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Effects of R&D internationalisation on R&D investment of firms in South Africa

A research report submitted to the Faculty of Commerce, Law and Management, University of the Witwatersrand, in partial fulfilment of the requirements for the degree of Masters of Commerce (Development Theory and Policy)

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Abstract

Using a multiple case study approach of three R&D performing firms in South Africa, this research explored whether current R&D internationalisation trends are having a positive or negative effect on South Africa's investments in research and development (R&D).

The research found that, contrary to theoretical proposition, the three firms have not relocated core parts or their entire R&D to technologically advanced countries abroad as a result of their increased international exposure. Instead, they have broadened their scope of R&D to integrate foreign-based knowledge inputs. The research also found that increased internationalisation causes firms to alter their approaches to R&D exploitation through incremental improvements on- and/or finding new applications of- existing technologies and creating new markets for them. Three motives influenced the firms, namely to access new knowledge not available locally, to access human capital and to exploit existing capabilities in new markets. Where firms reduced their local R&D investment, such activities were not being relocated to abroad.

Increased competition fostered firms' R&D efficiency. Firms reviewed their internal structures to maximise intellectual property (IP) value; they adopted stricter methods for evaluating new R&D requirements; and they afforded higher priority to R&D with better potential for success. Most of this is meant to exploit existing knowledge.

The findings are applicable to Emerging Economy Multinational Enterprises (EMNEs) that already have well-established R&D capability at home and experience operating in the international R&D environment.

Declaration

I, Mulima Godfrey Mashamba, declare that this research is my own except as indicated in the references. It is submitted in partial fulfilment of the requirements for the degree of Masters of Commerce in Development Theory and Policy at the University of Witwatersrand, Johannesburg. It had not been submitted before for any degree or examination in this or any other university.

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MG Mashamba

Signed at..........on the.......day of........... 2016

Dedication

To my wife, kids, parents, extended family, professional colleagues, who support and believe in me.

Acknowledgements

I thank my supervisors, Dr. Erika Kraemer-Mbula and Dr. Lotta Takala-Greenish and DTP programme head, Dr. Nicolas Pons-Vignon, for guidance in undertaking this research.

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1. Chapter 1: Introduction

1.1 Purpose of the research

The purpose of this research is to examine the effects of research and development (R&D) internationalisation on the orientation of R&D investment of South African firms. The research comprises of case studies of three R&D performing firms in South Africa to explore whether current R&D internationalisation trends are having a positive or negative effect on South Africa's investments in R&D.

1.2 Background and context

The Organisation for Economic Cooperation and Development (OECD) (2015:28) defines R&D as creative and systematic activity undertaken to increase the stock of knowledge and to devise new applications of available knowledge. By engaging in R&D, firms deepen their capabilities for innovation, to introduce new products, processes, techniques or improve existing ones, thereby enhancing their competitiveness.

Economic theory has long established that R&D contributes to productivity and long-term economic growth (Solow, 1957; Grilliches, 1979; Mohnen, 1996). R&D, in its various forms, contributes to the accumulation of a stock of knowledge, which is crucial for competitiveness of firms, economies and regions (Fagerberg, 1994; Hall and Mairesse, 1995; Mohnen, 1996; Engelbrecht, 1997; Nelson and Winter, 2002). This drives firms to engage in R&D, despite the high uncertainty of its outcomes. It is also a reason why countries and regions introduce policies to attract and retain R&D activities.

R&D internationalisation is an important dimension of the economic globalisation process (OECD 2008; Narula and Dunning, 2010). R&D internationalisation occurs when economic agents/actors perform R&D activities, or apply R&D resources or have R&D outputs in more than one country. Resources can be funding investment, people and institutions and knowledge inputs that are used to achieve R&D results (OECD, 2015:298).

Unlike three decades ago, where the focus of international economic exchanges was primarily on investment, production and trade, contemporary evidence shows acceleration in exchanges of R&D and its key drivers, namely human capital, knowledge and innovative ideas (UNCTAD, 2005a; Hatzichronoglou, 2008; Hall, 2010; OECD, 2014:37; NSF, 2014:4).

Firms, as major investors in R&D, now have a greater ability to locate, organise and exploit their R&D activities, or parts of their R&D value chain, in (different) places they consider most viable globally, than they would three decades ago (Grossman and Helpman, 1995:1281; Saggi, 2000; Cincera, Cozza and Tubke, 2010).

Multinational enterprises (MNEs) from developed countries have traditionally played a major role in R&D internationalisation and its evolution (UNCTAD, 2005b; Hatzichronoglou, 2008). This has influenced most of the earlier research in this subject. Such earlier studies were mostly about R&D internationalisation aspects of MNEs in North America, Europe and Japan (Ronstadt, 1976; Lall, 1979; Mansfield, Teese and Romeo, 1979; Dunning and Narula, 1995). Among other arguments, these studies maintained that MNEs centralised R&D and other strategic functions in developed country headquarters and only extended parts of their R&D to other countries for asset-exploitation purposes, i.e. to adapt their technology and access markets (Archibugi and Michie, 1995).

Trends on economic globalisation show that multinational enterprises from emerging economies, referred to as EMNEs, have grown in importance as contributors to global R&D efforts, both as significant R&D funders and performers in home countries and abroad (Von Zedtwitz, 2005; UNCTAD, 2005b; Di Minin, Zhang and Gammeltoft, 2012; Sanfilippo, 2013; Amighini, Cozza, Giuliani, Rabellotti and Scalera, 2014).

Several waves of changes are described in literature but differ depending on analytical perspectives of authors. With respect to EMNEs, Amighini *et al.* (2014), Sun, Du and Huang (2006), Mudambi (2008) and UNCTAD (2005b) note that from the 1960s to 1980s, Latin American firms (largely state-owned) expanded their R&D to other developing countries in order to access new markets; between 1980s and early 1990s, Asian firms expanded their R&D to fast-growing regions in both developed and developing countries, seeking strategic assets to augment their capabilities; from the 1990s and more recently, several developing countries have increased their attraction of inbound R&D investment, both from developed and other developing countries. In the latter phase, Hall (2010) notes that MNEs from developed countries have been increasingly establishing their core R&D facilities in developing countries for asset-augmenting purposes as well, i.e. to access new technological knowledge in areas they lack.

The trends highlighted above demonstrate a gradual departure from past trends, where R&D and knowledge-based production was a purview of firms in advanced economies, which according to UNCTAD (2005b:157), reflects the changes in the drivers and determinants of R&D internationalisation.

R&D internationalisation has implications for the firms involved as well as the economies in which they operate. Spillovers from knowledge and technology transfer and learning can help firms, economies and regions lagging in technology and productivity to upgrade and 'catch-up' (Xu, 2000; Sanfilippo, 2013). Firms with well-established capabilities can find opportunities to exploit their existing knowledge and expand their markets as shown by Verhoef (2011) and Awate *et al*. (2012) with respect to EMNEs. Furthermore, firms can also be exposed to greater risk associated with the international R&D environment, both in their home countries and in the countries in which they undertake R&D activities (Von Zedtwitz, 2005; Sanfilippo, 2013; Amighini *et al.,* 2014). Greater openness may lead to the erosion of an economy's existing capabilities as local firms increasingly engage in outbound R&D investment (ETAN, 1998; Criscuolo, 2004:71; Moncada *et al.,* 2011).

For South Africa, and other developing economies, R&D internationalisation and its effects remains a policy challenge given that such economies have to increase their levels of R&D investment as this is seen as a differentiator between countries' and regions' economic growth and development (Coe and Helpman, 1995; Dunning, 2000; Narula, 2003; Hall, 2010; Guimon, 2013).

1.3 Motivation

A review of the existing literature indicates that more exploratory research is needed to enhance understanding of South Africa's R&D internationalisation phenomenon in a contemporary context.

This study notes that local large firms such as Sasol, DeBeers, SABMiller, Sappi and a few others have operated internationally for several decades and become leaders in specific technological domains (Gelb and Black, 2004; Verhoef, 2011). As South Africa continues to integrate into global economic affairs, ever more local firms are involved in cross-border R&D activities (Baskaran and Muchie, 2008). Data published by international organisations, namely the OECD, UNESCO, World Bank and others provide an indication of South Africa's R&D internationalization. Such data is useful in assessing aggregated trends but has limitations in understanding the dynamics at firm and industry levels.

There are knowledge gaps on how South African firms adapt and influence the evolving global R&D environment. By using firms as unit of analysis of R&D internationalisation, this research adds to a growing body of empirical research on R&D internationalisation of developing countries, related to its drivers, actors, consequences and to test the relevance of extant theoretical propositions. A growing number of authors such as Von Zedtwitz (2005), Gammeltoft (2008), Narula (2010), Di Minin *et al.* (2012), Sanfilippo (2013), and Amighini *et al.* (2014) contend that the extant theory on R&D internationalisation does not fully comprehend the developing country contexts. Such authors argue that new theoretical explanations are needed, both on developing countries and EMNEs' R&D internationalisation.

Referring to a study by the National Advisory Council on Innovation (NACI), OECD (2007:146) noted a concern that as South African firms became more exposed to economic openness they engaged in international R&D in ways that were eroding local R&D capabilities. Along these lines, Kaplan (2011) lamented the dissipating R&D capability in South Africa's mining and services sectors following the democratic dispensation. Studies by Kahn *et al.* (2004), Kahn (2007) and Pouris (2003) also add perspective to the R&D internationalisation issue with respect to mobility of R&D-related human capital, cross-border funding flows and South Africa's contribution to scientific knowledge production globally. These studies recommended that further research be done to better understand the place of South Africa's R&D system in the global context and the implications thereof.

1.4 Structure of the report

This report is organised into six chapters. The next chapter (i.e. Chapter 2) explains the research methodology; Chapter 3 summarises the main ideas and lessons drawn from literature; Chapter 4 presents the main trends of South Africa's R&D internationalisation drawing from secondary data and indicators; Chapter 5 presents the analysis of case studies. Chapter 6 presents summary and conclusion, where appropriate, pointing towards issues for further research and policy consideration.

2. Chapter 2: Research methodology

2.1 Research questions and hypotheses

The research questions are: (1) how have South African firms responded to greater exposure to the international environment of R&D? And (2) why they responded the way they did?

Hypothesis 1: South African firms move core parts or their entire R&D to technologically advanced countries as a result of greater exposure to R&D internationalisation.

Hypothesis 2: South African firms change their orientation for exploiting R&D as a result of increased exposure to R&D internationalisation.

The research acknowledges that South Africa is a developing country or an emerging economy. In this regard, it is assumed, therefore, that South African firms operate in a different context from those in technologically advanced, industrialised economies in terms of relative advantages of home country systems of innovation and international competitive position i.e. location-specific advantages (Cincera *et al*, 2010; Amighini, *et al.* (2015. This interpretation is important in order to characterise the firms selected for cases studied in this research as EMNEs. Such firms, according to Von Zedtwitz (2005), Verhoef (2011), Ramamurti (2012), Di Minin *et al.* (2012), Awate *et al*. (2012) and Amighini *et al.* (2015), may have different motives and paths for R&D internationalisation compared to firms in advanced economies.

Three theoretical propositions are outlined in the next paragraphs to support the hypotheses.

Based on the lessons drawn from literature, it is expected that in internationalising R&D, firms in South Africa face a dilemma when deciding which R&D activities to retain at home and which ones to disperse in other countries. **Theoretical basis for this is**

that firms fine-slice their activities so that highest value-added R&D activities are located in technologically advanced countries and lowest value-added activities in emerging countries (D'Agostino and Santangelo, 2010). This theoretical proposition is found in literature about MNEs from technologically advanced economies.

The dilemma for EMNEs arises because they already have developed their strongest capabilities at home country, which according to Patel and Pavitt (1991), would likely be retained at home due to embeddedness to the home country capabilities. With R&D internationalisation, firms have to evaluate whether to retain all their R&D capabilities at home or to establish R&D capabilities abroad or ways to access knowledge externally. The latter can be done by way of moving all the R&D work abroad, parts of it or expand by initiating new activities in other countries. **A second theoretical proposition is, therefore, that EMNEs engage in R&D abroad in order to access new technology to augmenting their existing capabilities (i.e. home-based augmenting)** (Demirbag and Glaiser, 2010; D'Agostino and Santangelo, 2010; Di Minin *et al.*, 2012).

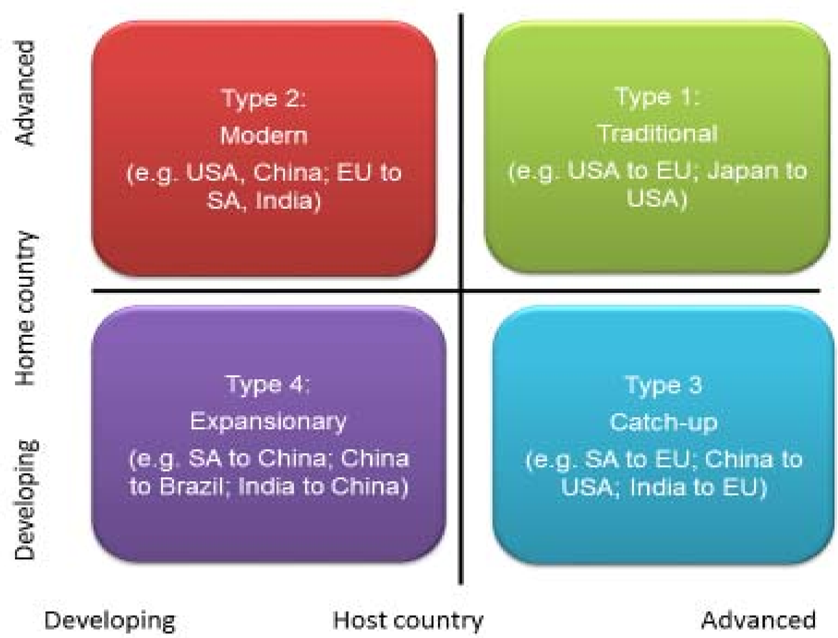
Again, based on lessons from literature, it is expected that South African firms will alter their orientation to R&D exploitation as a result of increased exposure to international markets and competition. In doing so, firms evaluate how the new R&D abroad may complement home-based R&D and increase efficiency in generating innovations (Archibugi and Michie, 1995; Von Zedtwits and Gassmann, 2008; Patel and Vega 1999). R&D exploitation means applying the results of R&D. Such activities include extending product development activities to adapt to new markets, increasing patenting and intellectual property (IP) management activities to facilitate entry and block/defend competition, forming new collaborations to extend the scope for knowledge exploitation into new markets, etc. (Archibugi and Michie, 1995).

A theoretical proposition, in this instance, is that EMNEs differentiate their R&D exploitation approaches between developed and developing economies. The basis for this is that EMNEs generate different experiences when exploiting their R&D in developed countries and in developing countries (Von Zedtwitz, 2005; Narula, 2010; Di Minin *et al.,* 2012 and Sanfilippo, 2013). The following scenarios, drawn from Von

Zedtwitz and Gassman (2008), Miozzo *et al.* (2011), Verhoef (2012), Amighini *et al.* (2014) are considered (depicted in Figure 1):

- From emerging economy to advanced economy, e.g. South African firms into USA and Chinese firms into Europe.
- From emerging to emerging, e.g. South African firms into China and Chinese firms into Africa.
- From advanced to emerging, e.g. USA firms into South Africa.
- From advanced to advanced, e.g. EU firms into USA.

Figure 1: Developing versus advanced country as home and host location



Source: Author's adaptation from Von Zedtwitz (2005).

2.2 Research design and data sources

The research comprises a combination of exploratory and descriptive methods. It involves case study of three firms that have performed R&D in South Africa over the period 2000 to 2015. The case study is supplemented by analysis of available secondary data and selected indicators to analyse the international openness of South Africa's R&D system. The case study has used qualitative data while secondary data analysis is based on quantitative data. This approach draws from the advantages of case study of in-depth examinations of the firms and the use of secondary data to understand the broader context of South Africa in the international R&D environment.

Three reasons motivate a choice for case study approach:

Firstly, R&D internationalisation of South African firms has not received extensive attention of academic research.

Secondly, the theoretical propositions to explain R&D internationalisation of EMNEs are still a subject of much debate and that case studies can assist with the in-depth examination of the topic.

Thirdly, according to Yin (2014:9), case study approach can be useful in studies seeking to establish the context and to explain "why and how certain phenomena occur". This is considered suitable for this research in order to understand the contextual factors at firm level, considering that various factors impact on the innovation system and its degree of internationalisation as well as on the strategies at the level of firms.

Examples of studies listed in Table 1 demonstrate how case study approach was used in studying R&D internationalisation and its dimensions. The advantage noted from such studies is the explanatory power of detailed evidence gathered through cases studies because of a range of possible questions used, a range of measurement variables considered and flexibility in using mixed methods for gathering data.

Table 1: Examples of case study research considered

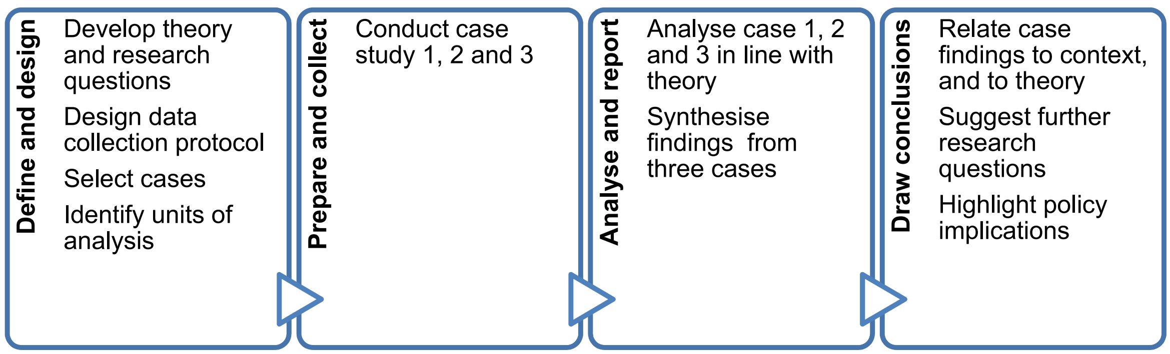
Study	Unit of observation	Lessons relevant for this research
Criscuolo (2004)	Six European pharmaceutical companies	To understand the impact of R&D internationalisation and knowledge transfer on MNEs and their home countries. This enabled identification of possible areas of such impacts and how that can be measured.
Sun *et al* (2006)	18 Shanghai based R&D facilities	Other than using aggregated indicators of R&D investment, contextual factors at firm level were explored to understand drivers of foreign R&D into Shanghai, China.
Von Zedtwits and Gassmann (2008)	Case of Pfizer; and 81 other firms controlling 1021 R&D sites globally	To understand the trends, driving forces and organisational and control forms in international R&D of Pfizer and other firms with R&D facilities globally.
Demirbag and Glaiser (2010)	1722 R&D projects of MNEs located in developing and emerging economies	To understand systemic conditions that attract and retain R&D investment in developing countries and the variables shaping international R&D organisation and R&D exploitation.
Miozzo, DiVito and Desyllas (2011)	Six UK-based pharmaceutical firms	To understand the effects of cross-border M&A on innovation activities of the firms involved, and on their respective locations. This enabled researchers to build inductively on the extant theory.
Awate *et al*. (2012)	Comparative case analysis of EMNE and counterpart in advanced economy	To understand the catch-up and knowledge strategy of a fast-follower EMNE relative to an incumbent technology leader from advanced economy.
Di Minin *et al.* (2012)	Five large Chinese MNEs with R&D in European locations	To understand the motives, location strategies and how these evolved over time in terms of the maturation model.

Source: Author's compilation

2.3 Case study procedure

An approach for case study followed the recommendations by Yin (2014:60), which is summarised in Figure 1.

Figure 2: Summary of case study procedure



Source: Authors' compilation adapting from Eisenhardt (1989) and Yin (2014:60).

The theoretical proposition was developed based on the literature review. This guided the formulation of research questions, the design of data collection protocol, the selection of cases to study, as well as the criteria and approach for analysing and interpreting the findings.

2.3.1 Selection of cases

Eight firms were approached with a request, written in a University letterhead, for case study research. An objective was to select three as cases to study. The number three suited the timeline for this research and also provided sufficient quantity for cross-case analysis and possible generalisation.

Any of the eight firms could have been selected because they all met preselection criteria: All of them, or their parent group or affiliates, were among a list of 189 firms that were nominated for South Africa's Technology Top 100 awards between 2011 and 2015; they have been performing R&D in South Africa for the period covered by the study, 2000 to 2015; they operated in high and medium-high technology industries (e.g. electrical machinery and apparatus, pharmaceuticals, telecommunication technologies, minerals research, aerospace, defence technology); and their industries have a high degree of exposure to international environments of R&D.

The procedure followed in selecting the cases had potential to lead to replication logic rather than sampling logic (Eisenhardt, 1989), either to predict similar results or offer contrasting findings that can be used in drawing conclusions and generalising from the cases studied.

The three firms that provided earliest confirmation of willingness to participate in this research were selected. The three selected cases are all subject to privacy clauses and as such they are named: Participant-A, Participant-B and Participant-C. All the three firms already have well-established R&D capability at home and experience operating in the international R&D environment.

2.3.2 Data collection protocol

The data collection protocol used in the study is attached in Annexure A. The protocol specified the measurement questions that were used as a guide for case study interviews with relevant officials of the respective firms and in sourcing other information. By specifying measurement questions, the protocol mitigated the risk of subjectivity and construct validity, which are the common challenges of case study approach.

The researcher interviewed executive(s) and/or senior manager(s) responsible for strategic R&D planning/finance in the companies. Names of interviewees are not revealed in the report for confidentiality reasons. The three firms confirmed in writing. Other information was accessed from the respective firms' websites and other documents that were requested (e.g. annual reports, relevant extracts from reports and presentations showing R&D strategy/planning, R&D investments/spending, locations, organisational and control structures), as well as media reports. The interviews ranged between 1½ hour to 2 hours, with follow-ups through emails and telephone for clarity, where necessary.

In summary, the case study information collected included the following:

- **Driving forces for R&D internationalisation:**
  - Internal factors within the firm.
  - External factors influencing the firm.

- **Modes for R&D internationalisation:**
  - Foreign subsidiary.
  - Cross-border M&A.
  - Cross-border collaborations, Joint Ventures (JVs) or partnerships.
  - R&D offshoring (i.e. outsourcing of R&D work to abroad).
  - Cross border technology licensing.
  - Influence of global group of companies.

- **How the firm has altered any of the following variables as a result of R&D internationalisation?**

  - R&D investment – whether there has been a step change in the overall R&D investment of a firm, by how much local and abroad and over what period of time.

  - R&D location – whether a firm has established R&D activities in new country locations or relocated part or its entire R&D to new locations.

  - R&D organisation – whether a firm has set up new or significantly changed structures responsible for its R&D activities.

  - R&D performance – whether there have been significant changes in the mix of R&D types.

  - R&D exploitation – whether a firm has undergone significant changes in the ways in which it generates and uses results of R&D, in knowledge transfers and learning and in attributing outcomes of R&D.

- Other.

- **Whether the firm's R&D internationalisation altered its orientation to R&D exploitation, indicated by:**
  - Increased dependence on foreign input of knowledge.
  - Increased share of output absorbed by foreign markets.
  - Improved efficiency in firm's R&D activities
  - Increased outbound R&D and technology transfer.

- **The effects of firm's R&D internationalisation on South Africa's innovation system:**
  - Positive and negative effects.
  - Factors encouraging and hampering firm's R&D in South Africa.

The information collected through the interview protocol was recorded in MS-Word and MS-Excel. MS-Excel database was used for sorting, categorising and coding the information for purposes of analysis. Coding assisted in standardising the information collected and ensured the reliability of the approach. The procedure followed in this research can therefore be replicated or extended in undertaking further case studies later and in other locations.

2.3.3 Approach for case study analysis

The analysis was conducted following three iterative steps. Firstly, case narratives were written up and sent to the respective firms for confirmation. Secondly, the case descriptions were analysed against the theoretical propositions found in literature review; thirdly, cross-case findings were noted, where appropriate highlighting rival explanations, to aid synthesis and to draw conclusions.

This approach was deliberately followed to ensure the reliability and external validity of the research. Studying three cases allowed testing the relevance of measurement questions and also drawing cross-case findings and illuminate differences. This improves the ability to generalise the findings (Miozzo *et al*., 2011; Yin, 2014:164).

2.4 Limitations of case study approach

With respect to case studies, the first challenge experienced relates to the scope and volume of information required in order to produce reliable findings. A data collection protocol was developed in order to guide the scope of information collection in a way that will enable the planned analysis of the cases.

Secondly, time constraints also played a role, limiting the volume of information that could be collected and the analyses done.

Thirdly, there were also confidentiality considerations that had to be taken into account. To address this limitation, some information collected was not reproduced in the report but assisted in the interpretation of the findings. Respondents were provided with the descriptive write-up of the cases to confirm that this report does not unnecessarily breach the agreed confidentiality protocol or misrepresent their information.

Fourthly, the approach adopted in this study by using three cases, instead of one case, was meant to address a challenge identified by Yin (2014:40) that case studies suffer from lack of generalisability of findings. The same measurement questions were used in collection and analysis of the information of all three cases.

2.5 Alternative methods considered

The topic of R&D internationalisation has numerous dimensions and relevance in several fields of study, including economics, international business and strategy, innovation policy, globalisation and others (Granstrand, Hakanson and Sjolander, 1993; Criscuolo, 2004; Carlsson, 2005). The literature review reveals some of the connections.

Several methods are used in studies of R&D internationalisation, covering quantitative and qualitative and combinations of these. In literature, there are studies focussing at the level of firms, industry/sector, geographic space or at aggregated/macro levels. In their literature survey, Granstrand *et al*., (1993), Archibugi and Michie (1995), Criscuolo (2004) and others have distinguished the following topics dominating the analysis of R&D internationalisation:

The wider context of economic globalisation and internationalisation of science and technology; Determinants (which includes key drivers, motives and enablers; Modes (which includes activities, knowledge flows, organisation of R&D functions across borders, their control and coordination); Effects (which includes resourcing and outputs as well as exploitation of R&D outputs; and Impacts (in terms of how aspects of R&D internationalisation alters the firms, its efficiency as well as activities of its associated firms, and impacts to the industries and economies in which the firm operates).

Studies at economy level mostly use quantitative and econometric analysis of R&D inputs/resources (this is discussed further in Paragraph 2.6). International databases and large scale data collections by the OECD, the European Union, UNESCO and the USA-based National Science Foundation (NSF) serve as sources of data collated from countries' national surveys of R&D statistics. Such datasets not only provide data on R&D funding flows but also cover human resources and patents.

Patent data analysis is one commonly used method to analyse changes in cross-border innovation activity over long periods (Guellec and Van Pottelsberghe, 2001; Criscuolo *et al*., 2005, Verspagen and Schoenmakers, 2004 and Hall, 2010).

Choice of methodology in this study, of using three case studies and analysis of selected quantitative indicators on R&D internationalisation, is based on its relevance to the research questions. Experimental design was not considered suitable because of its limitation in reliance on standard observations and questionnaire. The research questions required usage of multiple information sources to understand context of firms. Merits and limitations experienced with this approach are highlighted, where appropriate, in the report.

The approach in this research acknowledges that business R&D internationalisation is linked to activities of other actors such as government, public research institutions and higher education institutions, as well as activities on foreign direct investment (FDI), international trade, production and human capital mobility. Where the research makes reference to these issues, such references are done only for purposes of completeness.

2.6 Use of secondary data

Secondary data was sourced to empirically analyse international openness of South Africa's R&D system. R&D system (distinguished from innovation system) is a phrase used in this research to refer to resources/inputs devoted to R&D, the actors that fund and perform R&D as well as the outputs derived (OECD, 2015:24). Innovation system is a much wider concept, in which R&D activities and R&D system are part (OECD, 2015:3).

The data was sourced from the following specialised databases: The Centre for Science Technology and Innovation Indicators (CeSTII), which is responsible for the South African R&D statistics; the OECD's Main Science and Technology Indicators (OECD-MSTI) database; the UNESCO Institute of Statistics' database Science, Technology and Innovation; the United States Patent and Trademark Office (USPTO) database; and the World Bank database.

An advantage for using all the above mentioned databases is that each one contains data of different descriptions, formats and periods and that there are complements across some of the data, enabling triangulation of information.

The following sets of indicators are assessed:

- Size and scale of the R&D system:
    - Gross expenditure of research and development (GERD).
    - GERD as percentage of gross domestic product (GDP).
    - R&D personnel.
    - Outputs of R&D, i.e. scientific publications and patents.

- Cross-border R&D activities:
    - Foreign ownership of local R&D performing firms.
    - Cross-border R&D funding flows.
    - Cross-border R&D collaborations.
    - Technology balance of payments (TBP).

These indicators were used for similar analysis in Bloom and Griffin (2001), Kahn (2007), Hall (2010), Avallon and Chédor (2012) and Dachs *et al* (2012).

Where appropriate, benchmarks of comparator countries were used. In selecting comparator countries, 41 countries that have the required data were identified form a list of top 50 R&D spending countries published by UNESCO (See Annexure B). The list provided possibility for comparisons with the 20 largest economies (i.e. G20 countries), the BRICS (i.e. Brazil, Russia, India and China) countries, OECD countries, EU countries and the two African countries featured. Data availability influenced choice of country benchmarks per indicators area analysed.

Secondary data analysis in this research suffered a challenge of data gaps at macro-level on specific indicators about South Africa's R&D internationalisation. This is so both from local and international sources. Studies by Grilliches (1979) and more recently by Hall (2010), NSF (2012) and NEPAD (2014) acknowledge this challenge and some note the efforts underway to improve such data, for example by the OECD, Eurostat, UNESCO and the NSF. Many countries, including South Africa, are unable to produce certain data due to complexities involved. Several challenges impact on usability of data on R&D internationalisation. There are inconsistencies between countries in how they collect and publish data and reference periods covered; there are gaps in data availability of countries such as China and India, which could be significant role players in this area; furthermore, many countries do not produce data on outbound R&D (Dachs *et al* (2012). In some instances, increased/decreases on specific data points are associated with improvements in data production, so they are interpreted with caution.

The 7th edition of the OECD Frascati Manual (published in October 2015), for the first time, provides guidance in improving measurement and analysis of R&D internationalisation.

3. Chapter 3: Literature Review

3.1 Globalisation and R&D internationalisation

The past three decades have seen acceleration in internationalisation of R&D activities (UNCTAD, 2005a; Hatzichronoglou, 2008; Hall, 2010; OECD, 2014).

This is part of a broader phenomenon of economic globalisation, in which many economies have increasingly opened up to international exchanges of economic activities such as investment, production, trade, human capital, knowledge and competition. Trade and financial liberalisation and technological developments have accelerated the globalisation phenomenon (Narula and Dunning, 2000; UNCTAD, 2005b). For South Africa, the democratic dispensation in 1994 assisted this process (Gelb and Black, 2004:178).

Economic agents now have a greater ability to locate, organise and exploit their R&D activities on a global scale. Empirical research points to three important changes that emerged with R&D internationalisation. Firstly, the geography of global R&D activities has become more dispersed than ever before; secondly, the share of R&D activities that involve increased cross-border interaction of agents and resources has increased; and thirdly, the differences between countries and regions in terms of major scientific and technological priorities have narrowed (Hatzichronoglou, 2008; Hall, 2010; NSF, 2014:4; OECD, 2014:44; Battelle, 2013).

In economic literature, earlier work on R&D internationalisation include Ronstadt (1976), Mansfield *et al.*, (1979) and Lall (1979). Such studies and others (referenced by Archibugi and Michie, 1995; Patel and Vega, 1999; Storper, Chen and De-Paolis, 2000; Carlson, 2006, D'Agostino *et al.*, 2010; Miozzo *et al.*, 2011), maintained a view that global organisation of R&D was highly hierarchical. They argued that knowledge-based economic activities, of which R&D is one, are concentrated in technologically advanced regions. They also argued that MNEs in those regions undertake R&D in developing countries mainly to exploit and adapt their existing knowledge into new markets.

There is empirical evidence that supports these views. The list of top 10 R&D performing nations has remained the same (USA, China, Japan, Germany, South Korea, France, India, UK, Russian Federation and Brazil) over the past decade (UNESCO, 2012).

There are continuing shifts, however, in the relative positions of countries within the top 10. Analysis of longer term trends (Table 2 and Annexure B) reveal the following:

Firstly, global R&D expenditure has accelerated faster than global GDP, with global GERD as percentage of global GDP rising from 1.57% to 1.70% between 2007 and 2013 (UNESCO, 2015:24).

Secondly, the population of researchers has grown from 4.5 million to 7.7 million and researchers from developing countries contributing substantially to mobility and collaborations as possibility of cross-border recruitment increased (UNCTAD, 2012b; UNESCO, 2015:24).

Thirdly, the contribution of developing economies and regions to global R&D expenditure and human capital is rising.

Fourthly, the increases in R&D investments in the three traditional dominant R&D nodes, namely North America, Japan and the European Union (EU), have moderated, as developing countries, particularly in the south and East Asian and Latin American regions, emerged as favourites for new investments in R&D (NSF, 2014:4; OECD, 2014). Furthermore, Hall (2010) and OECD (2015:42) noted that MNEs in these three nodes have increased their share of outbound R&D spending between 1995 and 2005.

Fifthly, some emerging economies continues to attract international R&D throughout the period of global economic crisis (Yusuf, 2012; Dachs and Zahradnik, 2014).

Table 2: Selected indicators of global R&D expenditure per region

A. GERD in million current PPP$

	1996	2000	2006	2010	2012	2013
World	547,661	731,665	1,102,302	1,421,736	1,641,708	1,736,655
Arab States	4,322	5,606	8,561	13,132	15,562	17,933
Central and Eastern Europe	18,929	24,020	45,010	65,730	79,844	83,530
Central Asia	538	553	1,083	1,409	1,722	2,055
East Asia and the Pacific	130,058	175,592	326,902	474,481	587,877	647,885
Latin America and the Caribbean	19,398	23,675	34,231	51,256	57,346	60,984
North America and Western Europe	357,627	478,106	639,161	750,496	823,233	843,255
South and West Asia	13,198	19,521	39,121	54,863	64,137	68,124
Sub-Saharan Africa	3,591	4,592	8,233	10,370	11,988	12,889

B. Regional relative contribution to global GERD

	1996	2000	2006	2010	2012	2013
Arab States	0.79%	0.77%	0.78%	0.92%	0.95%	1.03%
Central and Eastern Europe	3.46%	3.28%	4.08%	4.62%	4.86%	4.81%
Central Asia	0.10%	0.08%	0.10%	0.10%	0.10%	0.12%
East Asia and the Pacific	23.75%	24.00%	29.66%	33.37%	35.81%	37.31%
Latin America and the Caribbean	3.54%	3.24%	3.11%	3.61%	3.49%	3.51%
North America and Western Europe	65.30%	65.34%	57.98%	52.79%	50.14%	48.56%
South and West Asia	2.41%	2.67%	3.55%	3.86%	3.91%	3.92%
Sub-Saharan Africa	0.66%	0.63%	0.75%	0.73%	0.73%	0.74%

C. Regional GERD as percentage of global GERD

	1996	2000	2006	2010	2012	2013
World	1.42%	1.53%	1.54%	1.63%	1.68%	1.70%
Arab States	0.22%	0.22%	0.22%	0.26%	0.27%	0.30%
Central and Eastern Europe	0.79%	0.81%	0.85%	0.94%	1.01%	1.01%
Central Asia	0.27%	0.22%	0.24%	0.20%	0.21%	0.23%
East Asia and the Pacific	1.41%	1.54%	1.73%	1.90%	2.03%	2.10%
Latin America and the Caribbean	0.52%	0.53%	0.55%	0.65%	0.66%	0.67%
North America and Western Europe	2.05%	2.20%	2.17%	2.36%	2.43%	2.43%
South and West Asia	0.51%	0.58%	0.70%	0.70%	0.71%	0.71%
Sub-Saharan Africa	0.37%	0.39%	0.41%	0.41%	0.41%	0.42%

D. Total researchers (absolute number) and regional contribution (in %) to global population of resea

	1996	2000	2006	2010	2012	2013
World total of researchers	4,567,682	4,923,702	6,133,699	7,074,185	7,572,578	7,758,862
Arab States	2.22%	2.16%	1.97%	1.83%	1.91%	1.93%
Central and Eastern Europe	19.49%	15.92%	12.68%	11.19%	10.76%	10.61%
Central Asia	0.91%	0.71%	0.60%	0.55%	0.61%	0.63%
East Asia and the Pacific	28.48%	30.14%	33.50%	36.76%	38.00%	38.46%
Latin America and the Caribbean	3.04%	3.04%	3.61%	3.87%	3.78%	3.72%
North America and Western Europe	40.77%	43.78%	42.74%	40.71%	40.00%	39.74%
South and West Asia	4.25%	3.32%	3.94%	4.04%	3.88%	3.86%
Sub-Saharan Africa	0.83%	0.92%	0.96%	1.05%	1.06%	1.06%

Source: Author's calculations using UNESCO data. **Note:** This report uses US$ Purchasing Power Parity (PPP) figures. PPP conversion eliminates differences in prices found in national currencies and makes comparisons across countries easier.

Interlinked with R&D internationalisation, Archibugi and Michie (1995) and Zedtwitz and Gassmann (2008), note a trend of global exploitation of R&D, indicated by invention and innovation activities that have increasingly become international in scope. Data at World Intellectual Property Organisation (WIPO) indicates that most of the increase in patenting activity between 2004 and 2014 comes from emerging economies (http://ipstats.wipo.int/ipstatv2/keysearch.htm?keyId=204).

The growing role of emerging economies in global R&D has prompted studies into the changing geography of R&D expenditure globally and its implications for developing countries. Examples are Dunning (2000), Archibugi and Pietrobelli, 2003; UNCTAD (2005a,b) and Sun *et al.* (2006).

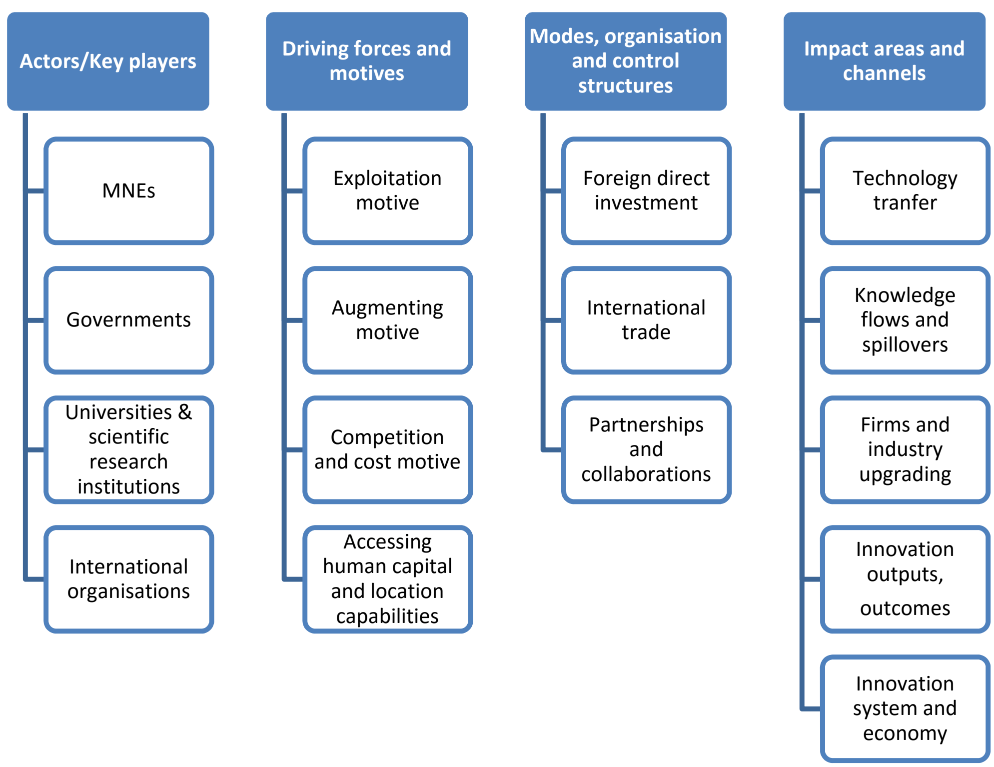
Developing countries are no longer seen as peripheral but as key sources of new knowledge and technological advances (Mudambi, 2008). However, not all such countries and their firms are moving at the same pace and to the same extent (Dunning and Narula, 1995; Narula, 2003; Narula, 2010; Sanfilippo, 2013). Trends show a mixed picture for developing countries, with China, South Korea and India leading the pack of countries that have attracted the bulk of the shifting global R&D expenditure over the past two decades, while several other developing countries, including South Africa, have not been able to significantly raise their shares of global R&D investments (OECD, 2014; Battelle, 2013).

Developing countries that have succeeded have done so because they have conditions that attract such investments, such as growing markets, the requisite human capital and appropriate technology, scientific networks and the associated cost advantages, etc. (Archibugi and Pietrobelli, 2003; Economist Intelligence Unit (EIU), 2004; Cincera *et al.*, 2010; OECD, 2011).

Literature in the 1990s presented the taxonomies on the subject of R&D internationalisation that influenced subsequent research interest. Such contributions are referenced by Archibugi and Michie (1995) and Dunning and Narula (1995), and include Freeman and Hagedoorn (1992) and Kuemmerle (1999) and others. Research that emanated from these studies were around data on cross-border R&D investments, motives and drivers for R&D internationalisation, forms of organisation and control, execution modes, as well as effects on the source and recipient countries/locations and firms/actors involved. The growing policy interest on the R&D internationalisation subject inspired the OECD, Eurostat, National Science Foundation and UNESCO to conceptualise data requirements and establish databases that can help measurement and understanding of R&D internationalisation (Hatzichronoglou, 2008; Hall, 2010). Such efforts are still underway.

Despite the rival theoretical explanations, there are some common elements that are discernible from literature on R&D internationalisation. Figure 2 summarises such elements.

Figure 3: Elements of R&D internationalisation



Sources: Archibugi and Michie, 1995; Dunning and Narula (1995), Kuemmerle (1999), Criscuolo (2004), D'Agostino *et al*. (2008) and Moncada *et al*. (2011).

3.2 Actors, driving forces and motives for R&D internationalisation

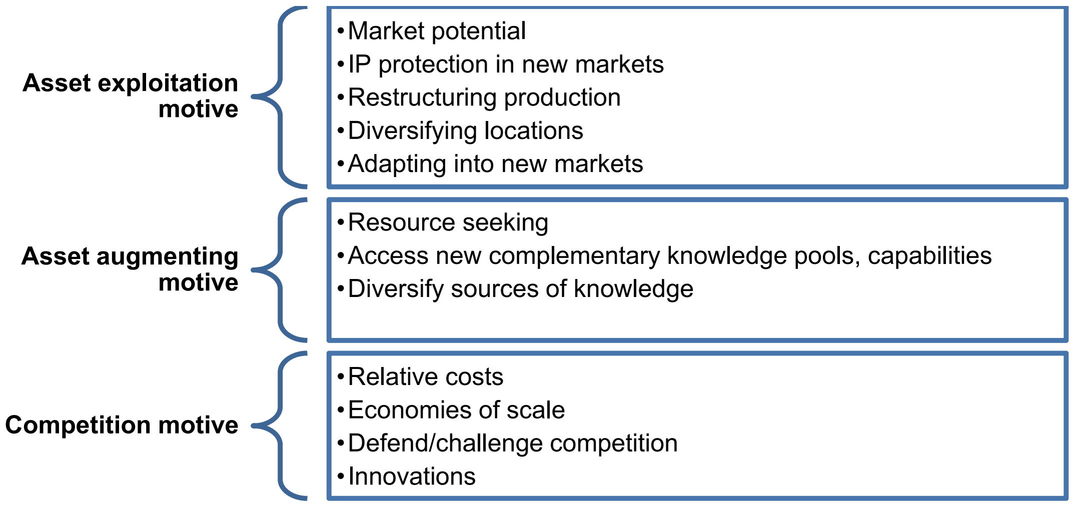
In terms of the actors/key drivers, MNEs play a major role in R&D internationalisation because of the large proportion of R&D resources they control globally (Hatzichronoglou, 2008; Hall, 2010; Battelle, 2013; NSF, 2014; OECD, 2014:42). Governments, universities and scientific research institutions as well as international organisations, through their policies and scientific programmes, also drive the R&D internationalisation trends. These actors drive the trends through direct investment and other resources they dedicate into specific scientific programmes, through decisions about the location of such programmes and also by influencing the decisions of firms (OECD, 2014:129).

R&D internationalisation occurs when any of these actors performs R&D activities or apply R&D resources or have R&D outputs in more than one country (OECD, 2015:298). Resources can be funding investment, people and institutions and knowledge inputs that are used to achieve R&D results.

3.2.1 Multinational enterprises

Both demand and supply side motives influence MNEs' decisions about the organisation of their R&D, their location choices, as well as their modes for R&D internationalisation (Sun *et al.*, 2006; Cincera *et al*, 2010). Although semantics may differ, literature generally agrees on two primary motives for R&D internationalisation, namely the asset-exploitation motive and the asset-augmenting motive (Archibugi and Michie, 1995; Kuemmerle, 1999; Narula and Dunning, 2000; Criocuolo 2004; Verspagen and Schoenmakers, 2004). Criosculo (2004) and Miozzo *et al.* (2011) have noted that market competitive pressures can be a motive for R&D internationalisation. The abovementioned motives can be mutually reinforcing. Key drivers for these motives are many, some are listed in the figure below.

Figure 4: Motives and driving forces for MNE R&D internationalisation



Source: Author's own compilation based on Archibugi and Michie (1995), Kuemmerle (1999), Criosculo (2004) and Miozzo *et al.* (2011).

In terms of **asset-exploitation motive**, an MNE engages in R&D abroad in order to adapt its existing knowledge from its home base into new markets (Narula and Dunning, 2000). Verspagen and Schoenmakers (2004) note that this type of R&D can best be performed in the locations it is meant to serve. This helps to facilitate close interaction with conditions in the area and incorporate specific requirements of the market when adapting the product/technology. With this motive, an MNE can expand by diversifying the markets it serves.

With the **asset-augmenting motive**, MNEs engage in foreign-bound R&D in order to access complementary knowledge to augment its existing knowledge base. Here, MNEs aim to access new knowledge pools and capabilities that are not available in home/current location(s), mainly to expand into new technological fields or find complementary capabilities (Narula and Dunning, 2000; Criscuolo, 2004; Verspagen and Schoenmakers, 2004). Criscuolo (2004) further argues that asset-augmenting activities are best undertaken near the sources of knowledge sought. With this motive, an MNE can diversify sources of knowledge and radically alter its existing R&D portfolio.

Competition motive–An MNE may also seek to enhance its competitive position through offensive moves or by defending against potential/existing competition.

Specific drivers can be to expand and achieve economies of scale and scope, to diversify into unrelated scientific/technological fields or geographical sites, to protect IP (D'Agostino and Santangelo, 2010; Miozzo *et al.*, 2011) or to reduce overall cost of R&D (Bloom and Griffith 2001). An MNEs can acquire or merge with promising technology companies abroad to facilitate access to new knowledge and capabilities and enhance complementary productive resources or to remove an existing/potential competitor from the market (Saggi, 2000; Stiebale, 2013).

R&D internationalisation can be facilitated from within a firm or influenced by events external to the firm. It can be inbound or outbound (Hatzichronoglou, 2008; Hall, 2010; Di Minin *et al.*, 2012). Parts of R&D can be located in one or more foreign countries (D'Agostino and Santangelo, 2010).

Some studies argue that MNEs pursue different motives when considering R&D location in developed economies versus less-developed economies (EIU, 2004; Hatzichronoglou, 2008; Hall, 2010; Guimon, 2013). Key distinctions are made between location specific advantages traditionally found in advanced economies such as high-level human capital, IP rights enforcement and concentration of innovative firms, compared to those typically found in developing countries such as lower R&D costs, potential for product adaptation and growing markets.

There are other possibilities between and outside of the abovementioned motives, which may reflect a confluence of firm-specific advantages, firm-specific strategy and location-specific advantages (Cincera *et al*, 2010; Amighini *et al*, 2014). Sun *et al.* (2006) and Storper (2000) further note that some MNEs have located their R&D activities mainly by following signals of earlier movers. This tendency explains the concentration of R&D and innovative activities in a few metropolitan areas in the host countries.

MNEs, as explained in the next section, also respond to policies of governments and strategies of other actors in R&D internationalisation environments.

3.2.2 Role of governments

Governments play a role in R&D internationalisation through policies, funding and the institutions they create (OECD, 2002:31; OECD, 2014:129). Increasingly, governments use tax incentives and subsidies to lure R&D investments as these reduce the relative costs of doing R&D (Bloom and Griffith, 2001; Hall, 2010; Köhler, Laredo and Rammer, 2012; OECD, 2014). Countries that have cost advantages and certain types of capabilities, and have been upgrading their technological innovation capabilities (e.g. China, India, Brazil, Russia, Singapore, Taiwan and Korea) have been successful in attracting new R&D investment (Amsden 1991; Cantwell, 1995).

Governments, as is done by South Africa's, also invest directly in scientific programmes, some of which may attract foreign funding and partnerships (DST, 2007).

Government policies may also influence the outward orientation of R&D investment, intentionally or not (Narula, 2003; Hall, 2010), for instance where they encourage international collaboration and cross-border knowledge transfer and exploitation. China and Korea have had specifically targeted programmes to encourage R&D internationalisation (Di Minin *et al.,*2012). South Africa, although at a lesser intensity, has instruments to achieve similar objectives (DST, 2007). Bad policies can also lead to outflow of R&D investments (Guimon, 2013).

Government actions have a strong bearing on local R&D capabilities and the national innovation system (Carlsson, 2005). Government actions impacts on the supply of human capital for R&D and potential for R&D collaborations and partnerships.

3.2.3 International organisations

International organisations influence R&D internationalisation through their scientific programmes, their funding, choice of partner countries and influence on policy approaches of countries. Their efforts influence the cross-border interaction of actors and resources and also help harmonise major scientific and technological priorities. Global challenges such as climate change, the food crisis, health research on

HIV/AIDS, tuberculosis and malaria have fostered scientific effort to generate global solutions, among others through large-scale projects that influence technology and scientific revolutions on a global scale (Dosi, 1982; UNESCO, 2012; Battelle, 2013; OECD, 2014).

At a local level, universities and public research organisations as well as non-profit organisations can attract donor funding and collaboration to deal with similar issues, including the basic research that is meant to advance scientific endeavours (OECD, 2014). R&D agenda of international organisations are partly a reason for several Sub-Saharan African countries having a high proportion of R&D funded from abroad (NEPAD, 2014).

3.3 MNE organisation and control of international R&D

The table below summarises some of the commonly cited modes that MNEs follow in internationalising their R&D, namely FDI, international trade and through collaborations and partnerships. These modes can be affected within the firm or its group (i.e. internal hierarchy between parent and affiliates) or through arm's length arrangements with other firms or actors.

Foreign direct investment can be a greenfield establishment of a production or R&D facility or merger and acquisition (M&A) of an existing one (Saggi, 2000; Hatzichronoglou, 2008; Miozzo *et al.,* 2011; Awate *et al*., 2012; Di Minin *et al.,* 2012; Stiebale, 2013).

With international trade, examples are: R&D offshoring, global value chains (GVCs) involving intermediate goods, capital goods trade, and trade in disembodied technologies (Grossman and Helpman, 1995; Cincera *et al.,* 2010).

Examples of collaborations/partnerships are cross-border R&D joint ventures, partnerships and/or collaborations, to close domestic technology supply gaps and access specialised technology, which is only available from specific supplies in foreign countries (Di Minin *et al.,* 2012).

Table 3: Modes international R&D by MNEs

	Foreign direct investment	International trade	Collaborations/ partnerships
Internal hierarchy	• Greenfield R&D establishment • Expansion of existing establishment • Mergers & Acquisitions	• Intra group trade	• Intra-group technology transfer
Arm's length		• R&D Offshoring • Integrating into global value chains • Trade in embodied (e.g. technology and capital goods) and disembodied forms (e.g. IP licensing, technical services) • Turnkey R&D work • Joint ventures	

Sources: Authors' compilation based on Grossman and Helpman, 1995; Criscuolo, 2004; Miozzo *et al.,* 2011.

These modes for R&D internationalisation, and their possible combinations, can determine the types of organisational control and coordination structures that may be used. Drawing on similarities from four studies, the table below proposes (in column 1) the terminology that has been adopted for purposes of this research to describe the organisational control and coordination structures.

Table 4: Organisational and coordination structures for international R&D

Column 1: Terminology adopted for the current research	Terminology from specific authors			
	Sun *et al.* (2006)	Gassmann and Von Zedtwits(1999); Zedtwitz and Gassmann (2008)	Moncada*et al.* (2011)	Archibugi and Michie (1995)
A. Centralised R&D for global markets	Central for global (centralised development of technology at home for global markets)	National treasure (domestic research and domestic development)	Centre of excellence (centralised lab with global mandate; economies of scale is key driver)	Global technology exploitation (where large share of output is absorbed by foreign markets)
B. Centralised research and dispersed development/ adaptation		Market driven (domestic research and dispersed development)	Supported specialisation (centralised core R&D and dispersed adaptation work)	
C. Globally linked specialised R&D facilities	Locally-linked (development of specified technology at each location for global markets) Globally linked (development of technology through R&D cooperation in different countries for global markets)	Technology driven (dispersed research and domestic development)	Network structure (Dispersed labs working on similar activities; economies of scope is key driver)	Global technology collaboration (where dependence on foreign partnerships and exchanges with other actors is high) Global technology generation (where dependence on global research networks is high)
D. Globally dispersed research for domestic development		Global approach (dispersed research and dispersed development)	Specialised contributors (specialised dispersed labs contribute to globally integrated initiatives – smart specialisation)	

Each of the above archetypes presents own sets of requirements in terms of resourcing, maturity paths, specific challenges and possible overlaps and requirement for coordination (Moncada *et al.*, 2011; Di Minin *et al*., 2012). Stage/phase of the R&D, the orientation of the firm's R&D and the industry or sector can determine what the most suitable form of organisation should be (Moncada *et al.,* 2011).

The literature reviewed in this sections suggest that the MNEs motives for R&D internationalisation, its mode of execution as well as organisational control structure has implications on the degree of exposure to international R&D environment. To sum up, increased exposure to R&D internationalisation can be in any of the following ways:

- Through establishing/launching a subsidiary or branch in a different country;
- Through cross-border merger or acquisition (M&A);
- Through cross-border R&D joint venture, partnership and/or collaboration;
- Through R&D offshoring;
- Through cross-border technology licensing (for accessing others' IP, or exploiting own IP);
- Through entering into a new foreign market, or local market entry by a competitor from foreign country; or
- Through entering/extending into a high-technology or science-based industry, which by nature entails globally linked activities, etc.

Any of the abovementioned events can influence the strategic variables concerning a firm's R&D activities, i.e. R&D investments, R&D locations, R&D organisation and R&D performance as well as its orientation of R&D exploitation. The same factors can determine a firm's degree of R&D internationalisation, its effects and the likely outcomes.

3.4 Implication for EMNEs R&D exploitation

R&D exploitation means applying the results of R&D. Examples include development of new products, processes, techniques or improvement of existing ones; in generation of different forms of IP; in establishing new enterprises or branches within firms; and in generation of new knowledge (Archibugi and Michie, 1995; Criscuolo, 2004; Zedtwitz and Gassmann, 2008; D'Agostino *et al.,* 2010).

Outcomes for knowledge exploitation cited above can be achieved with local oriented activities. However, that can be limiting. Engaging in international R&D can assist a firm in scaling up its effort and achieve better results than if all activities are local (Sun *et al.,* 2006, Archibugi and Michie, 1995 and Gassmann and Zedtwitz, 1999. This is because of technology flows, knowledge spill-overs and learning associated with international R&D (Coe and Helpman, 1995; Engelbrecht, 1997; Narula, 2003; Criscuolo, 2004).

Transmissions of technology flows, knowledge spill-overs and learning may occur at various levels. It can be at the level of the individual worker, a firm, industry or a (innovation or production) system level (Hall and Mairesse, 1995; Narula, 2003), and the nature, direction and intensity of such transmissions differ (Dosi, 1982).

In the case of firms, technology flows and the efficiency of knowledge spill-overs and learning can be dependent on the mode and motives for R&D internationalisation (Narula and Dunning, 2000). The modes cited earlier, namely FDI, international trade and international R&D collaborations, can facilitate these transmissions, primarily through externalities (demonstration effect), mobility of R&D personnel, as well as linkages (backward linkages to supplier firms, forward linkages to customers/markets and horizontal linkages with partners/parent/affiliates).

Effect of R&D internationalisation can be seen in the extent of changes in a firm's share of outputs absorbed abroad, its dependence on cross-border technology transfer, its extension of IP protection (patents) into new markets and changes in royalty income and sources, among other indicators. These effects apply differently for each firm and for industries. Challenges experienced by firms are also varied. Figure 1, in Chapter 2, indicate the heterogeneity of EMNEs.

Typical challenges, cited in literature, that EMNEs face when exploiting R&D in developed countries (represented by Type 3 on figure 1) related to being of small size versus competitors, lacking resources and management experience in advanced country markets, all of which limit their scale of activities especially when competing against firms with well established brands abroad (Von Zedtwitz, 2005).

Certain firms are predisposed to international R&D exploitation (Archibugi and Michie, 1995). Such firms are found to have a high proportion of output absorbed by international markets; they have some degree of patents applied/granted abroad; they are found to be trading in high technology intensive products; operating in R&D intensive sectors such as manufacturing; and/or where there is demand for disembodied knowledge in a form of IP licensing and technical services.

3.5 Implications for innovation systems

Under conditions of globalisation, innovation systems transcend national borders, hence the concepts of technology systems and regional systems (Carlsson, 2005; Scerri, 2013). The interaction of individual researchers, firms, public sector institutions, policies of countries in the regions and the funding sources, etc. are at the core of this (D'Agostino *et al.,* 2010).

Conditions that characterise an innovation system include factors such as the national policies, institutional orientation of knowledge production and flows, history of scientific advances, incentives for actors to innovate, anchor R&D programmes and policies, appropriate scientific infrastructure, human capital and its mobility, technology transfer capacity, IP policies, financial incentives, etc. (Carlsson, 2005; Scerri, 2013; Battelle, 2013), as well as the degree of openness of the system itself to foreign factors (Coe and Helpman, 1995; Cooke, 2005; D'Agostino and Santangelo, 2010; Avallon and Chédor, 2012).

All these factors can encourage or hamper, to some degree, the extent to which a system, and its actors, interfaces with the external systems/subsystems (Criscuolo *et al.,* 2005; Carlson, 2006). They can determine the extent to which an innovation system derives benefits from international openness (Dachs *et al*., 2012). This has implications for knowledge flows, spill-overs and learning (Coe and Helpman, 1995; Narula, 2003). An open R&D environment can galvanise the domestic R&D system, inducing local firms and industries to improve on their R&D and the way they use it (Coe and Helpman, 1995; Criscoulo *et al.,* 2005).

MNEs R&D internationalisation has implications for firms themselves and the economies of countries involved. Table 5 summarises some of the possible impacts of R&D internationalisation that were drawn by Patel and Vega (1999), Criscoulo (2004:3) and Moncada *et al.* (2011:9) from several studies.

Table 5: Possible impacts of R&D internationalisation

	Potential negative impacts	Potential positive impacts
MNEs	• Reduced domestic economies of scale and scope • Coordination challenges • Technology leakage	• Inter-firm technology transfer • Access to foreign pockets of excellence • Greater efficiency in innovation
Recipient country	• Foreign control over domestic R&D resources • Loss of economic benefit if results are exploited elsewhere • Testing ground for dangerous activities • Erosion of government subsidies and tax incentives	• Upgrading of local technical capability • Knowledge and technological spill-overs • Better tailored products • Knowledge-based employment
Source country	• Erosion of technological capabilities (hollowing out of industries) • Negative impact on industrial diversification • Loss of potential employment	• Access to expertise from elsewhere • Access to foreign markets • Economic benefits from local exploitation of R&D done elsewhere • Extended life-cycle of existing products due to demand in new markets

Sources: Archibugi and Michie (1995); Criscoulo (2004:3); Moncada *et al.* (2011:9).

Literature also shows that developing countries that fail to build local capabilities to attract and sustain R&D are most likely to lose out from the growing phenomenon of R&D internationalisation (OECD, 2013). Country policies should therefore be tailored to maximise the positive outcomes and minimise the disadvantages of R&D internationalisation.

Lessons on South Africa captured by Kahn *et al.* (2004) about leakages in the R&D-related human capital pipeline, through mobility of trained scientists to other countries or to local non-R&D activities during the first decade of South Africa's democracy are an example. Countries need the ability to maximise the contribution of international R&D to their own development (Saggi, 2000; Archibugi and Pietrobelli, 2003). However, voluntary effort of investing MNEs may be inadequate to foster local absorption and capability development. Policies are needed to help achieve this (Perez-Villa and Seric, 2015).

The system's capability to learn can have geographical, social and capability dimensions (Criscuolo, 2004). Clustering of innovative firms' activities and their proximity to knowledge sources and user markets is important for learning and innovation (Nelson and Winter, 2002). Equally is the absorptive capacity of firms and the system as a whole, in terms of identifying, assimilating and exploiting the knowledge (Lall, 2002).

Cross-border collaboration and partnerships are key success factors for certain industrial activities. To overcome local technology supply gaps, actors collaborate with foreign partners or acquire technology (D'Agostino *et al.,* 2010; Avallone and Chédor, 2012). Such exchanges can occur across sectors, e.g. between universities and private firms as well (Narula, 2003) and can facilitate quicker adaptation and introduction of products into new markets (Criscuolo *et al.,* 2005).

Firms, industries and systems have different capabilities to absorb various types of R&D (Narula, 2003). For instance, firms' ability to access and absorb external knowledge can be shaped by the systemic environment in which they operate (Narula, 2003; Carlsson, 2005). The presence of innovative MNEs can also help to accelerate the system's capacity for technology adoption and diffusion, partly because of their ability to access knowledge in foreign locations (Mudambi, 2008; Xu, 2000; Perez-Villa and Seric, 2015). Time lags for absorption and impact also differ depending on a variety of factors and systems that manage to achieve greater relative technological advantage over others, acquire this over long periods of capability building (Grossman and Helpman, 1995).

4. Chapter 4: Indicators for South Africa’s R&D internationalisation

This chapter draws from secondary data sources to understand the international openness of South Africa’s R&D system. The dimensions analysed are size of the R&D system, cross-border flows of R&D resources as well as R&D outputs.

4.1 Size of the R&D system

The size of the R&D system can be measured by the resources/inputs a country devotes to R&D, i.e. R&D expenditure and R&D personnel as well as the outputs attained, i.e. scientific publications and IP outputs such as patents, trademarks, etc.

Annexure B presents benchmarks of selected countries on three indicators, GERD figures in US$PPP, GERD as percentage of GDP and R&D personnel full-time equivalents (FTE) per 1000 employed.

Data shows that South Africa’s GERD, in current US$PPP terms, increased from $2.6 billion in 2001 to $4.8 billion in 2012. In current Rand terms the figures are R7.5 billion and R21.2 billion, respectively (CeSTII, 2015). Over the same period, South Africa’s contribution to global R&D expenditure remained at 0.3% (UNESCO, 2015); GERD stayed below one percentage of GDP; and R&D personnel FTE per 1000 in total employment increased from 1.76 to 2.46.

These measurements place South Africa among the leading developing countries in terms of R&D inputs. In contrast, the country appears to have a low R&D intensity when compared to its own policy targets and benchmarks of advanced countries (DST, 2007; Kahn, 2007). Its rate of GERD expansion is slower than those of its BRICS (i.e. Brazil, Russia, India, China and South Africa) partners. References in policy documents to benchmarks of OECD and strong emerging economies is an acknowledgement of a need to scale up the R&D system to those levels.

In terms of outputs, South Africa tripled its scientific publications from 3772 in 2001 to 12071 in 2014. This increased South Africa’s share of world’s scientific publications from 0.4% to 0.7% over the same period (UNESCO, 2015). South Africa’s publications have a superior impact, measured by citation index which was 1.74 in 2014, when compared to its BRICS partners even though its number of publications is lower (Pouris, 2003; NACI, 2016).

4.2 Cross-border flows of R&D resources

Local R&D is funded from local sources and from abroad. Furthermore, R&D undertaken abroad can be funded by local sources. Funding source from either side can be private sector firms, governments, higher education and public science research organisations, international organisations and donors.

Foreign sources of both GERD and BERD in South Africa have averaged around 12% between 2001 and 2012. Foreign funding contribution to GERD grew at an average of 7% over this period, with slack in 2009. A high proportion of foreign funding for R&D goes to the business sector and about 80% comes from parent companies and affiliates abroad.

Table 6: Domestic R&D funded from abroad, 2003-2012

Period	GERD (in R million)	GERD funded from abroad (in R million)	% of GERD funding from abroad	BERD (in R million)	% of BERD funded from abroad
2003/4	10,083	1,096	10.9%	5,591	9.6%
2004/5	12,010	1,833	15.3%	6,766	17.9%
2005/6	14,149	1,918	13.6%	8,244	14.5%
2006/7	16,521	1,747	10.6%	9,243	10.6%
2007/8	18,624	1,987	10.7%	10,738	11.0%
2008/9	21,041	2,395	11.4%	12,332	11.3%
2009/10	20,955	2,538	12.1%	11,139	13.8%
2010/11	20,254	2,445	12.1%	10,059	14.3%
2011/12	22,209	3,330	15.0%	10,464	14.9%
2012/13	23,871	3,117	13.1%	10,571	11.3%
2013/14	25,661	3,315	12.9%	11,783	11.0%

Source: CeSTII dataset (2016).

International benchmarks on business R&D funding from abroad vary widely and reflects the heterogeneity of R&D systems and economic structures. In the benchmarks listed in Annexure C, there are countries such as Israel (48%), Czech Republic (27%) and Ukraine (21%) that have very high proportion of their GERD and BERD funded from abroad. These are followed by countries such as the UK, Ireland and Austria. The claim by Dachs *et al.* (2012) that such countries are advanced economies with much of their industries in high technology sectors is disputable. Countries such as Uganda, Kenya and Senegal have high ratios of their GERD (not just BERD) funded from abroad, i.e. 57%, 47% and 40% respectively (NEPAD, 2014). The latter cases are a reflection of foreign donor funded R&D.

With about 13% of GERD funded from abroad, South Africa is just above the EU and OECD averages of 10% and 7% respectively. Extremes are Israel with about 50% of BERD funded from abroad, the UK and Ireland with 25% and Korea with 0.3%.

High ratio of foreign funding of BERD or GERD, in policy debates, can be an advantage or a risk. On the one hand it may imply higher degree of integration into global R&D value chains, while on the other hand funders' priorities may derail a country's R&D and development agenda. South Africa has a target to increase foreign funded GERD to 17% (DST, 2007).

Data to estimate outbound R&D funding is generally poor in many countries. This is the same with South Africa. Efforts of international organisation to develop guidelines in this regard have been initiated (Dachs *et al.*, 2012). Data on South Africa's outbound R&D funding are drawn from the R&D survey and appears incomplete. Such data estimates that about R328 million has been outsourced to R&D undertaken abroad by local firms. The bulk of which went to Europe (60%) and USA/Canada (33%), with the other regions receiving about 4% (OECD-MSTI). These figures represent an underestimate of the true scale of activity. Timeline of this research and scope did not permit extraction of data on financial flows for R&D service from the South African Reserve Bank (SARB) to complement the analysis. Dachs *et al.* (2012) notes that national R&D surveys often miss the activities between multinationals and their affiliates that are not identified as R&D performers. This could be true in South Africa as well.

4.3 Foreign ownership of local R&D performing firms

A foreign interest in local R&D performing firms is part of a broader phenomenon of FDI, trade and production. This has implications for cross-border R&D exchanges of R&D resources and knowledge spillovers.

Some local R&D performing firms have foreign ownership. Local firms also own R&D performing units abroad. These arrangements can influence decisions on slicing-up of various functions of a firm (including R&D) across two or more countries. In this way local firms are integrated in GVCs, international R&D arrangements and trade (UNCTAD, 2013:5).

Table 7 indicates that 92 firms, from a total of 323 covered by the R&D survey indicated to have some degree of foreign ownership. Thirty-four of these firms are wholly-owned by MNE parent abroad; 26 are majority-owned/controlled abroad; and 32 have minority ownership abroad. Data also shows that R4.9 billion, or 47% of BERD, was spent on R&D by local firms that have foreign ownership in 2012/13; that 40% of the business sector R&D personnel were in those firms; that 48% of these firms are in the manufacturing sector, followed by business services with 23% and then the mining sector with 9%. Firms in these sectors are amenable to R&D internationalisation. This analysis can be of great value if done at the industry level and specifically focussing on high technology industries. This was not possible due to confidentiality.

Table 7: Foreign ownership of local R&D performing firms, 2012/13

Extent of foreign ownership	Number of firms indicating foreign ownership	Intramural R&D expenditure of firms with foreign ownership (R millions)	Number of R&D Personnel in firms with foreign ownership
Wholly-owned from abroad (100%)	34	1,000	1,333
Majority-owned from abroad (51-99)	26	2,188	3,015
With 50% or less foreign shareholding	32	1,806	2,516
Totals	92	4,994	6,864

Source: CeSTII dataset (2016).

Some domestic firms have operated in the international R&D environment for a long time (Gelb and Black, 2004; Verhoef, 2011). Such firms have developed specific strengths operating in various markets globally. There are also foreign firms that have operated in the domestic R&D scene for decades.

Correlation between FDI activity and cross-border R&D exchanges can reveal further details which are not part of this research. Policies in South Africa include targets for increasing inbound FDI; the GERD portion funded from abroad; and intentions for outward FDI into the rest of Africa; and increasing exports (Presidency, 2012:6; DST, 2007). Gelb and Black (2004) and Baskaran and Muchie (2008) find that South Africa's economy has increasingly opened up but its attraction of FDI, measured by FDI as percentage of GDP, has been below policy targets and also slower compared to its BRICS partners. A concern is that South Africa's FDI activity is also dominated by equity investments that are not necessarily directed at expanding the productive base (Baskaran and Muchie, 2008).

Table 8: South Africa's FDI performance compared with selected economies

A: Foreign direct investment, net inflows (% of GDP)

	2000	2005	2008	2011	2014
Brazil	5.50	1.7	3.0	2.7	4.1
China	3.60	4.6	3.8	3.7	2.8
India	0.60	4.6	3.8	3.7	2.8
Sub-Saharan Africa	..	2.8	3.7	2.7	2.7
South Africa	0.80	2.5	3.4	1.0	1.6
Russian Federation	..	2.0	4.5	2.9	1.2

B: Foreign direct investment, net outflows (% of GDP)

	2000	2005	2008	2011	2014
Brazil	..	0.3	1.5	0.1	1.1
China	..	0.9	1.6	1.3	..
India	..	0.3	1.6	0.7	0.5
Sub-Saharan Africa	..	0.3	0.2	5.2	..
South Africa	..	0.4	-0.7	-0.0	2.0
Russian Federation	..	2.3	3.4	3.5	3.0

Source: World Bank database (2016).

South Africa's international trade and investment connections with countries that among the top 10 of global R&D investing nations (e.g. China, USA, Japan, Germany, India and UK) (as listed in www.southafrica.opendataforafrica.org and www.tradingeconomics.com) indicates potential exposure to international R&D environment. A limitation is that South Africa has a significant proportion of its exports as primary and semi-processed goods and that it lags its BRICS partners in increasing its share of world trade (World Bank, 2014:18).

4.4 International patenting activity

Patent data analysis is one commonly used method to analyse changes in cross border innovation activity over long periods (Criscuolo, 2005; Verspagen *et al*., 2004 and Hall, 2010).

Patent applications by South Africans at the USPTO increased from 942 in the period 2000-2003 and peaked at 1 295 in 2008-2011. This indicates readiness of South African inventors in exploiting their inventions in markets internationally; hence they protect their IP there. South Africa lags behind all BRICS countries on this indicator. Figure 5 shows South Africa's performance on this indicator alongside comparable developing countries.

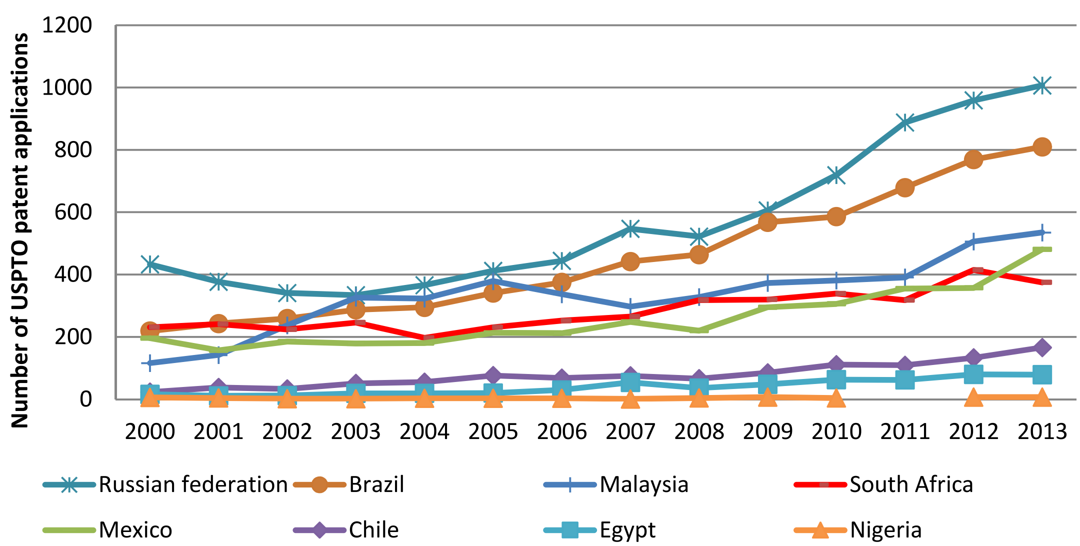
In terms of patent granted at the USPTO, Figure 6 shows that South Africa has increased its performance, from 111 in 2000 to peak at 161 in 2013. South African inventors file patents in various offices abroad. Figure 7 indicates the top five such offices for 2003-2011 as USA, Australia, Europe, China and Canada. The five jurisdictions provide a significant exposure to global markets.

Table 9: Utility patent applications at USPTO of selected countries, 2000-2014

	2000-2003	2004-2007	2008-2011	2012-2013 (shorter period)	Totals
South Korea	4,203	14,153	47,859	34,133	**100,348**
UK	4,029	8,652	17,110	13,727	**43,518**
India	1,485	1,769	2,735	1,966	**7,955**
China	1,008	1,453	2,297	1,579	**6,337**
Russian federation	821	1,336	1,473	1,041	**4,671**
Brazil	942	945	1,295	790	**3,972**
Malaysia	717	853	1,176	838	**3,584**
South Africa	**145**	**274**	**371**	**299**	**1,089**
Mexico	58	123	209	159	**549**
Chile	14	10	15	14	**53**

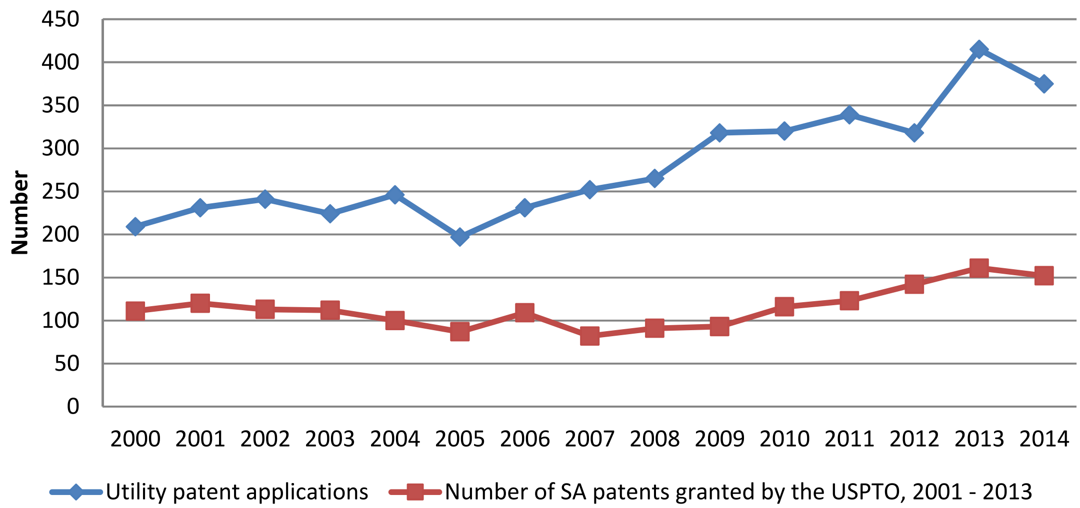
Source: USPTO database (2016).

Figure 5: Utility patent application at USPTO of selected countries, 2000-2014



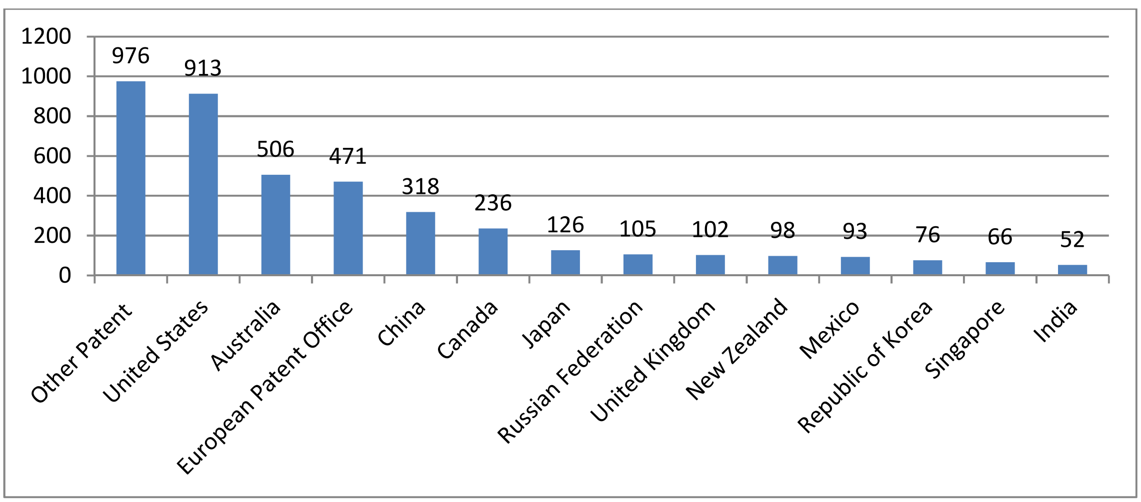
Source: USPTO database (2016).

Figure 6: South Africa's patents granted by the USPTO, 2000-2014



Source: USPTO database (2016).

Figure 7: South African patents granted in selected offices, 2003-2011



Source: NACI dataset (2016).

Kahn's (2007) analysis of first-named assignees in the USPTO granted patents indicates that a considerable number of patents granted to large firms, amongst them are locally-owned and foreign-owned affiliates. Within the top 20 list in Kahn (2007) are state-owned companies, universities and government agencies. This is an important indicator for system openness to international R&D and knowledge exchange.

The following limitations must be noted: Patent data does not reveal a nation’s overall inventiveness because inventors do not patent all their inventions. Furthermore, patenting does not necessarily imply commercial success of an invention. To assess commercial success at a firm level, indicators such as share of revenue generated from IP and share of output absorbed per markets abroad can provide such evidence (such are not part of the scope of current analysis).

4.5 Technology balance of payments

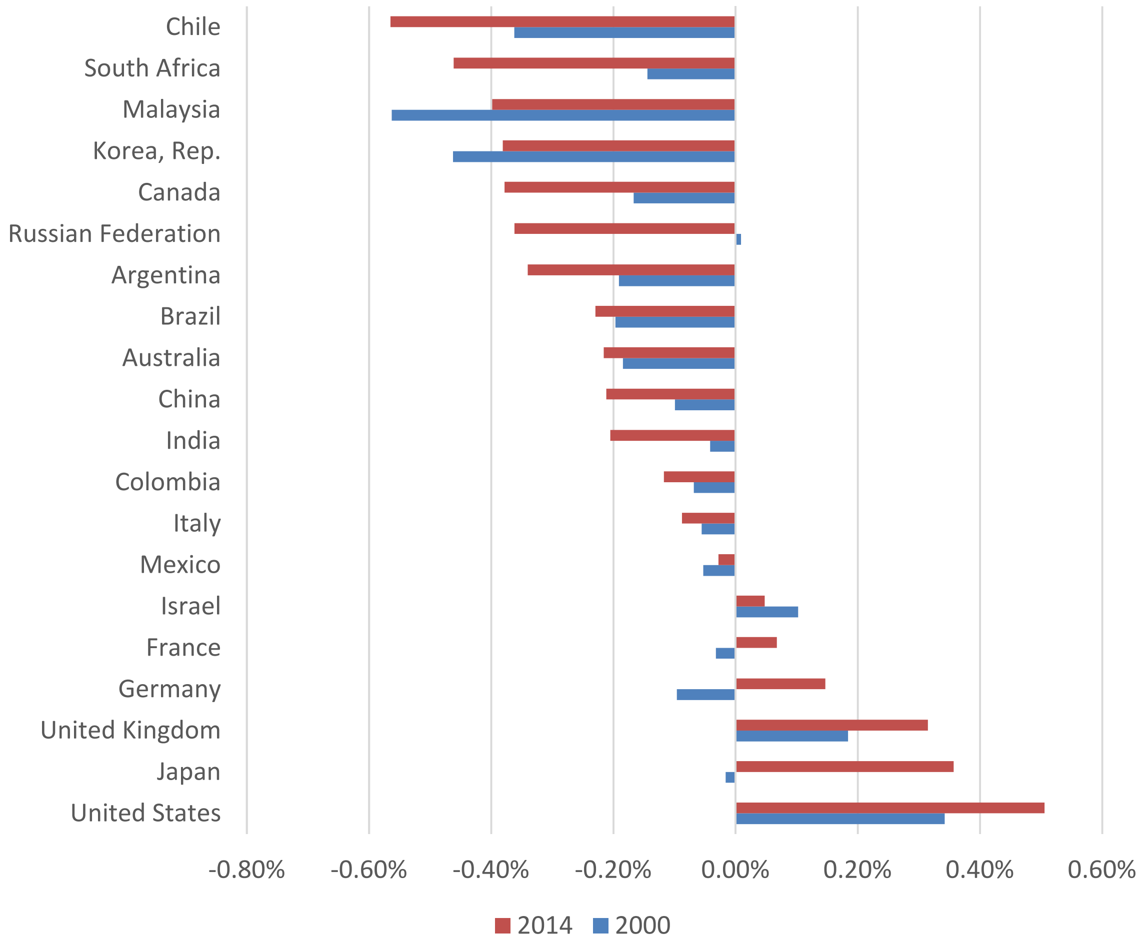
International R&D openness can also be reflected by cross-border exchanges in disembodied technologies. An indicator of technology balance of payments (TBP) is used for this purpose (Avallon and Chédor, 2012) using the data on “charges for the use of intellectual property” compiled by the World Bank. TBP measures the inflows and outflows of funds relating to use of “intellectual property” (IP) (patents, licences, techniques, trademarks, designs, know-how, patterns) and “services with significant technological content” (technical assistance, engineering studies, R&D services in a foreign location, etc.) (OECD, 2013).

Table 10: South Africa's technology balance of payments

Year	Charges for the use of intellectual property, receipts (in current US$ million)	Charges for the use of intellectual property, payments (in current US$ million)	TBP (Receipts - Payments) as a percentage of GDP
1997	52.1	258.2	-0.14%
1998	49.0	227.5	-0.13%
1999	44.2	212.8	-0.12%
2000	49.1	245.9	-0.14%
2001	21.5	329.5	-0.25%
2002	19.5	446.5	-0.37%
2003	26.6	616.7	-0.34%
2004	37.4	891.0	-0.37%
2005	45.3	1070.6	-0.40%
2006	55.1	1281.7	-0.45%
2007	75.1	1596.3	-0.51%
2008	78.8	1675.9	-0.56%
2009	75.7	1658.0	-0.53%
2010	114.0	1941.1	-0.49%
2011	134.5	2117.9	-0.48%
2012	124.9	2017.1	-0.48%
2013	120.0	1936.8	-0.50%
2014	116.5	1732.0	-0.46%
2015	103.1	1708.4	-0.51%

Source: World Bank database (2016).

Figure 8: Comparisons of TBP as percentage of GDP with selected countries



Source: World Bank database (2016).

South Africa's TBP payments increased from US$441.7 million in 2002 to US$2.1 billion in 2011, and the TBP receipts increased from US$19.3 million to US$134.5 million over the same period. The acceleration in these transactions indicates increased international openness of the innovation system, indicating the demand and absorption capacity for foreign technologies as well as the ability of a country to commercialise its knowledge outputs abroad. The data shows a widening gap between payments and receipts in letter years compared to early 2000, which has expanded South Africa as a net importer of intellectual property (IP) and know-how.

Comparisons in Figure X indicate that several countries are also net importers of IP and know. Chile, Canada, Brazil, Australia, Argentina, India, Columbia and China have widened the negative TBP ratio of GDP from 2000 to 2014. These comparisons are interpreted with caution. Countries have different economic structures. There are also differences in what countries include in their TBP data and that the transfers between multinationals and the subsidiaries may skew the data.

4.6 Conclusion

This chapter draws the following points to set the context within which the case study findings are interpreted:

- Indicators of the R&D system's size confirm Kahn's (2007) observation that South Africa is a low R&D intensity economy, which is supported by a small but efficient R&D system. Size and scale matters in order for an R&D system to be of significance globally. National policy targets on expanding mathematics and science education, training of R&D personnel, increasing GERD, among others are crucial to achieve this.
- Available data on South Africa's cross-border flows of R&D activity represent an underestimate of true scale of activity and may distort conclusion about the degree of openness of the R&D system. Supplementary data sources are required to enhance this type of analysis (which is not part of the current research).
- South Africa's trade and investment connections with some of the top 10 of global R&D investing nations indicates potential degree of exposure to international R&D environment of local firms, directly through ownership, partnerships and indirectly through competition and knowledge and learning.
- South Africa's increasing cross-border exchanges in disembodied technologies reflects an innovation system that continues to open up, indicating the country's ability to commercialise its knowledge outputs abroad and its ability to absorb foreign technologies.

5. Chapter 5: Analysis of case studies

This chapter presents the findings of this research. The first part describes the three cases researched. The latter part presents an analysis and synthesis of findings across the three cases, where appropriate, rival explanations are noted. The final section of the chapter draws conclusions based upon the findings.

5.1 Case 1: Participant A

5.1.1 General overview

Participant A's ("A") origins can be traced back to 1948. It is a specialist R&D entity within a multinational parent group. The parent group was established in 1888, and operates in various stages of the diamond industry value chain, namely exploration, mining, processing and trade of rough diamond, jewellery and other products.

The main focus of "A" is applied R&D, aimed at developing and improving technologies for the early stages in the diamond industry value chain, i.e. exploration, mining, recovery, verifying, sorting, tracing, etc. In 2010, "A" employed 65 people, most of them scientists, engineers and technicians.

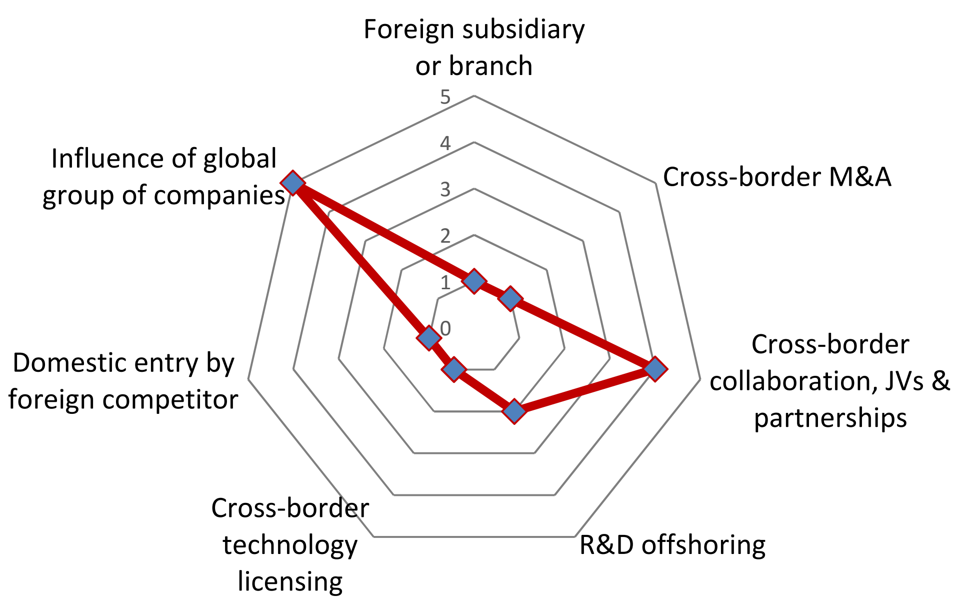
5.1.2 Participant A's R&D internationalisation

"A" has been operating in the international R&D environment for decades. Like other companies of its age, "A" experienced the strife of South Africa's economic isolation in the 1980s and the changes that came with the country's reintegration into global economic affairs from the 1990s.

Industry reports indicate that, over the past three years, mining firms in South Africa have experienced low productivity, escalating operating costs and labour unrests. Internationally, the mining industry experiences poor demand and the declining mineral prices. These factors hampered profitability and new investments. There is pressure for mining companies to innovate in order to stay competitive. The same applies to “A”.

Figure 8 rates the seven modes for R&D internationalisation from 5 (highly dominant mode of the firm’s approach) to 1 (least emphasised in the firm’s approach).

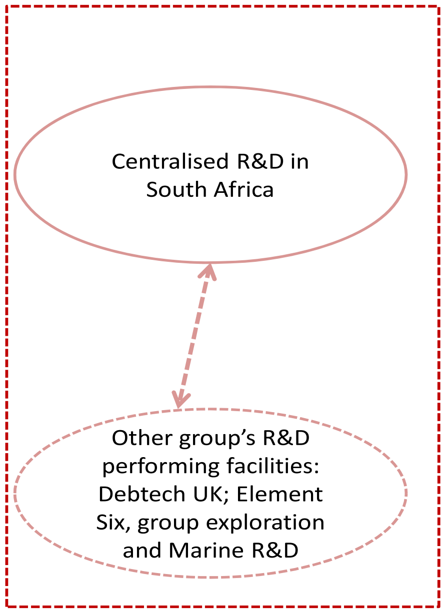
Figure 9: Modes for Participant A’s R&D internationalisation



Source: Author’s compilation based on interview with “A”;

“A” creates technologies in South Africa for the global market, drawing from the core technology and design capability it built locally over time. It operates a centralised R&D function locally to primarily serve the global network of its group’s operating companies, which are in various locations globally. The group operating companies absorb about 80% of “A’s” outputs. The remaining 20% serves companies outside the group.

Figure 10: Structures of Participant A's R&D internationalisation



• Parent group operating companies	• Botswana, Canada, Namibia, South Africa and others
• External companies using DeBeers technologies	• Other clients companies outside of group, locally and abroad.
• External collaborations, JVs and partnerships	• Universities, research institutions and companies abroad, e.g. Austria, Germany, Sweden, Switzerland, UK and others. • Collaborators locally.
• Links with Anglo-American R&D facilities	• Knowledge sharing and coordination activities.

Source: Author's compilation based on interview with "A".

"A's" R&D internationalisation is largely characterised by it being within a global group of companies, which is among the leading diamond companies globally. The group's main mining operations (by volume of diamond recovered) are in Botswana, where in 2013 it recovered 73% of its diamond carats, 15% in South Africa, and about 6% in Canada and Namibia apiece. The group has manufacturing operations in China, Ireland, and Germany among others.

"A" interfaces with other R&D-performing facilities within the parent group, namely DeBeers Technologies United Kingdom (Debtech-UK), Group Exploration, Marine R&D and Element Six. Each of these facilities performs specialised functions. Collectively, these facilities serve most of the group's R&D and technology needs at a global scale. Debtech-UK focuses more on the R&D for technologies in the mid- to downstream value chain activities of the diamond value chain, e.g. grading, weighing, classification, polishing, verification, cutting, etc. Element Six serves as a dedicated unit to design, develop and produce synthetic diamond materials (or "super-materials") for various industrial purposes. This unit has its head office in Luxembourg and manufacturing functions in Ireland, Germany, China, South Africa and the UK. Group Exploration focuses on advancing knowledge of diamond geology. Marine R&D focuses on offshore vessel mining technologies.

“A” also has international R&D exposure through the Anglo-American PLC, which has acquired 85% of the A’s parent group in 2012. Anglo American PLC operates globally, presenting a further area in which “A” serves international markets for its technologies.

Figure 8 also ranks cross border R&D collaborations, JVs and/or partnerships as a second dominant mode of “A’s” R&D internationalisation. This is followed by R&D offshoring.

“A” engages in cross-border R&D collaborations, JVs and/or partnerships in order to access capabilities not available internally. This approach was prevalent around 2003 and 2004 when “A” had a big project requiring external collaborations. Collaborators abroad included universities, research organisations and other companies. Each of the collaborations is defined around the needs of specific projects. Most of the foreign R&D collaborators are European based. This is due to historical connections, and convenience regarding time zones, ease of co-ordination and communication. This bias also reflects implications of legal restrictions against “A” operating in the USA (Kahn, 2002).

Traditionally, “A” has relied on internal employees in executing its R&D work. Over the past five years, it has become increasingly crucial for “A” to source specialised knowledge externally, both locally and abroad, to augment its capabilities and close the internal knowledge gaps. “A” is growing a network of specialist suppliers around the world for this purpose. This approach is already assisting projects requiring specialised input not available within the group.

Other modes of R&D internationalisation receive much lesser emphasis in “A’s” approach. The two modes, M&A and the establishment of foreign subsidiaries, are mostly executed at a group level. Lack of details on these modes, therefore, impacts on the findings of this research. There is therefore a lesser need for “A” to engage in these modes. Technology licensing is also not a major part of “A’s” approach. Instead of licensing, “A” utilises its knowledge to develop technology for its clients.

With regard to R&D exploitation, “A’s” designs and technology developments are mostly completed locally, and are done with the international market in mind. The technology development activities hinge on three aspects: firstly, to meet technological requirements of the group; secondly, to design fast and increase responsiveness; and thirdly, to meet standards and performance requirements in different countries.

Priority is increasingly given to research that extends on existing knowledge bases to adapt existing technology in serving new needs internationally and diversify the product portfolio. Partly, this effort is directed at finding new applications of existing technology in addressing emerging needs, not only for diamond, but other areas in the mining industry.

Increased internationalisation presented a greater need for co-ordination. An R&D Steering Committee has been established at a group level to implement a new model for R&D. This structure evaluates R&D needs and determines a portfolio of R&D projects to be funded at a group level. The structure also facilitates information sharing through monthly R&D reports among the group companies. At “A’s” level, the management structure co-ordinates the R&D activities. The Anglo Open Forum promotes knowledge sharing between “A” and Anglo-American research units and serve as an opportunity identification mechanism.

There is global competition in “A’s” R&D focus area, both locally and abroad. This is balanced because the group itself is the main customer of “A’s” technologies, and a leader in its industry globally. Competition in the market is mainly indirect, due to differentiation of technology offerings and specialisation. Companies that supply technologies for the diamond industry serve different requirements, operating methods and niches in the market, to those supplied by “A”.

5.2 Case 2: Participant B

5.2.1 General overview

Participant B ("B) was established in 1974 as a holding company of a local firm that acquired a foreign firm. "B" listed in the Johannesburg Stock Exchange (JSE) in 1975.

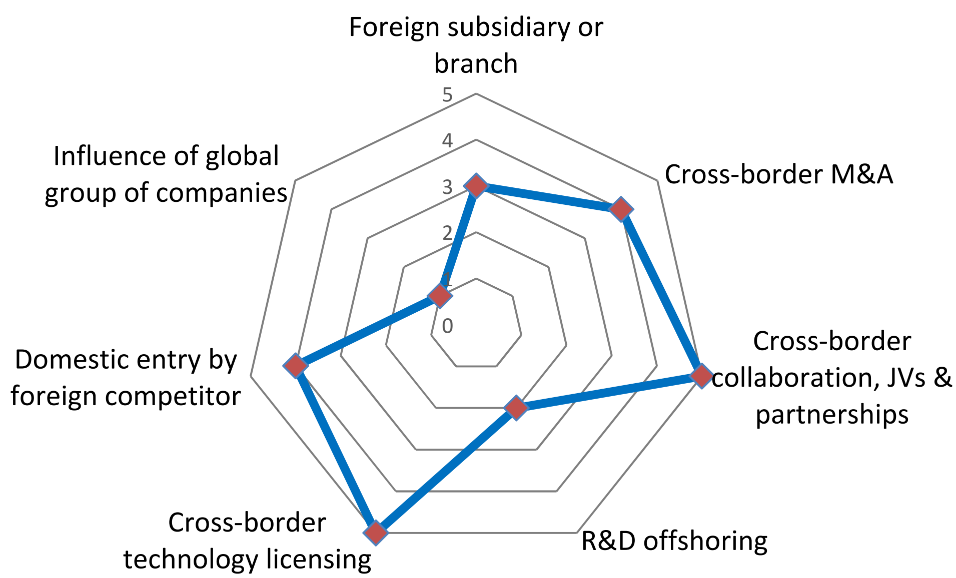
The group restructured over time, with some entities shifting positions and changing names. Latest structure shows a holding parent group with two entities. "B" operates under one of the entities and is responsible for the group's telecommunications, multi-media and information technology operations. Of the R981 million spent on R&D from 2006 to 2016 by the group, about 94% was concentrated in "B".

"B" is renowned globally for its innovative products, such as their specifically branded vehicle tracking technology and several novel technologies in the field of electronics and telecommunication technology.

5.2.2 Participant B's R&D internationalisation

Since its establishment, "B" has operated with an international focus. This is a characteristic of firms operating in high technology industries. The influence of the group, which has presence in the six continents, namely Africa, Asia, Europe, Australia/Oceania, South and North America, also play a role.

Figure 11: Modes for Participant B's R&D internationalisation



Source: Author's compilation based on interview with "B".

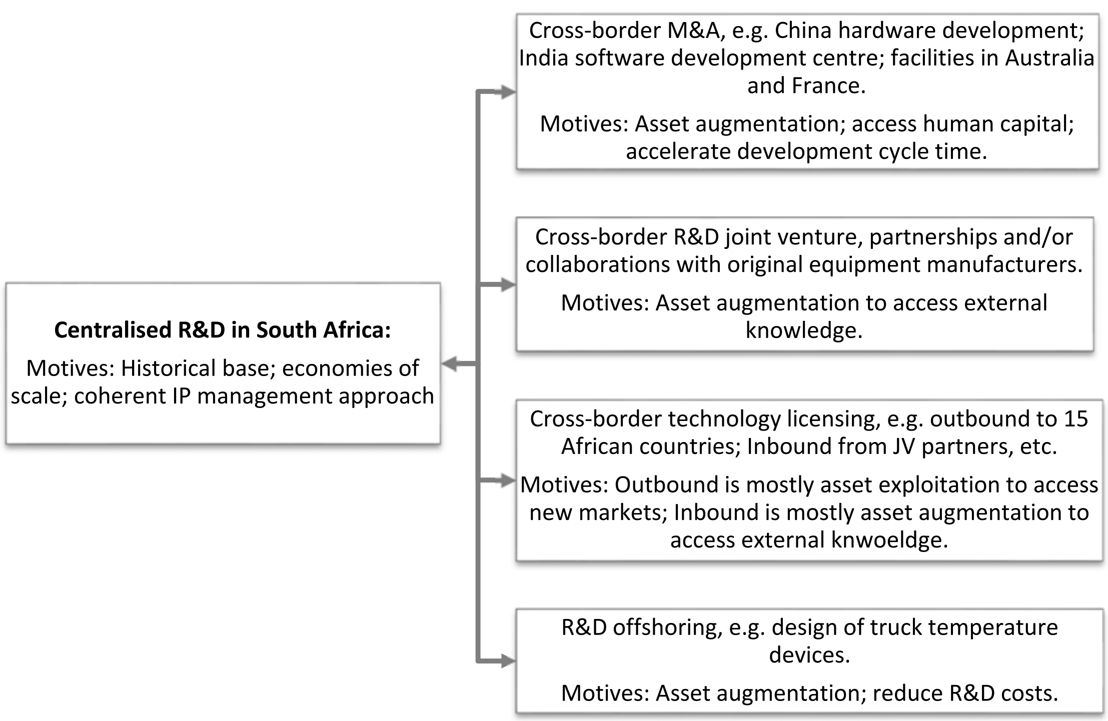
Figure 10 rates the seven modes of R&D internationalisation from 5 (highly dominant mode of the firm's approach) to 1 (least emphasised in the firm's approach). Two of the seven modes identified in the theoretical framework are highly dominant in "B's" approach. The company relies mostly on cross border collaborations and partnerships as well as technology licensing for its R&D internationalisation. These arrangements are used both for asset-augmentation motives (i.e. to access technological knowledge where the company lack capability internally) and for asset-exploitation motives (i.e. to adapt existing technologies in serving new markets abroad).

In the second order of ranking are further two modes, namely cross-border M&A and the pressure exerted by entry of foreign competitors. In M&A, "B" targets companies with IP to complement its own or potential to transform existing industries or create new ones. Examples include acquisition of Australian and French companies. The remaining three modes are lowly rated because they receive relatively lesser emphasis in the company's overall approach.

In practice, the various modes shown in Figure 10 are not mutually exclusive. They are implemented simultaneously.

"B's" current approach has characteristics of a geocentric centralised R&D structure, depicted in Figure 11. The company has its core R&D centralised at home, to create core technologies in South Africa for the global market. "B" regards this to be a successful approach. The company has also established various arrangements internationally in order to source new knowledge and complement its R&D programme. This is crucial given the short product life cycle in "B"'s industry.

Figure 12: Structure of Participant B's R&D internationalisation

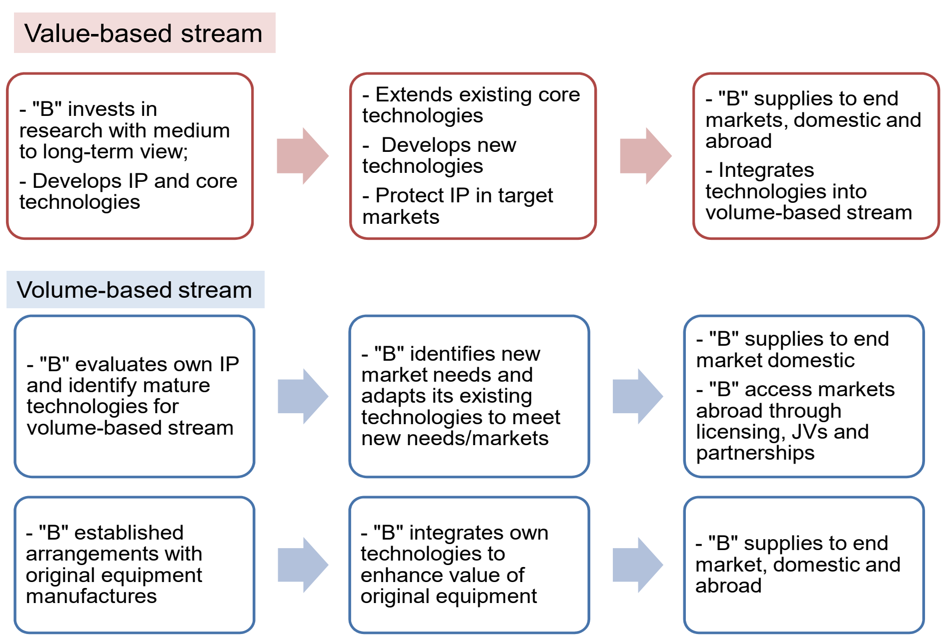


Source: Author's compilation based on interview with "C"; Diagram is the author's adaptation from Gassman and Zedtwitz (1999).

The current strategy aims at increasing the company's global orientation in terms of research, development, design and feedback mechanism. This is influenced by both the internal company strengths and externally by growth opportunities for convergence in the telecommunications, multi-media and information technology industry. Traditionally, "B"'s infrastructure and operations were oriented for local markets, but has since altered to scale up to international markets.

"B"'s strategy distinguished between two streams of work, namely the value-based and the volume-based business functions. This distinction enables the company to balance between the motives for asset-augmenting and for asset-exploitation. This approach points to some evidence of fine-slicing of activities in "B"'s R&D value chain in a way that favours its emerging country base.

Figure 13: Participant B's value and volume-based streams



Source: Author's compilation based on interview with "B"

In the value-based business, “B” develops the IP portfolio and manages it to expand its markets. In this stream, “B” invests in R&D with a long-term view. The IP generated is used to develop technologies to serve various markets. The company carefully segments countries to which it exports its products and those to which it serves through licensing to collaborators and partners abroad. These are areas such as vehicle tracking technology, telematics and fleet management. “B” has increased its local R&D in these technology streams because they demonstrate potential for increasing IP revenues. In 2012, “B” filed 18 international patents, and increased its trademarks to 449 and domain names to 159. Drawing on existing capabilities, “B” occasionally introduces novel technologies that facilitate innovations and efficiency in a range of downstream industries. “B” regards this as its important contribution to competitiveness of South Africa’s economy.

In the volume-based business, “B” has two further streams. Firstly, the company enters into arrangements with original equipment manufacturers (OEMs) with a view to integrate own technologies in ways that improve functional characteristics of the original equipment/technology. By doing so, “B” creates new capabilities of existing technologies, extends their lifecycle, and creates new markets. This stream enables “B” to serve as an exclusive provider in specific technology platforms, both in South Africa and in other countries.

The second stream of volume-based business is with respect to own technology. “B” continuously evaluates its portfolio to determine mature technologies that can be adapted and exploited in new markets. Partnerships with firms in 15 African countries were formed for this purpose. This approach facilitates entry and mitigates entry risk into new markets, helps in meeting regulatory and local ownership requirements and overcomes a need for establishing new infrastructure.

“B” also engages in some of the abovementioned cross-border arrangements with other entities within its parent group. This helps to leverage capabilities across the group for global expansion and is particularly proving valuable in markets that are driven by technology convergence.

5.3 Case 3: Participant C

5.3.1 General overview

Participant C ("C") was established in 1957. It is a specialist R&D entity within a multinational parent group. The parent group operates internationally in the chemicals and energy sectors, with a presence in over 30 countries. The group operates upstream and supplies to a range of industries, locally and abroad.

Among other functions, "C" manages R&D, technology development and engineering services for the group on a worldwide scale. It does not serve any external customers. WIPO database shows "C" as the leading domestic firm in international patenting activity.

5.3.2 Participant C's R&D internationalisation

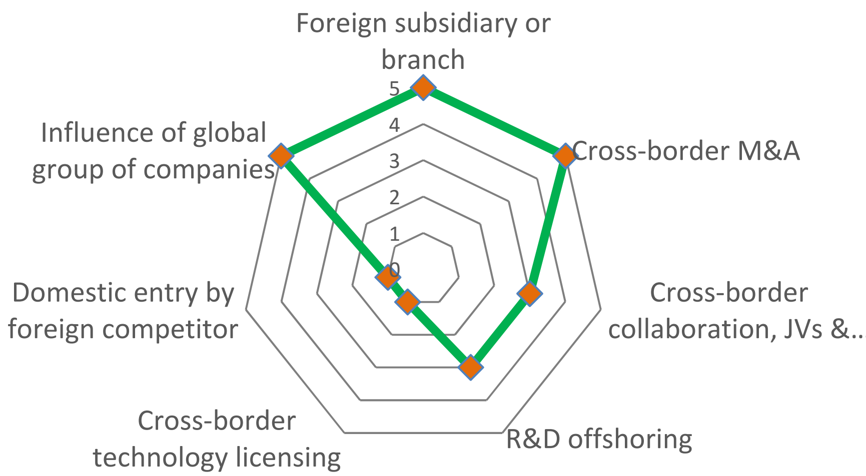
"C"'s group has been operating in the international environment for more than three decades. It has operation in North America and several European countries, e.g. Italy, Scotland, and Norway, and in Mozambique and Qatar.

Figure 13 rates the seven modes of R&D internationalisation from 5 (highly dominant mode of the firm's approach) to 1 (least emphasised in the firm's approach).

Three of the seven modes are highly dominant in "C's" approach. The company is mostly influenced by a global group approach and has affiliates abroad, some of which were acquired as existing operation while some were greenfield establishments. Primarily, the affiliates abroad were established for asset-augmentation motives.

In the second order of ranking are further two modes, namely cross-border R&D collaborations, JVs and partnerships and R&D offshoring. Some of these are for asset-augmentation motive while others are for asset-exploitation motives. For instance, collaborations with universities and research organisations abroad and R&D offshoring are aimed at sourcing new knowledge that is not available locally or within the group globally. JVs are usually with other companies to leverage each company's knowledge, IP, funding and other resources in achieving agreed commercial outcomes.

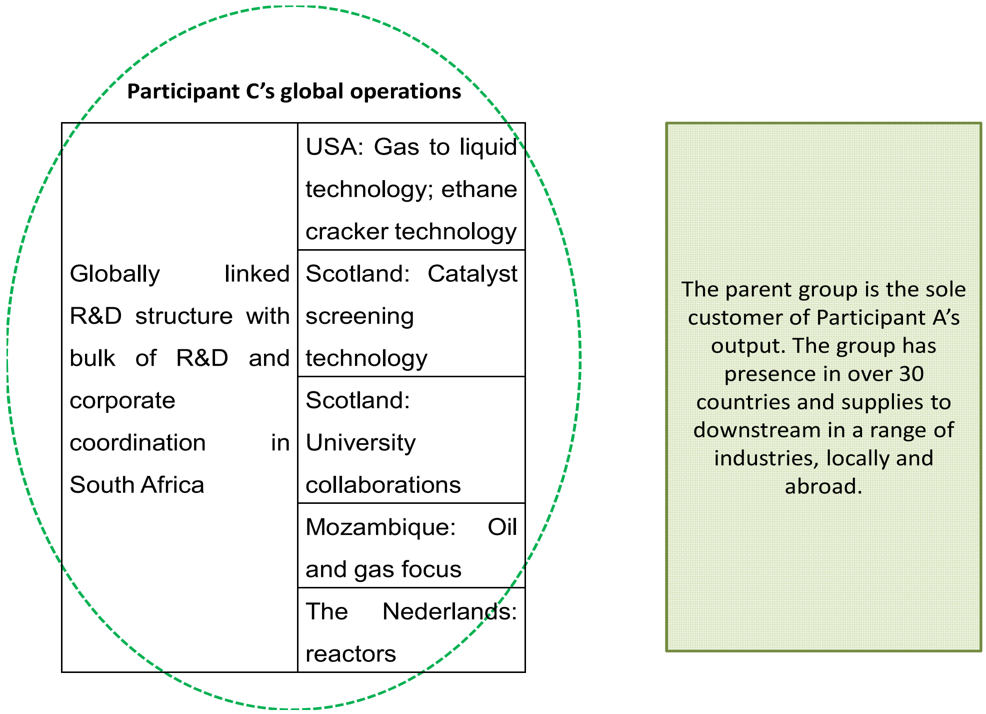
Figure 14: Modes of Participant C's R&D internationalisation



Source: Author's compilation based on interview with "C"

"C's" approach has characteristics of a globally-linked R&D structure, depicted in Figure 14. While the company has a global approach in which specialised R&D facilities are coordinated to achieve technological breakthroughs. Most of the activities are concentrated at home in South Africa. This helps leverage economies of scale on core technology and proximity to corporate planning and coordination and IP management. Specialised R&D facilities abroad are engaged in long-term, strategic R&D and were established for specific purposes to draw from unique capabilities in those locations. "C's" serves as an internal service provider for the group. All its work is meant to serve the group companies, which operate on a worldwide scale.

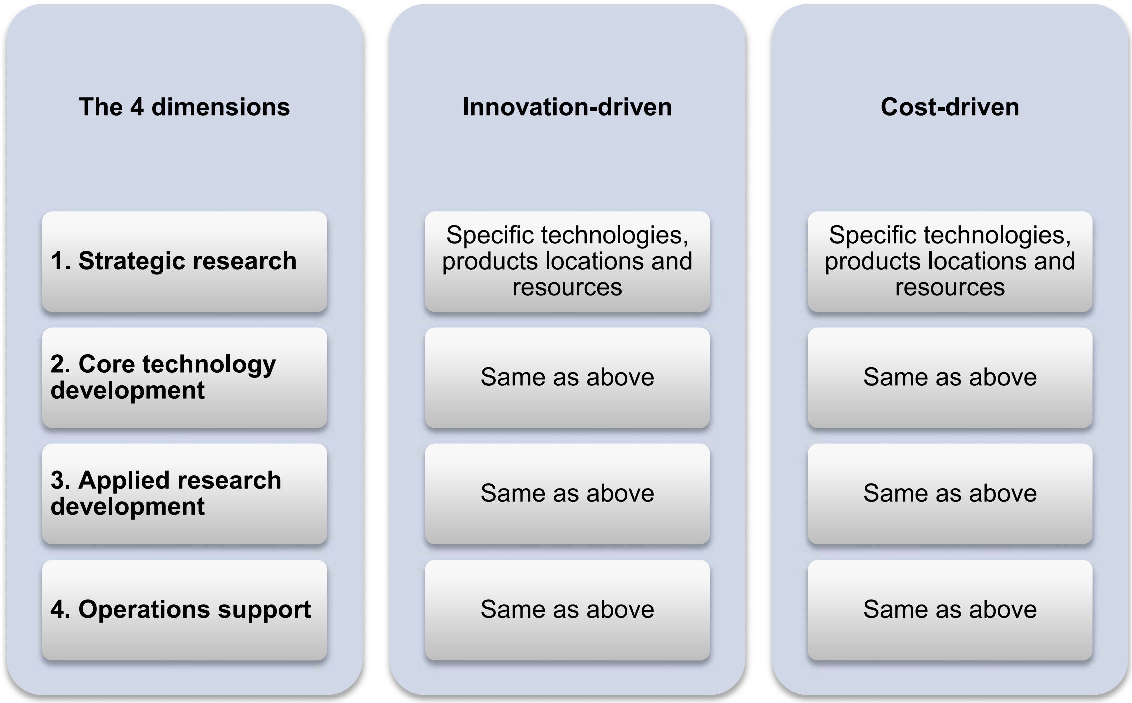
Figure 15: Structure of Participant C's R&D internationalisation



Source: Source: Author's compilation based on interview with "C"; Diagram is the author's adaptation from Gassman and Zedtwitz (1999).

"C" is guided by the parent group approach, which distinguishes between cost-driven and innovation-driven technologies/products across four dimensions, namely strategic research, core technology development, applied research development and operations support. This approach assists with prioritisation of effort for different markets as well as the nature of resources and external partnerships to source. Figure 15 presents a matrix to demonstrate this.

Figure 16: Participant C's cost-driven and innovation-driven areas



Source: Author's compilation based on interview with "C".

With the Innovation-driven technologies/products there is a significant requirement for innovation and differentiation in the markets. These areas require constant input of cutting edge research to stay competitive. In cost-driven areas there is high requirement for producing high volumes cheaper to stay competitive.

5.4 Analysis and synthesis

5.4.1 Effects on selected firm-level variables

Table 11: Effects of R&D internationalisation on selected variables

Variable	"A"	"B"	"C"
R&D investment	Shrunk	Shrunk	Increased
R&D locations	No change	Expanded	Expanded
R&D Organisation	Minimal change	Strengthened	Minimal change
R&D Performance	Minimal change	Minimal change	Minimal change
R&D Exploitation	Improved efficiency	Improved efficiency	Expanded scale

Source: Author's compilation based on interview with "A", "B" and "C".

In all three cases, major effects of R&D internationalisation are reported on changes in R&D investment and R&D exploitation. "A" and "B's" actual R&D expenditure declined compared to early 2000s. This is due to shrinking internal sources for R&D funding. The economic crisis is identified as a major external factor impacting on their financial performance, which in turn reduced R&D resources. Both firms have established stricter methods for evaluating new R&D funding requirements, mainly to cope with the rising R&D costs while drawing from limited resources and limiting the commercial risk of R&D. With these considerations, "B" in particular sharpened its strategy on R&D.

"C" has increased its R&D spending, locally and abroad. Locally, three metrics confirm this: The headcount of R&D personnel grew from 300 in 1998 to 600 in 2012 (salaries account for 70% of R&D spending); since 2000, annual spending on R&D infrastructure locally averaged R350 million, largely on research and piloting facilities; and the spending abroad to establish new facilities and on R&D offshoring.

Experiences of companies vary with respect to effects of internationalisation on R&D locations, R&D organisation and R&D performance.

For "A", there were minimal or no changes in all the three variables. Partly, this could be because its parent group already had other R&D facilities abroad, which perform different roles that complement “A”. Only minimal changes were introduced in the form of committees and forums to improve information sharing and coordination. Firms evolve the structure of their R&D organisation over time as they deepen and mature their international R&D activities (Von Zedtwitz 2005; Verhoef 2011; Di Minin *et al*., 2012).

With “B”, new centres were established in new locations abroad, e.g. in India and China, mostly for technology development and adaptation activities and one in the UK mostly for research. ”B” also acquired existing technology firms abroad, for instance in Germany, in France and in Australia, all of them from 2010 onwards. “B” also continues to evolve its structures in line with the overall restructuring process of its parent group. Certain functions are being centralised at group corporate level, e.g. IP management and commercialisation. Some business units have been discontinued while others are being combined. All these have altered the internal structures responsible for aspects of R&D value chain.

“C” made acquisitions and established new laboratories abroad in order to access knowledge not available locally or within the group globally. Europe and North America are preferred because they have the required specialisation in areas that the group lacks and for the convenience with historical connections, the language and time zones.

5.4.2 Generalisation from cases to theory

The three cases have specific similarities and differences that provide a useful base for testing the theoretical propositions in this research. The three firms are all already exposed to international R&D environment for periods longer than a decade. They have all established a degree of technological leadership in their industries at a global scale. They have all established strong R&D capability at home. Findings relating to theoretical propositions are outlines next.

Hypothesis 1: **South African firms move core parts or their entire R&D to technologically advanced countries as a result of greater exposure to R&D internationalisation.**

Evidence in all three cases refutes Hypothesis 1. The three firms have not relocated their core or their entire R&D to technologically advanced countries abroad as a result of increased international exposure. They have, however, extended certain functions of their R&D to abroad in order to undertake entirely new activities. In doing so, they were motivated by the need to access new knowledge and human capital and exploit their existing capabilities in new markets.

The three firms have already established strong R&D capabilities at home and have extensive experience operating in the international environment. Events in the past two decades, namely the economic globalisation process and South Africa's economy opening up, have facilitated their increased exposure to global economic factors. Empirical evidence to support this are threefold, namely the deepening role of South Africa in FDI inflows and outflows, international trade in high technology and the international patenting activity.

With increased exposure, R&D activities of local firms have become sensitive to factors in the international economic environment. In "A's" case, poor demand conditions in the downstream industry globally depressed revenues and profitability, thus reducing internal funding resources for R&D. Equally, these pressures also increase demand for mining technology as companies must innovate and improve productivity. In "B's" case, new opportunities for R&D exploitation have opened in developing countries, including South Africa, as user industries seek to modernise and improve efficiency. For this firm, there is a strong case for sourcing technologies from abroad with an idea to adapt them to meet local and regional technology gaps. Further pressure arises due to short product life cycle in some of its industries.

Having strong R&D, design and development capabilities at home confirm evidence that the three firms are embedded in the South African innovation system. "B's" vehicle tracking and digital broadcasting technologies were developed for South African conditions with relatively poor infrastructure. These two technologies are easy to adapt in countries with better infrastructure at reduced specifications. This is advantageous for "B" in international markets. "A's" proximity to raw material sources and primary users of its technology (i.e. diamond mining operations) in the Southern Africa region make a strong case for retaining the core R&D at home. The R&D that the three firms perform abroad is for complementing domestic activities rather than replacing it. These firms can increase their R&D investment locally given more funds and readily available capabilities locally. R&D is considered crucial to maintain competitiveness both locally and internationally.

Hypothesis 2: South African firms change their orientation for exploiting R&D as a result of increased exposure to R&D internationalisation.

Evidence confirms Hypothesis 2. Increased internationalisation has significantly altered R&D exploitation in all cases.

Three points explain this finding. Firstly, in all cases, there is sharper focus and even a higher preference for funding/performing applied R&D and technology development than exploratory fundamental research. In "A's", case, the funding pressures reoriented a focus towards "doing less, better with less". In "B's" case, priority is afforded to technologies that demonstrate the potential to generate funds for R&D reinvestment and for increasing IP revenues. The discoveries by "C" initiated a range of R&D projects based on the discovery of gas-to-liquid technology, which generated a global appeal. The technologies arising from this discovery could only be applied where the gas resources are located, in the Middle East.

Secondly, there is increased focus on incremental improvements to existing technologies, discovering new applications of existing technological platforms and creating new markets for them. Increased competitive pressures and reduced funding forced "A" and "B" to enhance R&D efficiency, in ensuring that the R&D funded has better potential for success. However, each of them follows different paths and generates different experiences. "C's" distinctions between cost-driven and innovation-driven technologies/products prioritisation of effort for different markets, e.g. adaptation research for speciality chemicals (innovation-driven products) in Europe is well-placed because of diverse and demanding customers in automotive design and manufacturing. This confirms that EMNEs, to some extent, differentiate approaches for R&D exploitation on the basis of location-specific advantages of host locations abroad. There is evidence of fine slicing of activities in the R&D portfolio in "B" and "C" but not as per theoretical proposition in hypothesis 2. Core traditional R&D in both cases is retained at home, while they initiate entirely new activities abroad in locations that offer specific advantages. In these two cases, there is also evidence of scaling up of knowledge exploitation, both at home and abroad, arising from learning internationally, tapping on knowledge signposts they established abroad.

Thirdly, in cases "B" and "C", there is stronger evidence for scaling up of R&D exploitation through internationalisation. This is achieved by tapping onto knowledge 'sign-posts' these firms have established abroad. "B" benefits from backward linkages with OEMs abroad and from forward linkages to customers/markets locally and in developing markets it serves. In "C's" case, a speciality chemical example cited above is relevant here.

Fourthly, in two cases, "B" and "C", deliberate strategies for international IP exploitation are in place. The two incur costs and effort for patenting abroad is carefully selected jurisdictions in order to maximise IP value, and protect it. With "B" specifically, new structures have been established to significantly alter its historical approaches to R&D exploitation. "B" has established an IP Management and Commercialisation Office in 2011 to actively manage IP as a driver of company's growth internationally and the Project Management Office (PMO) to monitor all R&D projects and their outputs with a view to monetise and maximise value for the company. A network of Chief Technology Officers (CTOs) and technical people located in various value-based streams supports these two functions. The two functions are centralised in Johannesburg but operate with a global focus.

Rival explanations are noted with respect to R&D exploitation. The three cases demonstrated that EMNEs have different experiences in R&D exploitation abroad. The approaches are influenced by company-specific factors, existing and potential sources of knowledge and the markets served locally and abroad.

Applying the framework proposed in Von Zedtwitz (2005) – Figure 1 (page 8), the three points are deduced.

Firstly, we focus on Type 3. While “A” and “C” are EMNEs exploiting R&D in advanced economies, the challenges anticipated of EMNEs (of being of small size versus competitors, lacking resources and management experience in advanced country markets, and being an unknown brand) do not apply because the two firms are already global leaders in their industries. These two firms’ conditions are more applicable to Type 1 instead even though they originate from an emerging economy. This research deduces, therefore, that the challenges listed above may apply to firms that are new in the international R&D scene that lack specific innovation and output capabilities (Awate *et al.*, 2012).

Secondly, “B’s” expansionary approach on volume-based technology stream is applicable to Type 4. This specifically related to its R&D exploitation of technologies that have been successful locally being deployed/adapted in developing countries.

Thirdly, there are instances where, in each case, they establish collaborations/partnerships abroad to bring technology into South Africa. This fits into quadrant Type 2.

Case specific contexts must be taken into account, however. For instance, “A” and “C’s” operations mainly service their groups globally while “B” competes for customers in an open environment. Extending this specific study to cover cases “A” and “C’s” at parent group level could illuminate the role of M&A, new establishment and reorganisation at group level and motives as well as overall impact on R&D investment and exploitation at that level. Furthermore, a similar research based on a sample of firms in the same industry can reveal industry level implications of R&D internationalisation.

6. Chapter 6: Summary and conclusion

6.1 Summary of findings

This research explored whether current R&D internationalisation trends are having a positive or negative effect on South Africa's investments in R&D. The research examined case studies of three R&D performing firms to understand how they responded to R&D internationalisation and why they responded the way they did.

This research, therefore, contributes to furthering knowledge on R&D internationalisation by EMNEs and the implications for developing countries.

The research found that:

Contrary to theoretical proposition, evidence in the three cases refutes Hypothesis 1. The three firms have not relocated core parts or their entire R&D to technologically advanced countries abroad as a result of increased international exposure. Instead, all the three firms, albeit at differing degrees, have broadened the scope of R&D to integrate foreign-based knowledge inputs. In doing so, they extended certain functions of their R&D to abroad to undertake entirely new activities. Such activities do not necessarily replace their R&D activities at home but complements it. Part of the reason is that the three firms have already established strong capabilities at home and that they are among the leaders in specific technology areas internationally. In their internationalisation efforts, the firms were primarily driven by three motives, namely to access new knowledge not available locally or within own groups globally, to access human capital and to exploit existing capabilities in new markets. The firms achieved R&D internationalisation through establishment of new R&D facilities, acquisition of existing facilities, collaborations with knowledge sources abroad and R&D outsourcing to access specialised inputs.

With increased exposure, R&D activities of local firms have become sensitive to factors in the international economic environment. Two of the firms reduced their overall R&D investment, locally and abroad, compared to early 2000s while one has increased its R&D investment locally and abroad over the same period. Pressures of international competition, combined with reduced market demand and rising R&D

costs depressed the firms' revenues and profitability. This has led to firms altering their approaches to organising and funding of new R&D.

Evidence confirms theoretical proposition in Hypothesis 2: In all three cases, increased internationalisation caused firms to alter their approaches to R&D exploitation. Combinations of changes were observed to substantiate this.

Firstly, firms adopted stricter methods for evaluating new R&D requirements. This is demonstrated in "A" and "B". Firms afford higher priority to funding/performing applied research and technology development than funding exploratory fundamental research. In doing so, priority was given to R&D projects that demonstrate greater chance for success and potential to generate funds for R&D reinvestment and for increasing IP revenues. There has also been increased focus on incremental improvements to existing technologies, discovering new applications of existing technological platforms and creating new markets for them.

Secondly, firms review their R&D capabilities in line with the requirements of new markets they serve and potential sources of knowledge they lack internally. With this in view, firms introduced certain changes to the structures and approaches for R&D exploitation. This is demonstrated strongly in "B", where entirely new structures were established to maximise IP value.

Thirdly, firms are more resolute about centralising most of their R&D in South Africa because this helps maintain scale efficiencies and leverage on their historical competences while preventing IP leakage, and secure economic returns (i.e. TBP) if licensing royalties are to accrue. This appears to be an important aspect of R&D exploitation strategies of the three firms.

Differences between the three cases illuminates the fact that firms, driven by company specific factors, sources of new knowledge and markets they serve abroad, follow different paths for R&D internationalisation and can generate very different outcomes. Contrary to theoretical proposition, challenges that are often cited for EMNEs exploiting R&D in advanced countries did not apply to two of the firms because they are already global leaders in their technological fields. Rather, such challenges may be mostly applicable to EMNEs that are new entrants in the international R&D environment (such type of firms were not covered in this research).

Background analysis established four crucial points, which helps to contextualise the abovementioned findings.

Firstly, several South African firms have decades of accumulated experience operating in the international R&D environment. The same applies to firms that served as case studies in this research.

Secondly, since the democratic dispensation in 1994, South Africa's policy pronouncements have supported R&D internationalisation, through science and technology policies that encourage cross-border flows of R&D resources and outputs, promotion of inward and outward FDI and promotion of international trade, among others. These policies create an enabling environment for R&D internationalisation of local firms.

Thirdly, opportunities for deepening South Africa's R&D internationalisation exist within the FDI and trade environment, particularly considering the already established FDI and trade connections with top R&D investing countries and multilateral arrangements such as the G20, OECD, EU and BRICS. Intra-Africa trade opportunities present further opportunity for technology adaptation. This is seen in the presence of foreign-owned affiliates, from both advanced and emerging economies, with some undertaking parts of their R&D in South Africa. Among such firms are affiliates of top global R&D spending firms listed in prominent industry sources over the years such as Bloomberg.com, Statista.com, Fortune.com. When compared to other BRICS partners, a policy challenge for South Africa is how to encourage the MNEs to not only to set up manufacturing and distribution facilities but to establish R&D functions or upgrade to higher value-added R&D (Baskaran and Muchie, 2008).

Fourthly, comparisons on selected benchmarks indicate that South Africa excel on specific technology niches in which local firms have competitive advantage internationally, e.g. chemicals and mining technologies. Local firms can continue to play a role in sustaining this. Also, South Africa lags its peers on some crucial aspects R&D internationalisation, which may hamper its competitiveness: share of global exports lags that of the BRICS partners, R&D as percentage of GDP has regressed while BRICS partners have expanded, and that international patent activity is also lagging the BRICS partners. Regrettably, the data on cross-border R&D exchanges, i.e. ownership/control of R&D entities and R&D funding flows, was found to be deficient, and need to be supplemented in order to enhance the analysis.

6.2 Implications for South Africa's innovation system

Finding of this research have implications for South Africa's innovation system.

The technological competence of large domestic firms is crucial for South Africa's R&D and innovation system. With strong capabilities well-established at home, the three case study firms have gained South Africa a reputation as an emerging economy capable of producing leading technologies in their fields and also absorb knowledge on a worldwide basis to introduce new innovations. The three firms are examples that EMNEs are anchor R&D funders and performers and influence the direction and scale of R&D in their domestic economies and facilitate cross-border flows of R&D resources and technology spillovers.

The three cases have demonstrated that domestic demand for technologies is essential for the viability of local R&D and can serve as a foundation for building capability for R&D exploitation abroad. Besides building a viable market for local technologies, the domestic economy also benefits from presence of these EMNEs. Through forward-linkages, innovations produced by these firms spill-over to downstream industries and help enhance competitiveness of local products in markets abroad.

South Africa appears to be missing R&D capability and potential new R&D investments when firms discontinue certain activities. Partly, this is an opportunity cost associated with technology and knowledge gaps in the local and regional innovation system. Factors that discourage R&D investment include public sector preference for foreign suppliers of technology; lack of engineering skills, which forces firms to undertake certain activities abroad; exchange rate, which makes importation of R&D equipment and knowledge inputs expensive; poor infrastructure in the Sub-Saharan Africa, which hinders cross-border intra-Africa trade and economic spillovers.

Programmes to promote expanding mathematics and science education, training of R&D human capital, increasing GERD, and incentives to encourage private sector R&D are practical steps in the science and technology policy domain to strengthen the R&D system, which can be a precondition for maximising positive outcomes of R&D internationalisation for the country. In the broader economy, FDI that support expansion of productive capacity and ways to enhance export performance, particularly in value-added goods are necessary.

6.3 Recommended further research

This report reveals three critical issues for further research.

Firstly, the limitation noted with respect to lack of data on South Africa's cross-border R&D exchanges requires further research to inform how data infrastructure can be developed to aid measurement and analysis in this area. Success in improving data on R&D internationalisation is also dependent on data exchanges between countries and require facilitation by international organisations and their databases.

Secondly, the study used the R&D function/subsidiary as unit of analysis and not the group corporate level as envisaged. Partly this was due to research time constraints and confidentiality requirements. This approach omits certain activities that are driven at group corporate level. Extending this specific study to cover the cases at parent group level could illuminate the role activities relating to M&A, new establishment and reorganisation at group level and motives as well as overall impact on R&D investment and exploitation at that level.

Thirdly, further empirical research on a similar study topic, using a sample of firms in the same industry can reveal industry level implication of R&D internationalisation. Such research can enhance the theoretical base on EMNEs R&D internationalisation and the implications thereof.

7. References

- "A's" sources. February 2016. *Year-end financial report 2015*. "A's" website. [accessed 12 March 2016].
- "B's sources. 2016. "B's" *Annual Financial Statements 2015*. "B's" website. [accessed 12 March 2016].
- "C's sources. 2015. "C's" *Annual Financial Statements 2015*. "C's" website. [accessed 12 March 2016].
- Amighini, A. Cozza, C. Giuliani, E. Rabellotti, R. and Scalera, V.G. 2014. Multinational enterprises from emerging economies: What theories suggest; what evidence shows – A literature review. *Associazione Amici di Economia e Politica Industriale*.
- Amsden, A. H. May 1991. Diffusion of development: The late-industrializing model and great East Asia. *American Economic Association Review Papers and Proceedings*, 81(2): 282-286.
- Archibugi, D. and Michie, J. 1995. The globalisation of technology: a new taxonomy. *Cambridge Journal of Economics*. 19:121-140.
- Archibugi, D. and Pietrobelli, C. 2003. The globalisation of technology and its implications for developing countries: Windows of opportunity or further burden? *Technological Forecasting and Social Change*, 70(9):861-884.
- Avallone, N. and Chédor, S. June 2012. Technological profiles and technology trade flows for some European and OECD countries. *International Business Research*, 5(6):24-35.
- Awate, S., Larsen, M. and Mudambi, R. 2010. EMNE catch-up strategies in the wind turbine industry: Is there a trade-off between output and innovation capabilities? *Global Strategy Journal*, 2 (205-223).
- Baskaran, A. and Muchie, M. 2008. *2008. Foreign Direct Investment and Internationalization of R&D: The Case of BRICS Economics.* Development,

Innovation and International Political Economy Research (DIIPER) Working Paper No. 8. Aalborg University. Denmark. http://eprints.mdx.ac.uk/4200/1/Baskaran_-_Mammo_DIIPER_Working_paper_2008-7.pdf [accessed 15 March 2016].

- Battelle. 2011. *Global R&D Forecast 2012.* R&D Magazine. USA.
- Battelle. 2013. *Global R&D Forecast 2014.* R&D Magazine. USA.
- Bloom, N. and Griffith, R. 2001. The internationalisation of UK R&D. *Fiscal Studies*, 22(3):337-355.
- Bloomberg. https://www.bloomberg.com/view/articles/2016-04-29/amazon-and-facebook-are-big-spenders-on-r-d
- Cantwell, J. 1995. The globalisation of technology: what remains of the product cycle model? *Cambridge Journal of Economics*, 19(1-4):155-174.
- Carlsson, B. 2005. Internationalization of innovation systems: A survey of the literature. *Research Policy*. 35(2006):56–67.
- Cincera, M. and Cozza, C. and Tubke, A. January 2010. *The main drivers for the internationalisation of R&D activities by EU MNEs.* Paper for the 4th Annual Conference of GARNET Network, IFAD, Rome 11-13 November 2009. www.researchgate.net/publications/46464582 [accessed 15 September 2015].
- Coe, D. and Helpman, E. 1995. International R&D spillovers. *European Economic Review*. 39:859-887.
- Cooke, P. 2005. Regionally asymmetric knowledge capabilities and open innovation: Exploring globalisation 2 – A new model of industry organisation. *Research Policy*. 34(8):1128-1149.
- Criscuolo, P. December 2004. *R&D internationalisation and knowledge transfer: Impact on MNEs and their home countries*. PhD Thesis, Maastricht University. www.merit.unu.edu [accessed 14 July 2015].
- Criscuolo, P. Narula, R. and Verspagen, B. July 2005. Role of home and host country innovation systems in R&D internationalisation: A patent citation analysis.

Economics of Innovation and New Technology, 14(5): 417-433. Routledge. www.dspace3-labs.atmire.com [accessed 14 July 2015].

- D'Agostino, L.M and Santangelo, G.D. 2010. *Global fragmentation of R&D activities: The home region perspective*. DRUID Working Paper No. 12-06. www3.druid.dk [accessed 14 July 2015].

- Dachs, B., Hanzl-Weiss, D., Kampik, F., Leitner, S., Scherngell, T., Stehrer, R., Urban, W. and Zahradnik, G. 2012. *Internationalisation of business investments in R&D and analysis of the economic impact.* European Commission.

- Dachs, B. and Zahradnik, G. *2014. R&D Internationalisation and the Global Financial Crisis.* Staff paper of Innovation Systems Department. Austrian Institute of Technology (AIT), Vienna.

- Demirbag, M. and Glaiser, K. April 2010. Factors determining offshore location choice for R&D projects: A comparative study of developed and emerging regions. Journal of management studies. 47(8):1534-1560.

- Department of Arts, Culture, Science and Technology (DACST). 1996. *White Paper on Science and Technology: Preparing for the 21st century*. Republic of South Africa.

- Department of Science and Technology (DST). 2002. *South Africa's National Research and Development Strategy*. Republic of South Africa.

- ....2007. *Innovation towards a knowledge-based economy: Ten-year innovation plan for South Africa (2008-2018)*. Republic of South Africa.

- Di Minin, A.D. Zhang, J. and Gammeltoft, P. June 2012. Chinese foreign direct investment in R&D in Europe: A new model of R&D internationalisation. *European Management Journal*, 30:189-203. www.web1.sssup.it [accessed 14 July 2015].

- Dosi, G. 1982. Technological paradigms and technological trajectories: A suggested interpretation of the determinants and directions of technical change. *Research Policy*, 11:147-162.

- Dunning, J. 2000. Industrial development, globalisation and multinational enterprises: New realities for developing countries. *Oxford Development Studies*. 28(2):141-67.
- Dunning, J.H. and Narula, R. 1995. The R&D activities of foreign firms in the United States. *International Studies of Management and Organisation*. 25:39-73.
- Dunning, J.H. and Narula, R. 2010. Multinational enterprises, development and globalisation: Some clarifications and a research agenda. UNU-MERIT Working Paper No. 029.
- Economist Intelligence Unit (EIU). 2004. *Scattering the seeds of invention: The globalisation of research and development*. The Economist.
- Eisenhardt, K. M., 1989. Building theories from case study research. Academy of management Review, 14(4):532-550.
- Engelbrecht, H. 1997. International R&D spillovers, human capital and productivity in OECD economies: An empirical investigation. *European Economic Review*, 41: 1479-1488.
- European Technology Assessment Network (ETAN) Expert Working Group. July 1998. *Internalisation of research and technology: Trends, issues, and implications for S&T policies in Europe*. Report prepared for the European Commission. Brussels.
- Fagerberg, J. 1994. Technology and international differences in growth rates. *Journal of Economic Literature.* 32:1147-75. www.deu.edu.tr [accessed 13 May 2015].
- Fortune. http://fortune.com/2014/11/17/top-10-research-development/.
- Gassmann, O. and Von Zedtwits, M. March 1999. New concepts and trends in international R&D organization. Research Policy, 28(2):231-250.
- Gelb, S. and Black, A. 2004. Foreign Direct Investment in South Africa. Eds. in Estein, S. and Meyer, K. Investment strategies in emerging markets.

- Granstrand, O. Hakanson, L. and Sjolander, S. 1993. *Internationalization of R&D—a survey of some recent research*, 22(5–6):413-430.
- Guellec, D. and Van Pottelsberghe, B. 2001. *The internationalisation of technology analysed with patent data*, 30(8):1253-1266.
- Griliches, Z. 1979. Issues in assessing the contribution of research and development to productivity growth. *Bell Journal of Economics*, 10:92-116.
- Grossman, G.M. and Helpman, E. 1995. *Technology and trade*. Chapter 25 of Handbook of International Economics (Vol. 3). Edited by Grossman, G.M. and Rogoff, K. Elsevier Science.
- Guimon, J. 2013. *National policies to attract R&D intensive FDI in developing countries*. The Innovation Policy Platform Policy Brief. World Bank.
- Hall, B.H. and Mairesse. 1995. Exploring the relationship between R&D and productivity in French manufacturing firms. *Journal of Econometrics*, 65:263-293.
- Hall, B.H. January 2010. *The Internationalisation of R&D*. Staff Working Paper at University of California (Berkeley) and University of Maastricht.
- Hatzichronoglou, T. March 2008. *Recent trends in the internationalisation of R&D in the enterprise sector.* Report prepared by for OECD Working Party on Statistics Special Session on Globalisation of industry. Paris.
- Insead. 2014. *Global Innovation Index: The human factor in innovation*. www.theglobalinnovatiionindex.org [accessed 13 May 2015]
- Jamasmie, C. 26 October 2015. *Weak metal prices to hit miners through 2016 – Moody's*. For www.mining.com [accessed 12 March 2016].
- Kahn, M. Blankley, W. Reddy, V. Maharajh, R. and Pogue, T. Reddy, V, Cele, G. Du Toit, M. 2004. *The flights of the flamingos: A study on the mobility of R&D workers. Project report by the HSRC in partnership with the CSIR for the NACI*. HSRC. South Africa.
- Kahn, M. February 2007. Internationalization of R&D: Where does South Africa stand? *South African Journal of Science*, No. 103: 7-12.

- Kaplan, D. March 2011. *South African mining equipment and related services: Growth, constraints and policy.* Making the most of commodities programme (MMCP) Working paper No.5. Development Policy and Practice, University of Cape Town, South Africa.

- Karpaty, P. and Tingvall, P.G. April 2015. Offshoring and home country R&D. *The World Economy*, 38(4):655-676.

- Köhler, C. Laredo, P. and Rammer, C. 2012. *The impact and effectiveness of fiscal incentives for R&D, Compendium of evidence on the effectiveness of innovation policy*. University of Manchester. http://research.mbs.ac.uk/innovation. [accessed 15 September 2015]

- Kuemmerle, W. 1999. Foreign Direct Investment in Industrial Research in the Pharmaceutical and Electronics Industries: Results from a Survey of Multinational Firms. *Research Policy.* 28: 179–93.

- Lall, S. 1979. The international allocation of research activity by US multinationals. Oxford Bulletin of Economics and Statistics. 41:313-331.

- ....1992. Technological capabilities and industrialization. *World Development.* 2(2):165-86.

- Mansfield, E.D. Teece, Romeo, A. 1979. Overseas R&D by U.S. based firms. Economica. 46:313-331.

- Miozzo, M. DiVito, L and Desyllas, P. 2011. *Cross-border acquisitions of science-based firms: Their effect on innovation in the acquired firm and the local science*. DRUID Working Paper No. 11-17. www3.druid.dk [accessed 14 July 2015].

- Mohnen, P. 1996. *R&D externalities and productivity growth*. OECD STI Review, 18:39-66.

- Moncada-Parterno-Castello, P. Vivarelli, M. and Voigt, P. March 2011. *Drivers and impacts in the globalisation of corporate R&D: An introduction based on the European experience.* Discussion Paper No. 5582 of the Institute for the Study of Labour (IZA). Germany.

- Mudambi, R. September 2008. Location, control and innovation in knowledge-intensive industries. *Journal of Economic Geography*. 8(5):699-725.
- Narula, R. December 2003. *Understanding absorptive capacity in an innovation systems context: Consequences for economic and employment growth.* DRUID Working Paper No. 04-02 prepared for the World Employment Report 2004. www3.druid.dk [accessed 14 July 2015].
- ....2010. Much ado about nothing, or sirens of a brave new world? MNE activity from developing countries and its significance for development. UNU-MERIT Working Paper No. 021.
- National Advisory Council on Innovation (NACI). 2016. South African Science, Technology and Innovation Indicators 2015. Pretoria. South Africa.
- National Science Foundation (NSF). 2012. Science and Engineering Indicators 2012. www.nsf.gov [accessed 13 May 2015].
- ....2014. Science and Engineering Indicators 2014. www.nsf.gov [accessed 13 May 2015].
- Nelson, R.R. and Winter, S. 2002. Evolutionary theorizing in economics. *Journal of Economic Perspectives*, 16(2): 23-46.
- NEPAD. April 2014. *African Innovation Outlook II*. NEPAD Planning and Coordinating Agency. Pretoria.
- October, A. 2016. *New technology heralds better TV for SA viewers*. For Cape Argus, 09 November 2005. www.mediaverge.co.za [Accesses 12 March 2016].
- OECD [Accessed 02 February 2016].
- OECD. 2002. *Dynamising National Innovation Systems*. OECD Publishing. Paris.
- ....2007. OECD reviews of innovation policy: South Africa. OECD. Paris.
- ....2011. *Attractiveness for Innovation: Location factors for international investment*. OECD. Paris.
- ....2013. *Science, Technology and Industry Scorecard 2013.* OECD. Paris.

- ....2014. *Science, Technology and Industry Outlook 2014*. OECD. Paris.
- Open data for Africa. 2016. www.southafrica.opendataforafrica.org [Accessed 15 March 2016].
- Patel, P. and Vega, M. 1999. Patterns of internationalisation of corporate technology: Location VS home country advantages. *Research Policy*, 28(2):145-155.
- Perez-Villar, L. and Seric, A. March 2015. Knowledge transfer in global supply chains: Multinationals in Sub-Saharan Africa. Kiel Institute for the World Economy Working Paper No. 1994.
- Pouris A. (2003). South Africa's research publication record. The last ten years. *South African Journal of Science.* 99: 425–428.
- Ramamurti, R. 2012. What is really different about emerging market multinationals? Global Strategy Journal. 2(1):41-47.
- Ronstadt, R. C. 1976. International R&D: The establishment and evolution of *Research and Development Abroad by seven US multinationals. Journal of International business studies. 9:7-24.*
- Saggi, K. May 2000. *Trade, foreign direct investment, and international technology transfer: A survey.* Policy Research Working Paper No. 2349. World Bank Development Research Group.
- Sampath, P. G. and Roffe, J. June 2012. *Unpacking the international technology transfer debate: Fifty years and beyond*. International Centre for Trade and Sustainable Development Working Paper. Geneva.
- Sanfilippo, M. 2013. Investing abroad from the bottom of the productivity ladder: BRICS multinationals in Europe. Bank of Finland Institute for Economies in Transition (BOFIT) Discussion Paper No. 26/2013. Bank of Finland.
- Scerri, M. 2013. Modes of innovation and the prospects for economic integration in Africa, *Africa Insight*, 43(3): 80-99.

- Solow, R.M. 1957. Technical change and the aggregate production function. *The Review of Economics and Statistics*, Vol. 39(3):312-320.
- Southafricaweb.co.za. South Africa full body scanning technology. www.southafricaweb.co.za (accessed 12 March 2016).
- Statista. https://www.statista.com/statistics/265645/ranking-of-the-20-companies-with-the-highest-spending-on-research-and-development/
- Stiebale, J. July 2013. The impact of cross-border mergers and acquisitions on the acquirer's R&D: Firm level evidence. *International Journal of Industrial Organisation*. 31(4):307-321.
- Storper, S. Chen, Y. and De Paolis, F. 2000. *The effects of globalisation on the location of industries in the OECD and European Union*. DRUID Working Paper No. 7. www3.druid.dk [accessed 14 July 2015].
- Sun, Y. Du, D. and Huang, L. 2006. Foreign R&D in developing countries: Empirical evidence from Shanghai, China. *China Review – Special issue on Science and Technology Development in China*. 6(1): 67-91.
- Trading economics. 2016. www.tradingeconomics.com [Accessed 15 March 2016].
- UNCTAD. 2005a. *World Investment Report 2005: Transnational corporations and the internationalization of R&D*. UNCTAD. Geneva.
- ....2005b. *Globalisation of R&D and developing countries*. Proceedings of the Expert Meeting, Geneva 24-26 January 2005. UNCTAD. Geneva.
- ....2013. *Global Value Chains and Development: Investment and value-added trade in the global economy (a preliminary analysis).* UNCTAD. Geneva.
- ....December 2012a. *Global investments in R&D. UNESCO Institute of Statistics Factsheet No. 22.* UNESCO. Paris.
- ....December 2012b. *Human Resources in R&D*. UNESCO Institute of Statistics Factsheet No. 21. UNESCO. Paris.

- UNESCO database on Science Technology and Innovation Indicators. http://data.uis.unesco.org/Index.aspx?queryid=115#. [Accessed 02 February 2016].
- UNESCO. 2010. *UNESCO Science Report 2010: The current state of science around the world.* UNESCO. Paris.
- ………….. 2015. *UNESCO Science Report: towards 2030*. UNESCO. Paris.
- USPTO database. http://www.uspto.gov/web/offices/ac/ido/oeip/taf/appl_yr.htm. [Accessed 02 February 2016].
- Verhoef, G. December 2011. The Globalisation of South African conglomerates, 1990 -2009. *Economic History of Developing Regions*, 26(2):83-106.
- Verspagen, B. and Schoenmakers, W. September 2004. *The spatial dimension of patenting by multinational firms in Europe*. Working Paper 02-11 of Eindhoven Centre for Innovation Studies (The Netherlands).
- Von Zedtwits, M. and Gassmann, O. 2008. *Market versus technology drive in R&D internationalisation: Four different patterns of managing research and development.* Solvay Business School. www.student.ulb.ac.be [accessed 15 September 2015].
- Von Zedtwitz. January 2005. *International R&D strategies in companies from developing countries: The case of China.* In UNCTAD 2005.
- Whitman, D. May 2007. *Globalisation of minerals industry R&D*. Address at the Bergforsk Annual Meeting – Lulea University of Technology, Sweden.
- WIPO. World Intellectual Property database. http://ipstats.wipo.int/ipstatv2/keysearch.htm?keyId=201. [Accessed 02 February 2016].
- World Bank database on World Development Indicators. http://databank.worldbank.org/data/reports.aspx?source=2&country=&series=BX.GSR.ROYL.CD&period=# [Accessed 02 February 2016].

- World Bank. 2014. *South Africa Economic Update: Focus on Export Competitiveness.* World Bank. Washington DC.
- Xiao, W. Lin, G. and Hou, T. 2010. *A study of the degree of R&D internationalisation and its affecting factors*. Zhejiang University (China) and Renmin University (China).
- Xu, B. 2000. Multinational enterprises, technology diffusion, and host country productivity growth. *Journal of Development Economics.* 62: 477-93.
- Yin, R.K. 2014. Case study research: Design and methods. Sage publications.
- Yusuf, S. 2012. *The changing geography of innovation, the current crisis, and implications for economic growth.* The growth dialogue policy brief 3-12. George Washington University, Washington DC.

Annexure A: Data collection protocol

A: Data collection protocol

Questionnaire for academic case study:

Effects of R&D internationalisation on R&D investment of firms in South Africa

Introduction

I thank your company for agreeing to participate in the abovementioned research and the time that you have committed. The research is done for a Masters study in Development Theory and Policy at the University of the Witwatersrand, Johannesburg.

The interview consists of eight questions aimed at finding out the following:

- Changes in your company's international environment of R&D.
- How the company is changing its R&D funding, organization, location and performance in keeping with trend of R&D internationalisation?
- How the company is altering its orientation to R&D exploitation (e.g. product development, patenting, managing of intellectual property, licensing, etc.) as a result of its international exposure?
- Factors encouraging or hampering your company investing in R&D in South Africa.

The interview will require about a 2-hour interview meeting with executive(s) and/or senior manager(s) responsible for strategic R&D planning/finance in the company. Besides the interview, the researcher also requests access to records showing R&D strategy/plan, R&D investments/spending, locations, organisational and control structures, e.g. annual reports, relevant reports and presentations.

This survey is both confidential and anonymous. Unless if the company grants permission, its name and those or officials to be interviewed will not be disclosed in the research report. Your participation is completely voluntary and involves no risk, penalty, or loss of benefits whether or not you participate.

Should you have any questions, please contact me on (082) 804-3758 or at 1259631@students.wits.ac.za, or my supervisors, Dr Erika Kraemer-Mbula, on email erikakm@gmail.com and Ms Lotta Takala-Greenish, on email Lotta.Takala-Greenish@wits.ac.za.

Thanking you in anticipation. Godfrey Mashamba

Company background information

Short background of the company, based on publicly available information, is sent to interviewees prior to the interview meeting. Its purpose is to allow the company to confirm or correct the researcher about his general understanding of the company and its major areas of focus.

Case study questions

DRIVING FORCES FOR R&D INTERNATIONALISATION

What have been the three key drivers of changes in your company's international environment of R&D since year 2000 to date?

EVENTS INDICATING FIRM'S R&D INTERNATIONALISATION:

Since the year 2000, has your company experienced any of the events listed below? Explain what happened.

Event indicating R&D internationalisation	Year(s)	Main considerations/motives					
		(i) To exploit company's existing knowledge (Asset exploitation)	(ii) To access/develop new knowledge (Asset augmentation)	(iii) To fight off (potential/existing) competition	(iv) To reduce the company's R&D costs	(v) To secure collaborations/ partnerships	(vi) Others, specify
Established or launched a subsidiary or branch in a different country with R&D in mind.							
Involved in a cross-border merger or acquisition (M&A) activity targeting R&D.							
Involved in a cross-border R&D joint venture, partnership and/or collaboration.							
Involved in R&D offshoring (outsourcing of R&D work to a different country).							
Involved in cross-border technology licensing (for accessing others' IP, or exploiting own IP).							
Domestic competition in your industry intensified due to entry of foreign competitor(s)							
Started new or expanded into new fields of research, requiring increased global orientation.							

STRATEGIC CHANGE VARIABLES

Did the event(s) you selected in question 1 affect any of the following strategic change variables concerning your company's R&D activities? Indicate in quantitative terms or provide reports showing the key changes.

Strategic change variable	How?			
Overall R&D investment of the company	Did it result in a step increase or decrease in overall R&D investment? What was the domestic/foreign dimensions of the changes (decrease/increase)? By how much? Over what period?			
R&D locations	In which country(ies) did the company set up new R&D activities since 2000? What was the one main attraction for each new location?			
R&D organisation	What new or significantly changed structures were set up to be responsible for international R&D activities? What records can you share to show that the structure(s) were, before and after?			
R&D performance	Did R&D internationalization effort result in significant changes in the mix of R&D types (basic, applied or experimental development) performed? What records can you share to show how the composition of R&D has changed? Use the following matrix:			
Domestic vs foreign R&D portfolio changes	*Domestic activities*		*Foreign-based activities*	
Basic research to create new knowledge (i.e. the 'R' in R&D)				
Development of new technology (i.e. the 'D' in R&D)				
Adaptation of existing technology and products to suit new markets				
	What considerations are made when your company decides on domestic/foreign mix of R&D portfolio?			

Has the company's approach to R&D exploitation changed in terms of the following?

	What evidence is available for the following:	Notes
In generating results of R&D	Increased dependence on own foreign-based research establishments	
	Dependence on exchanges with other foreign-based partner and collaborators	
	Other, specify	
In using results of R&D	Increased share of output absorbed by foreign markets	
	Extended patents into new markets	
	Other, specify	
In knowledge transfer and learning	Increased intensity of technology transfer among company's different research facilities	
	Increased intensity in exchanging company's knowledge with suppliers and customers abroad	
	Increased intensity of exchanging company's knowledge with other companies and actors abroad, e.g. IP licensing and technical services, including competitors.	
	Other, specify	
In attributing outcomes of R&D	Improved efficiency arising from improved processes	
	Expansion of market share abroad	
	Entry into new markets abroad	
	Increased royalty income from IP (e.g. patents, licenses, know-how, trademarks, designs and technical services)	
	Other, specify	
Other, specify		

IMPLICATIONS FOR SOUTH AFRICA'S INNOVATION SYSTEM:

What are three key factors encouraging your company to do its R&D in South Africa?

Three key positive effects?
Three key negative effects?
Are there factors hampering or encouraging your company to make R&D investments in South Africa? Mention top 3.

...End...

Annexure B: Selected benchmarks on size of the R&D system

Country	GERD in '000 current PPP$		GERD as a percentage of GDP	
	2001	2013	2001	2013
USA	280,238.0	456,977.0	2.64%	2.73%
China	38,547.7	333,521.6	0.95%	2.01%
Japan	103,825.8	160,246.8	3.07%	3.47%
Germany	54,453.4	100,441.4	2.39%	2.83%
Republic of Korea	21,284.9	68,937.0	2.34%	4.15%
France	35,822.4	55,594.1	2.13%	2.24%
UK	29,193.8	41,336.1	1.71%	1.66%
Russian Federation	12,657.9	40,694.5	1.18%	1.13%
Brazil	16,940.6	39,704.5	1.03%	1.24%
Italy	16,812.0	27,544.0	1.04%	1.31%
Canada	18,967.7	25,543.2	2.04%	1.69%
India	16,324.9	No data	0.72%	No data
Australia	No data	21,990.3	No data	2.20%
Spain	8,422.0	19,133.2	0.89%	1.26%
Netherlands	9,554.8	15,377.4	1.82%	1.96%
Sweden	10,379.5	14,151.3	3.91%	3.31%
Austria	4,791.5	11,341.6	2.00%	2.96%
Belgium	6,070.6	11,222.7	2.02%	2.43%
Israel	6,719.3	10,773.8	4.19%	4.09%
Mexico	3,634.9	10,020.3	0.34%	0.50%
Singapore	3,376.5	8,672.7	2.02%	2.00%
Poland	2,612.0	7,918.1	0.62%	0.87%
Denmark	3,767.1	7,583.8	1.10%	3.08%
Finland	4,568.4	7,175.6	3.20%	3.30%
Egypt	No data	6,167.5	No data	0.68%
Czech Republic	1,993.5	5,812.9	1.11%	1.91%
Norway	2,664.2	5,513.8	1.56%	1.65%
South Africa	**2,603.0**	**4,825.0**	**0.72%**	**0.73%**
Portugal	1,472.4	3,835.4	0.76%	1.33%
Ireland	1,294.0	3,312.1	1.05%	1.54%

Hungary	1,271.3	3,249.6	0.91%	1.40%
Ukraine	2,142.5	2,984.9	1.02%	0.76%
China (Hong Kong)	991.5	2,800.3	0.54%	0.73%
Pakistan	667.2	2,454.3	0.17%	0.29%
Greece	1,269.8	2,273.9	0.56%	0.81%
Indonesia	490.8	2,131.9	0.05%	0.08%
New Zealand	962.6	1,828.5	1.10%	1.17%
Slovenia	549.4	1,537.8	1.47%	2.60%
Colombia	302.9	1,536.8	0.11%	0.26%
Romania	559.1	1,480.7	0.39%	0.39%
Slovakia	411.7	1,190.6	0.63%	0.83%

Annexure C: Selected benchmarks on R&D funding from abroad

Country	Percentage of GERD funded from Abroad (in '000 current PPP$)		Percentage of BERD funded from Abroad (in '000 current PPP$)	
	2001	2013	2001	2013
Israel	20.43%	48.83%	25.71%	54.35%
Ukraine	0.00%	21.61%	No data	37.20%
UK	15.25%	18.68%	26.95%	21.55%
Ireland	8.38%	19.27%	4.56%	21.51%
Czech Republic	2.94%	27.15%	1.88%	21.15%
Austria	18.56%	16.61%	No data	20.73%
Hungary	8.17%	16.57%	16.87%	17.37%
Norway	0.00%	9.47%	8.35%	13.70%
Slovakia	2.13%	17.97%	1.13%	13.56%
Netherlands	0.00%	12.17%	14.41%	13.49%
Romania	4.10%	15.50%	4.00%	13.38%
Italy	0.00%	9.65%	6.64%	12.59%
Finland	2.58%	11.54%	0.70%	11.70%
New Zealand	0.00%	7.23%	11.79%	11.56%
Greece	0.00%	13.98%	8.28%	11.40%
Belgium	11.22%	13.13%	11.93%	11.39%
South Africa	**0.00%**	**13.00%**	**3.18%**	**11.00%**
Canada	15.39%	5.93%	19.82%	10.86%
France	6.62%	8.02%	8.66%	9.64%
Poland	1.81%	13.12%	1.79%	9.20%
Singapore	3.58%	5.84%	9.91%	8.89%
Spain	4.51%	7.36%	7.75%	7.48%
Denmark	0.00%	7.40%	9.20%	7.15%
Sweden	0.00%	6.71%	2.93%	6.88%
Slovenia	5.46%	8.91%	7.41%	6.80%
USA	0.00%	4.45%	No data	6.00%
Germany	2.06%	5.15%	2.43%	5.05%
Portugal	4.67%	6.12%	3.55%	3.83%
Russian Federation	9.92%	3.03%	9.16%	2.94%
Australia	No data	0.00%	5.53%	1.60%

China	2.30%	0.89%	No data	1.04%
Japan	0.40%	0.52%	0.54%	0.61%
Republic of Korea	0.05%	0.30%	0.56%	0.23%
China (Hong Kong)	0.42%	6.79%	No data	No data
Colombia	4.87%	2.85%	No data	No data
Pakistan	0.00%	1.31%	No data	No data
Mexico	0.85%	0.41%	0.61%	No data
Egypt	No data	0.12%	No data	No data
Indonesia	0.00%	0.00%	No data	No data
Brazil	0.00%	0.00%	No data	No data
India	0.00%	No data	No data	No data