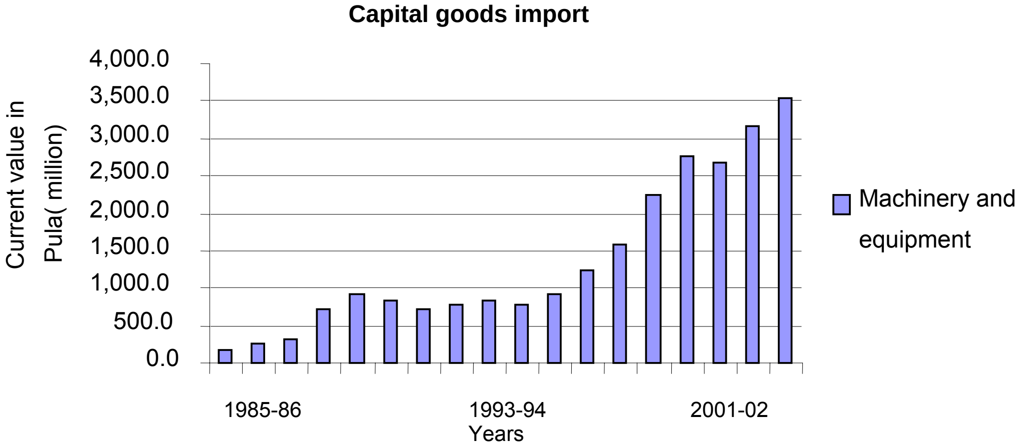
Economic activity	1966	1975/76	1985/86	2000/01	2004/05
Agriculture, %	42.0	20.7	5.6	2.6	2.4
Mining, %	–	17.5	48.9	36.5	35.9
Manufacturing, %	5.7	7.6	3.9	4.1	3.9
Water & electricity,	0.6	2.3	2.0	2.4	2.5
Construction, %	7.8	12.8	4.6	5.8	5.6
Hotel, restaurants & trade, %	9.0	8.6	6.3	10.3	10.5
Transport, %	4.3	1.1	2.5	3.8	3.5
Banks, insurance & business services, %	20.1	4.7	6.4	10.9	10.9
Central government, %	9.8	14.7	12.8	16.0	16.4
Social and personal services, %	–	2.8	2.5	4.0	4.0
Total GDP at constant market price, mln Pula	908.6	2,083.5	5,708.1	16,524.4	19,661.2
GDP excl mining, mln Pula	908.6	1,718.1	2,917.3	10,497.1	12,607.3
GDP per capita, Pula	1,682.5	2,861.9	5,175.0	9,793.4	11,112.6
Real GDP growth, %	–	18.4	7.7	8.4	5.6
Real GDP growth excl. mining, %	–	11.8	11.6	4.0	4.3

Source: Central Statistics Office.

Table 3
Number of operating firms in the Botswana manufacturing sector, 1991-2005

Industry	Sep 1991	Dec 1992	Mar 1993	Jun 1994	Sep 1995	Dec 1996	Mar 1997	Sep 1998	Dec 1999	Mar 2000	Sep 2001	Dec 2002	Mar 2003	Sep 2004	Sep 2005
Meat and meat products	7	7	11	8	8	10	9	9	10	11	11	11	11	11	11
Dairy products	19	19	22	22	22	23	22	22	22	25	24	24	24	23	26
Grain mill products	28	28	31	29	30	40	42	42	40	40	40	38	38	36	34
Bakery products	66	65	80	80	88	90	107	104	107	112	110	105	105	103	106
Other food products n.e.s.	33	33	42	41	41	41	44	43	43	43	44	43	43	41	41
Beverages	5	6	6	7	10	9	11	11	11	10	11	10	10	10	11
Textiles, excl. clothing	91	91	93	88	86	85	83	82	83	82	84	85	85	84	86
Clothing & other apparel, excl. footwear	125	127	168	173	197	199	219	216	221	228	232	233	233	229	236
Tanning & leather products, excl. clothing	13	13	14	14	14	15	13	13	14	14	11	11	11	10	11
Footwear	1	1	3	4	3	2	2	2	2	3	4	4	7	7	7
Wood and wood products	30	29	29	28	27	30	30	29	25	29	29	29	29	29	30
Paper and paper products	24	24	30	30	30	29	32	32	32	35	36	34	33	30	28
Printing and publishing	64	65	73	73	75	76	81	81	82	91	93	91	91	89	94
Chemicals and chemical products	41	41	47	46	47	50	55	55	57	60	58	59	60	58	57
Rubber and plastic products	15	15	17	19	18	19	26	25	26	25	22	22	22	20	20
Cement manufacturing	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Non-metallic mineral products, excl. cement	73	82	86	89	92	96	102	102	103	103	107	107	107	102	108
Basic metals	4	4	7	7	9	9	9	9	9	7	6	6	5	5	5
Fabricated metal products excl. machinery	133	134	165	164	175	179	198	195	198	195	194	192	190	186	181
Machinery and equipment, etc	9	9	11	11	11	11	19	19	19	22	23	23	23	20	23
Office, accounting and computing machinery	1	1	1	1	2	2	2	2	2	2	2	2	2	2	7
Electrical machinery and apparatus n.e.s.	0	0	1	1	1	1	3	3	3	5	4	4	4	4	4
Radio, television & communication eq.	0	0	1	1	2	2	2	2	2	2	2	2	2	2	2
Medical, precision, optical instruments	5	3	3	1	1	1	1	1	1	2	2	2	2	2	4
Motor vehicles, trailers & semi-trailers	9	9	13	11	11	14	14	14	14	19	19	18	18	18	17
Other transport equipment	0	0	2	2	3	3	3	3	2	3	3	2	2	2	2
Furniture	28	28	39	39	46	47	57	58	63	70	74	73	72	70	72
Manufacturing of jewellery	0	5	7	8	8	9	11	11	11	10	10	10	10	10	8
Manufacturing of other products n.e.s.	93	83	91	90	87	90	83	82	83	80	76	70	70	67	67
Recycling	0	0	0	0	0	0	1	1	1	2	3	3	3	3	3
Total	918	923	1,094	1,088	1,145	1,183	1,282	1,269	1,287	1,331	1,335	1,314	1,313	1,274	1,302

Figure 3
Current value of imported machines and equipment in millions of Pula



Source: Computed by author based on CSO data.

The manufacturing value added data of the selected manufacturing industries are compiled by the author from the records of the CSO, the ministry of trade and industry, Botswana Confederation of Commerce, Industry and Manpower (BOCCIM) and the Exporters Association Botswana (EAOB) during his research in Botswana. Data on manufacturing employment labour input and capital stock were also compiled by the author from the EAOB, BOCCIM and CSO records. Figure 2 gives an overview of machinery and equipment (SITC Rev 3 codes 711-751) import values between 1985 and 2005 (exclusive of machinery and equipment destined for mineral exploration) and the corresponding value added created by the manufacturing sector over the same period. As it clearly seen from the numbers, the value of capital imports has fluctuated at times but displays a clear increasing trend over the period. Finally, the data on foreign equity ownership and technology licensing agreements are gathered from company surveys conducted by the author between July and September 2006. The compiled data cover the period 1985-2005 and therefore allow for a multivariate timeseries and a panel data analysis of the relationship between technology flows and manufacturing performance over 20 years.

In terms of geographical spreading, the EER records show that most of the manufacturing establishments were located in Gaborone which was home to 73.4 per cent of the total manufacturing firms. Francistown and Kweneng followed with 8.9 and 5.9 per cent, respectively. Sowa Town, Chobe/Kasane, and Jwaneng had the least number of operating establishments. Sowa Town had 1 per cent of the total operating establishments, while Chobe/Kasane and Jwaneng had 1.2 per cent each.

As for the distribution of manufacturing entities into various activity types over the period 1991-2005, the largest number of enterprises is active in basic manufacturing activities such as food and meat processing as well as the production of packaged or bottled beverages (see Table 3). In terms of geographical growth in the number of manufacturing entities the EER records show that Chobe/Kasane experienced the largest change. The number of manufacturing entities in Chobe/Kasane increased by 6.8 per cent from the end of September 2004 to 24 at the end of September 2005; Francistown registered an increase of 2.0 per cent, while Mahalapye and Kweneng followed with 1.5 and 1.1 per cent, respectively, over the same period.

4.3 Results

We assume ergodicity and exogeneity in the first differences and use the OLS[5] to estimate the coefficients α and β in Equation (8) in which we impose the input shares α and β to add up to one (constant returns to scale). Before performing this estimation, we conduct an augmented Dickey-Fuller (ADF) test to establish the stationarity of the first differences. With a t-statistic of 3.831, 2.896 and 3.126 for respectively the ln(*MVA*), ln(*K*) and ln(*L*) variables, we found them to be I(1) so that their first differences are I(0). Given the limited timespan, however, the results of this test are to be taken with caution because their validity is relatively weak. For the same reasons although it would be interesting to perform a co-integration analysis to identify the nature of the long-term relationship between these variables and use an error correction model to estimate this relationship, the timespan covered by the available data is relatively short and co-integration test would not produce conclusive results. We estimate the relationship instead by assuming that the short-term relationships among the variables remain unchanged over time and we thus analyse the first differences. The regression results for the Botswana manufacturing sector are reported in Table 4. Instead, we obtain an estimate of α=0.314 and β=0.685. As we can observe from the estimation results, both coefficients are significant at 5 per cent and can now be used to estimate productivity growth.

With these estimates, we have all the needed elements to compute the value of manufacturing productivity growth for each year between 1985 and 2005 and estimate

Table 4
OLS estimates of factor shares for the manufacturing section, 1985-2004

Dependent variable: Δ*ln(MVA)*

Variable	OLS
ΔlnCapital stock	0.3146**
	(0.1546)
ΔlnLabour	0.6854**
	(0.3465)
Intercept	0.0218
	(0.0387)
R-squared	0.8656
Adj. R-squared	0.8550
Sum sq. resids	0.0878
S.E. equation	0.0822
F-statistic	91.2929
DW statisic	2.8842

Note: standard errors in brackets; * = 10% significance level, ** = 5% significance level, *** = 1% significance level.

5 Stewart (2005: 826) notes that variables related in the short run may be legitimately described by an autoregressive distributed lag (ADL) model in first differences and be efficiently estimated by OLS.

Equation (10), reported in Table 5. In the aggregated data, we find capital import to have a significant influence on the productivity growth as well as on the industry growth in the sales of new operating firms in the various industries. The share of skilled labour is also very important in increasing productivity, while size difference does not seem to translate in significant productivity differences. To allow for a comparison between South African and other foreign firms, we estimate the coefficients for all firms and estimate them again after removing all South African firms. The reason for this is the limited total number of firms in the manufacturing sector that does not allow a matched sample of South African and non-South African firms with similar characteristics. The results suggest that the better market knowledge of South African investors translates in better productivity gains from imported technologies. Industries where more firms use licensed technologies are also more likely to increase their productivity as can be derived from the significantly positive coefficients of the technology licensing variable.

Across the manufacturing sector, we find positive and strongly significant coefficients for the lagged capital imports and the share of skilled labour, while the coefficient of contemporaneous capital import now remains insignificant. The coefficient for the two-period lagged capital import is lower than that of one period lagged but its significance remains below 5 per cent, while the coefficients of lagged skilled labour share are all insignificant. This corroborates our view that the effects of imported capital on productivity growth are subject to time lags of between 1 and 2 years, while the effects of skilled labour input are likely to affect productivity increase immediately. The Granger causality test confirms the precedence of capital goods import on the corresponding productivity growth. Our results thus confirm existing view that capital imports in a given period influence productivity in subsequent periods.

Table 5
TFP growth and aggregated manufacturing sector expansion, 1985-2005

Dependent variable: Manufacturing productivity growth

Variable (ln)	All firms	Excl. South African	All firms	Excl. South African
Cap. import	0.1921**	0.1276*	0.0864**	0.0796**
	(0.0821)	(0.0713)	(0.0410)	(0.0378)
Share skilled lab	0.0328***	0.3639	-1.5485	-0.2897
	(0.0124)	(0.2567)	(14.3667)	(0.1675)
Cap. imp(-1)	0.4238***	0.0177***	0.8692***	0.1298***
	(0.1142)	(0.0067)	(0.2344)	(0.0436)
Share skilled l(-1)	0.0746	0.3639	0.4533	0.3965
	(0.0465)	(0.2568)	(0.3218)	(0.2154)
Cap. imp(-2)	0.1766**	0.0742	0.0647	0.5766
	(0.0819)	(0.0787)	(0.0689)	(0.2945)
Share skilled l(-2)	0.2065	0.3676	0.2796	0.2478
	(0.3464)	(0.1981)	(0.1658)	(0.2147)
Intercept	1.6359	1.4697	2.3931	2.1766
	(2.4916)	(0.6908)	(3.0231)	(1.8796)
R-squared	0.7656	0.6527	0.6630	0.5467
Adj. R-squared	0.7436	0.6416	0.6428	0.5319
Sum sq. resids	0.4543	0.4328	0.0185	0.0196
S.E. equation	0.0822	0.0792	0.0410	0.0416
F-statistic	91.2929	79.0418	47.7167	47.3412

Note: Standard errors in brackets; *= 10% significance level, **= 5% significance level, ***= 1% significance level.

Table 6
Panel corrected standard errors estimates for the 10 industries, 1991-2005

Dependent variable:	Manufacturing productivity growth		Section expansion in sales of new firms	
Variable	All firms	Excl. South African	All firms	Excl. South African
Capital import	0.0223*** (0.0061)	0.0164** (0.0053)	0.0205*** (0.0064)	0.0137 (0.1423)
Eq. investment	0.2596** (0.1045)	0.2142* (0.123)	0.2145** (0.0972)	0.1926 (0.1204)
Licensing	2.1978 (1.3917)	1.4832 (1.3364)	0.6816 (0.4137)	0.6143 (0.4126)
Skilled labour	4.8381*** 1.6647	4.3823*** (1.5315)	4.8957 (2.9397)	3.9478*** 1.0754)
Cap. import(-1)	0.0869*** (0.0234)	0.0527** (0.02616)	0.0335*** (0.0017)	0.0486** (0.0212)
For.equity inv.(-1)	2.9618*** (1.2795)	2.3125* (1.234)	2.8203** (1.3309)	2.1245* (1.2736)
Licensing(-1)	1.7785*** (0.3443)	1.2862*** (0.4125)	1.4819*** (0.1873)	1.2154** (0.4523)
Skilled labour(-1)	0.3307** (0.1687)	0.3015 (0.1726)	0.3833** (0.1827)	0.3431* (0.1643)
Cap. import(-2)	0.1864** (0.0897)	0.1375 (0.1041)	0.2897 (0.1817)	0.1545 (0.1156)
Skilled lab(-2)	1.1314 (1.2135)	1.1289 (0.8975)	0.1468 (0.1674)	0. 1137 (0.1203)
Intercept	-6.1693 (4.13720)	-2.4567 (3.2451)	9.9626 (17.9971)	8.1457 (14.7521)
R-squared between	0.8642	0.5742	0.8027	0.6854
R-squared within	0.8168	0.5624	0.7386	0.6245
Overall	0.7846	0.5543	0.7242	0.6046
F-statistic	8.5270	7.5681	5.1950	6.2415

Note: Standard errors in brackets; * = 10% significance level, ** = 5% significance level, *** = 1% significance level.

The next step is to examine with panel data how the import of machineries and equipment impacts on the productivity growth, skills intensification, and expansion of the various manufacturing industries and to assess where these effects are strongest. This is done by estimating Equation (11) by the PCSE method. The panel estimation results are reported in Table 6. Like in the aggregated data, we find capital import to have a significant influence both on the productivity growth and on the industry growth expressed in sales of new firms in the various industries. The ownership control structure visibly produces significant differences. Industries with a higher proportion of foreign-owned firms seem to gain more productivity growth from knowledge flows than those with a higher predominance of domestic ownership, while this productivity advantage becomes less pronounced if we remove South African firms from the analysis, as indicated by the lower coefficients. Foreign-owned companies tend to import technologically more sophisticated capital goods and implement management and organizational practices that increase productivity faster in comparison to domestically owned firms.

The results for the industry expansion rate display a slightly different significance structure from those of productivity growth. Capital import and the proportion of skilled labour are the most important factors associated with industry expansion. Foreign equity investment is also significant in explaining the entry of new firms in operation but this significance disappears as we take only non-South African firms in our analysis. South African equity investments thus account for a significant share in the expansion of the manufacturing sector in Botswana. As the number of active firms in each industry has been growing over the considered period, it is interesting to investigate the LKSY hypothesis and check whether the manufacturing productivity growth came from the newly created firms or from existing ones. In order to account for the possible diversification into more technologically advanced firms with higher shares of skilled labour and higher productivity corresponding to Hunt and Tybout's (1999) technological sophistication, we check whether industry level productivity increased because all firms became more sophisticated, or because of intra-industry market share reallocations toward more sophisticated firms.

Applying the Hunt and Tybout analytical approach, we analyse the productivity growth on the industry level in all industries classified by the BSIC as belonging to the manufacturing sector. The number of firms in each industry and their evolution over the period 1991-2005 are reported in Table 3. This analysis allows us to isolate the technological deepening by industry from the shift to more technologically sophisticated firms.

Each Δe_{jt} term in Equation (5) is decomposed into the effects of intra-industry changes in technical intensity, and the effect of changes in the allocation of skilled workers across firms. This exercise is basically the same as the sectoral decomposition; however, it is complicated by extra terms to deal with the entry and exit of producers over the sample period. The expression derived from the sectoral decomposition becomes:

$$\Delta e_{jt} = \overline{\alpha}_j [\sum_{i=1}^{I} \Delta e^c{}_{ijt} \overline{\theta}_{ij} + \sum_{i=1}^{I} \Delta \theta_{ij}{}^c \overline{e}_{ij}] + \Delta \alpha_j [\overline{e}_j{}^c - \frac{e^b{}_j + e^d{}_j}{2}] + (e^b{}_j - e^d{}_j)(1-\alpha_j) \quad (16)$$

Here *c*, *b* and *d* indicate continuing, entering (beginning) and exiting (dying) firms, respectively, and *i* subscripts refer to firms belonging to a given industry, while α_j is the share of continuing firms in total employment within industry *j*.

The first term on the right-hand side resembles the first equation of the Hunt and Tybout model. Its components disaggregate changes in technician intensity among incumbent producers into two subcomponents: one is incumbent upgrading, and the other is shifts in market share among incumbents. The second term measures the effect of changes in the market share of incumbent firms. This term indicates that when incumbents are more intensive in skilled labour than entering and exiting firms, then reductions in the amount of turnover (increases in θ_j) will increase industry-wide technology intensity. Finally, if entering firms are more technical-intensive than the exiting firms they replace, ongoing producer turnover will also increase industry-wide technology intensity. This replacement effect is described by the third term of the right hand side expression.

A selection of the results of this analysis is presented in Table 7. From these results, it is clearly noted that technological sophistication as measured by skilled labour intensity, although increasing over the considered period, was mainly due to upgrading within each of the industries rather than a replacement of less technological sophisticated by

Table 7
Sources of change in skills intensity of selected manufacturing industries in Botswana

Industry	Growth incumbent firms	Upgrading skills existing firms	Entry new firms	Total change
Beverages	-0.0276	0.5457	0.2137	0.7318
Textile	0.0067	0.0394	0.0198	0.0658
Clothing	-0.0011	0.0385	0.0216	0.0590
Chemical products	0.0580	0.4663	0.0410	0.5653
Paper products	0.0022	0.0373	0.0042	0.0437
Furniture	0.0044	0.0407	0.0204	0.0655
Glass products	-0.0028	0.0325	0.0179	0.0476
Metal	0.0048	0.0530	0.0198	0.0775
Average	0.0056	0.1567	0.0448	0.2070

more technologically sophisticated industries. Firms' growth accounts for a negligible portion of the total increase in skilled labour intensity, while the entry of new firms slightly increased the level of skills intensity in the industry in the considered period. Aggregate growth in technical intensity is therefore driven by a deepening of technological sophistication in all industries considered in our analysis, not because some more technologically performing industries grew relative to other industries. We therefore do not find convincing evidence of a capital import driven diversification in more technologically advanced industries.

Hunt and Tybout remark that other studies (e.g., Chenery and Syrquin 1986) document a systematic shift of production away from simple manufactured products as the development process unfolds, thereby validating the LKSY hypothesis. In the case of Botswana, we thus do not observe an inter-industry shift of resources towards more productive industries at the expense of less technical intensive industries. This is not surprising given the relatively young stage of industrialization in Botswana in which most of industries are still in the growth phase. Interestingly, similar decompositions such as those made by Behrman, Machin and Bound (1997), suggest that most of the rise in the skill intensity of production is due to skill deepening within existing industries rather than shifts in the product mix toward skill-intensive industries.

Finally, in order to assess the effects of sectoral linkages on technological diffusion between the two countries, we use the sectoral intra-industry trade (IIT) index as a measure of the extent of linkage and investigate whether sectors with more IIT benefit more from their interactions with technology leader. The rationale for this hypothesis is based on the assumption that a country is more likely to absorb foreign technologies if its imports are from the same sectors as the goods it produces and exports. Hakura and Jaumotte (1999) use this approach to compare the relative performance of intra- versus inter-industry trade in transferring technology to developing countries by examining the effects of inter- and intra-industry trade on the productivity growth in importing countries in a sample of 87 countries, with trade and growth data between 1970 and 1993. Extending the technology gap framework in which total factor productivity is specified as a function of technological difference, weighted by the degree of exposure to foreign technologies, they apply the Grubel-Lloyd IIT index[6] to determine each sector's involvement in IIT and its effect on TFP growth. At the sectoral level, the Grubel=Lloyd IIT index can be defined as:

$$IITs = \frac{(Xs - Ms) - |Xs - Ms|}{(Xs - Ms)}$$

where s denotes sector, X denotes exports and M imports. It measures the level of IIT in sector s. If there is no IIT in sector s (i.e., when the country is exclusively exporting or importing it in that sector, the index takes the value 0. Conversely, when all trade is intra-industry, the index takes the value 1.

Both their linear and nonlinear specifications confirm the expected technological catch-up and technological knowledge transmission to countries that trade with more technologically advanced ones. In addition, they find evidence that IIT had a stronger effect on TFP-growth than inter-industry trade, presumably because countries are more likely to absorb foreign technologies when their imports are from the same sector as their production and export sectors.

Following their methodology we examine the extend to which IIT speeds up the technology adoption process by specifying a technology gap model in which the difference in sectoral TFP is a function of trade exposure (imports/GDP) weighted by the IIT index in a nonlinear way:

$$g_{ist} = c + \alpha s * g_{lst} + h(IITs) * \frac{M_{ils}}{Y_{st}} * \ln\frac{TFP_l}{TFP_i}, \qquad (17)$$

where $(IIT)=\beta+\gamma*IITs+\delta*IIT^2s$. g_1 denotes the *TFP* growth rate of technological leader, g_i that of the importing countries and Y the output.

The IIT index is computed for ten exporting industries identified from the records of EAOB for which we had export and productivity data. TFP growth for South Africa

Table 8
Estimation results for the effects of intra-industry trade linkages

C	α	β	γ	δ	Fixed effects	R-sq	Adj. R-sq
0.006 (0.0012)	0.0941 (0.0435)	0.0156 (0.095)	-0.0147 (0.0876)	0.0246 (0.0133)*	yes	0.368	0.342

6 The Grubel-Lloyd IIT index is defined as: $IIT = 1 - \frac{\sum_1^n |Xi - Mi|}{\sum_1^n (Xi + Mi)}$ where 'i' indicates a product category and 'n' is the total number of products. This index varies between 0 and 1, and shows the share of total trade that is conducted among identical products (i.e., imports and exports of the same product category).

is determined by the use of growth accounting, whereby conventional factor shares are assumed.

For all sectors we analysed, the IIT indexes were relatively low and ranged from 0.06 in the chemical industry to 0.34 in the textile industry. The estimates of Equation (17) are presented in Table 8. Although IIT seems to be positively associated with catch up, the estimated effects are insignificant as a result of the relatively low export activities among Botswana industries.

5 Summary and conclusions

In this paper, we took the NIS-based approach to analyse the role played by the interaction between South Africa and Botswana in fostering technology diffusion between the two countries and contributing to Botswana's effort to reduce its dependence on diamond exports. Using industry-level data, we investigate whether external interactions, technological effort and technological interactions within Botswana's innovation systems have spurred an import-induced diversification into more technologically sophisticated industries. Our results from industry panel data analysis and growth decomposition of industry technical skills show a timid emergence of manufacturing industries with increasing technologically sophistication.

Our analysis of the learning attributes based on the NIS functions and the intensity of interactions between the various components of South African and Botswana's innovation systems suggests that the learning process is an increasing function of the extent of linkages between sectors and of the intensity of interactions. This learning is crucial in fostering the country's successful adoption of new technologies in the manufacturing sector as opposed to the dominant diamond mining industry. Since the nature of interactions among the various functions in the innovation system leads to reinforcing features, the fulfilment of any of its functions has positive effects on the others and vice versa. The overall performance of the Botswana innovation systems must therefore be evaluated over the whole range of functions it is designed to perform and thus on the basis of its ability to diffuse new technologies over time and reduce the country's diamond dependence.

Moreover, the examined manufacturing industries have been increasing their technical skills intensity, mainly as a result of incumbent technological and skills upgrading induced by interaction and business links with South African entrepreneurs. Finally, our results show that industries that have more linkages with technology leader South Africa in the form of intra-industries trade stand to gain more from their interactions, although these results are not statistically strong because of the embryonic stage of Botswana's export activities outside the diamond and mining sector. This suggests that South Africa is playing the role of leading goose in a regional flying geese paradigm. The potential gains from increased intensification of economic and business ties with South Africa are enormous not only for Botswana, but for the entire southern African subregion. In order to curb the dependence on diamond exports, Botswana will have to pursue the intensification of its interaction with the South African economy, and further align important capital resources and more sophisticated technological skills are necessary to boost its exports capabilities and achieve its diversification objectives.

Acronyms

ADF	augmented Dickey-Fuller test
BOCCIM	Botswana Confederation of Commerce, Industry, and Manpower
CSO	Central Statistics Office, Botswana
DST	Department of Science and Technology, African Cooperation Unit
EAOB	Exporters Association of Botswana
EER	Enterprises and Establishments Register
GDP	gross domestic product
FGLS	feasible generalized least squares
IIT	intra-industry trade
ISIC	international standard industry classification
JSE	Johannesburg Stock Exchange
MVA	manufacturing value-added
NACI	National Advisory Council on Innovation
n.e.s.	not elsewhere specified
NIS	national innovation systems
NSI	national systems of innovation
PCSE	panel corrected standard error method
PRIs	public research institutes
R&D	research and development
SACU	Southern African Customs Union
SADC	Southern African Development Community
SIDs	systems of innovation for development
SITC	standard international trade classification

Appendix A: South Africa's NIS: technological capabilities, incentives, and institutions

A1 Capabilities

South Africa is the economic powerhouse of Africa: with a PPP adjusted gross domestic product (GDP) estimated at US$576.4 billion for 2006 (US$13,000 per capita), its production is four times that of its southern African neighbours and accounts for around 25 per cent of the entire continent's GDP. The country leads the continent in industrial output (40 per cent of total output) and mineral production (45 per cent) and generates most of Africa's electricity (over 50 per cent). Its major strengths include its physical and economic infrastructure, natural mineral and metal resources, a growing manufacturing sector, and strong growth potential in the tourism, higher value-added manufacturing, and service industries.

A1.1 Physical investment

As a result of strong macroeconomic performance, fixed investment as a share of GDP has picked up since 2000, both in the private and public sectors. This expansionary process can be expected to continue since government plans to spend nearly SAR 400 billion (PPP US$148 billion or nearly 30 per cent of GDP) on public infrastructure projects over the next five years (NACI 2006). Fiscal policy performance has also been extremely good and the resulting strong macroeconomic performance has improved private sector business confidence, although the low and declining level of national savings poses a potential constraint on economic growth in the long run.

A1.2 Physical infrastructure

We analyse physical infrastructure along three main dimensions, namely the provision of transportation facilities, communication means, and energy production.

Transport

Through its borders with Namibia, Botswana, Zimbabwe, Mozambique, Swaziland, and Lesotho, well-developed road and rail links provide the platform for ground transportation deep into Sub-Saharan Africa. South Africa's national road network currently covers 7,200 kms, with about 20,000 kms of primary roads planned in the future. The roads include 1,400 kms of dual carriageway freeways, 440 kms of single carriageway freeways and 5,300 kms of single-carriage main roads with unlimited access. Approximately 1,900 km are toll roads, serviced by 27 mainline toll plazas. Government projects to maintain new and existing roads, as well as the construction of several new toll road developments, are underway.

For rail transport, Spoornet is the largest railroad operator in southern Africa: it has 31,700 kms of single rail tracks, 3,500 locomotives, and 124,000 wagons. For maritime transport, major shipping lanes pass along the South African coastline in the South Atlantic and Indian oceans, through its seven commercial ports which form by far the largest, best equipped, and most efficient network on the African continent. With respect to air transport, the Airports Company of South Africa (ACSA) has embarked on a series of ambitious capital projects aiming to transform South Africa's major airports into world class tourist gateways, planned to spend SAR 800 million in the next financial year on capital expenditure and a total of SAR 2.6 billion by the end of 2006.

Communication

South Africa ranks 23rd in telecommunication development in the world. The country has approximately 4.92 million installed telephones and 4.3 million installed exchange lines. This represents 39 per cent of the total lines installed in Africa. National operator Telkom has met and exceeded its roll-out targets of over 1.6 million lines, 175,488 more than the cumulative target. South Africa has a large transmission infrastructure, necessitated by the country's vast geographical area of 1.2 million km². Covering about 156 million circuit-kms, the transmission network constitutes the backbone of all telecommunications services. The network is almost wholly digital. Digital microwave and optical fibre serve as the main transmission media for the inter-primary network, interconnecting all major centres.

Energy

South Africa is one of the lowest-cost power producers in the world. State company Eskom ranks in the top-tem electricity suppliers internationally in terms of size and sales, supplying around 95 per cent of South Africa's energy requirements and two-thirds of Africa's. Eskom's network is made up of more than 300,000 km of power lines, 27,000 km of which constitute South Africa's national transmission grid. The main generating stations are located in Mpumalanga, where the vast coal reserves are situated.

The energy sector contributes about 15 per cent to South Africa's GDP. South Africa's energy intensity is above the world average, with only about 10 countries having higher commercial primary energy intensities. This is largely due to the historical structure of South Africa's economy. Large-scale, energy-intensive primary minerals beneficiation industries and mining industries have traditionally dominated, although a shift is under way towards higher value-added manufacturing and service industries. There is also a heavy reliance on coal for the generation of most of the electricity and a significant proportion of the liquid fuels consumed in the country. South Africa's industry has not generally used the latest in energy-efficient technologies, mainly due to relatively low energy costs.

Coal accounts for 75 per cent of primary energy consumption. The majority of this is used to generate electricity, while a significant amount is channelled to synthetic fuel and petrochemical operations. South Africa has a highly developed synthetic fuels industry, as well as small deposits of oil and natural gas. The country's prospects for natural gas production increased dramatically in 2000, with the discovery of offshore reserves close to the Namibian border. The reserve, named the Ibhubezi Prospect, contains around three trillion cubic feet of oil. Sasol and PetroSA are the two major players in South Africa's synthetic fuel and petrochemicals market. Sasol is the world's largest manufacturer of oil from coal, gasifying the coal and then converting it into a range of liquid fuels and petrochemical feed stocks.

A1.3 Human capital

South African human capital accumulation is supported by a qualitatively appreciable education system which gets a strong slice the total government expenditure. In the 2006 budget, education was allocated SAR 92.1 billion, amounting to almost 20 per cent of total spending. The minister of sciences and technology reported that the lion's share of the department's budget for 2007 through 2009—about SAR 323 million—would go to developing South Africa's human resources in science, engineering, and technology. South Africa has a vibrant higher education sector, with more than a million students enrolled in the country's 24 state-funded tertiary institutions: 11 universities, five universities of technology, and six comprehensive institutions. Many of South Africa's universities are world-class academic institutions, at the cutting-edge of research in certain spheres like liquid fuel. Although subsidized by the state, the universities are autonomous, reporting to their own councils rather than government. Higher education is also offered at hundreds of private institutions, which are registered with the department of education to confer specific degrees and diplomas.

In addition to the various universities, there are currently 12 major public research institutes (PRIs), which are exclusively R&D performing institutions, with the exception of the Medical Research Council, which has also an agency function. The first and largest PRI, the Council for Scientific and Industrial Research, was established in 1945. The other PRIs are the Agricultural Research Council, the Human Sciences Research Council, Mintek (for minerals processing research), the Medical Research Council, the South African Bureau of Standards, South African Weather Services, the Council for Geoscience, the South African National Energy Research Institute, the South African National Biodiversity Institute, the Marine and Coastal Management division (a division of the department of environmental affairs and tourism) and the Africa Institute of South Africa.

The main human capital challenge currently facing the country is redressing the inequality of the past by granting equitable access to education to all its citizens. Various programmes and instruments are being implemented to accelerate the flow of African students into graduate schools, but more money is always needed to address the huge backlogs left by 40 years of apartheid education. These efforts take place against the background of noticeable shifts at first-degree level, where the percentages of Africans and whites shifted from 39 per cent Africans compared with 53 per cent whites in 1995, to 50 per cent Africans compared with 35 per cent whites in 2002.

A1.4 Technological effort

South Africa has made many important contributions to the domains of both knowledge and technology. Research in indigenous knowledge is also one of the nine focus area programmes of the National Research Foundation because of South Africa's comparative advantage in this field. However, although in certain areas world-class innovation was successfully undertaken (such as liquid fuels, atomic energy and military hardware), these areas did not link strongly with the intrinsic competitive strengths of the South African economy and hence failed to leverage a long-term sustainable advantage and the links to regional economies remain weak (NACI 2006).

In the African context, South Africa plays an active role in promoting science and technology, as evidenced by its prominence in the context of the New Partnership for Africa's Development and the introduction of a research and development tax incentive system in 2006. Several agencies have been established to support technology transfer and commercialization (Godisa and Tshumisano trusts) as well as to support R&D directly within performing institutions (the Innovation Fund and the Technology and Human Resources for Industry Programme). The country currently manages 32 bilateral S&T agreements, accounting for a total of approximately 400 projects.

As of 2006, South Africa had a total of 29,692 full-time equivalent R&D personnel, comprising researchers, technicians and other support staff. Of this total, about 60 per cent (or 17,910 FTE) is made up of the researchers or academically qualified people who manage and guide the process of undertaking research (and are classified as researchers). While South Africa's R&D expenditure is fairly high compared with other developing countries, the total number of researchers, expressed as the number of researchers per thousand in total employment, is low relative to developed countries. According to the latest Human Sciences Research Council survey of R&D spending, South African businesses, universities, science councils, government research institutes, and non-governmental organizations spent SAR 14 billion, or 0.91 per cent of GDP, on R&D in 2005-06, up from SAR 12 billion, or 0.87 per cent of GDP, in 2004-05. In this year's budget address to the parliament, science and technology minister said the country's target of spending 1 per cent of gross domestic product (GDP) on R&D by 2008/09 was now 'well within sights'. The ratio of the gross expenditure on R&D (GERD) to gross domestic product (GDP) has thus grown from a low of 0.69 per cent in 1997 to 0.91 per cent in 2005/06 and is well on its way to reaching the government's target of 1 per cent.

The business sector in South Africa is the major performer and fund provider of R&D in the country, funding 45 per cent and performing 58 per cent of total R&D. In-house R&D in the business sector accounts for 59 per cent of total national R&D performance and 45 per cent of expenditure. The business sector also accounts for 25 per cent of all R&D workers employed. Manufacturing is the largest component of the business sector, and by far the largest contributor to R&D expenditure (accounting for 44 per cent of total business sector expenditure on R&D).

A2 Incentives

The incentive system comprises general macroeconomic incentives, the competitive environment and factor market conditions.

A2.1 General macroeconomic incentives

A selection of the key economic indicators over the past five years is shown in Table A1. In terms of purchasing power parity, South Africa is ranked as a middle-income economy. The average GDP growth rate between 1994 and 2004 was 2.81 per cent per annum, but the growth rate has been at or above this level since 2000, raising hopes that South Africa can meet the current growth targets, as expressed in the

Accelerated and Shared Growth Initiative for South Africa[7] of 4.5 per cent per annum until 2009 and 6 per cent between 2010 and 2014. The inflation rate has stabilized within a single-digit range since the early 1990s, and as from 2000, the South African Reserve Bank has successfully maintained inflation within its 3 per cent to 6 per cent target band, except for the spike in 2002, which was linked to the severe but short-lived currency depreciation in late 2001. Low inflation and strong appreciation of the South African rand have allowed for a more relaxed monetary policy since 2002, with interest rates declining consistently (NACI 2006). The department of science and technology also worked with the National Treasury and SA Revenue Service over the past year to introduce enhanced tax incentives for R&D.

Appendix Table A1
Key economic indicators, 2000-05

	2000	2001	2002	2003	2004	2005
GDP (current PPP USD millions)	428,598	455,861	478,433	502,585	533,330	na
GDP pc, PPP (current International USD)	9,741	10,173	10,551	10,967	11,417	na
GDP growth rate, constant PPP (%)	NA	6.00	4.40	3.30	8.30	na
GDP growth rate, constant prices (%)	4.20	2.70	3.70	3.00	4.50	4.90
CPI (% change per annum)	5.40	5.70	9.20	5.80	1.50	3.40
Prime interest rate (average)	14.50	11.52	15.75	14.96	11.00	10.50
Nominal exchange rate ZAR/USD	6.94	8.61	10.54	7.56	6.45	6.36
PPP exchange rate ZAR/USD	2.15	2.24	2.44	2.50	2.60	na

Source: NACI (2006).

A2.2 Competition

The small and medium enterprise sector in South Africa is relatively underdeveloped given the level of per capita income. The Global Entrepreneurship Monitor, an international survey of business start-up activity, reports that South Africa’s total early-stage activity rate was 5.1 per cent in 2005. In other words, 5 per cent of South African adults between the ages of 18 and 64 own and manage a start-up business (less than 3.5 years old). South Africa’s rate has remained relatively stable between 4.0 per cent and 6.5 per cent since 2001, but is extremely low, the lowest of all developing countries in the survey. Also lowest among the developing countries is the ‘opportunity entrepreneurship’ rate, reflecting businesses started in response to perceived market opportunity (as distinct from started for necessity, or survival, reasons). Only 1.3 per cent of South Africans own and manage an established business that has survived for more than 3.5 years, compared to more than 10 per cent of adults in Brazil, Thailand, Greece, New Zealand, and China.

A2.3 Factor market

The constantly growing South African economy is still characterized by surplus demand for highly qualified personnel in the labour market and most graduates in science and engineering find a job within six months of graduation. Labour productivity has grown

---

7 A new policy framework put forward in late 2005.

rapidly since 2000, including the manufacturing sector productivity levels, although less consistently. In addition, the capital-output ratio has fallen during this period, suggesting that capital productivity has also risen significantly; at the same time the unemployment rates for unskilled labour are still high, especially among the rural black communities.

South Africa has a modern banking sector and efficiently functioning credit institutions. South African banking regulations rank among the best in the world. The sector has long been rated among the top ten globally. There are 55 locally controlled banks, 12 foreign-controlled banks and five mutual banks. Some of the world's leading institutions have announced their intention to enter the local banking sector through mergers and acquisitions. As for the equity and bond market, the Johannesburg Stock Exchange (JSE Limited) is the 18th largest exchange in the world by market capitalization (some R3.3-trillion as of September 2005). The JSE's rules and their enforcement are based on global best practice, while the JSE's automated trading, settlement, transfer, and registration systems are the equal of any first-class system in the world.

A3 Institutions

It is virtually impossible to talk about South African institutions without referring to the legacy of apartheid. Despite many of its deplorable scars on the South African society, the apartheid era has paved the way to prosperity (albeit only for five million of its citizens in a country of 45 million inhabitants) that can now serve as a trampoline for extending prosperity to all citizens. The National Advisory Council on Innovation (NACI) has been created by legislation (NACI Act of 1997) to advise the Minister of Science and Technology of South Africa, and through the minister, the minister's committee and the cabinet, on the role and contribution of science, mathematics, innovation and technology, including indigenous technologies, in promoting and achieving national objectives.

The DST is also responsible for specific institutions (the Council for Scientific and Industrial Research, the National Research Foundation and the Human Sciences Research Council), but has a cross-cutting and steering function for areas such as S&T liaison across departmental line functions and sectors; large-scale, broad-scope new S&T platforms and challenges (such as astronomy, human palaeontology and indigenous knowledge); and system-wide oversight functions, including establishing and maintaining a common governance framework, priority setting, and performance and budgetary monitoring systems. Other government departments are responsible for sector-specific S&T activities such as energy research (department of minerals and energy) and animal health (department of agriculture).

The mandates of the DST and the department of education include responsibility for creating and overseeing the implementation and funding of S&T policy and instruments—the DST primarily with regard to R&D institutions and programmes and the Department of Education with regard to the training of high-level human resources and the support of university research (Higher Education Act No. 101 of 1997). Support of university research takes place through two mechanisms, namely a postgraduate component in the subsidy formula and an R&D publication subsidy.

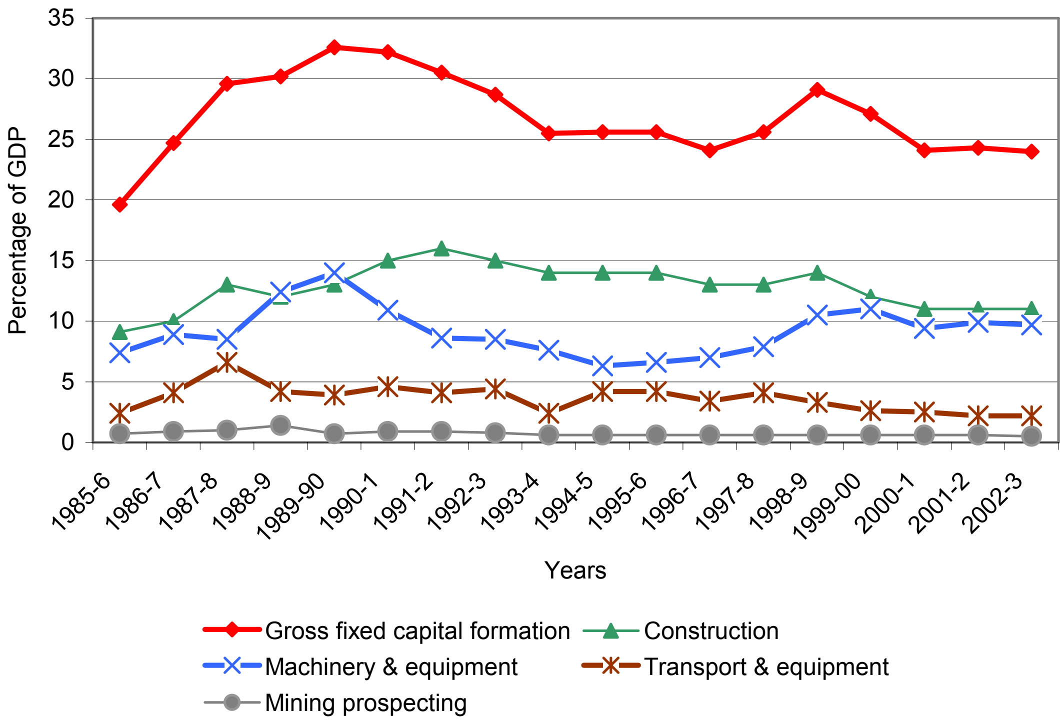
Appendix B: Botswana's SID

B1 Capabilities

B1.1 Physical capital formation in Botswana

Botswana's fixed capital formation over the last 15 years has been very substantial as a share of GDP. The table below provides the values of gross fixed capital formation as a per cent of GDP using Bank of Botswana's data computed on the basis of constant 1993 US$. With 971 kms (603 miles) of rail lines, 18,482 kms (11,484 miles) of roads (of which only 23 per cent are paved), and 12airports with paved runways, Botswana has a good infrastructure by African standards. The quality of infrastructure was greatly improved by the development of the mining industry, which required adequate transportation and communication networks. Botswana also benefits from its location next to South Africa. This has allowed Botswana access to South Africa's telecommunications infrastructure. Botswana's desire to become an international financial services centre is a key factor driving the improvement of the country's land line and cellular telephone networks. In 1998 there were 78,000 phone lines in use. Domestically produced coal generates 50 per cent of the electricity consumption for Botswana, which is approximately 1.619 billion kilowatts (1998). Every other source of energy, including oil, must be imported.

Appendix Figure
Gross capital formation in Botswana



Source: Computed by author based on data from CSO (Botswana).

B1.2 Human capital accumulation

Botswana has admittedly invested heavily in the accumulation of human capital as one of most important pillars of its development objectives. With 20 per cent of government recurrent expenditures devoted to education each year, the Botswana government gives a powerful signal of its commitment to human capital accumulation. The most commonly used indicators related to education and human capital policies would put Botswana and its government in the class of the assiduous learners. However, as indicated here, the levels of human capital and their potential for technological learning are still difficult to measure in Botswana as elsewhere.

Our purpose here is to give a multifaceted picture of human capital accumulation in Botswana by providing data and analysing issues of concern on various aspects of human capital. This overview is provided by the table below.

In the view of the acknowledged goal of developing enough technical skills for the economy to break into manufacturing, the current weak link between vocational education in secondary schools and the work world, the high rate of failure in vocational education and the bottlenecks in the educational system remain a serious element of concern for the accumulation of readily usable technical skills (Weeks 1997). Such systemic weaknesses resulting from the current, still limited capacity and shortage of competent training staff are elaborated upon in Appendix B1.3.

Appendix Table B
Accumulation of human capital in Botswana

Measure of human capital	Definition	Score
Primary school enrolment rates	No. of children attending school as % of relevant age group	103 (2004)
Secondary education enrolment rate	No. of children attending school as % of relevant age group	60
Adult literacy rate	% of population aged 15 and above who can read and write	Total population: 79.8 - male: 76.8 - female: 83 (2006)
Tertiary education The University of Botswana has only limited capacity with an academic staff of approximately 1,000 for all six faculties.	Total no. of students attending undergraduates and postgraduate studies	- 15,000 undergraduates - less than 900 postgraduate students

Source: UNESCO (2007).

B1.3 Botswana's technological effort

The government recognizes that the financing of research and development is still suboptimal in comparison to developed countries. It has been estimated that optimal R&D investment is at least four times larger than actual investment. Similarly, the 'new growth theory' has drawn the attention of economists and development specialists to the spillovers from investments in education and capital formation that raise social productivity above the gains that can be realized by the private- sector

The government's science and technology policy paper estimates that public funding of R&D as a percentage of GDP is still less than 1 per cent, while it is above 3 per cent in most developed countries. The government sees the urgency of the need to pursue S&T-led economic development in future development plans in order to strengthen and consolidate national efforts towards sustainable economic diversification. This is why it has decided to put in place a more efficient coordination of the public science and technological effort which have so far been scattered in various ministries and parastatals.

Research scientists and engineers as a proportion of population: like in many other Sub-Saharan countries, this rate is still very low in comparison to for instance the East Asian miracle economies.

Research institutes

- Botswana Technology Centre (BTC). The BTC is mandated to serve as a national focal point for the development and dissemination of S&T. Food technology research services (FTRS) to develop methods for preserving and processing food resources;

- Policies and programmes research unit at the ministry of commerce and industry, to deal with S&T issues;

- Botswana College of Agriculture, agricultural research department.

For a better coordination of the research activities, the various research efforts of all these institutions will be rationalized by the National Centre for Scientific and Industrial Research**.** It is estimated that despite the substantial effort undertaken by the government to foster research and development, the scientific and technological output is still very low.

B2 Incentives

B2.1 Macroeconomic incentives Botswana

From its accession to independence, Botswana has been exemplary for all Sub-Saharan countries in terms of fiscal and monetary discipline as underscored rating. Its dependence on diamond exports and a possible levelling off of the diamond reserves, however, pose a challenge to the economy. The prevalence of poverty in large layers of the population and the persistence of HIV/AIDS pandemic are a worrisome threat to the further development of human capital and technological capability.

With its 1.7 million inhabitants, and a PPP adjusted GDP of US$9,200, Botswana is too small as a market for manufactured goods and services. With 47 per cent of the population living below the income poverty line and a Gini coefficient of 0.54, the purchasing power of a large fraction of the population remains very limited. As it has often been argued, regional cooperation for market expansion is indispensable to allow scale economies in the presence of market exiguity. In this view, Botswana's appurtenance to the Southern African Customs Union (SACU, which it shares with South Africa, Lesotho, and Swaziland) suggests that the market open to potential manufacture is somewhat bigger than the home market alone.

B2.2 Competition: encouragement of foreign direct investment

The country has been open to FDI since independence in 1966 because of the recognized critical role of private capital including foreign, in stimulating growth, creating jobs and reducing poverty. Foreign investment is allowed in all sectors except those reserved for small and micro enterprises. There is no binding requirement for foreign investors to establish joint ventures, although this is encouraged. Moreover, there are no limits on foreign equity holdings and the processing of licences for foreign company is efficient and rapid. As a result, foreign investors play an important role in various sectors of the economy especially in the banking, mining, and tourism sectors. Development of indigenous entrepreneurship has been encouraged through the protection of small and micro enterprises from foreign equity ownership.

B2.3 Incentives from the factor market

Capital markets

The banking sector is fairly developed in Botswana and the exchange rate has been liberalized for a long period. Bank and insurance play an important role in the economy of Botswana where they account for some 11 per cent of GDP. Access to credit by enterprises and businesses is crucial to their operational performance and even their survival. Furthermore, the proper development of equity markets is indispensable for the sound functioning of a rapidly growing economy. The equity market is generally underdeveloped in SSA economies and Botswana, being a small economy, is no exception. However, Botswana is a dynamic economy with its own stock exchange, however small it may be judged. Its sheer existence underlines Botswana's determination to optimize the functioning of financial markets.

Labour markets

The Botswana's labour market is still characterized by an excess supply of unskilled workers, and a serious shortage of skilled labour for the modem sector. This mismatch has jeopardized the objective of rapid economic growth. A dual approach was followed to remedy this problem. A minimum wage equal to the average rural income of farmers with an allowance for any differential in the overall costs of urban living has been established for unskilled workers to achieve fairness and avoid the job destruction effects of excessive minimum wages observed in some other countries. The government has also set wages and salary scale regulations for the modem sector to avoid bidding wars for the limited supply of skilled labour.

Despite the sustained investments in human capital, Botswana still has to deal with chronic shortages of skilled workforce. Expatriates have been welcomed to fill in the gaps and the current supply of human capital in some specialized areas suggests that this will remain the case for quite some time. On the other side, Botswana has to deal with a relatively high rate of unemployment, especially among the young rural population where unemployment rates are still as high as 25 per cent compared to an average rate of 21 per cent for the total labourforce.

B3 Institutions

Acemoglu, Johnson, and Robinson (2003) essentially attribute Botswana's success to its institutions of private property, which protect the property rights of current and potential investors, provide political stability, and ensure that political elites are constrained by the political system and by a broad cross-section of society. In turn they explain these institutions in terms of the following five factors:

- First, inclusive pre-colonial traditions and institutions, which ensured that political elites faced effective constraints;
- Second, the relatively limited effects of British colonization on these institutions because of Botswana's peripheral relationship (in the sense of Botswana's 'benign neglect' compared to other colonized countries);
- Third, the political power of important rural interests upon independence and the alignment of the interests of the post-colonial elite with the protection of private property. They consider it important that the political elites in Botswana did not fear becoming political losers from the process of growth, which both derived from and reinforced political stability;
- Fourth the income of diamonds which generated sufficient rents to the main political actors that it increased the opportunity cost of further rent-seeking, and together with the above institutional features ensured that diamond revenues could be productively utilized; and
- Lastly, they credit far-sighted decisions by post independence political leaders. They argue that the particular combination of these factors in Botswana facilitated its successful growth. The authors acknowledge that they cannot test their hypotheses empirically.

Botswana's longstanding political stability is both exceptional and exemplary for SSA. Since independence, Botswana has been led by a freely elected civilian government in a multiparty democracy. From the beginning of its modern existence as an independent state, Botswana has adopted a market economy and a free trade orientation that allowed it to prosper. This political stability along with the long-term vision of the government and the freedom from corruption allowed a sound management of diamond revenue that helped avert the spectrum of the resource curse encountered in other resources endowed countries. This is remarkable and certainly laudable for a diamond rich SSA country, as the abundance of minerals is usually associated with high levels of rent seeking and corruption. In addition, Botswana has a strong commitment to maintaining stringent intellectual property rights regime which guaranteed full protection of IPR in order to encourage invention and foreign investment. It is party to the TRIPs Agreements. Botswana adheres to standards in line with requirements by the International Organization for Standards (ISO) and to raise the quality and variety of Botswana and foreign products for the local market.

References

Acemoglu, D., S. Johnson, and J. A. Robinson (2003). 'Institutional Causes, Macroeconomic Symptoms: Volatility, Crises and Growth'. *Journal of Monetary Economics*, 50: 49-123.

Adeoti, J. (2002). 'Building Technological Capability in Less Developed Countries: The Role of National Systems of Innovation'. *Science and Public Policy*, April.

Akamatsu, K. (1962). 'A Historical Pattern of Economic Growth in Developing Countries'. *The Developing Economies*, Preliminary Issue 1: 3-25.

Aitken, B., and A. E. Harrison (1992). 'Does Proximity to Foreign Firms Induce Technology Spillovers?'. Washington, DC: World Bank and IMF. Mimeo.

Bardhan, P. K., and S. Lewis (1970). 'Models of Growth with Imported Inputs'. *Economica*, November: 373.

Barba Navaretti, G., and D. Tarr (2000). 'International Knowledge Flow and Economic Performance: A Review of the Evidence'. *The World Bank Economic Review*, 14 (1): 1-15.

Barba Navaretti, G., and I. Soloaga (2001). 'Weightless Machines and Costless Knowledge: An Empirical Analysis of Trade and Technology Diffusion'. WB Policy Research Working Paper 2598. Washington, DC: World Bank.

Beck, N., and J. Katz (1995). 'What to Do (and not to Do) with Time Series Cross-Section Data'. *The American Political Science Review*, 89 (3): 634-47.

Beck, N. (2001). 'Time Series Cross-Section Data: What Have We Learned in the Past Few Years?'. *Annual Review of Political Sciences*, 4: 271-93.

Behrman, E., S. Machin, and J. Bound (1997). 'Implications of Skill-Biased Technological Change: International Evidence'. NBER Working Paper W6166. Cambridge, MA: National Bureau of Economic Research.

Bozeman, D., S. Sarewitz, S. Feinson, G. Faladori, M. Gaughan, A. Gupta, B. Sampta, and G. Zachary (2003). 'Knowledge Flows and Knowledge Collectives: Understanding the Role of Science and Technology Policies in Development'. A Project for the Global Inclusion Program of the Rockefeller Foundation. New York.

Caves, R. (1974). 'Multinational Firms, Competition and Productivity in the Host Country'. *Economica*, 41 (162): 176-93.

Chenery, H., and M. Syrquin (1986). 'Typical Patterns of Industrialization'. In H. S. Chenery, S. Robinson and M. Syrquin (eds), *Industrialization and Growth: A Comparative Study*. New York: Oxford University Press.

Coe, D., and E. Helpman (1995). 'International R&D Spillovers'. *European Economic Review*, 39 (5): 859-87.

Dahlman, C., and R. Nelson (1995). 'Social Absorption Capability, National Innovation Systems and Economic Development'. In D. H. Perkins and B. H. Koo (eds), *Social Capability and Long-term Growth*. Basingstoke: Macmillan.

Djankov, S., and B. Hoekman (1998). 'Foreign Investment and Productivity Growth in Czech Enterprises'. WB Policy Research Working Paper 2115. Washington, DC: World Bank.

Eaton, J., and S. Kortum (2001). 'Trade in Capital Goods'. *European Economic Review*, 45 (7): 1195-235.

Eaton, J., and S. Kortum (2002). 'Technology, Geography, and Trade'. *Econometrica*, 70 (5): 1741-79.

Edquist C. (2001). 'Systems of Innovation for Development'. Background paper prepared for the UNIDO World Industrial Development Report (WIDR). New York: UNIDO.

Feinson, S. (2003). 'Knowledge Flows, Innovation and Learning in Developing Countries'. A Project for the Global Inclusion Program of the Rockefeller Foundation. New York.

Freeman, C. (1987). *Technology Policy and Economic Performance: Lessons from Japan*. London: Francis Pinter.

Gachino, G. (2006). 'Foreign Direct Investment, Spillovers and Innovation: The Case of Kenyan Manufacturing Firms'. Maastricht: Maastricht University. PhD thesis.

Grobbelaar, N., and K. Sotetsi (2005). 'Africa's First Welfare State: The Experience of South African Firms Doing Business in Botswana'. Johannesburg: South African Institute of International Affairs.

Hakura, D., and F. Jaumotte (1999).'The Role of Inter-and Intra-industry Trade in Technology Diffusion'. IMF Working Paper WP/99/58. Washington, DC: IMF.

Hekkert, M., R. Suurs, H. Van Lente, and S. Kuhlman (2005). 'Functions of Innovation Systems: A New Approach for Analysing Socio-economic Transformations'. Utrecht: University of Utrecht. Mimeo.

Hunt, J., and J. Tybout (1999). 'Does Promoting High-Tech Products Spur Development?'. FEEM Working Paper REG 42. Milan: Fondazione Eni Enrico attei.

Johnson, A. (2001). 'Functions in Innovation System Approaches'. Paper presented at the Nelson and Winter Conference arranged by DRUID, 12-15 June. Aalborg.

Johnson, A., and S. Jacobsson (2001). 'Inducement and Blocking Mechanisms in the Development of a New Industry: The Case of Renewable Energy Technology in Sweden'. In R. Coombs, K. Green, A. Richards and V. Walsh (eds), *Technology and the Market: Demand, Users and Innovation*. Cheltenham: Edward Elgar, 89-111.

Jacobson, S., B. A. Sanden, and L. Bangens (2004). 'Transforming the Energy System: The Evolution of the German Technological System for Solar Cells'. *Technological, Analytical and Strategic Management*, 16 (1): 3-30.

Juma, C., K. Fang, D. Honca, J. Huette-Perez, V. Konde, and S. Lee (2001). 'Global Governance of Technology: Meeting the Needs of Developing Countries'. *International Journal of Technology Management*, 22 (7/8): 29-55.

Keller, W. (1995). ‘Are International R&D Spillovers Trade-Related? Analysing Spillovers among Randomly Matched Trade Partners’. Madison, WI: Department of Economics, University of Wisconsin. Mimeo.

Keller, W. (1997). ‘Technology Flows between Industries: Identification and Productivity Effects’. *Economic Systems Research*, 9 (2): 213-20.

Keller, W. (2001). ‘International Technology Diffusion’. NBER Working Paper 8573. Cambridge, MA: National Bureau of Economic Research.

Keller, W. (2002). ‘Trade and the Transmission of Technology’. *Journal of Economic Growth*, 7 (1): 5-24.

Keller, W. (2004). ‘International Technology Diffusion’. *Journal of Economic Literature*, 42 (3): 752-82.

Kesidou, E., and A. Szirmai (2007). ‘Local Knowledge Spillovers, Innovation and Economic Performance in Developing Countries Empirical Evidence from the Uruguay Software Cluster’. Paper presented at the UNU-MERIT conference on Micro Evidence on Innovation in Developing Economies, 31 May-1 June. Maastricht.

Khan, M., and M. Knight (1988). ‘Import Compression and Export Performance in Developing Countries’. *Review of Economics and Statistics*, 70 (2): 315-21.

Lall, S. (1992). ‘Technological Capabilities and Industrialization’. *World Development*, 20 (2): 165-86.

Liu, X., and S. White (2001). ‘Comparing Innovation Systems: A Framework and Application to China’s Transnational Context’. *Research Policy*, 30: 1094-111.

Lundvall, B.-Å. (1985). *Product Innovation and User-Producer Interaction*. Aalborg: Aalborg University Press.

Lundvall, B.-Å. (ed.) (1992). *National Systems of Innovation: Towards a Theory of Innovation and Interactive Learning*. London: Pinter Publishers.

Lundvall, B.-Å. (1997). ‘Information Technology in the Learning Economy’. *Communications & Strategies*, 28: 117-92.

Mazumdar, J. (1999). ‘Imported Machinery and Growth in LDC’. *Journal of Development Economics*, 65 (1): 209-24.

Mutz, C., and T. Ziesemer (2005). ‘Simultaneous Estimation of Income and Price Elasticities of Export Demand, Scale Economies and Total Factor Productivity Growth for Brazil’. MERIT–Infonomics Research Memorandum 2005-004. Maastricht: UNU-MERIT.

NACI (National Advisory Council on Innovation) (2006). ‘The South African National System of Innovation: Background Report to the OECD Country Review’. Pretoria: NACI.

OECD (1987). *Structural Adjustment and Economic Performance*. Paris: OECD.

OECD (1999). *Managing National Innovation Systems.* Paris: OECD

Plümper, T., and V. Troeger (2006). 'Efficient Estimation of Time-Invariant and Rarely Changing Variables in finite Sample Panel Analysis with Unit Fixed Effects'. Jena: Max Planck Institute for Economics. Mimeo.

Plümper, T., V. Troeger, and P. Manow (2005). 'Panel Data Analysis in Comparative Politics: Linking Method to Theory'. *European Journal of Political Research*, 44 (2): 327-54.

Rickne, S. (2001). 'Assessing the Functionality of an Innovation System'. Paper presented at the Nelson and Winter Conference arranged by DRUID, 12-15 June. Aalborg.

Rivera-Batiz, L., and P. Romer (1991). 'Economic Integration and Endogenous Growth'. *Quarterly Journal of Economics*, 106 (2): 531-55.

Stewart, J. (2005). *Introduction to Applied Econometrics*. Florence, KY: South-Western College Publishing.

UNESCO (2007). Unesco Institute of Statistics. Montréal: UNESCO. Available at: www.uis.unesco.org/ev.php?ID=2867_201&ID2=DO_TOPIC.