

INNOVATION POLICY AT THE INTERSECTION

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GLOBAL DEBATES & LOCAL EXPERIENCES

EDITED BY

MBG CELE, TM LUESCHER, A WILSON FADIJI



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Contents

| | |
|------------------------------------|-----|
| List of Figures | vi |
| List of Tables | vi |
| Preface | vii |
| Acknowledgements | ix |
| List of abbreviations and acronyms | x |

PART 1: STI FRAMES, MODELS, POLICIES AND IMPLEMENTATION 1

| | | |
|---|---|----|
| 1 | At the Intersection of Social Challenges and the Fourth Industrial Revolution | 3 |
| | <i>Mlungisi B.G. Cele, Thierry M. Luescher and Angelina Wilson Fadiji</i> | |
| 2 | Transformative Innovation Policy: Insights from Colombia, Finland, Norway, South Africa and Sweden | 9 |
| | <i>Chux Daniels, Johan Schot, Joanna Chataway, Matias Ramirez, Ed Steinmueller and Laur Kanger</i> | |
| 3 | Towards Inclusive and Sustainable Economic Growth through Innovation | 31 |
| | <i>David Phaho and Thulani Dlamini</i> | |
| 4 | Science and Technology Policies and Directions for Solving Socioeconomic Problems in Korea | 43 |
| | <i>Sea-Hong Oh</i> | |
| 5 | Towards a Coherent and Inclusive NSI: Building Network Alignment through Strengthening Dynamic Interactive Capabilities | 48 |
| | <i>Il-haam Petersen and Glenda Kruss</i> | |
| 6 | Building Regional Innovation Ecosystems and the Role of Government | 60 |
| | <i>Mziwandile Madikizela</i> | |

PART 2: STI MEASUREMENTS, MONITORING AND EVALUATION 75

| | | |
|---|--|----|
| 7 | STI Measurements in South Africa: The State of Affairs | 77 |
| | <i>Anastassios Pouris</i> | |
| 8 | Measuring National Innovation Performance: The Case of Austria | 85 |
| | <i>Hannes Androsch, Johannes Gadner and Jürgen Janger</i> | |
| 9 | The Impact of Swedish Innovation Policies on Firm Growth: Some Insights from Evaluations | 93 |
| | <i>Enrico Deiano</i> | |

PART 3: NATIONAL STI ORGANISATIONS 107

| | | |
|----|---|-----|
| 10 | Ambiguities in Financing Innovation: A Case of Rio de Janeiro | 109 |
| | <i>Thiago Renault, Daniel Pereira de Almeida, José Manoel Carvalho de Mello, Sérgio Yates and Marcus Vinicius de Araújo Fonseca</i> | |
| 11 | The Science and Technology Advisory Forum and the Mexican Experience in Technology Assessment | 121 |
| | <i>Liliana Estrada Galindo and José Franco</i> | |
| 12 | The Profile of the National Advisory Council on Science, Technology and Innovation in Iran: An Overview | 129 |
| | <i>Akram Ghadimi, Naser Bagheri Moghaddam, Sahar Kousari and Vahid Zahedi Rad</i> | |
| 13 | The Evolution and Functioning of South Africa's National Advisory Council on Innovation | 137 |
| | <i>Mlungisi B.G. Cele</i> | |

| | |
|-------------------|-----|
| About the authors | 151 |
| Index | 153 |

List of Figures

- Figure 2.1: STI policy frames and how they aspire to achieve public welfare and a clean environment 14
- Figure 3.1: Interrelationship between economic growth, competitiveness and innovation in the era of the fourth industrial revolution 37
- Figure 3.2: The double diamond model for global competitiveness 38
- Figure 5.1: A framework for presenting a measurable model of dynamic capabilities 51
- Figure 6.1: Illustration of an innovation ecosystem 62
- Figure 6.2: Model for building innovation ecosystems 66
- Figure 6.3: Key success factors for developing regional innovation ecosystems 68
- Figure 7.1: SA Innovation Index 82
- Figure 8.1: Visualising innovation performance: Outcomes over time based on the combinations of current and future goal distance 89
- Figure 8.2: Development of distance to targets and probability to reach the target in the area of research and innovation in the corporate sector, 2010–2015 90
- Figure 9.1: The Swedish innovation system 95
- Figure 9.2: Effects on sales of Almi loan 97
- Figure 9.3: Trend dummy coefficients of CEOs before and after incubation (95% confidence intervals) 101
- Figure 9.4: Effect of support on growth with respect to the programme's focus 103
- Figure 11.1: S&T system in Mexico 122
- Figure 13.1: South African GDP (1990–2015) at constant 2010 prices 138

List of Tables

- Table 4.1: Characteristics of 'existing research on technology development' versus 'research focusing on solutions to social problems' 46
- Table 6.1: Model of development of the triple helix in regional economic development 64
- Table 7.1: Categorisation of indicators of the Japanese science indicators system 78
- Table 9.1: The impact of participation in any selective support programme on firms' competitiveness 99
- Table 10.1: Open calls according to the directorate of origin 115
- Table 10.2: Open calls involving innovation 115
- Table 10.3: Open calls issued by FAPERJ from 2007 to 2017 according to the proposer 117
- Table 10.4: Innovation projects financed between 2007 and 2017 118
- Table 12.1: Science and technology and innovation in Iran at a glance 131
- Table 13.1: Recent periodisation of South Africa's STI 140

Preface

Building successful societies is a meritorious goal to enhance the quality of life for humankind. High-quality education is the foundation to achieve this objective. Knowledge acquisition and understanding can result in transformative, as well as incremental innovation, based on science and technology. The World Economic Forum estimates that a substantial majority of economic and societal advancement is due to science, technology and innovation (STI).

Key to success in facilitating our relentless pursuit of next generation STI is the creation and implementation of policies to address the opportunities and challenges facing the world, be it on a national, regional, or global basis. We are at a crossroads from an STI policy perspective. The ways of conducting research, development and commercialisation have evolved appreciably in the past thirty years. For instance, while the vast majority of researchers prior to the 1990s engaged in individual research endeavours, often on narrow subjects, the current reality is that watershed discoveries and inventions are often the outcome of transdisciplinary and multidisciplinary research and development. Coupled with the lightening speed of developments through digital technologies and the internet, it is not surprising that the policy dimension needs to be *au courant* to have maximum impact on the activities, needs, support, etc. in the STI, regulatory and related sectors. Consequently, this book is a very timely contribution to energise discussions and debates leading to sage decision-making, so as to position individuals and nations more favourably in the development of more successful societies.

Following an excellent introductory chapter which informs the reader of the principal issues to be considered by contributors to the rest of the book, five chapters of Part 1 on STI Frames, Models, Policies and Implementation describe experiences by a number of countries in innovation policies. Also dealt with are interactive initiatives and the roles of different stakeholders. The authors of the four chapters in Part 2 on STI Measurements, Monitoring, and Evaluation make some compelling arguments related to benchmarking, including performance indicators and their reliability. The influence of a country's innovation policies for the growth of companies is well-described in one of the chapters. The last section, Part 3, dealing with National STI Organisations, provides perspectives on Advisory Councils in two nations in Latin America, as well as in South Africa and Iran.

In summary, the contributions mentioned herein will help to shape the future through the design and implementation of new STI policies aimed at benefiting society.

Howard Alper, O.C.

Chair, Canvassing Committee, Global Excellence Initiative

Chair (2007–2015), Government of Canada's Science, Technology, and Innovation Council

Distinguished University Professor, University of Ottawa.

Acknowledgements

In the wake of the 3rd Global Forum of National Advisory Councils which took place in Pretoria, South Africa in 2017, the National Advisory Council on Innovation (NACI) and Department of Science and Innovation (DSI)¹ of South Africa decided to produce a book to provide a reflective review of the topics of the forum, including papers on the discussions and presentations by different countries that were participating.

In order to facilitate the production of the book, NACI partnered with the Inclusive Economic Development Division in the Human Sciences Research Council (HSRC) and jointly developed a call for proposals. In the course of 2018, presenters and contributors from the 3rd Global Forum were invited to contribute chapters on their presentations as well as profiles of their organisations to the book. In addition, an open call for submissions was published. The chapters in this book are the outcome of a rigorous process that started with the dissemination of the call, receiving and reviewing proposals, draft chapters and eventually final chapters, an anonymous peer review of the full manuscript, and eventually the copy-editing and publishing process managed by the HSRC Press.

We would like to express our sincere gratitude to all the contributors to the book who participated in this process from all across the globe. It is due to their interest, commitment and expertise that this book brings together a unique spread of perspectives on current global debates and local experiences in the science, technology and innovation (STI) policy sector.

We are grateful to the two anonymous peer reviewers of the full manuscript whose insightful comments and suggestions improved the overall quality of the book and assisted us to bring it into its current form.

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Finally, we thank the DSI for the funding approved to see through the production and publication of this book. We trust that the insights gained from it will support the work of the Department as it seeks to boost socioeconomic development in South Africa through research and innovation.

The Editors

Drs M.B.G. Cele, T.M. Luescher and A. Wilson Fadiji

October 2019

¹ Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

List of abbreviations and acronyms

| | |
|----------------|--|
| AI | Artificial Intelligence |
| ARWU | Academic Rankings of World Universities |
| BII | Bloomberg Innovation Index |
| BNDE | National Bank for Economic Development |
| CEM | Coarsened Exact Matching |
| CeSTII | Centre for Science, Technology and Innovation Indicators |
| CIS | Community Innovation Survey |
| CONACyT | National Council of Science and Technology |
| CSIR | Council for Scientific and Industrial Research |
| DACST | Department of Arts, Culture, Science and Technology |
| DBE | Department of Basic Education |
| DoA | Department of Agriculture |
| DSI | Department of Science and Innovation |
| DST | Department of Science and Technology |
| EC | European Commission |
| EIS | European Innovation Scoreboard |
| EPTA | European Parliamentary Technology Assessment |
| EU | European Union |
| FAPERJ | Foundation of Support to Science, Technology and Innovation in the state of Rio de Janeiro |
| FINEP | The Brazilian Innovation Agency |
| FNDCT | National Fund for Scientific and Technological Development |
| FRD | Foundation for Research Development |
| GDP | Gross Domestic Product |
| GERD | Gross Expenditures for Research and Development |
| GII | Global Innovation Index |
| HSRC | Human Sciences Research Council |
| HTS | High-Tech Strategy |
| IBGE | Brazilian Institute of Geography and Statistics |
| ICT | Information and Communications Technology |
| IDC | Industrial Development Corporation |
| IDZ | Industrial Development Zone |
| IF | Innovation Fund |
| INCyTU | Office of Science and Technology Advice for the Mexican Congress |
| INSEAD | Institut Européen d'Administration des |
| IOT | Internet of Things |
| IT | Information Technology |
| IUS | Innovation Union Scoreboard |
| KZN | KwaZulu-Natal |
| LST | Law of Science and Technology |
| M&E | Monitoring and Evaluation |
| MCT | Ministry of Science and Technology |
| MSRT | Ministry of Science, Research and Technology |
| NACI | National Advisory Council on Innovation |
| NDP | National Development Plan |

| | |
|-----------------|--|
| NIP | National Incubator Programme |
| NIPMO | National Intellectual Property Management Office |
| NIT | Technological Innovation Centre |
| NPM | New Public Management |
| NRDS | National Research and Development Strategy |
| NRISP | National Research Institute for Science Policy |
| NSB | National Science Board |
| NSF | National Science Foundation |
| NSI | National System of Innovation |
| OECD | Organisation for Economic Co-operation and Development |
| OTA | Office of Technology Assessment |
| PECITI | National Plan of Science, Technology and Innovation |
| POST | Parliamentary Office of Science and Technology of the United Kingdom |
| PPP | Purchasing Power Parity |
| R&D | Research and Development |
| RCTs | Randomised Clinical Trials |
| RD&I | Research, Development and Innovation |
| RRI | Responsible Research and Innovation |
| R&I | Research and Innovation |
| RTI | Research, Technology and Innovation |
| S&T | Science and Technology |
| SciSTIP | Scientometrics and Science, Technology and Innovation Policy |
| SDG | Sustainable Development Goals |
| SECTI | Secretariat of Science, Technology and Innovation |
| SET | Science, Engineering and Technology |
| SKA | Square Kilometre Array |
| SKBE | Size of Knowledge-Based Economy |
| SME | Small and Medium-Sized Enterprises |
| SMME | Small, Medium and Micro Enterprises |
| SPRU | Science Policy Research Unit |
| SSI | Sectoral System of Innovation (RSA) |
| STEM | Science, Technology, Engineering and Mathematics |
| STI | Science, Technology and Innovation |
| TA | Technology Assessment |
| TIA | Technology Innovation Agency |
| TIP | Transformative Innovation Policy |
| TIPC | Transformative Innovation Policy Consortium |
| TVET | Technical, Vocational and Education Training |
| TYIP | Ten-Year Innovation Plan |
| UN | United Nations |
| UNESCO | United Nations Education, Science and Cultural Organisation |
| US | United States |
| WEF | World Economic Forum |
| WIPO | World Intellectual Property Office |
| 4IR | Fourth Industrial Revolution |

PART ONE

**STI FRAMES, MODELS, POLICIES
AND IMPLEMENTATION**

CHAPTER 1

At the Intersection of Social Challenges and the Fourth Industrial Revolution

Mlungisi B.G. Cele, Thierry M. Luescher and Angelina Wilson Fadji

Two previously distinct conversations have begun to converge in debates on science, technology and innovation (STI) policy at global and national levels. One conversation is about the contemporary societal challenges that policy makers are facing, such as increasing social inequality, poverty, food insecurity and climate change, to name a few. Globally, these societal challenges, what our respective aspirations are, and what should be done about them, have been defined by the United Nations (UN) by means of the sustainable development goals (SDGs). Their message is clear: the world we live in is characterised by unbalanced, inadequate and uneven development and growing demands for a better life. Many people feel left behind, excluded, unequal or less important than others, and that they have no future – in part, because their children ‘do not have equal opportunities to reach their full potential’ (Gurria 2018: 3). Too many people live precarious lives, at the edge of falling through the cracks of unemployment and poverty, feeling at the ‘mercy of big impersonal forces of globalisation, technological change, large corporations and financial institutions – they want to regain control’ (Gurria 2018: 3).

At the same time, we are living through an age of unprecedented and exponential advances in the techno-sciences whose effects are beginning to permeate virtually every sphere of human and planetary life. This includes major advances in information and communications technology (ICT), biotechnology, nanotechnology, the Internet of Things (IOT), robotics, artificial intelligence (AI), machine learning, blockchain, and 3D-printing, amongst many others, all of which are elements of a new production revolution or fourth industrial revolution (4IR) that transforms production processes and products; markets, services and trading systems; entire industries; and entire economies (NACI 2019). In particular, the fourth industrial revolution serves as a heuristic to help us understand and respond to these radical and potentially disruptive socio-technical transformations, including those associated with Industry 4.0 and digitalisation, that we are witnessing (Gastrow & Oppelt 2019). Their social impact is widely acknowledged: they are changing the nature of work; indeed, they are even expanding the boundaries of ‘the human’ and may impact on our collective sense of humanity. While we are only beginning to understand how these technologies work, it seems absolutely crucial to acknowledge their Janus-faced character – their promises and perils, the light and shadows – in the quest to determine the best possible pathways for ensuring the emergence of a fairer, more equal, sustainable and socially just world (Gastrow & Oppelt 2019; NACI 2019).

Countries have diverse views on the challenges and opportunities presented by the fourth industrial revolution, depending on their present situation, level of development, objectives and STI interests. Some developed countries such as Germany, Italy, Japan and the United States (US) have articulated and determined how they seek to exploit the fourth industrial revolution to meet local

needs. Developing countries equally have an opportunity to determine ways to seize and use the opportunities offered by the fourth industrial revolution while simultaneously preparing to deal with unintended and negative consequences. In the latter cases, having younger populations can be a huge advantage and a catalyst in the context of rapidly accelerating technological innovation and the socio-technological transformations associated with the fourth industrial revolution.

It is clear that the societal challenges are systemic in nature; they require longer-term planning and policy actions across technological, economic and social structures and boundaries, and across national borders. While they can be seen as offering opportunities to the global community, turning these challenges into opportunities for sustainable and inclusive growth is not straightforward (Organisation for Economic Co-operation and Development [OECD] 2015). Firstly, the societal challenges may be interlinked or have unexpected knock-on effects. For example, ageing societies can lead to a reduced labour force, increases in healthcare costs, and a reduction in the tax base. Secondly, some challenges have a global dimension, such as climate change, which means that national policies alone are insufficient to solve them. Current government policy structures and policies, including research and development (R&D) and STI policy, are ill-adapted to tackle such complex challenges (OECD 2015).

A rethink in public policy-making that takes a more systemic view of the varied challenges and problems and an inclusive and holistic approach to STI policy appears to be the only way forward for governments. Such policy-making and policies must be horizontal in order to be able to mobilise technology, market mechanisms, regulations and social innovations to respond to complex societal problems in a set of interacting and interdependent actors and components that form a whole 'socio-technical system' (OECD 2015). What this suggests is that policy makers must have a clear understanding of the systemic nature of the problems and their role in instituting changes to the design of the system. Complex and systemic problems also require a rethink of the indicators and measurement that underline and inform evidence-based policy processes. A lack of indicators will make it very difficult to measure innovation and determine the achievement of policy as will a strict focus on economic indicators only, which would neglect measurement of the impact of policies on societal factors. Thus, policy-relevant indicators should go beyond traditional input and output measures and consider process measures and other measures of transition such as quality-of-life indicators (OECD 2015).

This book is thus located at the intersection of these conversations as they simultaneously occur at the global level and in various national STI policy-making contexts. From the theoretical perspective, the book debates whether contemporary STI policies are capable of addressing societal challenges by examining their foundations, rationales, assumptions, features, conceptions of innovation, their relationship with other policies and the role of stakeholders (including non-traditional R&D stakeholders, civil society, etc.), amongst others. As part of this, the notion of three framings of innovation policy emerges, which forms the basis for a number of critical observations. The book also provides a range of highly practical perspectives informed by experiences that are drawn from several countries on the role and contribution of STI in addressing societal challenges, amongst others. These experiences are context-specific and reflect on coordination, planning, monitoring and evaluation capabilities that exist within and across different countries. As different contributions show explicitly and implicitly, gaps exist both in the conception and application of 'universal standards' and measurement frameworks. This is a reflection of the state of development of specific countries and their STI systems, and the extent of global influence, and misfits to context-specific needs. While the national cases are insightful in their own right, they also offer critical lessons for other countries whether or not they have more advanced or less advanced systems of innovation or STI policies.

The structure of the book is therefore informed by global/local and theoretical/practical considerations. Following this introduction, it is divided into three parts. The first part engages in theoretical reflection on current STI policies, their historical evolution and their ability to address issues of inclusiv-

ity and sustainability. The second and third parts share the particular experiences of different countries in designing, implementing, and evaluating innovation policies as well as their experiences of innovation governance, paying specific attention to STI advisory bodies.

Part 1: STI Models, Policies and Implementation

Harnessing STI policy to address societal challenges such as inequality and climate change is the underlying concern of the opening three chapters in Part 1. While they are all different in their approach and coverage, they are deeply connected in respect of theorisation and application. Drawing on insights from Colombia, Finland, Norway, South Africa and Sweden, Daniels, Schot, Chataway, Ramirez, Steinmueller and Kanger contend, in Chapter 2, that traditional innovation policies are incapable of addressing societal challenges such as inequality and climate change. This realisation has contributed to the recent efforts to theorise innovation policy differently and to develop a new or 'Third Frame' of innovation policy called 'Transformative Change' (Schot & Steinmueller 2018). Integral to the new approach to STI policy should be a concern with the transformation of socio-technical systems rather than a focus on technological innovation in specific industries and sectors.

Frame 1 suggests mission-oriented R&D which is focused on challenges associated with social needs and the environment, and on the regulation and organisation of a social benefit system, to compensate those who are left behind. It is a supply-driven model which focuses on research and scientific breakthroughs. Although links with the markets and users are recognised as important success factors for innovation, the main emphasis is on stimulating investment in an effective way. While this frame can integrate needs by means of the allocation of research funding in areas pertinent to addressing social and environmental needs (for example medical research on new vaccines, clean technology programmes), typically it does not enable sustainability transitions, transformative change, or inclusion of new non-research actors in the frame. Conversely, sustainability transitions, transformative change, and inclusion of new non-research actors are central elements in Frame 3 (Daniels et al. 2019).

Frame 2 suggests intervening in existing national systems of innovation to achieve better alignment and coordination (for example innovations in the coordination between medical research and healthcare delivery) or stimulating entrepreneurship in relevant areas. Initiatives using this framing can and often do include a wider array of actors, yet they focus on process and product innovation, learning and incremental change. They do not focus on radical (or transformative) change and continue to leave civil society actors at the periphery. Thus, for both Frame 1 and Frame 2, a deeper transformation which would 'align social and technological change and redirect mobility, energy, food, agricultural and healthcare systems (to mention but a few) away from unsustainable pathways is not a core aim. Instead, the main focus is on stimulating innovation in order to generate economic growth. Questions about the directionality embedded in these innovations are not central' (Daniels et al. 2019: 8).

Frame 3 puts the issue of directionality, social and environmental needs front and centre. Frame 3 suggests anticipating and experimenting with new approaches to innovation for social and environmental needs to go beyond a focus on creating knowledge or improving the functionality of innovation systems and focus directly on creating conditions for deep socio-technical system changes. Here the main rationale for policy is transition to sustainability and transformative change at the systems level. Frame 3 policies are 'open-ended, focused on learning, and on bottom-up emergence of transformation, while maintaining the transformation rationale as a main driving question' (Schot & Steinmueller 2018 cited in Daniels et al. 2019: 8).

In Chapter 3, Phaho and Dlamini identify inequality and exclusion as key social challenges and propose an inclusive innovation policy, namely the development of goods and services for and with those who

have been historically excluded from mainstream development, as a solution for countries such as South Africa. They propose three objectives for such inclusive innovation policies.

1. Industrial inclusiveness specifically targets support for less innovative firms by strengthening their innovative capacities as well as building an adequate business environment for innovation;
2. Territorial inclusiveness targets lagging and less innovative regions to narrow performance gaps with leading innovation regions. Large companies' R&D centres in Israel's Periphery programme, South Korea's Technoparks, Mexico's special economic zones and China's Spark programme are examples of government policy instruments intended to address territorial inclusiveness; and
3. Social inclusiveness seeks broader participation including marginalised communities. This is to a large extent dependent on the previous two types of inclusiveness. The uneven distribution of innovation capacities will have an impact on the social wellbeing of disadvantaged sectors of society.

Rooted in the second framing focused on National System of Innovation (NSI) or Frame 2 is the chapter by Petersen and Kruss (Chapter 5) which proposes a dynamic interactive capabilities model as solution to systemic concerns around coordination, networks and partnerships. This dynamic interactive capability model can enable policy makers to integrate various policies of government on a broader systemic level. The authors also consider provincial, regional and municipal levels, viewing them as complementary to the way we normally think about national or systems level.

To a large extent, the conceptual notions and theoretical models presented in this part of the book are shared on a general level in different contexts. This is illustrated in the case studies, including those by Sea-hong Oh (Chapter 4) on South Korea, and Madikizela (Chapter 6) on South Africa in this part. They also show, however, that there is specificity, especially in the two South African papers (see Chapters 5 and 6), where there is reference to a unique local context since some insights may not lend themselves to being easily transferable to other countries. An example is the Square Kilometre Array (SKA), which is a large radio telescope project in South Africa. Although it is a global project, it has unique attributes specific to the South African context. This would imply that when countries elsewhere in the world read the case study, in terms of how it has been used in the application of models they might draw some useful lessons. The different context may enable some people to start thinking differently about their own issues.

Part 2: STI Measurements, Monitoring and Evaluation

Part 2 consists of three case studies of different approaches to the monitoring and evaluation (M&E) of the achievement of STI policies from Austria, South Africa and Sweden. The South African chapter by Pouris (Chapter 7) starts by reviewing the international experience of the development of the STI policy during the post-World War II era. The chapter highlights the US and Japanese experiences in particular, followed by the OECD methodology, to eventually discuss STI measurement in South Africa. The chapter shows that the South African innovation index has three pillars which respectively deal with enablers, firm activities and outputs. The author further argues that South Africa is in the 'institutionalisation phase' of its STI system, where specific reference is made to the DSI¹-NRF Centre of Excellence in Scientometrics and Science, Technology and Innovation Policy (SciSTIP) established in 2014 at Stellenbosch University, the Centre for Science, Technology and Innovation Indicators (CeSTII) at the Human Sciences Research Council (HSRC), and the National Advisory Council on Innovation (NACI), amongst others.

¹ Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

Androsch, Gadner and Janger (Chapter 8) present an Austrian perspective on STI M&E, highlighting the history of STI indicators, the need for the Austrian system to develop its own set of indicators and eventually the Austrian framework for measuring research technology and evaluation. The case of the Austrian system shows how M&E indicators can visually illustrate innovation performance in relation to what they call 'leading countries' and Austrian policy targets.

In Chapter 9, Deiaci presents the Swedish experience of measuring STI policy achievement, illustrating the insights that can be gleaned from M&E on the performance of different policy instruments, such as subsidy schemes, business incubators and targeted support for small and medium-sized enterprises (SMEs). The chapter shows, for example, that there is no guarantee for a subsidy innovation programme to generate growth and jobs; conversely, loan schemes are identified as the best for growth, and incubators are best for innovation. The mixed evidence from the evaluation of various Swedish policy interventions therefore illustrates the importance of STI M&E systems for evidence-based policy-making.

Part 3: National STI Organisations

The final part of the book outlines different national experiences of innovation governance. Here the focus is especially on the evolution, role and functions, and composition of STI advisory bodies within their respective national STI environments and policy contexts. Chapter 10 by Renault, Pereira Almeida, Carvalho de Mello, Yates and de Araújo Fonseca outlines the case of a science and technology (S&T) environment that was gradually constituted over the course of the 20th century along with the evolution of Brazilian STI policy. The chapter then focuses on an STI body at state (or province) level – the Foundation of Support to Science, Technology and Innovation in the state of Rio de Janeiro (FAPERJ) – to present a longitudinal analysis of the outcomes of financing of innovation activities over a 10-year period. The analysis shows that funding from FAPERJ had actually resulted in very little innovation; rather, it resulted in improved infrastructure. Another challenge with funding innovation projects is that they may fail to establish a link with the market and end up developing products that are not actually in demand.

In the Mexican case, (Chapter 11), the Science and Technology Advisory Forum or Foro Consultivo Científico y Tecnológico (Foro) was designed as a programme to increase the impact of social innovation and also to act as an S&T office for the Mexican Congress. Estrada Galindo and Franco show the positioning of the Foro in the governance structure of the Mexican S&T system, its vision and mandate and some of the challenges and successes that the Foro experiences in its operation.

A third case of a national STI advisory body is presented by the National Research Institute for Science Policy (NRISP) in Iran (Chapter 12). Ghadimi, Moghaddam, Kousari and Rad provide a historical background to the development of Iranian R&D policy and infrastructure within the context of the Islamic Republic's 20-Year Vision Document as well as successive 5-Year Development Plans. The chapter describes in detail the goal, functions, organisation and governance of the NRISP as think tank for the Ministry of Science and Technology. The chapter concludes with an analysis of the key challenges facing STI policy in Iran.

Chapter 13 by Cele concludes the review of national STI advisory bodies. It discusses the evolution and functioning of the South African National Advisory Council on Innovation (NACI) which was established by the post-apartheid democratic government as part of building a national system of innovation. Cele outlines the socioeconomic and political context of South Africa and the historical trajectory of STI policy in the country along with the place of STI in the current National Development Plan. The

chapter then shows the performance of the NSI over the last 20 years and provides an outlook into the future by referring to the 2019 White Paper on STI and its implications for NACI. In the appendix to the chapter, NACI's mandate, role, function and structures are briefly outlined. Overall, Cele argues that, although the South African NSI has made progress in a number of areas, it continues to experience several challenges related to vertical and horizontal coordination, transformation and expansion of human resources, and investment.

Conclusion

In the context of global social challenges and globalised socio-technical transformations that hold both promise and peril, STI policy-making, policy structures and processes are rapidly shifting into the centre of the public policy gaze. This chapter has introduced three concerns in contemporary debates on STI policy at global and national levels. The first relates to the theories, frames, models and approaches that inform STI policy-making, especially those that hold the promise of building vibrant innovation ecosystems for inclusive and sustainable socioeconomic development. The second focuses on a key instrument for evidence-based policy-making, namely the development and application of comprehensive M&E systems to measure and evaluate the performance of the NSI and effectiveness of specific STI policy instruments. The third concerns key governance and coordinating mechanisms in a national system of innovation: national STI advisory bodies. Expanding on them in ways outlined in this chapter, the book thus serves as an international resource of theoretical exposition, historical and context-specific policy analysis, critical reflection and empirical description. It makes these contributions by considering the theoretical and practical applications on the global as well as local levels. The latter involves case studies drawn from a unique diversity of national contexts, including Austria, Brazil, Columbia, Denmark, Finland, Iran, Mexico, Norway, South Africa, South Korea and Sweden.

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CHAPTER 2

Transformative Innovation Policy: Insights from Colombia, Finland, Norway, South Africa and Sweden¹

Chux Daniels, Johan Schot, Joanna Chataway, Matias Ramirez, Ed Steinmueller and Laur Kanger

Numerous and critical interlocking economic, social, environmental, technological, political and cultural challenges confront our world. These challenges include resource depletion, environmental degradation, population growth, industrialisation, climate change, urbanisation, inequality and exclusion. These challenges are expressed in various national, regional and continental frameworks. One such continental framework is the United Nations Agenda 2030, which articulates 17 sustainable development goals (SDGs) towards addressing such challenges (United Nations 2015). These challenges concern both low- and high-income countries, and they exceed the ability of any single country, government, body of governance or scientific discipline to manage them.

While innovation is widely invoked as essential to addressing these challenges, the innovation engine often appears to be faltering with the fruits of creative destruction increasingly morphing into destructive creation (Soete 2013; Swilling & Annecke 2012). Innovation may become as much part of the problem as the solution. The ambivalent and open-ended nature of innovation needs be incorporated into the thinking about science, technology and innovation (STI) policy. In this chapter, we argue that innovation needs to be redirected in ways that lead to transformative change, and that for transformative change to take place, a different type of policy and policy-making is essential – transformative innovation policy (TIP). In this sense, innovation policy needs to incorporate concerns that relate to the choice of various innovation options, asking questions about which directions of innovative pathways will indeed address the pressing global challenges confronting our world.

This type of thinking about alternative innovation pathways has begun to be articulated under many different labels, for example, responsible research and innovation (RRI) (Stilgoe, Owen & Macnaghten 2013), inclusive innovation (Agola & Hunter 2016; Chataway, Hanlin & Kaplinsky 2014), social innovation (Joly 2017; Mulgan 2007), grassroots innovation (Gupta 2012; Smith & Seyfang 2013; Smith, Fressoli & Thomas 2014), frugal innovation (Radjou & Prabhu 2014), and innovation for inclusive development (Daniels, Ustyuzhantseva & Yao 2017; Organisation for Economic Co-operation and Development [OECD] 2012, 2013). While differing in many aspects, the basic and recurrent themes of these approaches are attention to alternative futures and the co-production of STI with society; emphasis on the non-neutral nature of technology; and greater consideration for the environment. Other themes include emphasis on the transformative potential of civil society, attentiveness to the needs and wants of users and non-users alike, and the necessity for innovation to respond better to the needs of lower-income segments of our societies.

¹ An earlier version of this chapter was presented as Chataway, Daniels, Kanger, Ramirez, Schot and Steinmueller (2017): 'Developing and Enacting Transformative Innovation Policy: A Comparative Study' at the 8th International Sustainability Transitions Conference, 18–21 June 2017 in Gothenburg, Sweden.

Integral to the new approach to STI policy should be a concern with the transformation of socio-technical systems rather than a focus on technological innovation in specific industries and sectors. This concern is also inspired by the sustainability transitions literature (Grin et al. 2010; Schot & Steinmueller 2018). The main argument for the need for transforming these systems is that optimising existing institutions and practices in individual sectors – such as energy, healthcare, mobility, agriculture, food, communication and water management – will not lead, over the medium and long term, to an adequate response to defined societal challenges such as those encapsulated in the SDGs. In other words, a systemic approach is required. Problems are embedded in the fundamental framing of socio-technical systems and reforms which ameliorate externalities and negative impacts may extend the lifespan of existing socio-technical configurations but might not resolve underlying problems. For example, changes to taxation may lead to resource redistribution but will not provide incentives for different patterns of investment in innovation and economic growth, which could have a more direct and lasting impact. Investment in health systems may lead to short-term improvements in people's ability to access healthcare but long-term pressures on health budgets and demographic changes mean that more radical changes in health, social care and approaches to wellbeing will be needed.

The Transformative Innovation Policy Consortium

The Transformative Innovation Policy Consortium (TIPC) was formed in 2016 at the 50th anniversary conference of the Science Policy Research Unit (SPRU) at the University of Sussex. The TIPC is designed to allow members to co-create a shared understanding about new ways of using STI to directly address economic, social, and environmental challenges (Schot et al. 2017). In its pilot phase, from 2016 to 2017, the TIPC carried out national reviews of STI policies combined with case studies involving five countries – Colombia, Finland, Norway, South Africa and Sweden. The objective of the pilot year was to undertake a mutual learning process between policy makers and researchers with a view to understanding existing efforts to move policy in a more transformative direction.

The TIPC, a global consortium of innovation policy agencies and funders, brings together policy makers and researchers, with a view to documenting the emergence of new ways of framing innovation policy in specific country contexts. In addition, working within this global context of co-creation, TIPC work also explores new approaches to evaluation and governance of innovation policies and capacity building to support transformative innovation policy-making. The theoretical underpinning for the consortium's work, that is, the new framing² referred to as TIP (or Transformative Innovation Policy), is inspired by Schot and Steinmueller (2018), (see also Diercks, Larsen & Steward 2019; Steward 2012; Weber & Rohracher 2012). This new framing is informed by theoretical perspectives and literature on innovation and sustainability transitions/transformation and relates to other broader sets of literature, including political economy perspectives and evolutionary economics. TIP ideas question and address the relationship between STI, economic priorities and benefits and social, environmental and sustainability objectives.

The goal of the TIPC is to strengthen innovation, including S&T policy formulation, implementation, evaluation and governance in order to ensure better prospects for achieving transformative change across structures, systems and societies. In this chapter, we provide further background to the TIPC and discuss insights from the work of the consortium in its pilot period year in 2016–17. The following questions underpin the discussions that follow:

1. How can we differentiate between ways of framing research and innovation policy?
2. What are some of the emerging issues involved in promoting transitions to sustainability and formulating and implementing TIP?

2 The three frames of Innovation Policy, discussed further in Section 2.

3. What are some of the challenges, barriers and potential pitfalls to transformative innovation policies and policy-making?

Based on Schot and Steinmueller (2018), we briefly characterise two dominant innovation policy frameworks and introduce a third alternative, the new framing. The appendix provides an overview table which fleshes out the three frames. Based on the consortium's pilot year work in 2016 and 2017, we then present a number of issues that the consortium is currently working on in developing TIP initiatives.

The three frames for innovation policy

Before presenting different ways of framing research and innovation it is important to caveat the analysis. We recognise that the frames below are not water-tight, nor static categories. The three frames (1, 2 and 3) overlap and influence each other but they do not replace each other. They need to be combined. At this stage, Frame 3 is only emerging and it represents a variety of types of policy framings and interventions aimed at directly addressing economic, social and environmental issues related to research and innovation (R&I) and S&T. The characterisations of the frames should therefore be seen as evolving and an attempt to better understand the nature of innovation-related policies and interventions, broadly, rather than as detailed and finalised categories.

Frame 1: Research and development and regulation

The conceptualisation of the relationship between Research and Development (R&D) and innovation in this frame is quite straightforward. Research (or science) leads to innovation. In this conceptualisation, the key challenge is to invest in research in an enabling way. This frame emerged out of the 2nd World War and in the aftermath of the scientific milestones that occurred in those years as a result of significant investment in R&D in addition to regulation. The main justification for investment in research under this frame of thinking revolves around market failure. Market failure argues that it is not possible for private sector funders to recoup investment in basic research, resulting in a 'tragedy of the commons' (Hardin 1968) – no single entity from the private sector will invest in the public good of knowledge. In this way, Frame 1 provides a rationale for why the state needs to step in to fund basic science and research. A further element is the thinking that excellence in science and research (Tijssen & Kraemer-Mbula 2017; Chataway & Daniels 2020) leads to innovation, which in turn can lead to economic growth. In response, governments in Europe and in the US began to expand the research funding architecture. Consequently, institutional support mechanisms, such as peer review and other 'supply-push' mechanisms, began to take hold.

The decades that followed from this expanded investment in research and S&T witnessed a rapid growth in new technologies and economic growth, along with the expansion of sectors and industries such as agriculture, aviation, transport and health. However, alongside this rapid growth came new challenges to the environment and health. In addition, a raft of negative consequences of technological advances began to emerge (not unlike that which was seen after the Industrial Revolution). In keeping with the predominance of science and scientific expertise, these environmental and health consequences from the 1960s onwards were dealt with through science-based regulation. In addition, a parallel infrastructure began to emerge to link experts with policy makers around regulating STI (see for example Jasanoff 1990).

The implications of this approach resulted in the dominance of the so-called 'linear model' of innovation, based on the notion that science or research leads to innovation. While we now appreciate that

the rhetoric of such a linear model failed to capture the complexity of the innovation process, it nevertheless prevailed in policy circles for many years and is still influential in 'pure' or modified forms that see the state investing in the supply of basic and more applied R&D.

Frame 2: National systems of innovation

During the 1970s and 1980s, increased economic pressures and international competition began to expose the limitations of the first policy framework (namely innovation policy-making based on Frame 1). Differences in countries' ability to withstand economic shocks became more apparent and the lack of substantial progress in bridging the gap between the poorest and richest countries in the world caused concern.

One major issue that analysts such as Nelson (1993) began to note is that research does not flow freely. Knowledge is 'sticky' and tacit and difficult to transfer. Countries also do not follow a similar path; varieties of development pathways persist. Development is bound in complex ways with the institutions that produce it. Evolutionary economists such as Dosi (1982) and others began to write about the importance of path dependence in innovation – essentially arguing that countries should follow their own established pathways, and not try to break from established routines and practice in order to follow an idealistic model.

To capture these complexities, numerous scholars from different disciplinary and intellectual backgrounds increasingly began to refer to a variety of innovation systems (Freeman 1982, 1987; Lundvall 1992; Nelson 1993). The capacity, capabilities and nature of the relationships between organisations and institutions in any 'system', be it national, regional or sectoral, deeply impact the rate and nature of R&I that occurs. This framework shifts attention from the creation and diffusion of research to a consideration of how institutions and organisations function and interact (and create demand for research). In this conceptualisation, it is the (interactive) learning and absorptive capacity between different actors in the system which emerges as important, as well as entrepreneurship (the availability and readiness of actors to bring research to the market). This gave rise to the National Systems of Innovation (NSI) approach to science and technology (S&T), and latterly, innovation policy-making. This framing is referred to in this context as Frame 2.

Frame 3: Transformative innovation policy

In the last decade (since 2010), STIs have been widely invoked not simply as the foundation for future growth strategies but as an important component for resolving a range of social issues such as agricultural, environmental and health challenges. The view of R&I as socially relevant in a multiplicity of interdependent ways, as well as economically beneficial, has led to increasing recognition that the first two policy frames are not well suited to this ambition. This is because neither Frame 1 nor Frame 2 conceives R&I in ways targeted to the scale of transformation that is needed to address complex societal and developmental challenges.

The relationship between R&I in this frame is not focused on ensuring that innovation happens (as fast and as much as possible) but about the direction of innovation. In addition, it is important whether innovation addresses social and environmental challenges, alongside economic goals. A differentiating feature of Frame 3 is therefore the conception of directionality failure (Weber & Rohracher 2012). For the notion of directionality, see Stirling (2007, 2008, 2009). In Frame 1, the challenge is to overcome market failure, whereas in Frame 2, the challenge is to link up organisations and actors which enable

effective relationships for research translation into innovations with (commercial) impact. The aim in the policy approach of Frame 2, therefore, is overcoming institutional failure and shaping markets. Frame 3, however, grapples with directionality failure, or 'needs failure' – a failure to address how to meet social and environmental needs with STI (acknowledging that these needs are not predefined or given but are to be explored in the process too).

Meeting development needs depends on bringing together a diverse understanding and engagement of a wide range of stakeholders across all stages of R&I pathways in non-linear ways. This calls for a stronger shift towards a culture of co-creation or co-production of knowledge (for example science and research) with formal and 'informal' innovation systems actors. Formal in this sense refers to main innovation actors, such as academia, industry and government, while informal relates to innovation systems actors, usually considered to be at the periphery of the innovation ecosystem such as civil society and grassroots innovators. This is consistent with recent research in four African countries which show that policy learning and policy experimentation that incorporate actors and innovations from the informal sector are essential to achieving transformative change through innovation (Daniels, 2017; Daniels & Ting 2019).

Furthermore, there is a need to rethink the governance of STI, research and policy. Rooted in theoretical work on socio-technical transitions and long-term transformative change, initial thinking about Frame 3 indicates that experimental approaches which will challenge existing socio-technical patterns are important. Coordination among actors can emerge through these experiments. Even where new macro level institutions aiming for coordination emerge and signal the need for new direction, such as national councils for innovation, any profound change will revolve around bottom-up socio-technical transitions achieved through opening up a range of options, experimentation, learning, networking, and participation. This thinking underpins the work of the TIPC.

How does each frame address social, economic and environmental challenges?

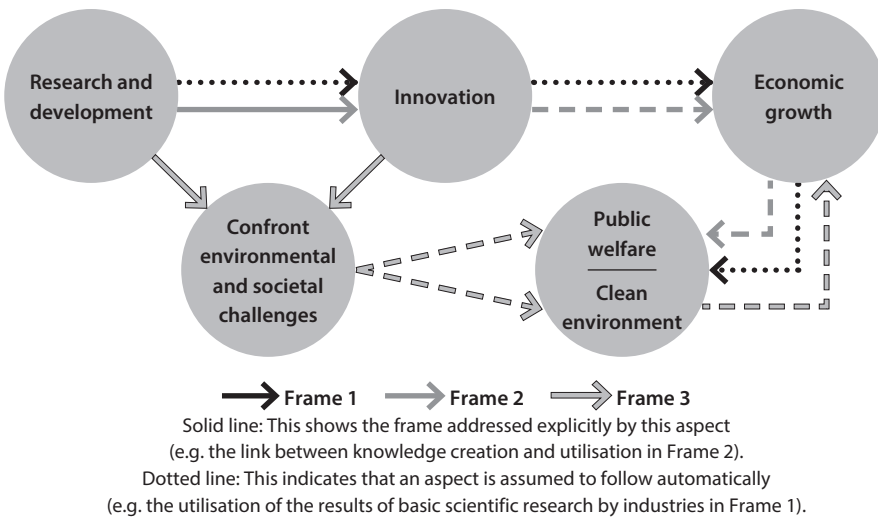
While Frame 3 is explicitly aimed at directly addressing societal challenges, each frame is, in principle, able to address social needs and environmental issues. Frame 1 would suggest mission-oriented R&D focused on challenges associated with social needs and the environment and the regulation and organisation of a social benefit system to compensate those who were left behind. It is a supply-driven model which focuses on research and scientific breakthroughs. Although links with the markets and users are recognised as important success factors for innovation, the main emphasis is on stimulating investment in an effective way. While this frame can integrate needs by allocation of research funding in areas pertinent to addressing social and environmental needs (for example medical research on new vaccines, clean technology programmes), typically it does not enable sustainability transitions, transformative change and inclusion of new non-research actors into the frame. Conversely, these are central elements in Frame 3. The term 'sustainability transitions' refers to the long-term transformation of social and technical (that is, socio-technical) systems in ways that lead to more sustainable modes of, for example, mobility, production, or consumption (Grin et al. 2010; Schot & Steinmueller 2018). In the era of the SDGs, the goal is not only to focus on transitions towards sustainability but to also address challenges such as inequality, inclusion and environmental degradation. Achieving this requires actors to address issues of directionality explicitly, in realisation that technologies are not only technical but also have social and environmental aspects embedded in them.

Frame 2, on the other hand, would suggest intervening in existing NSI to achieve better alignment and coordination (e.g. innovations in the coordination between medical research and healthcare

delivery) or stimulating entrepreneurship in relevant areas. Initiatives using this framing can and often do include a wider array of actors, yet focus on process and product innovation, learning and incremental change. They do not focus on radical (or transformative) change, and tend to leave civil society actors at the periphery. In sum, for both Frame 1 and Frame 2, a deeper transformation which would align social and technological change and redirect mobility, energy, food, agricultural and healthcare systems away from unsustainable pathways is not a core aim. Instead the focus is on stimulating innovation in order to generate economic growth. Questions about the directionality embedded in these innovations are not central.

Frame 3 puts the issue of directionality, social and environmental needs front and centre. It would suggest anticipating and experimenting with new approaches to innovation for social and environmental needs that go beyond a focus on creating knowledge or improving innovation system functioning by focusing directly on creating conditions for deep socio-technical system changes. Here the main rationale for policy is transition to sustainability and transformative change at systems level. Frame 3 policies are open-ended, focused on learning and bottom-up emergence of transformation, while keeping the transformation rationale up as a main driving question (Schot & Steinmueller 2018).

Frames 1 and 2 on the one hand, and Frame 3 on the other hand, are following a distinct conception of how STI policies contribute to achieving, for example, economic growth, public welfare and a clean environment (see Figure 2.1 below). This figure shows that a main difference between Frames 1 and 2, on the one hand and Frame 3, on the other hand, is that the former (Frames 1 and 2) address public welfare and a clean environment through the stimulus of economic growth and regulation, while the latter (Frame 3) encourages addressing public welfare and a clean environment in the innovation process itself, assuming economic growth will follow too (albeit one with a different content). Frame 3 incorporates the notion of directionality, which might also lead to a redefinition of economic growth. Missions can be integrated into Frame 3 as long as the implementation is done in an open-ended way through experimentation.



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FIGURE 2.1: *STI policy frames and how they aspire to achieve public welfare and a clean environment*
 Source: Authors

Using the three frames to map STI policy in consortium countries

The TIPC, as stated earlier, carried out its pilot phase between 2016 and 2017. The part of the work associated with the pilot phase was to map national STI policy ecosystems – focusing on research funding and innovation initiatives, using the three frames as the basis for discussion and analysis. The mapping and case-study work was achieved with background research carried out by SPRU and TIPC partners in the context of country-based interviews, focus group meetings, workshops with stakeholders and analysis of policy documents. These workshops brought together a wide range of STI policy stakeholders – government, industry, academia, civil societies, funders and others – to explore the notion of transformative innovation based on selected national case studies.

The case studies cover diverse areas but have been selected according to the following principles, referred to as TIP criteria: 1) directionality: focus on alternative futures associated with technological design choices; 2) goal: focus on grand societal challenges – economic, environmental or social; 3) impact: focus on socio-technical systems and system-level issues; 4) degree of learning and reflexivity: focus on second-order learning, problematisation of operating routines of different actors and the creation of spaces for experimentation; 5) conflict: focus on disruptive change, possibly resulting in major disagreements between actors; and 6) inclusiveness: focus on initiatives with a broad base of participation, including the consideration of non-users as potentially affected parties.

Methodology

To reiterate, data for the case studies was collected through focus group discussions, semi-structured interviews, analysis of policy documents, and workshops. The workshops with stakeholders were used to construct transformative innovation (policy) learning histories (TILH). Use of the TILH methodology helped to ensure that although the case studies were diverse, there is value in comparing the various transformative innovation attempts to formulate and implement Frame 3 policy and innovation approaches. The transformative innovation and TIP insights we discuss below are based on the five country case studies and results of the mapping exercise.³

Insights based on results of mapping the STI ecosystems and policies of case-study countries

All five countries provide evidence of a move from Frames 1 and 2 towards a Frame 3 rationale. The findings suggest that addressing societal and environmental needs through STI policies is recognised in all five countries and an emerging set of initiatives have already been put in place to implement the new rationale. All consortium member countries are experiencing a different range of economic, social and environmental challenges and these challenges shape both the articulation and implementation of Frame 3 approaches. Cultural and political histories are important and account for some of the differences and particularities. For example, the importance of consensus and bottom-up approaches in Sweden, the legacy of apartheid in South Africa, and of conflict in Colombia have all played a role in shaping the content and institutional features of emergent Frame 3 approaches. While it is true that Frame 3 policies are still marginal, they are presented as critical and, in some cases, as part of urgent and priority policy agendas. There is a weight of expectation which reflects a clear need for new directions in policy but may present problems if policies do not deliver rapidly.

3 The various mapping and case-study reports or TILHs are available from the TIPC website at <http://www.tipconsortium.net/materials/>

Each country has its own specific approach and its own narrative around the emergence of R&I policies targeted at social, economic and environmental challenges. In the case of Colombia, the country's emerging Frame 3 policies are interwoven with its peace process and attempts to overcome regional divisions. Finland's development of Frame 3 policies is integrated into initiatives aimed at overcoming the economic crisis resulting from the loss of Nokia which was the leading technology company and main economic driver in Finland. In Norway, a move towards a more knowledge-based economy is accompanied by using RRI thinking to make R&I more responsive to societal demands. South Africa's Frame 3 type policies are closely aligned to goals towards broader transformation of an economy based on the legacies of apartheid and are integrated into efforts to overcome exclusion and unemployment. Lastly, Sweden is developing green business as it restructures its industrial base and is using state-supported R&I to support that transition.

The findings from the case studies also reveal that some consortium members are currently grappling with how to integrate Frame 3 elements more explicitly into their STI policies, develop relevant policy interventions and build clearer conceptual apparatus to guide their policy formulation, implementation and evaluation. One expression of this desire is that during the mapping process, two consortium agencies began to think about a more extensive mapping exercise that would map all instruments and programmes onto the multilevel perspective representation of transformative change in order to identify gaps in instruments. Here, niche experiments would be thought about in relation to changes needed to facilitate broader meso-level change and in relation to support or obstacles presented by broader policy tools and environments. This kind of exercise would potentially have many benefits, including encouraging reflection on 'policy mixes' which could facilitate successful transition to sustainability (Mohamed 2018; Rogge & Reichardt 2015) and political economy factors which facilitate or impede transition and transformation (Byrne, Mbeva & Ockwell 2018; Chataway et al. 2019).

Actors and new management and organisational practices

In each country, the constellation of actors involved in initiatives with Frame 3 characteristics and ambitions is different. In all countries, traditional funders of R&I have played a key role. Thus, there is evidence that funders are seeking to move more to a role of change agents for transformative change. This, of course, is far from straightforward. Initial analysis suggests that this may be linked to the point made previously, namely that explicit articulation of Frame 3 rationale and theories of change for how to address societal and environmental challenges through STI policies are missing or at best under-developed.

The active involvement of multiple government ministries, and a host of local actors, including grassroots innovators, informal economy actors, and civil society and city actors, is key to Frame 3 initiatives and policy-making. Involving a multiplicity of actors does not necessarily mean constructive or non-rivalrous relationships between them. In addition, transformation processes typically will induce and provoke conflict, such as oppositions and a diversity of views and positions. This can be productive since it might lead to second-order (or deep) learning, yet obviously it can also lead to non-action or even counter-action. Whether or not conflict exists, Frame 3 approaches add complexity to participation, and this again raises questions about appropriate management and governance arrangements. Thus, one of the aims in the case studies was to explore the way in which conflict and disagreement were handled.

The case studies mapping exercise highlighted important questions. For instance, a host of questions need to be asked in relation to the way that more engaged agendas develop. Will 'bottom-up' participative mechanisms actually reflect the need for more radical transformation to achieve environmental or particular social goals or will they reflect lowest common denominators and a series of compromises that

may need to be made? Or, might more radical agendas be captured by powerful interests? In Sweden, an Organisation for Economic Co-operation and Development (OECD) assessment indicates that the Challenge-Driven Innovation programme, used as the case study, builds explicitly on action-oriented approaches involving multiple stakeholders, including end-users, and gives those users more responsibility in implementing and monitoring projects.

Another question often asked is whether the relationship between actors should be managed through administrative coordination such as in various inter-ministerial committees or even a national science, technology or innovation council. Or, might this approach run counter to the experimental ethos which Schot & Steinmueller (2018) suggest plays a crucial role in the development of Frame 3 approaches? In that case the best option is perhaps not to focus on administrative coordination but to engage a range of actors in new initiatives to ensure coordination on the ground.

Experimentation

The Frame 3 perspective contests the idea that there is a best or optimal approach to achieving the socio-technical innovations necessary for meeting social and environmental needs. It therefore focuses on experimental approaches (Schot, Kivimaa & Torrens 2019). Experimental approaches, in this case, do not imply that randomised clinical trials (RCTs) are the most appropriate means of progressing policy. The levels of contextual difference and variation are too great to make that approach the most relevant vehicle for learning or establishing good practice, and the focus on a broad change process cannot be captured through RCTs. Experiments have to be seen as instruments contributing to niche formation. The relationships between niche experiments, socio-technical transition and transformation are important components of the theoretical framework underpinning TIPC work (Schot & Steinmueller 2018). This includes a focus on shielding, nurturing and empowering of niches. At the same time, a destabilisation of prevailing socio-technical systems is seen as a necessary condition for enduring change too.

The need to view smaller-scale niche experiments as triggers for the introduction of more radical change highlights another aspect of analysis: the need to develop thinking and understanding of the political economy of Frame 3 initiatives. Recent work on political economy perspectives makes a strong argument for ‘discursive institutionalist’ approaches to political economy analysis (Kern 2011; Byrne et al. 2018; Chataway et al. 2019) which are particularly relevant to situations characterised by high degrees of uncertainty in which actors may not fully understand their interests (Hudson & Leftwich 2014). From this perspective, it is important to focus on ideas and narratives, as well as interests and institutions.

In all of the five TIPC case-study countries, there was evidence of experimentation (Schot et al. 2019) with new policy practices and discussions on how new directions for innovation policy can be discerned (while destabilisation policies are not present). In South Africa, the triple challenge of eradicating inequality, poverty and unemployment was the backdrop for new initiatives, such as Cofimvaba Tech4RED,⁴ which attempted to devolve responsibilities to local communities, sought to support grassroots-based entrepreneurialism and bring stakeholders together for improvements in rural

4 Cofimvaba Technology for Rural Education and Development (Tech4RED) is an integrated and experimental rural development initiative in the Eastern Cape district of South Africa. Tech4RED was led by the Department of Science and Innovation (DSI) (previously Department of Science and Technology [DST]) in partnership with the Department for Basic Education (DBE), the Province of the Eastern Cape’s Department of Education (DoE), the Department of Rural Development and Land Reform (DRDLR), and other innovation ecosystem actors from industry (for example Vodafone), academia and civil society. As a transformative innovation project, Tech4RED focused on six thematic areas – ICT, Nutrition, Health, Sanitation, Energy, and Science communication. The goal was to foster transformative change at systems level and support the realisation of South Africa’s national development goals as articulated in the country’s National Development Plan (NDP).

education. There is also an indication of broader involvement of actors in Colombia in a limited range of programmes with a particular emphasis on articulating problems from a community level and expressing these online to encourage ideas for solutions from a variety of sources.

One example of experimentation relates to policies and programmes that specifically aim to link research to social goals. The objective is for such policies and programmes to remain oriented to traditional actors but also supported by a new national strategy and by taxation on mineral royalties. A regional development bank has also played an important role in helping to bridge broader development efforts in science and research policy. In both countries, South Africa and Colombia, experiments with new configurations of actors and more decentralised initiatives are secondary to efforts aimed at maintaining or improving traditional STI institutions. A similar conclusion can be drawn for Norway, Sweden and Finland for their responsible R&I initiatives and their challenge-led and strategic programmes.

The role of funders

The consortium's composition focuses attention on the role of national research funders on the balance between the three frames and the understandings and definitions of social and environmental needs. Because research funders have an ongoing responsibility for the knowledge infrastructure and because they are major players in the national innovation systems, it would be surprising if they chose to cast aside established practices of governance and evaluation mechanisms which support that governance. However, conventional indicators associated with spending on research are powerful and they shape as well as measure behaviour. Governance and evaluation are key to the extent to which Frame 3 is able to take root in policy environments.

The experimentation with practice, noted in the previous section, involves an ongoing set of changes in the structure of governance, encompassing both dispersal of administrative control to other actors and assumption of a more active role in the implementation of initiatives. The principal type of dispersal is in the definition of initiatives where it now seems broadly accepted in all the countries that a local (in terms of geography or sector) definition of objectives and the means of meeting those objectives are desirable. This change, in turn, leads to other questions concerning governance.

Where traditional funding arrangements might focus on well-established actors, new initiatives are likely to involve a multiplicity of organisational types, most of which are less formal and perhaps less stable than the traditional actors. This has implications for the funding agencies' roles in monitoring activities and implementing interventions during the life of particular projects. It also suggests a less arms-length relationship between the funding agency and those who might seek to be included in new initiatives. This raises the following question: To what extent do funding agencies need to develop new capabilities for promoting the availability and assisting in the application for support for social and environmental initiatives that have Frame 3 elements (broader participation, openness to experimentation and attention to issues of anticipation or foresight)?

Indicators, measurement and evaluation

The TIPC is at an early stage of developing STI indicators and evaluation tools and perspectives for transformative change. Frames 1 and 2 are associated with a variety of supply, networking and demand policy interventions. The relative success of those interventions can be measured against theoretical and practice-based expectations and learning. Frame 3 initiatives make use of some of the same mechanisms in targeting social, economic and environmental challenges, but as yet, little thought has

been given to whether new instruments are needed or different policies may be combined in novel ways to achieve different aims and objectives, and whether initiatives that do not achieve immediate goals should be judged to have failed.

In summary, the following issues and evaluation criteria will be important to consider as part of developing Frame 3 policy thinking for evaluation:

1. Democratisation of deliberation and choice with regard to goals and possibly implementation (with the accompanying question of how to democratise governance and evaluation). How can TIP criteria be built into evaluation frameworks?
2. Explicit consideration of the means to disrupt existing arrangements that are negatively affecting or blocking paths to meeting social and environmental needs (not only 'bad' prospective innovations but existing innovations that have negative implications) is required. What is the best way to identify and evaluate the impact of negatives?
3. Explicit pursuit of experimental approaches based upon the logic that (a) more of the same (policies and practices) produces more of the same (outcomes, perpetuation of policies and practices); and (b) prior or ex-ante knowledge of best alternatives is unavailable without experience. But, adaptation will be important. How can we promote adaptive approaches?
4. Existing evaluative frameworks and methods reinforce existing practices and bias planning and implementation toward prioritising traditional goals. Nonetheless, new evaluative frameworks and methods are needed for accountability. Can ex-ante methods and theory of change approaches be helpful here or do we need to develop new and alternative evaluation tools and methods? If yes, what resources, capabilities and theories will underpin this exercise?
5. A broader scope of analysis is needed to anticipate alignment in changes with specific socio-technical systems in the direction of more profound change. What should be the indicators and signs of change that we identify and use?

These questions are at the core of the evaluation and accountability analysis that the TIPC hopes to develop and will be important as consortium members carry out experiments in Frame 3 policy. What makes an experiment worth doing? Can an experiment that fails to achieve its initial objectives be seen as an investment with a social return? If there is not a universal path to transformation, how can we evaluate the nature, outcomes and impacts of transition? How can we assess when a particular initiative is to generate higher-order or double-loop learning (learning useful insights about the larger process in which the initiative is lodged that will positively influence the definition and implementation of future initiatives)?

At present, the mapping work suggests that Frame 3 initiatives are being undertaken because of their self-evident value, that is, because their objectives are consistent with addressing social or environmental challenges. In some cases, particularly in the cases of the Scandinavian countries, initiatives have been taken under the premise that better outcomes might be possible by a more 'bottom-up' definition of initiatives. In either case, the eternal evaluative question – how can we know whether progress or transformation has been achieved? – is relevant. For this reason, recent TIPC work has focused on developing an evaluation methodology for addressing this question (see for example Boni, Giachi & Molas-Gallart 2019).

It is important to note that in developing the evaluation tools and techniques, theories of change and development of Frame 3 narratives may be usefully supported by various types of 'futures' and ex-ante evaluation work. Consortium members have begun to think about this. For example, Finland and Norway are to some extent integrating foresight activities into current efforts to link R&I with targeted social and environmental goals. Foresight and other future techniques may well be an important tool for provoking more creative and radical approaches to transformation.

Scenario-based approaches, particularly those that are agent-based and look at how behaviours may change and evolve, could help both in designing and monitoring work and encouraging experimentation. Using futures work in developing theories of change may also be a way to counter the inherent conservatism in ex-ante evaluation of proposals for Frame 3 type work. Inherent conservatism, as used here, refers to the tendency to look for evidence to approaches that have worked in the past, and not to consider the scenarios which may allow them to work in future.

Conclusion and areas of further work

This chapter has provided an overview of the thinking behind TIP designed to foster new approaches to science, technology and innovation policy for transformative change, and the work of the TIPC. From the analyses, we found that elements of the three frames were present in all the case studies across the five countries – Colombia, Finland, Norway, South Africa and Sweden. In all five countries, there are examples of important experimental initiatives of local municipalities, cities, regional authorities and national governments in promoting Frame 3 (for example, transformative change) approaches.

In terms of fostering experimental approaches, creating space in broader regulatory, organisational and institutional frameworks for these initiatives is a significant issue. An important question relates to how to connect the various experimental initiatives, upscale them and make them transformative. This question may be answered on a national, regional or transnational scale. This connecting-up work might be an important role for national funders and innovation or policy agencies. Ways to join up various experimental initiatives, upscale them and ensure that they are transformative, constitute an area of ongoing or future research and further policy work. Current programmes in the TIPC are exploring policy experimentation, evaluation and related issues (Boni et al. 2019; Schot et al. 2019).

Also, in all five countries, the differences between the frames were found to be implicit rather than articulated. This has consequences for the way in which policy is formulated, implemented, monitored, evaluated and governed. In addition, it seems likely that a lack of a more clearly defined Frame 3 agenda may limit consideration of a more formal reflection of how different framings of policy and policy instruments might support or hinder each other and what gaps might exist. Rather, there is an implicit assumption that policies and policy instruments associated with the policies can be easily combined. There is also limited consideration of new policy instruments and mechanisms that might need to accompany changes in how organisations fund research, build networks or govern STI policies. Frame 3 aims are largely pursued using Frame 1 and 2 instruments, which thus far have proven to be inadequate in delivering intended objectives.

Work in the pilot phase of the TIPC is informing the development of a broader research agenda, experimentation and evaluation approaches, and the development of Frame 3-based theories of change. These evaluation strategies need to be rooted in a theoretical understanding of the relationships between niche experimentation, socio-technical transition and transformation, political economy perspectives, as well as initial learning from the mapping exercise and insights from the case-study findings, discussed in this chapter. Currently, the lack of explicit articulation of Frame 3 rationales and logics is a barrier to being able to develop more precise thinking about what specific partnerships, networks, interventions, and policy instruments or mixes are meant to achieve. This again constitutes an area for future research and further policy work.

Analysis of the TIPC pilot year produced other important insights. For example, the findings revealed that transformative change follows a non-linear policy process and requires proactive policy engagements over a number of years. The proactive policy engagements might be fraught with many uncer-

tainties in the processes involved, necessitating fragmented policy mixes, and often work best through employing a mixture of bottom-up and top-down approaches. In addition, agency matters. Human resources and leadership (policy champions) are important, as people are required to maintain transformative change processes. Successful transformation results in the formation of new routines and new framings of societal challenges. Such challenges have to be open-ended and allow for opening up, tensions and conflicts and then for closing down to allow for acceptable sustainable pathways to emerge. Furthermore, there is a need for evaluation of transformative change policies. Evaluation of transformative change policies, processes, programmes and projects must be context-specific and will require new types of programme theory, indicators and metrics. Early indications from TIPC work suggest that formative evaluation is likely to yield better results in contrast to evaluation for accountability. There is need for more robust empirical evidence in this regard.

To reiterate, elements of all three frames were present in all five case-study countries. Nevertheless, Frame 3 misses a strong narrative, consistency and specific policy instruments required to operationalise the relevant policy objectives articulated in the case-study projects, programmes and policies examined. This has a negative implication for the governance to be exercised in this regard. TIPC members and associates are currently working on developing a more coherent approach to Frame 3 thinking. Learning and adaptation are central to a Frame 3 approach and so is the ability to continually iterate between intended impacts and outcomes. Incorporating TIP ideas into policy formulation is not enough: implementation is vital if we are going to see transformative change. To this end, ongoing TIPC research and policy work aims to accomplish objectives that include: (a) developing new narratives around TIP and Frame 3 thinking; (b) building a set of demonstrators on how to approach, implement, evaluate and govern TIP; and (c) establishing a network of people and organisations working from transformative perspectives in relation to innovation across the globe.

TIPC members and associates believe that innovation should serve the quest for transformation. In order to achieve this goal of transformative change, innovation (including science and technology) policies must focus on societal goals, deep socio-technical changes and a sustainability agenda – as captured in the SDGs. The main aim of public policy should be to induce transformation and ongoing technological change processes.

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Appendix: Three Frames Summary

The table below is a selective mixture of ideas relating to the description of the three frames of R&I policy. The table aims to function as a simplifying device so that the distinctiveness of each frame can easily be grasped at a glance. This leads to certain implications:

- Avoidance of excessive specification: each frame is more nuanced than the table allows and has also developed over time (for example, innovation systems literature has started to pay attention to civil society, entrepreneurship approaches have started to talk about social entrepreneurship). The simplifications in the table are made purposefully, reflecting a trade-off between precision and clarity. It is always possible to add more nuance and complexity in the text describing the literature around each framework.
- Choice of criteria: ideally the table should not contain too many criteria, otherwise it would become too difficult to follow. This indicates a (future) need to agree on the crucial criteria. Admittedly, there is much work to be done in this regard. This work has begun and is continuing.

The Three Frames – A Comparison

| | <i>Frame 1: R&D</i> | |
|---------------------------------------|--|--|
| Time of dominance | 1960s–1980s | |
| Main geographical focus | National | |
| Focal actors | Government, scientists and industry actors with a tendency to prioritise large firms | |
| Justification for policy intervention | Fixing market failures: industries fail to conduct basic scientific research that is not fully appropriable or support for basic and applied science | |
| Nature of critical knowledge | Appropriate and transferable: easy to adopt, apply and utilise without protective measures | |
| Focal areas | High technology: stress on the creation of radical novelty | |

- **Exclusivity:** as a general rule, cells in each row should differ substantially from each other. Therefore, criteria common to all or most of the approaches should be avoided where possible. Moreover, since the frames are cumulative with each partly reacting to, but also, building on the previous ones, it is sensible to construct the table in such a manner that each cell would focus only on the novel additional features of each frame.
- **Symmetry:** the essential differences between the frames should be outlined symmetrically (for example 'conflict vs. consensus' should be specified for each frame, not only some of them). If this creates difficulties with completing the table, it indicates some gaps in current thinking that require additional reflection. However, it is not necessary to achieve symmetry for criteria containing descriptive characteristics (such as 'typical policy activities' for which the number of activities in each cell may well differ).

Finally, the table proposes that Frame 2 contains two variants. In reviewing policy frameworks in the existing five consortium countries, we noted that within the NSI framing there are a number of variants and in the table, we have delineated more and less market-based approaches and have begun to characterise a market-based approach ("entrepreneurship"). The latter can be seen as an application of a more general neoliberal approach to the domain of innovation policy. Hence, we have highlighted the distinctive emphases of each with (a) and (b) where appropriate.

| | <i>Frame 2: Systems (a) and entrepreneurship (b)</i> | <i>Frame 3: Transformative change</i> |
|--|--|---|
| | 1980s to today | Emerging |
| | (a) National and regional systems of innovation intersecting with sectoral and technological innovation systems (b) National with particular attention to 'centres of excellence' or 'clusters' of innovative activity | Multi-scalar: focus on grand challenges that extend to multiple scales exceeding geographical, sectoral, technological and disciplinary boundaries |
| | (a) Interlinked configurations of government, science, and industry actors, with particular attention to the role and missions of universities (b) Enterprises, markets and the government, with a particular focus on new technology-based firms and start-up culture | Government, science, industry, civil society, end-users and non-users (as potentially affected parties and contributors to the innovation processes) |
| | (a) Fixing institutional system failures, including failure to generate entrepreneurship: an increase in R&D spending does not automatically lead to high performance in terms of system performance by creating of links between actors and facilitating mutual learning (b) Promoting entrepreneurship and facilitating the creation of markets for innovative goods and services | Fixing transformational socio-technical system failures: R&D, innovation systems and commercialisation challenges. More space for experimentation with niche solutions enabling socio-technical systems change and tilting the institutional and regulatory regime field towards transformative change of socio-technical systems |
| | Sticky and situated: utilisation requires proximity, absorptive capacity and interactive learning | Emergent and co-produced: generated through dialogue between multiple actors as part of a collective search process |
| | Radical and incremental product and process innovations: stress on significant price/performance improvements through successive incremental innovations | Socio-technical systems: stress on fundamental transformation of system architecture, changing both its components and its directionality of development |

| | | |
|------------------------------------|--|--|
| | <i>Frame 1: R&D</i> | |
| Typical policy activities | <p>R&D stimulation (subsidies, tax credits, procurement, mission-oriented programmes)</p> <p>Building the intellectual property rights regime</p> <p>Education policy with emphasis on science, technology, engineering and mathematics (STEM) subjects</p> <p>Science communication to explain the importance of STEM to a wider public</p> <p>Foresight to select focus areas; regulation and technology assessment to manage negative impacts</p> | |
| Underlying model of innovation | <p>Linear model: invention (discovery) leads to innovation (commercialisation) leads to diffusion (adoption)</p> | |
| Basic assumptions about innovation | <p>Division of labour: clear division of labour – government provides, science discovers, industry applies and consumer adapts; increase in R&D will automatically translate into more innovation</p> <p>Conflict vs. consensus: most often embedded in a military-industrial complex that takes defence needs as forerunners and large industries as the ‘natural’ intermediary to translate scientific advances into commercial application; open conflict with new firms and industries that are not part of the club</p> <p>Technological and social progress: the link between the two is largely uncontested</p> | |

| <i>Frame 2: Systems (a) and entrepreneurship (b)</i> | <i>Frame 3: Transformative change</i> |
|--|--|
| <ul style="list-style-type: none"> (a) Constructing links between actors (building platforms, networks, databases) and organising technology transfer (b) Stimulation of learning-by-doing, learning-by-using, learning-by-interacting (c) Use of demand stimuli (for example procurement) to enhance and accelerate market development (d) Building regional and national systems of innovation by assessing capabilities gaps and technological opportunities, and implementing policies to address them (e) Enhancing skills development based on proactive analysis of skills gaps and shortfalls (f) Programmes to stimulate entrepreneurship and incubators (including indoctrination in the social value of entrepreneurship) (g) Improving business conditions for SMEs and start-ups (h) Addressing the nature of equity markets (mezzanine level finance, initial public offering (IPO), inclusion in exchanges), especially angel and venture capital markets | <p>Stimulation of experimentation with niche technologies, scale-up and acceleration of socio-technical transitions (for example Strategic Niche Management, innovation intermediaries, Transition Management)</p> <p>New institutional solutions for changing the directionality of existing R&D and innovation activities (for example technology forcing, Responsible R&I, policy mixes for stimulating niches and destabilising existing systems)</p> <p>Promoting social, inclusive, frugal and pro-poor innovation</p> <p>Bridging science/engineering, social sciences and humanities in the education system</p> |
| <ul style="list-style-type: none"> (a) Interactive and system-bound: chain-linked model stressing feedback loops between invention, innovation and use; evolutionary model, stressing ongoing interactions between actors, networks and institutions resulting in path dependency (b) Demand-pull model – needs of organisations and individual consumers largely drive innovative activities | <p>Socio-technical and experimental: quasi-evolutionary model including non-random (purposeful) variation, selection and retention while accepting emergence as main dynamic; stress on feedback loops between invention, innovation and use, and ongoing interactions between actors, networks, institutions and technologies across scales. Focus on circulation and appropriation instead of diffusion</p> |
| <ul style="list-style-type: none"> (a) Division of labour: multiple closely interacting actors with different but partially overlapping roles contributing to the overall performance of the system (b) Clear division of labour – the task of the government is to facilitate the operation of existing markets and to create markets where they do not yet exist; left to themselves markets provide novel products and services at optimum quantity and price (c) Conflict vs. consensus: evolutionary in rhetoric but functionalist in practice, emphasis on cooperation and orchestration between various actors, leading to the fulfilment of system functions (d) Tends to be conflict-oriented, mainly stressing international competitiveness of states and competition between enterprises. Technological and social progress: the link between the two is largely uncontested | <p>Division of labour: blurred boundaries, multiple actors crossing various domains and enacting overlapping roles, resulting in the co-production of science, technology and society</p> <p>Conflict vs. consensus: mix of competition, cooperation and intermediation is required to achieve disruptive socio-technical systems change</p> <p>Technological and social and environmental progress do not automatically go together: technology choice is not neutral but contains societal choices and directionality with implications for equality and the environment</p> |

| | <i>Frame 1: R&D</i> | |
|----------------------------------|--|--|
| Basic assumptions about outcomes | <p>Dealing with consequences: new technologies are associated with high degree of uncertainty and unpredictability, making it virtually impossible to address major environmental and social impacts proactively</p> <p>Causality: stress on innovation as an engine of economic growth leads to public welfare as a bonus</p> | |
| Main hazards | <p>Government failure: insufficient funding for basic R&D</p> <p>Market failure: negative externalities that require regulation</p> | |
| Parallel counter-narratives | <p>Appropriate technology movement, focus on small-scale solutions</p> | |

Source: Authors

| <i>Frame 2: Systems (a) and entrepreneurship (b)</i> | <i>Frame 3: Transformative change</i> |
|---|--|
| <p>(a) Dealing with consequences: largely reactive, major environmental and social impacts are usually addressed after they have occurred, sometimes with a particular emphasis on the provision of adequate market stimuli</p> <p>(b) Causality: stress on innovation as an engine of economic growth and increased competitiveness leads to public welfare as a bonus</p> | <p>Dealing with consequences: proactive, stress on anticipating alternative futures associated with certain technological choices</p> <p>Causality: stress on innovation as a means of directly addressing environmental and social challenges leads to economic growth and increased competitiveness as a bonus</p> |
| <p>(a) System failure: innovation system fails to perform as a synergistic whole and to enhance innovative activities</p> <p>(b) Government failure: too many state restrictions on business activities</p> <p>(c) Market failure: regulatory need to deal with negative externalities in a way that would not stifle entrepreneurship</p> | <p>Transformative failure: failure to induce fundamental transformation to socio-technical systems forming the backbone of modern societies</p> <p>Societal and environmental needs failure: failure to solve extra-economic and collective problems on multiple scales</p> |
| <p>(a) Politics and democratisation of science and technology</p> <p>(b) Inclusive and interactive technology assessment</p> | <p>Technological fix: strong state intervention with massive investment in Big Technologies which promise to solve large environmental and social problems</p> <p>Social innovation: move away from technical solutions which are perceived as part of the problem</p> |

Towards Inclusive and Sustainable Economic Growth through Innovation

David Phaho and Thulani Dlamini

The problem of inequality is more prevalent in developing countries than in developed countries (Soares, Scarrie & Maharajh 2014). Among developing countries, South Africa has one of the highest levels of inequality, with former President Thabo Mbeki describing the country as a dual economy: one First World and the other Third World. Albeit dated, Gelb (2003) provides a useful analysis for understanding the root causes of inequality in South Africa, arguing that inequality arises primarily out of exclusion of certain sectors of society.

The drive for inclusive economic growth and meeting sustainable developmental goals is gaining currency amongst policy experts (see for example Cafod 2014; Gumede 2018; Pansera 2018). New terms such as 'frugal innovation', 'reverse innovation', 'Jugaad Innovation', 'bottom of the pyramid innovation', 'pro poor vs for the poor innovation', 'long tail and long tailored innovation' and others have emerged to describe the intersection between innovation, development and poverty alleviation (Pansera 2018). Specifically, there is widespread acknowledgement that the impact of science, technology and innovation (STI) can go beyond economic growth and can provide solutions to address a number of broader socioeconomic challenges such as access to information and communication technology (ICT), climate change, education and the delivery of services to all citizens (Botha, Grobbelaar & Bam 2016; Organisation for Economic Co-operation and Development [OECD] 2012).

In this chapter, the authors review global innovation policy trends to address the challenges of inequality and exclusion. Furthermore, the authors illustrate the potential of technological innovation to fast track or hinder inclusive and sustainable socioeconomic development in both developing and developed economies. The chapter also explores how prudent STI policy is key to enhancing the impact of the fourth industrial revolution (4IR) to address the global triple challenges of inequality, unemployment and poverty. To that end, a model is proposed to address inequality through inclusive innovation, for example, the development of goods and services for and with those who have been historically excluded from mainstream development.

The outline of the chapter is as follows: Firstly, it presents an overview of innovation policies from other regions around the world. This is followed by a view of the current South African innovation policy landscape as well as key challenges and opportunities in the country with a specific emphasis on inclusive innovation in the era of the fourth industrial revolution. Lastly, a number of proposals for South Africa's innovation policy framework are presented to drive inclusive innovation and competitiveness.

Innovation policy review

The centrality of innovation to economic growth, poverty reduction and global competitiveness is well documented (Planes-Satorra & Paunov 2017). Innovation can be broadly defined to ‘encompass the processes by which organisations master and get into practice designs and manufacturing processes that are new to them, if not to the universe or even to the nation’ (Kozul-Wright & Stanbury, 1998: 2). It is for this reason that the development and implementation of coherent policies to stimulate innovation is a particular focus of governments across the world. Innovation policy refers to a set of policy instruments that affects the innovation performance of a country and defines its innovation system (Fagerberg & Fosaas 2014). At the heart of a vibrant innovation system is a cluster of research and development (R&D) intensive firms driven by the commercialisation of innovations, research and technology organisations (RTOs) as well as a responsive education sector (specifically universities) which consistently churn out highly skilled labour and other services germane to the needs of the economy. The institutional framework driving innovation is the concept of the national system of innovation (OECD 2003). This is, in essence, a diverse system with a large number of actors such as public agencies, universities, the private sector as well as branches of government supported also by non-profit and other essential organisations (Shapira & Youtie 2010).

Traditionally, innovation policies have underpinned economic growth by creating an environment that enhances productivity, competitiveness and job creation (Planes-Satorra & Paunov 2017). As such, most innovation policies focus on (i) providing incentives to promote innovation activities; (ii) investing in public R&D infrastructure; (iii) removing barriers to innovation and entrepreneurship by providing special support for small, micro and medium enterprises (SMMEs) and easy access to credit; as well as (iv) addressing systemic issues such as science, engineering and technology (SET) education and collaboration. However, these conventional approaches to innovation could have the unintended consequence of accentuating inequality in both developing and developed countries.

With a marked increase in global inequality, there is a strong focus now on what is referred to as inclusive innovation policies described as a ‘specific set of innovation policies that aim to boost the capabilities and opportunities of disadvantaged individuals to engage in innovation activities such as R&D as well as entrepreneurship’ (Planes-Satorra & Paunov 2017: 3). As articulated by Foster and Heeks (2015), there is now more than ever an urgent need for innovation policies to expand horizontally in order to bring in sectors that matter most to poor, marginalised people, such as health, education, small-scale agriculture, water and sanitation, as well as vertically, to bring in innovators, entrepreneurs and consumers at the base of the economic pyramid.

It is thus envisaged that inclusive innovation policies would fast-track access to resources for marginalised groups, leading to a measurable reduction in poverty and inequality. Empirical evidence shows that enhanced standards of living, education attainment and enterprise growth can only flourish when the gateways to innovation are opened to all in a society, without consideration of economic status, race, national origin or gender. Stanley, Glennie and Gabriel (2018) argue that inclusive innovation policies are most impactful when the benefits and risks of innovation are more equally shared, with the envisaged outcomes being sustainability, health and societal wellbeing.

Key challenges to implementation as well as effectiveness of innovation policies among disadvantaged groups are aspects such as: (i) low level of awareness; (ii) limited capabilities; and (iii) low skills levels to access established business and financial networks (Planes-Satorra & Paunov 2017). These tend to exacerbate an already dire situation for these groups to have the means or use opportunities to lift themselves out of poverty and deprivation.

Inclusive innovation policies have three broad objectives:

1. Industrial inclusiveness – specifically targets support for less innovative firms by strengthening their innovative capacities as well as building an adequate business environment for innovation. Hence, a specific focus for inclusive growth is the recommendation to prioritise small businesses as these provide most of the job opportunities for poor and marginalised people (Cafod 2014).
2. Territorial inclusiveness – target-lagging and less innovative regions to narrow performance gaps with leading innovation regions. Large companies' R&D centres in Israel's Periphery programme, South Korea's Technoparks, Mexico's special economic zones and China's Spark programme are examples of government policy instruments that are intended to address territorial inclusiveness (Planes-Satorra & Paunov 2017).
3. Social inclusiveness – seeks broader participation by including marginalised communities. This depends largely on the previous two types of inclusiveness. The uneven distribution of innovation capacities will have an impact on the social wellbeing of disadvantaged sectors of society (Planes-Satorra & Paunov 2017).

Another issue most countries have to deal with, especially in the developing South, pertains to the explicit roles of all the actors in a country's innovation ecosystem (Stanley et al. 2018). In the OECD countries specifically, the distinct roles of government and the private sector are clearly articulated to ensure alignment and impact. The universal consensus is that the private sector is responsible for job creation and innovation. Government on the other hand, through sound and practical policies, invests in the 'building blocks' of innovation, namely fundamental research, human capital and an enabling infrastructure (Pavone et al. 2015).

In the global North, which is also dominated by OECD member countries, innovation policies are premised on the belief that they have the potential to contribute to economic growth and improved wellbeing in these countries. These specifically focus on, among others, government funding for R&D, direct and indirect subsidies, tax credits and other deductibles of research expenses (Atkeson & Burnstein 2011). As indicated above, inclusive innovation policies are specifically seen as a conduit to enhance broader participation of previously disadvantaged groups (for example women, minorities, immigrants) in mainstream economic activity. A number of countries in the developed North have developed and implemented a suite of policy initiatives to this end. For example, key issues faced by entrepreneurs, especially in disadvantaged communities, are access to funds, information and networks to support their innovative capacities and competitiveness in the market.

A number of European countries, including Germany, Ireland, the Netherlands and the United Kingdom, have introduced Innovation Voucher Programmes to enhance participation of entrepreneurs from marginalised groups in the innovation ecosystems by connecting and partnering with universities and RTOs (see for example Planes-Satorra & Paunov 2017). These efforts have had a significant impact and led to a marked increase in the use of innovation services. In turn, this has enhanced the commercial offerings by previously marginalised entrepreneurs financed through using these vouchers. Another element critical to innovation is skills allocation. Hsieh, Hurst, Jones and Klenow (2013) have shown that up-skilling of formerly disadvantaged groups, such as African Americans in the United States (US), has led to an increase of up to 20% in aggregate output per employee over the past 50 years.

Switzerland provides a good example of the use of innovation to drive global competitiveness and development. According to the World Economic Forum (WEF) (2018b), Switzerland ranked amongst the top five countries in global competitiveness. The number of patents and registered trademarks and designs is a clear indication of the high level of innovation in Switzerland and so is the number of people employed in knowledge-intensive sectors. Furthermore, the country has a very high proportion of SMMEs bringing new products and processes to the global market. The Swiss innovation system is

based on a bottom-up approach that is supported by strong institutions which provide legal frameworks, infrastructure, funding, advisory services and networks for entrepreneurs.

Germany's innovation policy framework is underpinned by the country's High-Tech Strategy 2025 (HTS) (Federal Ministry of Education and Research 2018). The HTS is supported by the Pact for Research and Innovation and the Federal Government's Strategy for the Internationalisation of Education, Science and Research. This policy framework has created a fertile environment for new ideas and their implementation in marketable products and services, for more value creation and new employment potential.

South African inclusive innovation policy landscape

The innovation policies of the South African government are informed by the White Paper on Science and Technology (RSA, 1996), which was aimed at establishing key enabling mechanisms to inform the strategic development of science and technology in post-apartheid South Africa. Furthermore, the government approved the National Research and Development Strategy as the basis for the national system of innovation in 2002 (RSA 2002). This R&D strategy focuses on three key areas: (i) enhanced innovation; (ii) provision of science, engineering and technology human resources and economic transformation; and (iii) the creation of an effective government science and technology system.

A major topic of discussion amongst innovation actors in South Africa since the dawn of the democratic dispensation in 1994 is the negligible level of commercialisation of publicly funded research (the so-called 'innovation chasm') at most, if not all, universities and public research institutions in the country. This chasm reflects the extent to which the country is not commercialising its inventions (Hill 2005). This is, however, not unique to South Africa as this phenomenon is also observed in other countries and is described as the 'innovation paradox' (Tomes 2003). To address this innovation challenge through legislation, two Acts were introduced to the South African Parliament for ratification in 2008. The first Act was the Intellectual Property Rights from Publicly Financed Research and Development Act (Act 51 of 2008) (RSA 2008a). (Similar to the Bayh-Dole Act in the US.) The Act is aimed at providing a more effective utilisation of intellectual property derived from publicly financed R&D through commercialisation for the benefit of society. The second Act, the Technology Innovation Agency Act (Act 26 of 2008) (RSA 2008b) created the Technology Innovation Agency (TIA) which provides an institutional base to drive commercialisation of publicly funded research outputs.

According to US Government Accounting Office (1998), the Bayh-Dole Act is meant to serve two purposes: Firstly to enable universities, not-for-profit corporations, and small businesses to patent and commercialise their government-funded inventions and, secondly, to allow US government agencies to grant exclusive licences for their technology to provide more incentive to businesses. A number of countries, including South Africa, followed suit and passed pieces of legislation.

Over and above these critical pieces of legislation, there are other institutional structures and instruments established to accelerate and broaden the participation of historically disadvantaged people in the mainstream economy. Besides the TIA, there is the Small Enterprise Development Agency (SEDA), Industrial Development Corporation (IDC), and the Council for Scientific and Industrial Research (CSIR) to name but a few. These entities' core mandate is to spearhead innovation as well as small enterprise development (SED), the key drivers of economic growth and global competitiveness.

Other than the CSIR which does research, development and technology transfer, the other entities provide financial and non-financial support to enterprises. A critical success factor for these institutions is ensuring that their R&D and investment strategies are aligned with the country's economic

policy to create seamless integration of new products and services into existing or new value chains and markets. This unfortunately is not always the case. This misalignment has led to diminished returns on investment and a lack of sustainability of new enterprises. Further, there is need for policy makers to appreciate the centrality of innovation as a key lever for economic development and ensuring that government takes a holistic and integrated approach in the formulation of innovation policy.

To address the issue of industrial exclusion and low exports, especially in less developed provinces of the country, the South African government introduced Industrial Development Zones (IDZs) in 2003, which were later replaced by Sector Development Zones (SEZs) through the SEZ Act 16 of 2014 (the DTI 2012). Coega is the largest IDZ in South Africa with a focus on agro-processing, automotive, aquaculture, energy, metals logistics and business process services sectors. This IDZ has advanced socio-economic development in the Eastern Cape region through skills development, technology transfer and job creation. The SEZs were intended to address some of the shortcomings of the IDZs in recognising that industrial inclusion requires more than investment in infrastructure, and should include development of human capital; research, development and innovation; environmental management; business incubation; and logistics support.

In spite of the plethora of legislation, policies and instruments, there is still a disjuncture in their implementation and execution. Phaho and Mazwai (2011) highlight poor policy coordination in the delivery of support services across the respective government departments and agencies as the primary reason for the sub-optimal functioning of the instruments with respect to their stated objectives.

Proposals to enhance the performance of policy instruments include a more integrated architecture of support. Phaho and Mazwai (2011) proposed an Integrated Institutional Framework to address these challenges with the end goal being to ensure effectiveness and eliminate duplication among government-funded instruments and initiatives to optimise the deployment of limited resources. For example, a part of IDC business development funding support can be allocated to enhance innovation of the supported firms (to improve their products, processes and/or services), thereby enhancing their competitiveness and sustainability. Science Councils such as the CSIR can then act as innovation partners through short- to long-term contract research with the cost covered by the IDC grant portion suggested above.

Envisaged impact of the fourth industrial revolution on economic growth

The fourth industrial revolution refers to the fusion of technologies in the physical, digital and biological domains leading to the creation of new technologies that will usher in a new industrial era characterised by exponential growth, interconnectedness, increased human productivity and the blurring of the lines between man and machine. Underpinned by the metaphor 'Data is the New Oil', the fourth industrial revolution is being promoted by policy makers as the lynchpin for a more inclusive, innovative and resilient society (WEF 2018a).

A myriad of technologies underscores the fourth industrial revolution, including, but not restricted to, artificial intelligence (AI) and machine learning, connected devices and smart cities, precision medicines, the Internet of things (IOT), big data analytics and autonomous vehicles. Coupled with the challenges of moving billions of people out of poverty, especially in developing economies, through the creation of decent paying jobs and better living conditions, rapid technology as expressed by the advent of the fourth industrial revolution can be seen either as a serious threat or an opportunity to the attainment of these goals within the specified timeframes.

On the economic front, especially for emerging economies such as South Africa with high levels of unemployment and inequality, there is a rational fear that the fourth industrial revolution might exacerbate an already dire situation, with automation and AI having the potential to cause job losses. It is estimated that the advent of the fourth industrial revolution will displace more than 39% of the current skills in South Africa (Samans & Saadia 2017). Specifically, the prospects of automation in the crucial but already declining manufacturing and mining sector in South Africa is top of mind for policy makers and organised labour.

At the same time, technological advancements brought about by the fourth industrial revolution have the potential to accelerate, closing the gap between the top and bottom of the socioeconomic pyramid. Thus, as the world embraces technological advances brought about by innovation, there is a need to ensure that these are supported by appropriate policies to address issues of education and skills, security, transformation, inclusive growth and sustainability.

The WEF (2018a) envisages that the fourth industrial revolution could also pose other significant societal challenges in equal measure; for example, limiting access to information, especially in less democratic societies, or justifying discrimination as well as access to job opportunities or even influencing political election outcomes. Other undesirable outcomes of the fourth industrial revolution include data security breaches leading to identity theft and fraud.

Clearly, the fourth industrial revolution is changing how people live, work, and communicate. It is reshaping government, education, healthcare and commerce – almost every aspect of life. The fourth industrial revolution will also have a profound impact on education and access to information, which, if utilised correctly, can improve the lives of many people. Through increasingly powerful computing devices and networks, digital services and mobile devices, easy access to education and information is becoming a reality for many people around the world, including those in developing countries (WEF 2018a).

On the negative side, workers with less education and fewer skills are at a disadvantage as the fourth industrial revolution progresses. Businesses and governments need to adapt to the changing nature of work by focusing on training people for the jobs of tomorrow. Talent development, lifelong learning and career reinvention are going to be critical to the future workforce. The positive side of this is that people can spend more time on creative, collaborative and complex problem-solving tasks that machine automation is not well suited to handle (WEF 2018a).

If one adopts the management school approach to country competitiveness (Smit 2010), it follows that the fourth industrial revolution will also impact global competitiveness (Liu 2017). The WEF (2018a) describes competitiveness as the set of institutions, policies and factors that determine the level of productivity of a country. The level of productivity, in turn, sets the level of prosperity and rates of return obtained from investments in the economy, which are the fundamental drivers of its growth rates. A more competitive economy is one that is likely to grow faster over time. Figure 3.1 depicts the virtuous circle that shows the interrelationship between economic growth, competitiveness and innovation in the era of the fourth industrial revolution.

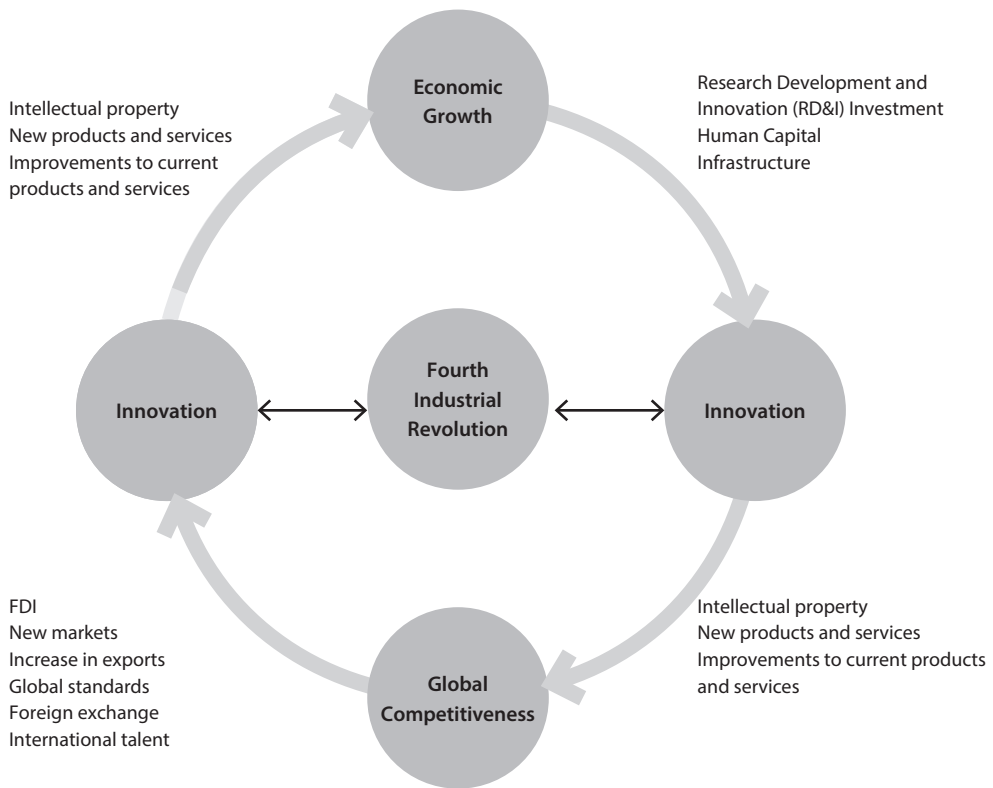


FIGURE 3.1: *Interrelationship between economic growth, competitiveness and innovation in the era of the fourth industrial revolution*

Source: authors

Achieving significant levels of economic growth and global competitiveness in South Africa will therefore require significant improvements in innovation, as described above. The South African gross domestic product (GDP) grew by 2.2% during the 3rd quarter of 2018, driven primarily by growth in manufacturing (StatsSA 2018). How does South Africa achieve the objective of sustainable, inclusive and competitive economic growth? The answer lies in the innovation policies that are adopted and effectively implemented to drive economic growth.

An assessment of country-level competitiveness theories could provide useful insights for South Africa to position itself for sustainable, inclusive and competitive economic growth in the era of the fourth industrial revolution. We used the double diamond model for economic competitiveness by Rugman and D’Cruz (1993), which is an adaptation of Porter’s diamond model, to perform the analysis for South Africa’s competitiveness. The focus of the analysis is on the impact of innovation as a key driver for economic growth. Figure 3.2 presents the double diamond model mentioned above.

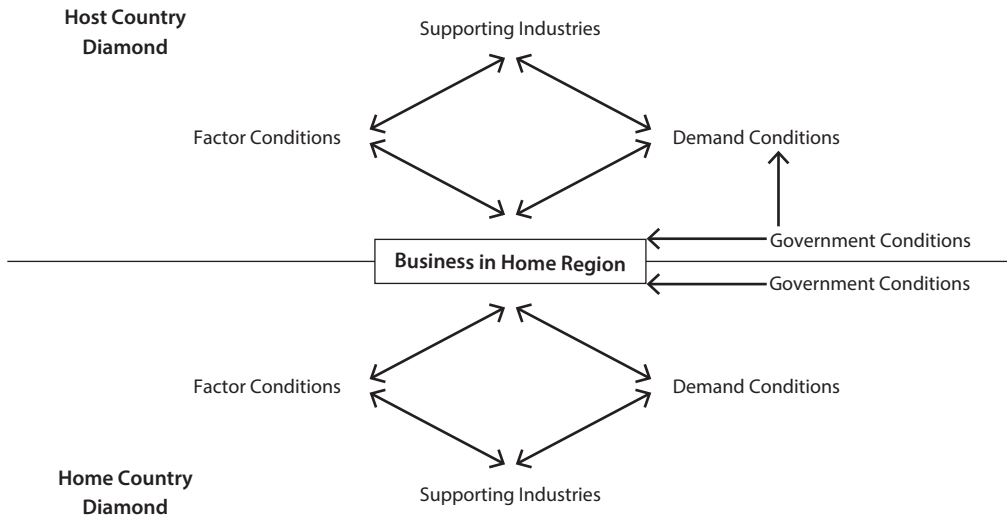


FIGURE 3.2: *The double diamond model for global competitiveness*

Source: Rugman & D’Cruz (1993)

The model presents four dimensions that underpin global competitiveness, as described below, with recommendations for South Africa to achieve inclusive and sustainable economic growth.

1. Factor conditions

Factor conditions include natural resources, human capital and infrastructure. South Africa has one of the most valuable mineral reserves in the world. South Africa’s mineral wealth is estimated at USD 2.5 trillion, with the world’s largest reserves of manganese and platinum. This is a source of competitive advantage for South Africa provided the economic development policies support (a) the transition from the trap of low-wage, labour-intensive jobs to high-end, knowledge-based jobs, (b) local mineral beneficiation and, (c) geographically distributed and sustainable socioeconomic development. Policies and investment in the development of skilled human capital and infrastructure need to align with the socioeconomic development trajectory of the country. The key is to invest in digital skills as well as concerted efforts to support and invest in the ICT sector to create much needed employment and enhance productivity.

2. Business context

This relates to the conditions that govern how enterprises are created, organised and managed. South Africa has a well organised business environment, with the private sector contributing 32% to the country’s tax revenue (South African Revenue Service [SARS] 2018). The country has mature regulations, codes and practices on corporate governance and processes for the registration of enterprises. The South African informal business sector, however, needs to be better organised and supported. This sector employs 15% of the South African employed population (Fourie 2018). For South Africa to remain competitive and achieve inclusiveness in the age of the fourth industrial revolution, the technologies brought about by this revolution must benefit all sectors in the economy.

3. Related industries

The presence and sophistication of industries in the supply chain is also an important contributor to competitiveness. In the case of manufacturing, South Africa has unique opportunities to strengthen

supply chain enterprises through innovation and supportive policies which can effectively address issues of industrial and territorial exclusion. These opportunities include the value addition of strategic and abundant minerals such as titanium, fluorspar and platinum group metals, which are key inputs in modern manufacturing. The local beneficiation of these minerals through innovation as well as usage of the resultant higher value products in the manufacturing industry would go a long way in addressing the country's unsustainably high current account deficit made worse by the trend to import finished manufacturing components from other countries.

4. Demand conditions

This relates to the nature of the demand for goods and services and the sophistication of the buyer. South Africa being a small country will inherently have a weaker local demand for goods and services in general. This is compounded by the high levels of unemployment and social disparities. Hence, there is a need to build and develop a strong export market of high-value products from South African enterprises in order to drive competitiveness and economic growth.

To be an effective player in the new dawn promised by the fourth industrial revolution, South Africa should:

- Invest in human capital with a specific focus on mathematics and Information technology (IT) skills, such as coding, drawing, designing and other cognitive skills essential for the digital age. This will have to become mandatory in South African schools. Furthermore, vocational training, including entrepreneurship, must be made attractive to poorer communities because of their lower costs relative to tertiary education. This has the potential to move a high number of young South Africans into meaningful and well paid jobs, which are less likely to be threatened by the fourth industrial revolution.
- Institute a business- and investor-friendly legislative framework to encourage and attract much needed foreign direct investment into the country. This has been illustrated in a number of Asian countries where trade and investment have played a critical role in the rapid economic growth and competitiveness in the region.
- Enhance government policy coordination to ensure strong alignment between the country's STI policies and the economic development agenda. Government departments and affiliated institutions need to focus and deliver on their respective mandates to avoid duplication. For example, the Department of Trade and Industry (the DTI) and its entities should deliver relevant business support services, while technological innovation programmes should be the preserve of the Department of Science and Innovation (DSI)¹ and its entities.
- Institute prudent public policies to facilitate innovation, entrepreneurship and infrastructure development. Inward investments as well as collaboration between governments, academic institutions and the private sector can enhance technology adoption and diffusion, which in turn can spur economic growth and competitiveness. These collaborations will also address mechanisms to manage potential risks occasioned by the advances in the fourth industrial revolution such as data-security breaches.
- Provide equitable and broad-based provision of basic services, such as health and other social services. Access to key services can only enhance participation in the broader economy of the country, which is critical to inclusive and equitable growth.
- Build appropriate and cost-effective infrastructure to address the cost and ease of accessibility to key inputs essential for doing business in the digital age, for example, a national fibre optic infrastructure to enhance access to broadband as well as high-speed supercomputing facilities for big data, amongst others. However, for these to be effective and have the desired impact, a number of issues have to be addressed. The South African government needs to:

¹ Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

- Establish mechanisms to enhance active participation of disadvantaged groups to foster social mobility and inclusion.
- Enable easier access to relevant skills development opportunities to deserving youth to enhance their participation in the more productive activities of the economy.
- Actively promote innovation and other policy instruments to ensure awareness and participation to benefit all sectors of society. Consultation is critical. It is highly unlikely, notwithstanding the sophistication of the South African Innovation Institutional Framework, that the broader South African public is well informed on government innovation policies, as these are erroneously viewed as the preserve of policy makers, scientists and academics. Hence there is an urgent need for better communication and more robust and broader consultation with key stakeholders.

It is our belief that a focus on the above elements would enhance inclusive and sustainable economic growth underpinned by industrial competitiveness (Vellala, Madala & Chattopadhyay 2014). Enabling more people across the population to gain adequate access to quality education and basic services, for example, health and social services, will increase their opportunities to find gainful employment to enhance their living standards. This must be supported by prudent government policies as well as a business-friendly environment. This will spur economic growth which should be equitably shared by the broader population, leading to a marked reduction in poverty and inequality.

Conclusion

The DSI in South Africa, as the custodian of the national innovation agenda, must give expression to inclusive social development by emphasising the role its technology and innovation policies can play in addressing the triple challenges of poverty, unemployment and inequality. Well-constructed innovation policies can go a long way to addressing key development goals such as unemployment, as well as lifting people out of poverty.

Although South Africa is committed to supporting innovation in the private sector, a case can be made for the existing instruments to be deployed more effectively. To that end, inclusive innovation policies cannot be viewed in isolation. It is imperative that complementary policies that can accelerate social inclusion are also optimised and made fit for purpose. For example, education policies must address the skills imperative of the new digital age. Furthermore, concerted efforts for previously disadvantaged sectors of the population to have access to quality education and training are critical, especially for people at the bottom of the socioeconomic ‘pyramid’.

In summary, the overarching objectives of a nation’s inclusive innovation agenda should include:

1. Enhancing access to innovation support instruments, especially amongst marginalised communities.
2. Orienting innovation activities to also address societal needs.
3. Quality and relevant education to enhance participation and absorptive capacity amongst marginalised or disadvantaged communities.
4. Enhancing awareness of existing innovation policies and instruments among all sectors of the community (including those at the bottom of the economic pyramid) to facilitate broader participation.

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CHAPTER 4

Science and Technology Policies and Directions for Solving Socioeconomic Problems in Korea

Sea-hong Oh

Korea has achieved the fastest growth in the world but is rapidly becoming an ageing society. Korean society is facing serious challenges: the middle class is shrinking, and issues of employment insecurity, polarisation and income inequality are worsening. Korea has learned two lessons from its accelerated growth. The first point is that science, technology and innovation (STI) and education have been an important foundation for economic growth. The second point is that past a certain point, economic growth reaches its limit, due to societal issues such as inequality and polarisation.

National research and development programmes for solving societal issues

The Korean government is paying attention to resolving societal issues and has taken an active role in identifying a policy agenda and shifting the paradigm of innovation and development policy. Specifically, the Korean government has started to drive the paradigm shift to 'inclusive innovation'. The focus is on utilisation of research outcomes to benefit society and to promote national research and development (R&D) programmes that aim to address the challenges society faces.

The Korean government initiated special national R&D programmes for addressing societal issues in 2013. They adopted the following four approaches:

1. Identifying issues by considering the needs and concerns of citizens (including women, youth and the socially disadvantaged).
2. Adopting interdisciplinary approaches to address the issues at hand, incorporating different technologies or social sciences.
3. Promoting improvement of infrastructure, fostering human resources and regulatory reform to maximise capacity.
4. Providing support to facilitate translation from research to market and better-linked researchers and end-users. This is an approach to expand support from R&D to Research and sustainable development (R&SD), and from supplier-oriented R&D to consumer-participatory R&D.

In 2014 and 2015, a total of 15 R&D programmes were carried out. The Korean government is looking to expand them in the future by assessing their outcomes. The total budget was USD 72.2 million in 2016, and the programmes were conducted with the participation of 17 ministries (Ministry of Science & ICT, 2016). These programmes were driven by social needs rather than technological advancements. The essence of these R&D programmes was the identification of societal issues through consensus and

active participation of members of society. Here, an appropriate R&D management system was necessary to support the new paradigm. Changing perceptions is not an easy task when it comes to practical management, and changing the way programmes are run and regulated is a continued challenge.

However, the initiative was led by the central government and researchers, who are suppliers that focus more on technology development than addressing issues in a comprehensive way. In addition, societal issues were not immediately addressed due to poor coordination/cooperation at the ministry level; many critics pointed out that it was not enough for the people to feel the benefit. This was how the *2nd S&T-based Comprehensive Plans for Solving the Issues found in People's Living (Society) 2018–2022* was devised after being revised and supplemented to move beyond technology transfer and commercialisation, making it mandatory to provide actual proof that it resolves issues (Presidential Advisory Council on Science and Technology 2018). The comprehensive plan expanded the number of issues from 30 to 40, based on the urgency and seriousness raised by citizens, related departments and local governments. The comprehensive plan mainly focuses on promoting a 'Living Lab', which involves local residents, civic/environmental groups, and experts in the problem-solving processes to ensure consumer-oriented societal problem-solving.

The direction of science and technology innovation within the policy framework of inclusive growth

On 24 July 2018, President Moon Jae-in defined the concept of the new economic policy framework of 'inclusive growth' as 'growth which widely distributes its outcomes to many people sharing the benefits' and said, 'income-led growth, innovation growth, fair economy, etc. are being implemented as specific measures for the realisation of the larger concept of inclusive growth' (The Kyunghyang, 24 July 2018). Recently, the Korean government has made various efforts to revitalise the economy through innovation growth via regulatory reform, amongst others. Policies such as deregulation (for example, comprehensive negative and regulatory sandbox allowing the test of new industry), technological development and infrastructure expansion are taking shape to facilitate corporate investment and support job creation.

In order for inclusive growth to be established as an overarching concept in economic policy, it needs to be reviewed on the continuum of technological innovation and sustainable growth. In particular, it is necessary to apply the concept of 'inclusive growth' to the areas of STI and R&D activities to provide support for securing innovative competitiveness and to examine the possibility of a conceptual expansion of the existing STI policies and national R&D projects. In addition, the significance of inclusive growth in the process of planning STI and R&D policies needs to be reviewed.

Technological innovation in the policy framework of inclusive growth presupposes a development model which encompasses the entire realm of society, culture and the environment. In other words, the key questions are to what extent the social contribution of science and technology can be expanded, and how effectively social and economic issues can be resolved. In principle, this depends on reducing the 'gap' in general areas ranging from problem investigation to inputs of innovation resources for R&D, the alignment between the R&D process and the creation of research performance and feedback of results and pursuing breakthroughs in innovation activities through 'cooperation & collaboration' rather than 'separate operation'.

To summarise these policy changes, the science and technology (S&T) policies of the new Moon Jae-in government are moving toward inclusive growth based on STI. The policies aim to solve the various gaps in S&T that are changing the innovation ecosystem. At the same time, we are constantly creat-

ing technological innovations that deal directly with various social issues. In summary, the key to the 'Inclusive Growth Policy' based on Korea's technological innovation in the future depends on how to determine the social problem itself and how to solve it pragmatically.

In this context, we examine directions of STI in socioeconomic problem-solving.

Locus and focus of inclusive growth and science and technology innovation policy

So far, we have thought of the concept of inclusive growth as developing appropriate technologies that are suitable for resolving social problems or problems of a certain region. However, while technological development changes a local society, economy and industry, social needs change technology as well. Digital innovation (such as smartphones), changes in the means of transportation and artificial intelligence (AI) have completely changed our lifestyles. Our continued low growth, ageing population and low birth rate, brain drain, disasters and safety problems cause changes, not only in the problem-solving capabilities of science and technology but also in the recognition of problems, approach methods (preparation of preventive methods) and our way of working (convergence research, collaboration).

Therefore, to approach this in the context of the social contribution of STI, the locus of the STI policy related to inclusive growth should be expanded to 'industrial inclusiveness' (business/sector), 'territorial inclusiveness' (place/region) and 'social inclusiveness' (people) (Paunov 2017). Here, there are various types of gaps, including the size and ratio of investment in each industry/region, brain drain, and the capability of commercialisation. The focus should be on how the 'gaps' influence innovation growth and distribution of growth.

The unique characteristics of the production system of a nation play a central role in forming inclusive growth of STI (Paunov 2017). The application methods and content of 'inclusive growth' in STI will inevitably differ between developing countries and advanced countries. While developing countries focus on appropriate technologies by using and improving knowledge, for example through existing knowledge and patents, advanced countries tend to focus on digital conversion using information and communication technology (ICT) in the era of the fourth industrial revolution and deal with inclusive growth in a secondary dimension. The distribution of the capabilities and opportunity to participate in innovation activities in the area of industrial inclusiveness and territorial inclusiveness are the most important factors in the determination of the characteristic of inclusive growth. Industrial inclusiveness and territorial inclusiveness are closely related to social inclusiveness. Various disadvantages, such as lack of access to technology and low income, may result in insufficient capacity to carry out innovative activities.

As stated earlier, STI is a very important impetus for inclusive growth. The focus of STI has shifted to improvements in quality of life, the demand for continuous economic growth, the increased use of technologically innovative products and services, and solutions to various social problems. In principle, it means applying STI to continuously secure future growth engines, solve various social problems caused by technology gaps, and create good jobs. Specifically, while the Technology Development Project for Solution of Social Problems of the Ministry of Science & ICT is a good policy for inclusive growth, it is necessary to concentrate on other policies that can enhance the innovation capabilities of small and medium-sized enterprises (SMEs). This is because they tend to be innovative companies that can change quickly; policies to encourage talented people to knock on the doors of SMEs and policies to strengthen the digital connection between government-funded companies and SMEs if

the focus is put on STI gaps. If job creation is the flower, we will only see it bloom if strong stems are grown by giving nutrients to the root of the plant and removing pollutants (an excessive regulatory environment). In general, it is necessary to reinterpret the locus and focus of ‘inclusive growth’ and initiate a paradigm shift accordingly.

The narrowing of the science and technology gap and the implementation of inclusive growth

If the gap is reduced properly, based on S&T, innovation growth can be accelerated and, as a result, inclusive growth can function as the fuel for the engine. In principle, the effect of the reduction of gaps based on S&T could be considerable if attention is paid to the value of cooperation and collaboration among the principal agents of innovation (industry, academy, and research institutes) rather than attempting to impose some form of ‘distributive justice’. Those are the directions and strategic tasks that need to be included in the policy frameworks of inclusive growth. Ideally, innovation growth and general social innovation can be accelerated and growth engines for the activation of the economy can be created by pulling the policy lever based on S&T innovation.

Rather than seeking the unconditional removal of gaps in the area of STI, the question of whether the causal loops connected with gaps are included in the performance indicators that can be replaced by the acceleration of innovation should be examined carefully. In fact, the success or failure of innovation usually depends on implementation capacity rather than the removal of the gap itself. Here, the point is that focusing too much on innovation input and expecting that the input will be directly connected with output will not only cause a vicious cycle but also generate side effects. If cooperation in each area of technology and the factors related with inclusive growth, such as consideration and respect, operate in the process of converting inputs to outputs, various delays and obstacles could be resolved, accelerating the effect of innovation in a virtuous cycle.

TABLE 4.1: *Characteristics of ‘existing research on technology development’ versus ‘research focusing on solutions to social problems’*

| <i>Existing research on technology development</i> | <i>Research focusing on solutions to social problems</i> |
|--|---|
| <ul style="list-style-type: none"> • Solving the problem of technology itself | <ul style="list-style-type: none"> • Research for groups that do not benefit from technology (marginal class, alienated region, etc.) |
| <ul style="list-style-type: none"> • Innovation for pursuit of profits by business enterprise | <ul style="list-style-type: none"> • Business enterprise is not the principal agent • If assistance is provided by engineers with good will and spare time: proper technology • In case of support by the state: R&SD (S=solution) for solution of social problems |

Source: Hong Seong-wook (2017)

Different problems and diagnoses need different prescriptions. The existing research on technology development and the research that focuses on solutions to social problems run contrary to each other (see Table 4.1). Furthermore, different approaches will be used in the research, focusing on solutions to social problems depending on how social problems are defined. It is difficult to establish a method of business operation that is appropriate for problem-solving. For example, business operations focusing on technology development for analysing/capturing micro-dust aimed to address the problem of micro-dust, or one focusing on reduction efforts and the engagement of interested parties to reduce the generation of micro-dust in the first place, are not easy to implement as they require changes in consciousness.

Effective implementation strategies and challenges

The pattern of occurrence and details of social problems will become increasingly diverse and complex. Above all, innovative inclusive growth will have to be implemented by significantly expanding policy support for inclusive growth, converting problem-solving capacity into future growth engines and maximising the resulting benefits (job creation, for instance). STI may cause some social problems while it may solve others. The benefits of the solution may be concentrated in a certain group. Secondly, the science and technology world needs to ensure that the benefits are returned to society by re-creation of jobs, for example. Thirdly, while the new opportunities and solutions in ICT and other new technologies may generate a digital gap, their benefit also lies in the fact that they can solve various social problems. There are, thus, various benefits that can be generated by inclusive growth based on STI. Therefore, it is time to create new types of social benefits by combining existing technology development with digital technology.

It is not unusual to try to combine innovation in an era of low growth with the concepts of sustainable growth and inclusive growth. Conflicts over distribution come ahead of optimism about growth in an era of low growth and these cannot be overcome by the development of a certain industry through simple technology innovation. A model of inclusive growth based on STI should be prepared that encompasses the entire realm of society, culture and the environment. In particular, its realisation requires a social consensus on technology innovation and the allocation of its benefits together with legal/institutional support which work in harmony. This means that it is necessary to encourage entrepreneurship that can break through the barrier of low growth in the model of inclusive growth.

Finally, to resolve societal issues, active policy efforts by the public sector are crucial, as is private sector participation. Solutions for societal issues will not come solely from advancements in S&T and they must be accompanied by social and regulatory reforms.

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Towards a Coherent and Inclusive NSI: Building Network Alignment through Strengthening Dynamic Interactive Capabilities

Il-haam Petersen and Glenda Kruss

Introduction

National innovation systems are made up of multiple overlapping subsystems and networks of actors with different purposes operating at different levels: national, sectoral, regional and local (Von Tunzelmann et al. 2010). Alignment of goals and capabilities within and between these subsystems and networks is crucial for innovation policy coordination at the macro level. Interaction and alignment are even more critical in the current context of rapid change and uncertainty. Unfortunately, interaction and collaboration do not occur automatically, even when intentionally promoted through specific policy mechanisms, as has become the norm. Individual actors and organisations must have the will and capabilities to form effective linkages and to learn through interaction. They require 'interactive capabilities' (Von Tunzelmann & Wang 2003, 2007).

This chapter focuses on a dimension that has been relatively neglected in the policy space thus far: how can coordination, interaction and collaboration between different types of actors and components be strengthened in systems of innovation at the regional, sectoral and local levels, in addition to the national level? Drawing on over five years of empirical research conducted at the Human Sciences Research Council (HSRC), we focus on a specific set of actors, subsystems and processes: knowledge producers in higher education and research institutes that play a key role in transferring and co-producing knowledge with users in the private sector, government and civil society (and other knowledge producers).

We cannot assume that knowledge produced by higher education and research institutes is useful and relevant to the needs of users in firms, government or civil society. Furthermore, users may not have the necessary capabilities to use or apply the knowledge to address their development needs. We also cannot assume that the main goals of actors in the higher education and research and other key subsystems are aligned with national development goals in any way. An assessment of alignment in goals and capabilities, within and across subsystems, at different levels, is thus necessary for strengthening coordination and inclusion in the National System of Innovation (NSI).

Seeking direction from the literature on dynamic capabilities, the chapter begins with a conceptual exploration of how dynamic interactive capabilities support network alignment and functioning in innovation ecosystems in contexts of uncertainty and rapid change. Dynamic capabilities refer to those capabilities that are needed to sense and adapt to changing opportunities, and reconfigure the organisation in response (Teece et al. 1997; Teece 2007; Von Tunzelmann et al. 2010). The chapter then draws on the conceptual insights from this body of work and uses specific empirical cases of innova-

tion networks in the South African context, to illustrate how dynamic interactive capabilities are key to addressing challenges of policy coherence and coordination.

Network alignment and dynamic interactive capabilities

Why is network alignment significant for policy implementation?

For an innovation systems approach, at the heart of explanations of growth and inclusive development is a focus on the alignment between knowledge, skills and capabilities for learning in firms and in the education and training organisations. Emphasis is thus on aligning capabilities for producing and using knowledge, technology and innovation. Grounded in evolutionary economics, the approach traces change over time but also captures path dependence, that is, how previous historical trajectories and conditions shape what is possible within an organisation and system. It provides tools for mapping the main actors and linkages in key networks, and for analysing the flows of knowledge and resources and the capabilities for learning and innovation.

The interactive capability and network alignment framework of Von Tunzelmann (2010a, 2010b) provides useful concepts for policy makers, based on the premise that innovation is an interactive or 'networked' activity shaped by the institutions in which the actors are embedded. Networks here refer to 'any mode of governance that is neither a pure market nor a pure hierarchy' (Von Tunzelmann et al. 2010: 92), which requires the integration of multiple overlapping systems with different purposes and operating at different levels. The key tasks for policy makers are to promote alignment between networks and systems and to overcome the potential coordination failures of networks in order to achieve common developmental goals. The networks of actors include interaction between firm and other non-firm organisations and individuals connected through market and non-market relations.

Network failures typically result where the network itself does not exist, the network is not oriented to development goals or the outcomes of the network are misaligned. An example of the first type of failure is where firms and universities do not share knowledge and technology through partnerships in the national system of innovation, which is evidence of a lack of interactivity in the system. The second type of failure occurs where the system has a degree of interactivity but actors are oriented to different priorities and the system lacks dynamic properties. The third type of network failure is evident where there is a degree of interactivity and of dynamism but a lack of alignment. The role of the policy maker is to work to promote network alignment and avoid such network failures which, in turn, requires dynamic capabilities from all actors in the system.

What are dynamic interactive capabilities and how do they support network alignment?

Specific sets of capabilities are required to promote network alignment. Von Tunzelmann has developed an analytical framework (Von Tunzelmann & Wang 2003; 2007) that differs from the models typical in the management literature in that it applies a model of capabilities informed by Sen's work (Sen 1999) and a model of networking to the innovation policy-making field (Von Tunzelmann et al. 2010).

Competencies stem from the pre-set attributes of individuals and organisations, typically produced by education and training organisations (Von Tunzelmann & Wang 2003). An actor's organisational processes or routines are shaped by its competencies, and both its competencies and routines, as well as the strategic alternatives available to it, are path dependent (Teece, Pisano & Shuen 1997). Competencies include cognitive aspects such as beliefs and attitudes which influence learning. For instance, the recruitment of university graduates or artisans may be a necessary internal competence

for firms that want to adopt new technologies. However, merely employing those graduates or qualified artisans does not guarantee learning or the successful adoption of new technologies.

This requires 'interactive capabilities' – defined here as the capacity for learning and accumulation of new knowledge on the part of the organisation – and the integration of behavioural, social and economic factors into a specific set of outcomes (Von Tunzelmann & Wang 2003; 2007). Interactive capabilities are the result of adaptive learning processes that in their collective dimension can be highly localised, giving rise to system capabilities. This means that within a specific region or locale, a concentration of highly qualified human resources is not a capability per se, but a resource that, through learning, may become technological capabilities for firms or academic capabilities for education and training organisations or innovation capabilities for the system as a whole. All variables related to competences such as human resources or strategies such as cooperative linkages with external actors are to be considered as determinants of an organisation's interactive capabilities.

In the context of dynamic change – in conditions of dynamic competition and institutional change in the business, education and policy environments – actors require an additional set of capabilities, that is, the capability to effectively and efficiently respond to non-routine changes in circumstances (Von Tunzelmann et al. 2010). Changes in circumstance often result in changes in the organisations' capabilities.

A literature that bridges resource-based and strategic management perspectives of the firm has emerged to elaborate models and identify these sets of 'dynamic capabilities', which at their core emphasises: 'the key role of strategic management in appropriately adapting, integrating, and reconfiguring internal and external organisational skills, resources, and functional competences to match the requirements of a changing environment' (Teece et al. 1997: 515).

Teece's (2007) conceptual work has been core to this literature, arguing that in the current conditions of dynamic change, sustainable advantages for firms require not only knowledge assets but also dynamic capabilities to sense change, seize opportunities and reconfigure assets and organisational structures in response to new and changing opportunities. In a wide-ranging review of this literature, Wang and Ahmed (2007) designed conceptual distinctions to inform a measurement and research agenda that can be used to inform strategic management of firms. (See also the attempt to design a prescriptive theory of dynamic capabilities by Pisano 2016.) Navarro and Gallardo (2003) applied these concepts and models to inform strategic management of universities, as did Teece (2018). (See also Kruss et al. 2016; Kruss & Petersen 2016, for similar analysis in the South African context.) Von Tunzelmann et al. (2010) extended the notion of dynamic capabilities to analyse the interactive and dynamic capabilities required for policy-making at the sub-national level to align the goals of all actors across macro, meso and micro levels towards addressing common developmental goals.

Drawing on Von Tunzelmann et al. (2010) and Von Tunzelmann and Wang (2007), our focus is on 'dynamic interactive capabilities', to distinguish the interactive capabilities necessary for routine activities and the interactive capabilities requiring greater flexibility to respond to environmental turbulence and non-routine changes in circumstances. The focus is on assessing capabilities at the organisational level in order to strengthen coordination at the systemic level. We thus analyse dynamic capabilities as drivers of effective interaction in conditions of dynamic change (Von Tunzelmann, 2010a).

Although useful as a concept, dynamic capabilities is difficult to operationalise such that it has been viewed by some as an 'elusive "black box"' (Pavlou & El Sawy 2011: 240; see also Pisano & Figgie 2016). As a starting point, we work with four dynamic capabilities identified by Pavlou and El Sawy (2011) – sensing, learning, integrating and coordinating – as a set of useful dimensions. These are similar to Teece's distinction of the capacity to 'sense, filter, shape and calibrate opportunities' (Teece, 2007: 1342). Figure 5.1 below provides a more detailed description of the four types of capabilities.

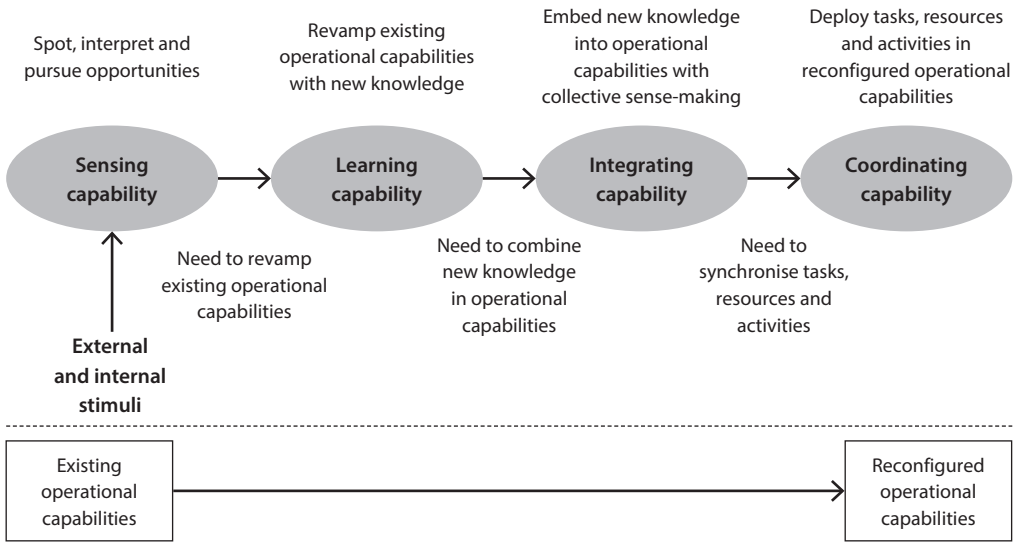


FIGURE 5.1: A framework for presenting a measurable model of dynamic capabilities

Source: Pavlou and El Sawy (2011: 243)

We use Von Tunzelmann’s interactive capabilities framework (Von Tunzelmann & Wang 2003) to identify specific organisational attributes for each dimension. The interactive capabilities framework distinguishes between competences and capabilities, and the importance of internal and external interface structures. External interface structures refer to the different mechanisms and strategies organisations use to interact and partner with other organisations, whereas internal interface structures refer to the mechanisms and strategies they use for learning and accumulating knowledge gained through their interactions – essentially, how they use the knowledge to inform their functions (see Kruss et al. 2012). Organisations build and refine their competencies through their internal and external interface structures. In this way, an organisation builds its interactive capabilities. To ensure that they are keeping up with dynamic change, their interface mechanisms need to be appropriate and effective for sensing change in the environment (market intelligence), learning by using the market intelligence to create knowledge, coordinating knowledge across the unit or organisation through allocating tasks and resources, and integrating the knowledge gained into the unit or organisation’s activities (Pavlou & El Sawy 2011).

An organisation’s ability to effectively and efficiently respond to changes in the business, education and institutional environments hinges on the coordination capability of its management and leadership. Management needs to identify or sense changes in the environment that may present opportunities, threats or constraints to the organisation, and identify the organisation’s competencies and capabilities to respond. An appropriate response often involves the acquisition of new knowledge and competencies which transform and are transformed through learning. The new knowledge and competencies then need to be integrated into existing organisational structures and routines.

The strategic management literature commonly refers to the crucial role of managerial or leadership skills without clear definitions. The concept of ‘social skill’ identified by Fligstein (2001) and Fligstein and McAdam (2012) is apt for this purpose. Essentially, social skill refers to the ‘ability to induce co-operation’ among actors in an organisation or any other field (Fligstein & McAdam 2012: 46). With the

notion of social skill, we understand that those in managerial and leadership positions (for example, unit managers or principal investigators of projects) have to possess effective skills for sensing changes in the external environment and being aware of the organisation's competencies. They should be able to sense which external changes are relevant and appropriate for the organisation to take on board and devise effective strategies for coordinating and integrating new knowledge into the organisation. These strategies may include the identification of appropriate actors with which to collaborate in order to best address those changes and improve the performance of the organisation. This process of coordination and integration involves the identification of matches and mismatches in competences and capabilities and finding effective ways of getting individuals and groups of individuals within the organisation on board for changes. Skilled strategic actors possess a repertoire of social skills (for example, agenda-setting or presenting themselves as a neutral actor) which they use as appropriate.

The importance of feedback between actors in interaction and the co-evolution between actors and the wider institutional contexts in which they are embedded is critical as is the relative compatibility of the capabilities of actors in the subsystems representing the 'pool' or 'networks' from which actors can source essential knowledge and other resources. Hence, the critical role of alignment in capabilities and goals between networks of actors in the subsystems that make up an innovation system.

The remainder of the chapter uses the framework presented in Figure 5.1 to analyse network alignment and dynamic capabilities in South African systems of innovation.

Network alignment in South Africa

In South Africa, a policy shift is underway, based on a vision of 'Science, technology and innovation enabling inclusive and sustainable South African development in a changing world' (Department of Science and Innovation [DSI]¹ 2019: 11). A new White Paper (DSI 2019) foregrounds new mechanisms for enhancing the coherence, coordination and linkages across and within the national system of innovation. Government adopted the concept of a national system of innovation as the core of the Science, Technology and Innovation (STI) policy over twenty years ago (White Paper 1996) and has created many new structures and organisations. Recent reviews suggest that challenges remain in the performance of the system, evident, amongst others, in a lack of policy coherence and coordination, insufficient involvement of business and society, and an environment that does not sufficiently enable innovation (DSI 2019). The new policy intent is therefore to 'improve the coherence and inclusiveness of the NSI, thereby realising its potential to transform society' (DSI 2019: 22). Network alignment and building dynamic interactive capabilities of multiple actors at macro, meso and micro levels will be critical to achieving the policy objectives.

The potential value of such a conceptual model for bringing about alignment in policy goals is illustrated by a recent review of policy intent² across nine government departments, to harness STI to improve income, livelihoods and/or wellbeing for marginalised groups, and thus, to promote socioeconomic inclusion (Petersen & Kruss 2019). It became evident that the problem was not a lack of appropriate policy instruments. Government has designed many instruments promoting socioeconomic inclusion, targeting the 'right' groups, namely those that have been historically excluded and marginalised. The challenge is a high degree of fragmentation and potential lack of

1 Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

2 After scanning department websites and government policy overview documents, we selected a total of 83 policy documents for review, which together propose approximately 300 policy instruments for promoting socioeconomic inclusion and innovation.

synergy between the policies reviewed. Policy actors use a range of terms to describe innovation and socioeconomic inclusion in formulating their strategic policy objectives and goals. Moreover, the emphasis tends to fall on socioeconomic inclusion rather than innovation. The challenge for the DSI is to find ways to integrate STI into the existing strategies, programmes and instruments of other departments aimed at promoting socioeconomic inclusion.

Using the concept of network alignment, it was possible to identify spaces for the DSI to intervene, to integrate STI and coordinate networks to achieve goals to promote innovation for inclusive and sustainable development, by recommending:

- Where development goals could be more effectively shared across government
- Where alignment could be deepened and models could be extended and strengthened
- Where coordination is required to address misalignment
- Where to intervene to address gaps or missing competences

The question remains – how is network alignment to be implemented in practice? This is where building the dynamic interactive capabilities of key actors and organisations across the system of innovation becomes critical. To illustrate this, we draw on case-study research on alignment and dynamic interactive capabilities in a set of innovation networks involving a range of formal knowledge producers.

Dynamic interactive capabilities across the South African system: Evidence from case studies

The starting point was to map the existing actors/organisations and their strategies and dynamics as they interact in the networks intersecting in innovation systems at sectoral, local or national levels. On this basis, we analysed how dynamic interactive capabilities facilitated or constrained interaction between firms, private and public sector intermediary actors, and a wide range of public and private education and training organisations. In this section we provide evidence from two main sources: first, from a set of skills development networks (see Kruss et al. 2019) and second, from a study of networks linking universities and marginalised communities around livelihoods (Kruss & Gastrow 2015).

The impact of strategic leadership at the organisational level

Dynamic interactive capabilities at the organisational level are critical to the competitiveness, relevance and sustainability of a firm, government agency or education and training provider.

The first example focuses on how technical, vocational and education training (TVET) providers build the capabilities to support skills development in the sugar growing and milling sectoral system of innovation (SSI) in KwaZulu-Natal. Technological change to the process of growing and milling sugar is not dramatic. While South Africa is a cost-competitive producer of high-quality sugar (South African Sugar Association 2013), the global sugar market is highly distorted by subsidies and tariffs, so that the scope for export growth is very constrained and employment is slowly declining. Skills development in the sugar industry is driven and coordinated by a sugar sectoral association, an intermediary organisation that is funded mainly by the small number of large sugar-milling firms active in the network. We noted one significant change in skills needs: to build the capabilities of a large pool of emerging and 'land claim' farmers who have been targeted as potential informal small-scale producers of sugar. These farmers tend to have low levels of numeracy and literacy and require basic business skills. The education and training needs of land-claim farmers thus go beyond sugar-specific technical skills offered by the private sector actors. Training to meet routine skills needs is concentrated in a single private TVET provider that was established and is managed by the sugar industry sectoral association.

Rather than focusing on the needs of a core industry in their local contexts, eight of the nine public TVET colleges in the KZN region interacted with firms in the sugar sector only in isolated instances and in informal ways. Moreover, they struggled to respond to changes in national policy or even to changing student preferences. These public TVET colleges act as a 'weak link', hindering alignment in skills supply and demand in the sugar innovation networks. Their weak interactive capabilities were reflected by a manager from a college located on the sugar belt who remarked that she drove past the cane fields every day and had never thought of the potential benefits of interaction for the college or her students. This reflects the complete absence of dynamic interactive capabilities – specifically, an inability to sense new opportunities to grow the college and its socioeconomic impact.

In contrast, interaction between private sector actors and public agricultural colleges was relatively strong, in relation to training future suppliers to the sector. One college reflected strong dynamic interactive capabilities in its decision to develop a Centre of Excellence for Sugar, given its contextual location. While the public TVET colleges relied entirely on government for funding and direction, the agricultural colleges were able to build strategic linkages in response to changing needs that provided a clear direction and funding stream for future sustainability.

Prior to 1994, historically black agricultural colleges focused on training extension, nature conservation and home economics officers, whereas the historically white colleges focused on training agricultural technicians (Van Rooyen et al. 2008 cited in Department of Agriculture, Forestry and Fisheries 2008: 8). In 2008, in response to a situational analysis of the 12 agricultural colleges in South Africa, the National Department of Agriculture (DoA) introduced a new Agricultural Education and Training Strategy 2008.³ This strategy required the colleges to improve their responsiveness to local economic development needs. The curriculum was changed to a more competence-based model that better aligned with farmer/industry needs.

Both colleges in the KwaZulu-Natal region included sugar-specific training in their Diploma in Agriculture programmes. The historically white institution had well-established linkages with the sugar industry. The younger, historically black institution had a more turbulent history, fewer resources and little interaction with the sugar industry. Developing strong dynamic interactive capabilities is critical for building the college as an agricultural education training institute, a new requirement by the DoA.

The agricultural college is located in the region with the largest number of small-scale cane growers and approximately 40% of the cane growers nationally (National Agricultural Marketing Council 2013). Forming linkages with industry/farmer and universities was a key part of the strategy for improving its offering and facilities. Key external interface mechanisms include an advisory board and academic council that includes representatives from industry/farmer and universities in the region. The curriculum champion convenes an annual curriculum committee that includes stakeholders in industry, farmers and educational institutions (mainly universities). This is an informal structure. The objective of the committee is to gain input for reviewing and updating the content of each field of training offered at the college. This then translates into the college's formal advisory committee and academic council's five-yearly review of the curriculum. The informal structure allows for flexibility in making relatively small changes on an annual basis to ensure that the offerings are relevant to industry and employers' needs. These formal and informal external interface structures support the college's capabilities for research and learning. Other external interface structures include an emphasis on formal partnership arrangements with key industry stakeholders, administering student bursaries offered by industry and a student internship programme as part of work-integrated learning. Through formal agreements

³ At the time of the research, a task team was assigned to investigate the implications of moving the agricultural colleges to the National Department of Higher Education and Training.

with a major sugar firm and the main private training provider in the industry, the college revamped their Crop Production stream to include three sugar-specific modules. For example, the objective of a public-private partnership with a large milling firm was to develop a 200ha seed cane scheme near the college, which would be used as a training facility for students.

To facilitate coordination and integration, the principal displayed strong social skills by creating (informal) positions within the college, for each of the three diploma programmes. The positions are not part of the formal organisational structure recommended by the DoA and are thus not resourced. Three lecturers act as heads of department. One head of department plays the role of the curriculum champion to ensure that the curriculum is relevant and responsive. Another acts as liaison officer, managing relationships with industry and farmers and ensuring placement for students. The lecturers took on these management tasks without additional pay. Instead, the principal negotiated an agreement with the lecturers whereby they are allocated time for the additional activities.

This is an example of how the innovative leadership and culture of teamwork reflect strong dynamic interactive capabilities. The agricultural college was able to sense the opportunities in its environment and learn how to respond through using a public-private partnership scheme, integrated into daily routines and functions.

Dynamic interactive capabilities are needed to overcome path dependent trajectories

A different set of issues is highlighted when we analyse the network alignment around the Square Kilometre Array (SKA) project which is effectively a hub for numerous innovation networks, each of which is interrelated to the others and each of which is global in its reach. This complex structure requires advanced dynamic interactive capabilities in order to operate effectively, both among international partners and among South African actors in the innovation system at the national and provincial levels (Gastrow, Kruss & Petersen 2016).

The SKA reflects strong network alignment with knowledge and skills producing actors with regard to (university) curriculum, research and funding. The sensing and learning capabilities of the SKA organisation are strong and it has formal mechanisms to integrate and coordinate the ways in which it functions within complex networks. One key integrating mechanism is a human capital development programme which manages skills needs assessments through interaction and engagement with relevant stakeholders, and on this basis, engages with education institutions – public and private, local and international – to enhance their capacity to develop relevant high-level skills as required.

In South Africa's highly unequal education system, pockets of excellence exist where resources, networks and skills are concentrated. The SKA represents a successful attempt at developing dynamic interactive capabilities to link these pockets of excellence (Gastrow et al. 2019). As a highly specialised niche area, skills in astronomy are rare, and a handful of astronomers and highly specialised engineers enter a labour market consisting of only a few employers. Each employer requires such narrow skills bands that they are largely aware of who the specific individuals within the system are that hold or are developing these skills. The SKA organisation has effectively connected and aligned knowledge producers in universities, research institutes and science facilities with the requirements of firms for knowledge- and technology-intensive innovation outcomes. In doing so, it improves South Africa's ability to access and compete effectively in the global knowledge economy (Gastrow et al. 2016).

The dynamic interactive capabilities evident in interactions with higher education organisations across the system are instructive. The SKA builds capacity by awarding bursaries, grants and fellowships, as

well as establishing research chairs, through the dedicated human capital development programme. The administrators are skilled in sensing changing skills requirements, which they use to closely monitor and maintain control over the range of disciplines, research topics and skills domains covered. They do this through intensive interaction with scientists and engineers, facilitated by an administrator positioned at the top of the organisation with easy access to senior management, who displays strong social skills for the task (Fligstein & McAdam 2012). The administrator is well placed and skilled to consult widely and interact with many different stakeholders in order to coordinate the process and optimise the match of skills and knowledge.

Academics from the main partner universities serve on the selection committee which allows them to sense new requirements and inform changes in their own organisations. Dynamic interactive capabilities are also fostered through interaction in an informal, non-institutionalised working group of university partners that meets regularly to discuss the progress of the project, the scope of research projects, and any other items of relevance to the interaction between universities and the SKA. Strong relationships are fostered with senior university managers and with academics at all levels that enable rapid, responsive and informal communication between senior staff. These mechanisms create space for strategic agency on the part of knowledge producers. For example, at one university of technology, participation in the SKA network has largely been driven by one researcher with strong social skills, who has made a case for the institution's involvement in providing the technical training required.

In contrast, there has been weak interaction with a public TVET college located in the immediate vicinity of the SKA site and the contribution to the network goals has been minimal. Over the course of several years, the SKA has sought to engage with the college and provided bursaries but only a few graduates were produced with intermediate-level skills of electrical, carpentry, plumbing and welding required to install the satellite dishes. One reason is that the college leadership and staff displayed limited capabilities to sense and learn, with evidence of constrained communication with the SKA and limited capacity to internalise planning and respond to specific skills requirements. Another reason is that the SKA organisation did not have the same historic relations with the TVET sector as it had with the university sector. It thus had to find a different strategy, such as working through an established public intermediary organisation with good linkages to the TVET sector. To address the misalignment, the SKA organisation initiated a process of long-term capability building with the objectives of training TVET staff and building basic competences that could provide a platform for improved relations and increased outputs of relevant skills over time.

The differential success of the SKA interventions in relation to the high-level and intermediate-level technical skills required highlights how history shapes the development path we are able to take and how dynamic interactive capabilities may make a difference in the ability to have global impact.

Dynamic interactive capabilities are critical to sustainable policy interventions

Universities have been encouraged to become more accountable to national social and economic development goals (Kruss et al. 2012). Linkages with firms are incentivised through policy instruments such as the *Technology and Human Resources for Industry Programme* (THRIP) and the Innovation Fund. Social responsiveness and engagement strategies are mandated to drive linkages with civil society and local communities. Universities have developed their interactive capabilities by creating a range of interface structures such as incubators, technoparks or advice centres, both physical and virtual.

Our research highlights the significance of dynamic interactive capabilities in ensuring the success and sustainability of such policy instruments. The final case examined is a 'Research and development (R&D) laboratory' hub – an agricultural park – established on the relatively isolated rural campus of

a university in the Eastern Cape (Kruss & Gastrow 2015). The intent was that this would be a model, formal, external interface structure that could be replicated on a larger scale across the small rural towns and villages in the province. Starting from the premise that the most important challenge is to empower small-scale farmers to participate in formal markets, the university used the model of an innovation hub or incubator for small businesses. Public procurement policies at provincial and local level that promote the participation of Small, Medium and Micro Enterprises (SMMEs) and small-scale producers were seen to provide opportunities to secure large markets for such a hub. At the same time, the hub could provide an opportunity for student learning and staff research.

The agri-park housed a set of cooperatives that employed retrenched workers, contributing to three interconnected units: a nursery for seedlings to supply plants to small-scale farmers, a farming enterprise and an agro-processing unit for dried processed vegetables to serve local farmers and the cooperatives. At the time of the research, the processing facility, with expensive equipment such as industrial dryers, was standing idle. The cooperatives were producing at only a small fraction of the output of the facility but, we argue, the main blockage lay in a lack of dynamic interactive capabilities to access local markets.

The intended market was local schools in the province, to tap into national social development budgets through formal agreements for public sector procurement from the cooperatives and small-scale farmers. However, the provincial Department of Basic Education (DBE) changed its procurement process from a centralised system to an individual school basis, and the actors involved in the network lacked the capabilities to respond to this change. To access individual public sector markets at the local level required stronger interactive capabilities than the cooperatives displayed, to identify, secure and respond to multiple schools. Cooperative members reported a lack of competences to access formal financial institutions for loans and evinced a lack of agency in accessing markets. To identify alternative formal private sector markets also required compliance with food safety standards and regulations, for which both the agri-park⁴ staff and the small-scale farmers did not have the required competences and capabilities.

The university academics and project managers leading the project equally lacked the capabilities to respond to the environmental turbulence by sensing new markets and adapting their strategies accordingly. Significantly, they lacked the social skills to identify appropriate new actors and to coordinate the diverse set of actors in the network, with their differing competencies and capabilities. The top-down, unidirectional approach of bringing communities into a dedicated space in the university to operate as a business was a blockage to network alignment. It did not take into consideration the skills and capabilities required and those available, both from the cooperatives and for running the agri-park. In practice, the main form of interaction with the university was the training of agricultural students in the seedling nursery and the farming enterprise, which involved little knowledge exchange with the local farmers. Missing actors and capabilities resulted in network misalignment where the system had a degree of interactivity, but the key actors were oriented to different priorities: the university to teaching and learning and the farmers to securing their livelihoods. These priorities were potentially mutually beneficial but the system lacked a strong intermediary to bridge across the set of actors and goals, leading to network failure.

⁴ The Department of Rural Development and Land Reform defines an agri-park as 'a networked innovation system of agro-production, processing, logistics, marketing, training and extension services, located in a District Municipality' (Heimann 2017: 9). An agri-park comprises three basic components: a Farmer Production Support Unit, an Agri-hub (AH), and a Rural Urban Market Centre.

Conclusion

Dynamic interactive capabilities are not the only reason that firms and cooperatives fail to keep up with competitors or that education and training organisations are unable to effectively respond to knowledge, technology or skills needs in their local environments. The empirical cases show that network failures can result from a complex array of gaps and types of misalignment. Political will and support at the macro-level, as in the case of the SKA, can be crucial.

Dynamic interactive capabilities, however, could make the difference between success and failure, as Teece and Falconi (2018: n.p.) state in relation to universities:

Campus leaders must, of course, pursue both operational efficiency and ecological fitness, but when torn between these two demands, they should remember that fitness actually matters most. Mistakes with respect to efficiency get corrected by hiring ordinary consultants (or a new CFO/COO) and reallocating financial and other resources, but a lack of dynamic fitness leads a university to become less attractive to students, faculty, donors and other stakeholders.

All three cases illustrate that having strong competencies and interactive capabilities in the form of interface structures at the meso level is critical. The role played by intermediaries in coordinating actors, and bridging and filling network gaps, may enhance the dynamism of the system. The strength of dynamic interactive capabilities at the organisational level is a key determinant of the extent of alignment and coordination at the systemic level.

Policy incentives typically support the development of competences and may promote interaction, but the evidence suggests that for better alignment across the national system of innovation, we need to pay attention to building the capabilities of leaders, managers and other key strategic actors to sense changes and learn through interaction.

There is a precedent for policy intervention at this level, in the form of the South Africa municipal innovation maturity index, which draws on the Open Innovation Maturity Framework of Enkel, Bell and Hogenkamp (2011) (see Sinyolo, Booyens & Jacobs 2018). The index is motivated by evidence suggesting the key role of what Sinyolo et al. (2018) call 'innovation capabilities', that is, the capacity of municipal officials to learn and implement innovation at the local level, in relation to the delivery of basic public services.

This development of a method and approach to measure innovation capabilities as a way to inform policy strategies at the local level is instructive. The analysis in this chapter likewise proposes the significance of building dynamic interactive capabilities at all levels for implementing innovation policy and systems in our country context.

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Building Regional Innovation Ecosystems and the Role of Government

Mziwandile Madikizela

In both developed and developing nations, the high degree of global competition, growing inequality and slow economic growth has presented national governments, local and regional authorities, city planners and economic development managers with the challenge of stimulating innovation to enable growth and improve the lives of their citizens (Tukiainen, Leminen & Westerlund 2015). Together with social partners such as the private sector, academia and civil society, governments have an important role to play in fostering innovation to drive competitiveness at both a national and regional level. Innovation is often associated with setting up new enterprises to provide the market with new offerings and the creation of new jobs. It can also play an important role in addressing urgent societal challenges such as providing access to drinking water, eradicating neglected diseases or reducing poverty and contributing towards access to energy. In the public service sector, innovation is increasingly seen as important in improving service delivery to citizens.

Originally, the common misconception was that the innovation process is linear, and it is sometimes represented as a simplistic input/output model. While this approach is partially true, in reality, the innovation process often includes many iterations, interactions and influences. As a result, the term ‘innovation ecosystem’, which is the subject of this chapter, was coined to reflect the complex network of people, organisations, institutions, government policy and regulations that support and promote innovation. The term innovation ecosystems depict such systems as evolutionary and self-regulating. The ecosystem approach has received attention because it has added valuable dimensions to economic development. The phrase has captured the attention of policy makers who are looking for new solutions for growth, especially at regional level, and has motivated public initiatives of substantial size (Oh et al. 2016).

The aim of this chapter is to address the following questions: What is an innovation ecosystem? How are regional and sectoral innovation ecosystems built? What role should government play in fostering such innovation ecosystems?

To answer these questions, the chapter is structured as follows. Following this introduction, the second section provides a conceptual review of the innovation ecosystem construct. Regional and sectoral ecosystems are discussed, including the importance of the regional dimension. The process of building such ecosystems is outlined in the third section together with key success factors. In the fourth section the role of government is examined. There is a summary of the key conclusions and insights at the end of the chapter.

Innovation ecosystems

This section introduces the innovation ecosystem construct and its origin. This is followed by a discussion of regional and sectoral ecosystems.

The innovation ecosystem approach

The innovation ecosystem approach has recently received considerable attention from various scholars and policy makers. Although the phrase was proposed by Adner (2006), it owes its origins to the business innovation ecosystem concept, which was coined by Moore (1993). Moore (1993) coined this term to describe a set of producers and users around a focal organisation that contributed to its performance. He observed that firms do not generally innovate successfully alone but rely on external and internal actors to complement their offering. To illustrate the ecosystem approach, the case of the aircraft manufacturer Boeing is useful. Boeing required a wide range of partners to address the high risk and uncertainty associated with manufacturing radically new aircraft such as the Boeing 787. In order to meet the challenges, Boeing collaborated and partnered with various suppliers to develop the different subsystems and parts that were required (Nambisan & Sawhney, 2011; Walrave et al. 2018).

According to Moore (1993), a firm does not necessarily belong to an industry, but to a network of partners in a business ecosystem. A business ecosystem is 'a dynamic structure which consists of an interconnected population of organisations. These organisations can be small firms, large corporations, universities, research centres, public sector organisations, and other parties which influence the system' (Peltoniemi & Vuori 2004: 13). As the Boeing example illustrates, ecosystems provide firms with resources and they are a platform in which firms co-create value. As a result, the performance of any firm is dependent on the characteristics and the structure of the business ecosystem. This in turn is influenced and shaped by the interactions of its participants (Koch & Windsperger 2017). Therefore, the innovation ecosystem is a conceptual analogy that is used to help illustrate how innovation actually occurs.

An innovation ecosystem, like the term innovation, is subject to many different definitions and conceptual understandings. Jackson (2011) drew a conceptual analogy between an innovation ecosystem and the biological ecosystems observed in nature. A biological ecosystem models the complex set of relationships among the living resources, habitats and residents of an area. Jackson (2011: 2) defined an innovation ecosystem as 'the complex relationships that are formed between actors or entities whose functional goal is to enable technology development and innovation'. According to Adner (2006: 2), an innovation ecosystem is a 'collaborative arrangement through which firms combine their different individual offerings in order to co-create value'. Other authors such as Mercan and Göktaş (2011: 102) define innovation ecosystems as 'the economic agents and economic relations as well as the non-economic parts, technology, institutions, sociological interactions and the culture'. Oksanen and Hautamäki (2014: 25) simply refer to an ecosystem of innovation as 'a dynamic, interactive network that breeds innovation'.

The following diagram (Figure 6.1) is a simplified illustration of an innovation ecosystem and illustrates the various actors and their interaction. The diagram shows the key elements such as the actors, finance, regulations, infrastructure, knowledge and ideas. Although this figure is useful, it does not reveal some of the key intangible aspects such as culture.

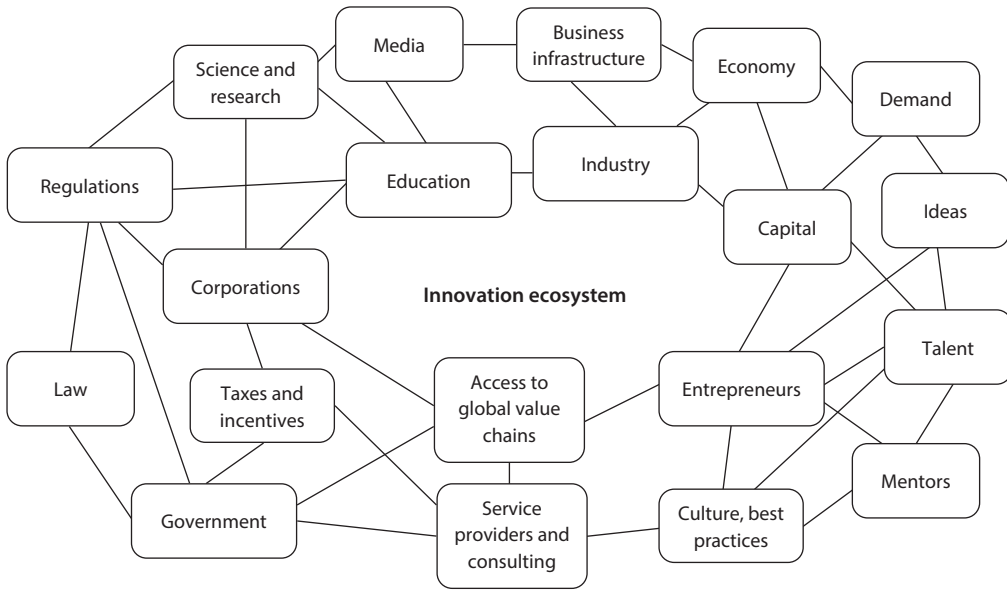


FIGURE 6.1: *Illustration of an innovation ecosystem*

Source: Ryzhonkov (2013)

To summarise, the innovation ecosystems construct provides an attractive metaphor to describe a range of interactions and interlinkages between multiple organisations. The aim of an innovation ecosystem is to produce knowledge, spread information and use it for economic development. Innovation ecosystems are multilevel as they have been analysed as regional, sectoral, technological, national and international systems. This chapter focuses on ecosystems at the regional and sectoral levels.

Regional and sectoral innovation ecosystems

Currently, regions and cities are regarded as powerhouses for innovation (EU [European Union] 2016). As a result, there is a shift in innovation policies from national to regional level. Moreover, it can be argued that national innovation ecosystems are in fact made up of regional and local innovation ecosystems. Regions and cities are attractive because they are the closest entities to enterprises and citizens and are well positioned to know best the specific needs on the ground (EU 2016).

The regional dimension of innovation was popularised by various scholars such as Porter's highly influential industrial cluster concept (Porter 1998). Clusters are groups of firms, related actors and institutions that are located close to one another and that draw productive advantage from their mutual proximity and connections. Porter (1998) argued that certain geographic environments were conducive to innovation. He conceptualised clusters as mutually reinforcing systems comprising of the strategy, structure and competition of enterprises, demand conditions, related and supporting industries and factor conditions. The intensity and depth of the interrelationships between these four factors within the national or regional 'competitive diamond' has a profound impact on regional economic performance. Furthermore, the closer the four factors are to each other and the enterprise geographically, the higher the interaction between them, which implies that the most successful industries in a country are often the most geographically 'clustered' (concentrated) (Porter 1998).

Cooke (1997 cited in Cooke 2004: 3) came up with the notion of a regional innovation system, which he referred to as 'interacting knowledge generation and exploitation subsystems linked to global, national and other regional systems', 'in which firms and other organisations are systematically engaged in interactive learning through an institutional milieu characterised by embeddedness' (Cooke et al. 1998: 1581). Furthermore, Cooke (2008) pointed out that successful local innovation is achieved via a network of interactions and linkages between public, private and academic partners. An important insight is that the regional system of innovation develops over a long period and is built around regional assets, competencies and strengths, and is path dependent.

To illustrate the dynamic, evolutionary nature of these regional innovation systems, they have since been referred to as regional innovation 'ecosystems'. The most well-known regional ecosystems are Silicon Valley in San Francisco, Route 128 in Boston and Cambridge in the UK. These regions are regarded as innovation hotspots in which innovation thrives. The question is: what makes these regions innovation hubs and how can they be built?

The sectoral innovation ecosystem perspective was inspired by evolutionary theory and the innovation systems approach (Freeman 1988, Lundvall 1992, Marleba 2002, 2004) proposed that a sectoral system is a set of products and agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a specific knowledge base, technologies, inputs and existing and emergent potential demand. The actors or agents are private (for example companies, venture capitalists) and public organisations (for example universities, research centres, government agencies) at various levels of aggregation.

The actors interact through processes of communication, exchange, cooperation, competition and command, and these interactions are shaped by institutions (rules of the game). A sectoral system undergoes change and transformation through the co-evolution of its various elements. The sectoral system perspective enables a better understanding of the structure and boundaries of a sector; the actors and their interactions; the learning, innovation and production processes; and the transformation of sectors. The sectoral perspective provides insights regarding the differential performance of sectors. In the Sectoral System of Innovation view, firms are the key actors. Firms also include users and suppliers who have different types of relationships with the innovating, producing or selling firms. A sectoral system is therefore composed of a network of relationships among heterogeneous agents with different beliefs, competencies and behaviour (Marleba 2004).

Regional and sectoral innovation ecosystems are closely related to each other. A regional innovation system may include and affect several sectoral innovation systems, where companies, organisations of knowledge creation and exploitation are systematically related to each other. However, a sectoral innovation system may be wholly or only partly covered by a regional innovation system.

Building regional innovation ecosystems

Many regions are developing innovation ecosystems to boost their innovation capability and performance. However, the exact process for fostering ecosystems is still poorly understood. The aim of this section is to elaborate on how regions can overcome economic and structural crises by transforming themselves into vibrant innovation ecosystems.

To illustrate how innovation ecosystems can be built, the Triple Helix Model of Innovation is adopted. The concept of a triple helix of university-industry-government relations was initiated in the 1990s by Etzkowitz (1993), and Etzkowitz and Leydesdorff (1997). The basic idea within the triple-helix model lies

in the recognition of the shift of innovation policy from the traditional linear approach towards a dynamic network model which involves different innovation actors. Specifically, it advocates the strengthening of the collaborative relations between academia, industry and government. These three social partners – universities, business and the state – have to work as one system to implement innovations and generate economic growth (Etzkowitz 2002). The triple-helix metaphor is therefore an integrative mechanism to increase competitive advantage and long-term sustainable economic growth.

To promote regional or national economic development, many developed and developing countries have adopted the triple-helix approach in designing innovation programmes (Etzkowitz 2008). The theory towards knowledge-based regional development was developed by Etzkowitz and Klofsten (2005). They used longitudinal data from a region in Sweden and international comparison to identify the four stages of development of triple-helix type interactions. These are the inception, implementation, consolidation and renewal stages (see Table 6.1).

TABLE 6.1: *Model of development of the triple helix in regional economic development*

| <i>Stage</i> | <i>Goal</i> | <i>Structure</i> | <i>Process</i> | <i>Activities</i> |
|---|---|--|---|---|
| 1. Incipient stage: Idea about new regional development model | Generate a new economic base for the region | Informal interaction between different actors as university, municipality, research labs, large and small firms | Searching for success; informal meetings; discussion about regional plans; influence of external ideas and successful cases | Building the first incubator; initial service activities for early firms in incubators; basic infrastructure |
| 2. Implementation stage: Starting new activities | Supply adequate infrastructure (hard and soft) for different types of entrepreneurs | Formation of networks of entrepreneurs; informal educational and social activities | Starting new organisations for promoting entrepreneurship | Spin-off firms, clubs, networks, incubators and science parks; initiatives outside and inside of the university |
| 3. Consolidation and adjustment stage: Integration of hard and soft activities | Increase the efficiency of the system | Cooperation among regional actors for the purpose of increased efficiency of resources, to get closer to firm needs in order to satisfy needs of firms | A new networking plan and network of support organisations | Meetings between actors to define the roles and to support each other in marketing |

| <i>Stage</i> | <i>Goal</i> | <i>Structure</i> | <i>Process</i> | <i>Activities</i> |
|---|---|---|--|---|
| 4. Self-sustaining growth stage: Avoiding decline—create continuous redevelopment | Renew the system by identifying new areas of growth linked to new research by questioning existing activities | University leads with other actors, at highest levels of the region a political system with power and influence emerging; to avoid decline there is a need for more entrepreneurs and university expands to new research areas for continued growth in the region | Discussion by regional actors of what is lacking in the region | Meetings in smaller groups to contribute new ideas in newspaper articles and brochures; all actors try to participate and place their efforts in the best light |

Source: adapted from Etzkowitz and Klofsten (2005: 249)

According to Etzkowitz and Klofsten (2005), in the first stage, the regional actors are at the strategic level. In this stage, the idea about a new regional development model emerges and the goal is to generate a new economic base for the region. This is followed by stage 2, the implementing stage, in which new activities are started by providing adequate infrastructure. As a result, new organisations for promoting entrepreneurship, and activities such as spin-off firms, clubs, networks, incubators and science parks, as well as initiatives outside and inside of the university, are established. Stage 3 is the continuation, consolidation and adjustment stage and the goal is to improve the efficiency of the system. This requires that regional actors cooperate to enhance the efficiency of resources in particular and also to better meet the needs of firms. The process includes forming, for example, a new networking plan and a network of support organisations. The last stage is about self-renewal, avoiding decline and creating continuous redevelopment. The goal of stage 4 is to renew the system by identifying new areas of growth linked to new research and by interrogating existing activities. This stage is crucial because self-sustaining growth is at the core of the innovation ecosystem.

According to Etzkowitz and Klofsten (2005), the outcome of these initiatives is a self-sustaining dynamic in which the role of academia and government appears to recede as industrial actors come to the fore and a linkage between firms is created. As one technological paradigm is exhausted or declines, the role of academia and government comes to the fore again in creating the conditions for the next wave of innovation.

The triple-helix approach to regional ecosystem development has been enhanced and elaborated upon by Oksanen and Hautamäki (2014). Using this model as an analytical framework they developed a model for building innovation ecosystems as shown in Figure 6.2 below. The model was derived from a case study on the development of a regional ecosystem in the industrial city of Jyväskylä in Finland. The core elements of an ecosystem approach are open dialogue, triple-helix cooperation between universities, industry and government, the concept of core organisation, and future studies.

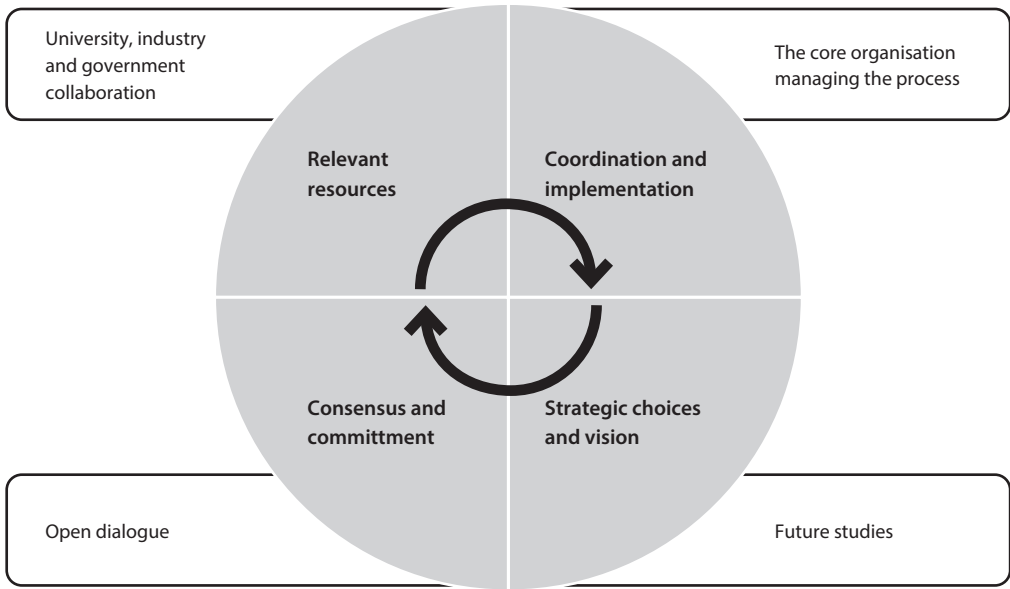


FIGURE 6.2: *Model for building innovation ecosystems*
 Source: Oksanen and Hautamäki (2014: 11)

To achieve a common vision and goals, open dialogue among the innovation actors is essential and stakeholders must invest in developing a shared future. Long-term relationships based on triple-helix interaction among the social actors of universities, industry and government are the glue that holds the partners together. Future studies help actors to be proactive and anticipate future changes. The core organisation is responsible for orchestrating the system as a whole, which includes planning and implementing the measures needed, as well as project coordination and communication.

Oksanen and Hautamäki (2014) stress that the four concepts and development measures need to be achieved systematically. The development does not have to be linear, but some linear elements can usually be found. For example, linear regional development often begins with the development of a knowledge base, and this is followed by interaction among triple-helix actors as Etzkowitz and Klofsten (2005) also observed.

The triple-helix approach and the model presented in this section provide a flexible framework to guide efforts from different starting points to achieve the goal of knowledge-based economic and social development. The stages provide a systemic framework for innovation-based regional development under a wide variety of circumstances. The model is relevant and can be used for cities and regions, especially those whose real challenge is how to transform their regional economies into innovation economies.

Although the triple-helix approach is widely accepted by policy makers and academics around the world as a key mechanism for providing conditions for innovation, it has been a subject of criticism. Some of the relevant criticism worth mentioning is that the concept has been developed from the experience of advanced economies. According to Cai (2013), it is important to consider empirical evidence on whether the triple-helix model is applicable in non-Western contexts. The triple-helix para-

digim is still recognised as a 'new' concept for some developing countries (Saad & Zawdie 2011). In developing countries, where institutions are characterised by widespread fragmentation and rigidities, there is a low volume of interaction between the institutional players (Saad & Zawdie 2011). There is also low stock of social capital and limited scope for innovation in these countries. Although triple-helix actors exist, they are differentiated, and the system is essentially dysfunctional. Critics have argued that the university systems in most developing countries are academically oriented and industries are either non-existent or too weak and governments too bureaucratic to play their respective roles envisaged by the triple-helix model. However, the problem as noted by Konde (2004) does not lie with the model, but the fact that in many countries these triple-helix entities seem to be weak because their elements tend to work in isolation.

Cultural issues among the three spheres in triple-helix interactions also present challenges. For example, academics are driven primarily by publication pressures, not by commercialisation possibilities. On the other hand, industry may not be united but is made up of competing firms, none of which naturally wants to share any advantageous knowledge with the others. Government is made up of politicians who seek re-election and therefore generally lack the ability and capacity to consider long-term development goals (Lu 2006). The difference in incentives means the three spheres may not work in partnership in practice. The willingness for cooperation between institutional partners has also been underestimated. Empirical evidence clearly suggests that academics and firms are motivated by different objectives when collaborating on innovation projects (Lu 2006).

Critical success factors in developing sectoral and regional innovation ecosystems

Some regional innovation ecosystems such as Silicon Valley in California and Route 128 in Boston experience higher, faster and more sustainable growth than others. These regions enjoy a higher number of start-ups, investment, employment and economic growth. In this section, the key success factors that drive successful innovation in regions and cities are highlighted.

To identify these key success factors, this section draws mainly from the EU Committee of Regions report (EU CoR 2016). The report is an attractive source because it emerged out of a comprehensive study of innovation ecosystems at several cities and regions in the EU. The EU study identified nine necessary success factors for a regional innovation ecosystem, as shown in Figure 6.3.

The nine success factors are discussed briefly below.

1. Regional vision

A vision for a region to drive growth and economic development through innovation is a critical success factor for developing a regional system of innovation. Such a strategy should inspire the long-term aspiration of the actors, including its citizens. The strategies should be based on a diagnosis of the regional strengths and opportunities. It is important that such a strategy is aligned with the local economic development strategies and national priorities. For example, in the EU, smart specialisation is the strategy for regional innovation (Foray et al. 2012). Smart specialisation seeks to leverage the competitive advantages of the region by prioritising certain areas which are identified through an entrepreneurial discovery process (Foray et al. 2012). For example, in South Africa, the Gauteng Province's Department of Economic Development (2012: 4) in its Gauteng Innovation and Knowledge Economy states that the role of the its' regional strategy is 'to accelerate innovation in all its forms, in order to bolster and support the broader strategic objectives of employment creation, and sustainable social and economic development'.

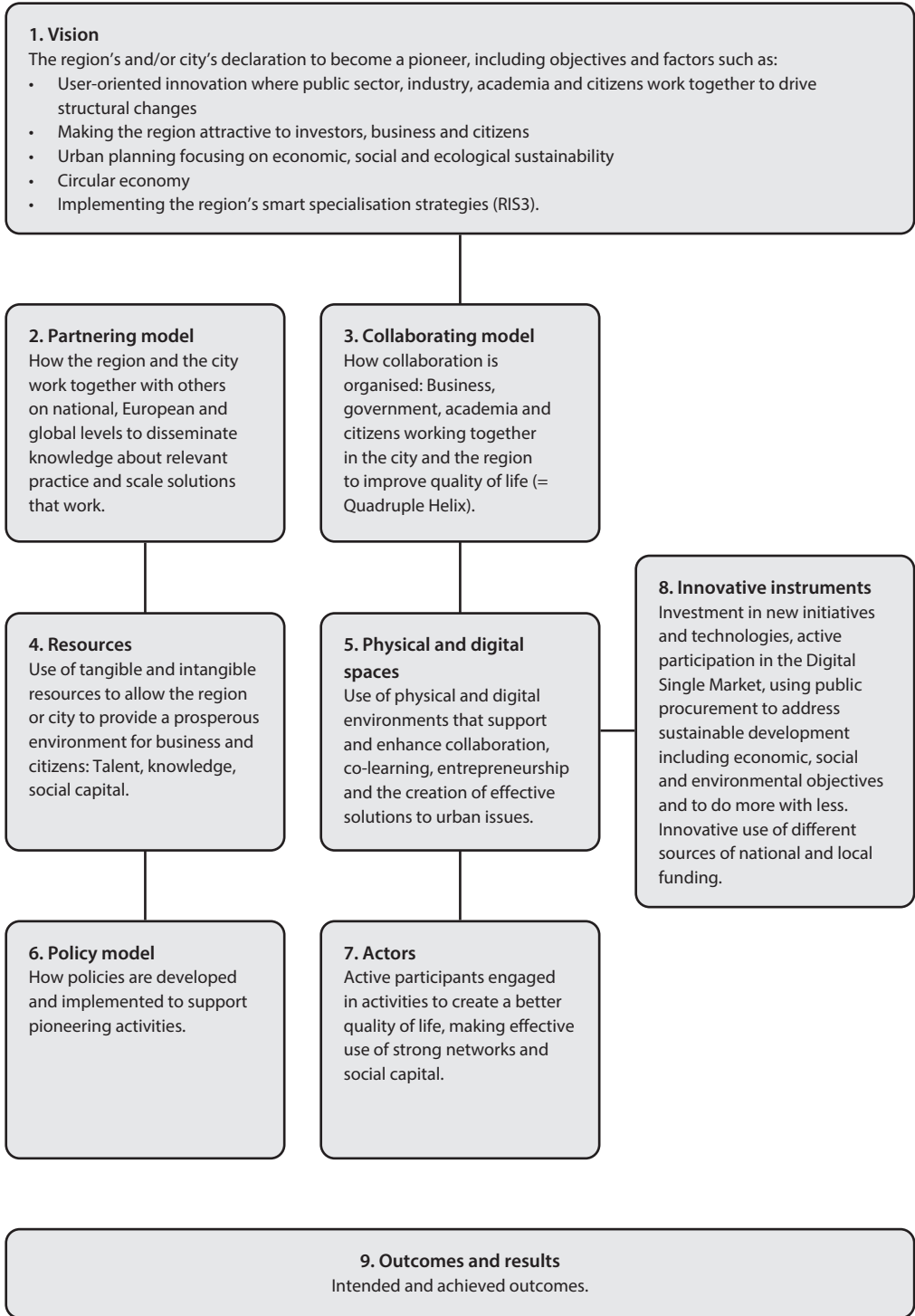


FIGURE 6.3: Key success factors for developing regional innovation ecosystems

Source: Adapted from EU CoR (2016)

2. Partnering model

Regional authorities must be made aware of the importance of partnerships at a national and international level. A common approach to partnership is through public-private partnerships for innovation. Regions partner with others to disseminate knowledge, scale solutions and learn from others. For example, to exchange best practice and to present local solutions that can be replicated, the region of Berlin organises cross-sectoral events with guests from all over the world (EU CoR 2016).

3. Collaboration model

Having knowledge assets, talent or infrastructure is not sufficient. One of the most important success factors is collaboration (Stensson & Wessman 2015). Innovation, especially radical innovation, is often a result of collaboration and new connections between areas of knowledge. The triple-helix model of collaboration mentioned earlier is one of the most popular conceptual frameworks for increasing interaction. Collaboration is meant to strengthen the links and expand the flow of knowledge between key actors. This will upgrade the system as a whole and enhance the region's competitiveness. Collaboration in joint innovation activities can reduce time to market as well as provide access to new resources, infrastructure and new markets. For collaboration to occur, there must be mutual benefits that accrue to the collaborating partners. There is a need for interaction and collaboration between diverse sets of innovation actors and this is key to developing a healthy innovation ecosystem (Organisation for Economic Co-operation and Development [OECD] 2016).

4. Resources

Innovation depends on the availability of distinct regional resources that give it a competitive advantage. For example, some regions such as Boston are endowed with unique expertise in fields such as life sciences (Ferguson et al. 2018). There are also intangible resources, such as knowledge and information access, leading to the generation of intellectual capital and social capital. While a wide range of resources is required to support innovation, perhaps the most important resource is a well-educated and skilled workforce. A pool of talented individuals is a prerequisite for innovation. Regions that have excellent talent or can attract talent are a source of regional competitiveness. World-class universities are knowledge assets from which new ideas can emerge. Having the resource configurations alone is inadequate: regions need to make better use of them. Examples of regional innovation resources in South Africa include, but are not limited to, regional firms and industry associations, universities, public and private research centres, science parks, incubators, living labs, financial organisations and venture capitalists and, of course, local talent and unique skills. The resources also include intangible assets like intellectual property such as patents and trademarks (EU CoR 2016).

5. Physical and digital spaces

Entrepreneurs and innovators require enabling workspaces for enhancing collaboration. Physical infrastructure is critical to provide innovators with space to engage, interact and network. Regular meetings, conferences and workshops can significantly reinforce interaction between universities, businesses and government for the purposes of innovative development. Government is the initiator of web infrastructure development. Physical and digital environments are needed to support and enhance collaboration, co-learning, entrepreneurship and the creation of effective solutions to urban issues. Science parks, incubators and innovation labs provide physical spaces for interaction and exchange of knowledge.

6. Policy models

The right policy models and tools are essential to support regional innovation ecosystems. These must be designed and implemented, taking into consideration the regional context and that there is no one-size-fits-all model (Asheim, Boschma & Cooke 2011). Adopting policy models that are successful elsewhere is a passport to failure. Regional policies which are inappropriate are naive attempts to

transfer best practice without understanding the local context or to advocate cluster identification and creation. Examples of policy models are smart specialisation and a clustered approach.

The policies must take into consideration the stages of development of the innovation ecosystem. For example, the expansion phase calls for policy tools that support start-up activity and the growth of small enterprises. The ecosystem can be stimulated by attracting and utilising different funding sources to help new businesses to develop and grow. In addition, the availability of support systems and networks for start-ups, business mentors and incubators is important for new businesses to start and join the ecosystem. In the self-renewal phase, it is essential that policy specifically supports the renewal process instead of supporting old industries and structures that no longer show future potential (Oksanen & Hautamäki 2014).

7. Actors

In broad terms, the regional actors in an innovation ecosystem can be categorised as private, academic, public and citizens. Specifically, these include professional organisations such as chambers of commerce, technology/science parks, incubators and innovation labs, universities, clusters, entrepreneurs and start-ups and regional authorities. These actors must interact to make their territory a fertile ground for innovation. All the actors must participate and work collaboratively with commitment towards achieving their vision and its objectives to make their territory an innovation hub.

An asset that should not be underestimated is the social capital available in the region. The OECD (2001: 41) defines social capital as 'networks with shared norms, values and understandings that facilitate cooperation within or among groups'. Social capital refers to high levels of trust, commitment, and congruence among partners. Regions with strong networking effects and high levels of social capital are conducive to innovation.

8. Innovation instruments

To stimulate ecosystems, a set of innovation instruments is necessary to support innovating actors. There is an array of instruments at the disposal of regional actors. The most common instruments are science and technology parks, systematic initiatives such as clusters, competence centres, networks, competitiveness poles, innovation vouchers, innovative support for start-ups, funding for research and schemes for attracting skills and talent (EU 2011).

However, it is important that the mix of instruments should complement each other. Some of these will increase diffusion of innovations, clustering and smart specialisation or foster and support early-stage start-ups and high-growth firms. Collectively these instruments should address the strategic goals of the region and their relevance is important. Regions should develop instruments for knowledge generation, knowledge diffusion and knowledge commercialisation (Foray et al. 2012).

9. Outcomes and results

This reflects the intended and achieved outcomes.

The role of government in building regional innovation ecosystems

Although innovation ecosystems are described as self-organising and self-supportive systems, public authorities play a crucial role in promoting the interfaces between innovation actors in order to orchestrate regional innovation ecosystems. The ecosystem approach requires that governments change the manner of intervention. In this section, the role that local and regional authorities in the South Africa context can play in developing innovation ecosystems is discussed. The practical use of the conceptual models and key success factors are also discussed.

In South Africa, efforts to build regional innovation systems started in 2008. This was due to a realisation of the growing importance of the regional dimension in innovation policy. As result, several provinces such as the Western Cape, Gauteng and Limpopo developed regional innovation policies. Others such as the Free State and Eastern Cape established regional innovation fora.

The White Paper on Science and Technology Innovation which was published in 2019 reinforced the importance of the regional dimension. One of the objectives is ‘to integrate innovation strategies into local and regional economic development planning’ (Department of Science and Innovation [DSI]¹ 2019: 31). The White Paper calls upon local and provincial growth and development strategies to include innovation plans. Furthermore, ‘innovation hubs’ will be expanded to enhance provincial growth and development strategies and promote provincial technology competencies (DSI 2019: 37). This creates an urgent need for effective frameworks, tools and best practices to assist regions in building effective innovation ecosystems or ‘innovation hubs’. The conceptual frameworks and key success factors discussed in the previous section will guide regional authorities in building and implementing innovation ecosystems.

A key but underestimated exercise in building innovation ecosystems is identifying and mapping the key stakeholders. There is a tendency, especially in South Africa, to focus on and involve mainly the scientific community and not broaden the stakeholders. Figure 6.1 in this chapter illustrates that regional actors are broad-ranging. A key insight is the importance of linkages. The existence of the actors alone is inadequate – the interfaces between them are essential. This approach is a sophisticated way of seeing the innovation system as a whole that enables policy makers to pay close attention to the collaborative, interdependent nature of the innovation process. As a result, they can identify the best means of stimulating productive networks and relationships within and across disciplines and sectors. The Triple Helix Development Model for regional economic development models that is displayed in Table 6.1 provides a structured process for local authorities. It can be used to assess the ecosystem stage of development, set relevant goals and determine the specific activities that should be undertaken during the various phases. Figure 6.2 also illustrates an alternative framework to depict the process of developing a regional ecosystem of innovation.

An important aspect is monitoring and evaluation. Monitoring changes is important to determine what is working and not working. A monitoring and evaluation framework should be an integral part of the strategy formulation process. This is important to assess the effectiveness of the policy measures that have been employed. This monitoring process should be based on innovation indicators that have been decided upon by the regional actors. Monitoring should also be used to build up a better understanding of the actors present in the innovation ecosystem and the networks they form. In South Africa, there is no evidence of monitoring the regional innovation initiatives that have been undertaken to evaluate whether they have improved regional innovation performance or not.

To summarise, policy makers play an important role in harnessing the innovation potential of their local economies. Government should identify and capture the barriers and weaknesses of existing ecosystems and remedy them with new policies. Perhaps the most crucial role of public authorities is promoting the interfaces between innovation actors in order to orchestrate regional innovation ecosystems.

¹ Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

Conclusions and policy insights

In the era of the knowledge-based economy, innovation-led growth has become a new policy imperative that cities and regions should follow in order to prosper and be competitive in a globalised world. Regions have become more prominent actors in the innovation field in the past decades. The fostering of regional innovation ecosystems has emerged as an attractive approach for producing and using innovation for economic growth and regional prosperity. The eco-systemic approach to innovation provides understanding of the interactive and collective nature of innovation and describes the roles of the variety of actors.

The process of building a regional ecosystem is evolutionary, as the studies which are cited in this chapter show. This is a dynamic, self-regulatory process which depends on the resource configuration of the region. A regional or sectoral innovation ecosystem strategy will therefore depend on proper diagnosis to reveal the regional or sectoral competitive advantages, opportunities and challenges. There is also no one-size-fits-all solution on how to build an innovation-friendly environment and different countries are taking different approaches.

As this chapter has shown, to be successful in building an innovation ecosystem, certain ingredients are necessary. Ideally a city or region should address all of them. Indeed, pioneering regions such as Silicon Valley and Route 128 in Boston either possess or address most of these key success factors. However, in reality, not all regions can succeed in achieving all of them. What is important is to identify and develop these success factors during the innovation ecosystem lifecycle.

The innovation ecosystem approach to economic development symbolises the emerging network-based economy. Through this approach, innovation-led technological advancement and economic development are achieved through a network of self-organising and self-renewing interactions and dispersed patterns of production among network actors. The expected outcome is increased innovation performance through co-creation and collaboration.

The eco-systemic approach emphasises the pivotal position and roles of local and regional authorities in stimulating innovation activity. Hence, the government should proactively engage and foster innovation.

To build healthy ecosystems, policy makers should consider:

- Leading the formulation of a regional innovation strategy;
- Building infrastructure such as research innovation centres to help others innovate;
- Creating places where regional innovation actors can meet face to face so that successful innovations can emerge;
- Ensuring a friendly regulatory environment and reducing bureaucracy that inhibits innovators;
- Lowering barriers to innovation by encouraging 'balanced risk-taking' while providing financial incentives to innovators;
- Promoting the successes of domestic entrepreneurs to foster an entrepreneurial culture; and
- Recognising which start-ups are more likely to succeed and channel the resources to them instead of trying to support as many start-ups as possible.

To conclude, while there is significant interest in the eco-systemic approach, building functioning ecosystems is difficult to achieve in practice. Each region is different but the recommendations in this chapter can assist policy makers and their partners in the journey. Policy formulation and implementation, then, is the result of intensive communication, close interaction and consensus building between all regional stakeholders. Policy makers are just one type of actor amongst others in these networks. Consequently,

the key role governments play in encouraging innovation shifts from direct intervention towards stimulation, intermediation, orchestration, promoting regional dialogue and building up social capital.

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PART TWO

**STI MEASUREMENTS,
MONITORING AND
EVALUATION**

STI Measurements in South Africa: The State of Affairs

Anastassios Pouris

The measurement of various facets of scientific, technological and innovative activities in an economy is an increasing challenge faced by science and technology authorities, statistical agencies and members of parliament around the world. As science and technology (S&T) have been recognised for the pivotal role they play in fostering innovation, growth and productivity, the resources allocated for them increased substantially. It is estimated that the world's total research and development (R&D) spending was approximately USD 1.8 trillion in purchasing power parity (PPP) (Desjardins 2018, with UNESCO data).

The increase in the support of science, technology and innovation (STI), coupled with the need to provide the basis for informed policy formulation and analysis, has been the main reason for the measurement and collection of S&T indicators internationally. International experience shows that good policies on STI and industry cannot be formulated without acquiring an appropriate pool of information (Irvine & Martin 1985). Decision-makers need to know not only the cost of research and development but also the results of these activities, as well as the environmental factors hindering or enabling the practical usage and popularisation of these results.

Godin (2005), investigating the history of the measurement of statistics related to S&T, identifies that quantitative information on S&T is based on the groundwork of governmental organisations such as the National Science Foundation (NSF) in the United States (US) in the 1950s (NSF 1959) and inter-governmental organisations such as the Organisation for Economic Co-operation and Development (OECD) in the 1960s. Furthermore, Godin credits the work of Schmookler (1950; 1954) and De Solla Price (1961; 1963) for directing the attention of university researchers to the measurement of science and technology. Schmookler and De Solla Price may be considered the fathers of scientometrics and bibliometrics.

The objective of this chapter is to describe briefly international efforts to develop STI metrics and to highlight similar efforts in South Africa historically and currently. The chapter notes, with reference to the establishment of key institutions such as the Centre for Science, Technology and Innovation Indicators (CeSTII) and the National Advisory Council on Innovation (NACI), amongst others, that South Africa's approach to monitoring the National System of Innovation (NSI) has taken the route of 'institutionalisation'. In addition, particular emphasis is placed on activities of NACI and its efforts at developing a science indicator system for South Africa.

International experience

Japan and the USA are the countries that became involved with measurements of STI and the development of relevant indicators early on. The Japan Science and Technology Agency (JST) (1986) in Japan, in one of the earlier studies in the field, investigated the issue of science indicator systems in the process of the development of their system. The main findings of that analysis underpin the current theoretical and empirical understanding of science indicator systems. The report suggests that:

- A science indicator system should be used to grasp the status quo of a country's scientific and technological activities;
- It should be used to set goals which will be attained within a certain time period; and
- It should be used to formulate and evaluate alternative policies which have already been or will be implemented.

Table 7.1 shows the structure of the Japanese science indicator system. Sixty-five of the 103 indicators are related to research and development infrastructure and research and development results.

The *Science & Engineering Indicators* report is prepared by the NSF's National Centre for Science and Engineering Statistics on behalf of the National Science Board (NSB) as required by law. The first report *Science Indicators 1972* was published in early 1973 to immediate acclaim. At its October meeting, the board approved a biannual publication schedule. Renamed *Science and Engineering Indicators* in 1984, the series continues to be a widely used resource around the world.

TABLE 7.1: *Categorisation of indicators of the Japanese science indicators system*

| Major Category | | Sub-category | | Sub-sub-category | |
|-------------------------|-----|---------------|----|---|---|
| Societal Infrastructure | 3 | | | For example, Scientists and Engineers in Government and Companies | |
| S&T Infrastructure | 14 | Education | 6 | | |
| | | Economy | 4 | | |
| | | Culture | 4 | | |
| R&D Infrastructure | 35 | R&D Elements | 14 | Input Elements | 8 |
| | | | | Support Elements | 6 |
| | | Institution | 12 | R&D Evaluation | 8 |
| | | | | R&D Support | 4 |
| | | | | Evaluation | 9 |
| R&D Results | 30 | Knowledge | 9 | Accumulation | 6 |
| | | | | Creativity | 3 |
| | | Private Goods | 15 | Direct Effects | 7 |
| | | | | Indirect Effects | 8 |
| | | Public Goods | 6 | Standard | 3 |
| | | Service | 3 | | |
| S&T Contribution | 18 | Industrial | 6 | For example, Tech.; Balance of Payments | |
| | | International | 6 | | |
| | | Societal | 6 | | |
| Societal Acceptance | 3 | | | For example, Public Understanding of Science | |
| Total | 103 | | | | |

Source: JST (1986)

The NSB was established by the US Congress to serve as a national science policy body, as well as to oversee and guide the activities of the NSF. It has dual responsibilities to: (1) provide independent national science policy advice to the USA President and the Congress; and (2) establish policies for the NSF. Though the report does not offer policy options and recommendations, it is used by different governmental and non-governmental entities to formulate their own policies and recommendations.

As the research system has grown and changed over the years, the Science & Engineering Indicators have evolved in style, content and presentation. The 1976 edition, reflecting a relatively emergent time in the measurement of science and technology for policy, contained chapters titled '*International Indicators of Science and Technology*', '*Resources for Research and Development*', '*Resources for Basic Research*', '*Industrial R&D and Innovation*', '*Science and Engineering Personnel*' and '*Public Attitudes toward Science and Technology*'. In contrast, the 2018 report (NSB 2018) contains eight chapters with the following titles:

1. Elementary and secondary mathematics and science education
2. Higher education in science and engineering
3. Science and engineering labour force
4. Research and development: US trends and international comparisons
5. Academic research and development
6. Industry, technology and the global marketplace
7. Science and technology: public attitudes and understanding
8. Invention, knowledge transfer and innovation

The main report is followed by a digest that summarises the report.

In the above context it is important to mention the OECD efforts in the field. The OECD series of methodological documents facilitated the international compatibility of national indicators. Currently most countries develop their own STI indicators in accordance with OECD standards (Netherlands Observatory of Science and Technology [NOWT], 2010; Secretariat of Science, Technology and Productive Innovation [SENCYT], 2006; Department of Industry, 2013). The methodological documents related to measuring STI by the OECD are listed below:

- The Measurement of Scientific and Technical Activities: Proposed Standard Practice for Surveys of Research and Development (*Frascati Manual*, 1962)
- Proposed Standard Practice for the Collection and Interpretation of Data on the Technological Balance of Payments (1990)
- Proposed Guidelines for Collecting and Interpreting Technological Innovation Data (*Oslo Manual*, 1992)
- Data on Patents and Their Utilisation as Science and Technology Indicators (1994)
- Manual on the Measurement of Human Resources in Science and Technology (*Canberra Manual*, 1995)
- Measuring Productivity (2001)
- Guide to Measuring the Information Society (2011).

It is interesting to discuss briefly the promotion of composite indicators by the European Commission (EC). The EC has led the promotion of the use of 'composite indicators'. It appears that the need to compare the performance of the various member countries was facilitated by the use of such indicators (EC 2003). Composite indicators refer to aggregation of different types of indicators into simpler constructs for the purpose of summarising complex multi-dimensional phenomena. It has been argued that: 'By aggregating a number of different variables, composite indicators are able to summarise the big picture in relation to a complex issue with many dimensions' (EC 2003: 43).

Recently a variety of composite indicators have been produced and publicised. Examples include the Global Innovation Index produced by Johnson Cornell University, the Institut Européen d'Administration des Affaires and the World Intellectual Property Office, the Innovation Union Scoreboard produced by the EC, the Abu Dhabi Innovation Index produced by the Department of Economic Development Abu Dhabi, and the Bloomberg Innovation Index produced by Bloomberg Limited Partnership LP and others.

There are also a number of indicators partially covering the innovation process (partial composite innovation indicators). Partial indicators have the advantage that they can focus on a particular component of the innovation system and provide in-depth understanding and coverage. Examples are the Global Talent Index produced by the Economist Intelligence Unit, the Composite Indicator for Knowledge Transfer produced by the expert group of the EC and the composite indicators of the Size of Knowledge-Based Economy produced by the Joint Research Centre of the EC.

International rankings of universities are also based on composite indicators. They took off in the 2000s although university rankings have a long history. The first proper university ranking ever, produced as early as 1910, was by the American psychologist James McKeen Cattell (Godin 2007; Hammarfelt, de Rijcke & Wouters 2017). Cattell used two concepts for his statistics: productivity, defined as the number of men of science a nation produces, and performance or merit, defined as scientific contributions to research as judged by peers. These are the two dimensions that still define measurement of scientific productivity today: quantity and quality.

The Academic Rankings of World Universities (ARWU), Shanghai (2003) and the Quacquarelli Symonds (QS) World University Rankings (2004–2008) were the first modern rankings to appear internationally. The Shanghai Rankings include the world's Top 500 universities. ARWU uses six indicators to rank world universities. These include the number of alumni and staff winning Nobel Prizes and Fields Medals, the number of highly cited researchers selected by Clarivate Analytics, the number of articles published in journals of Nature and Science, the number of articles indexed in the Science Citation Index – Expanded, and the Social Sciences Citation Index and per capita performance of a university. More than 1 200 universities are actually ranked by ARWU every year and the best 500 are published.

The QS World University Rankings evaluate more than 1 000 universities according to six metrics: academic reputation; employer reputation; faculty/student ratio; citations per faculty; international faculty ratio; and international student ratio.

Science, technology and innovation measurements in South Africa

The first measurement of S&T in South Africa is probably that of research and development expenditures. The first survey appears to have been undertaken in 1966 by the Council for Scientific and Industrial Research (CSIR). The survey was undertaken every two years up to 1989. The Department of National Education put the R&D Survey 1991/92 out to tender. The 1990/91 Survey was undertaken by the Foundation for Research Development¹ (FRD) (1991). During the rest of the 1990s, the R&D surveys were undertaken after tendering procedures by Science Consultancy Enterprises. The 2001/02 Survey was commissioned to the Human Sciences Research Council (HSRC). Blankley and Kahn (2005) describe the challenges of collecting relevant data.

In South Africa, the first scientometric study was produced in 1987 on contract for the FRD. The report by Pouris and Pouris (1987) addressed the question: Is research in the field of physics good and research

¹ Now the National Research Foundation (NRF)

in the field of plant sciences unsatisfactory in South Africa? At the time, a large-scale peer evaluation of researchers initiated by the FRD indicated that physicists in the country had higher evaluation ratings and plant scientists' lower evaluation ratings than those in other disciplines.

Based on the intuitive assumption that scientists are assessed according to their research activity and performance, the results of the FRD assessment led to the argument that physics research was stronger than plant sciences research in the country. The report utilised scientometrics in order to test that assertion. The indicators used included the South African contribution to world scientific literature in the particular disciplines, the country's rating according to publication output per discipline and the citations per paper for South Africa in the given fields in comparison to the world norms. The NSF's Science Literature Indicators Database, compiled by Computer Horizon Inc. Research, was used for the scientometric analysis. Contrary to the beliefs at the time, the report provided evidence that botany research was much stronger than physics in South Africa (see Pouris & Pouris 1987).

The word 'scientometric' also appeared in the FRD's structure during 1989 as the organisation established the 'Scientometric Advisory Service' in order to receive relevant science policy advice. A number of other researchers moved over time into the field of scientometrics (for example Ocholla & Onyancha 2005; Schubert & Sooryamoorthy 2010; Kahn 2011; and others). During 2014, the Department of Science and Innovation (DSI)² established the DSI-NRF Centre of Excellence in Scientometrics and STI Policy, recognising the importance of measuring STI for policy development.

Pouris (2003) estimated the social benefits of tax incentives for research and development and compared the relevant fiscal environment in South Africa with those of other countries. He planted the seed and years later the DSI introduced tax incentives for research and development in the country.

The first indicators reports were produced by the FRD (1991 and 1994) and appeared in South Africa in the 1990s. Subsequently, NACI undertook to produce booklets (NACI 2002) providing indicator statistics. During 2006, NACI published the report *Development of a Profile of Best Practices in the NSI*. The report, among others, included a section titled 'Best Practices in Monitoring S&T Systems – Science Indicator Systems' and it recommended that 'The NACI develop in regular intervals (for example, biennially) the South African Science and Innovation Indicators. The report should present quantitative descriptions of key aspects of the scope, quality and vitality of the country's science and innovation enterprise. The report should be submitted to Cabinet and Parliament and should be publicly available for public and private policy makers' (NACI 2006: 14).

During 2009, NACI published the South African Science and Technology Indicators 2009 which provided an overall picture of South Africa's national system of innovation by presenting statistical data relating to trends and performance. The South African Science and Technology Indicators 2017 (NACI 2017), among others, draws from the South Africa Composite Innovation Scorecard. The South Africa Composite Innovation Scorecard has been developed in order to monitor the performance of the NSI over time. It uses the same theoretical framework as the European Scoreboard. The scorecard has been developed in accordance with the international standards, ensuring that the normalisation process maintains comparability over time (Pouris 2013).

The South Africa Composite Innovation Scorecard distinguishes between three main types of indicators, that is, enablers, firm activities and outputs, and eight innovation dimensions, namely, human resources, open excellent research systems, finance and support; firm investments; linkages and entrepreneurship; intellectual assets; economic effects; and social effects. A total of 20 indicators (with

² Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

completed data) are used. The enablers capture the main drivers of innovation performance external to the firm and differentiate between three innovation dimensions, namely human resources; open, excellent and attractive research systems; and finance and support. Firm activities capture the innovation efforts at the level of the firm and differentiate between three innovation dimensions – firm investments, linkages and entrepreneurship, and intellectual assets. Outputs capture the effects of a firm’s innovation activities, i.e. economic effects and social effects. Figure 7.1 shows the measurement framework of the South Africa Composite Innovation Scorecard.

During 2014, the Summary Indicator had a value of 0.105, indicating an overall improvement during the 5-year period since 2010. The performance of the three pillars was as follows:

| | |
|-----------------|---------|
| Enablers | 0.13 |
| Firm Activities | - 0.104 |
| Outputs | 0.29 |

It is important to note that the performance of the pillar ‘Firm Activities’ was negative during the period. Similarly, the pillar ‘Outputs’ grew more than twice as fast as the pillar ‘Enablers’. It can be argued that there is a lag between the ‘Enabling’ indicators and the ‘Outputs’. The report suggests further research on the topic.

It is also important to notice that the European Scoreboard 2015 (European Union [EU] 2015) also identified a weak performance of the South African innovations system. The EU report states that ‘the innovation performance of South Africa is lagging behind that of the European Union (EU 2015: 43) and is slowly declining. Relative performance peaked at 18% of the EU level in 2008–2009 and then declined to 13% in 2014’. The two indicators together show that the South African innovation system

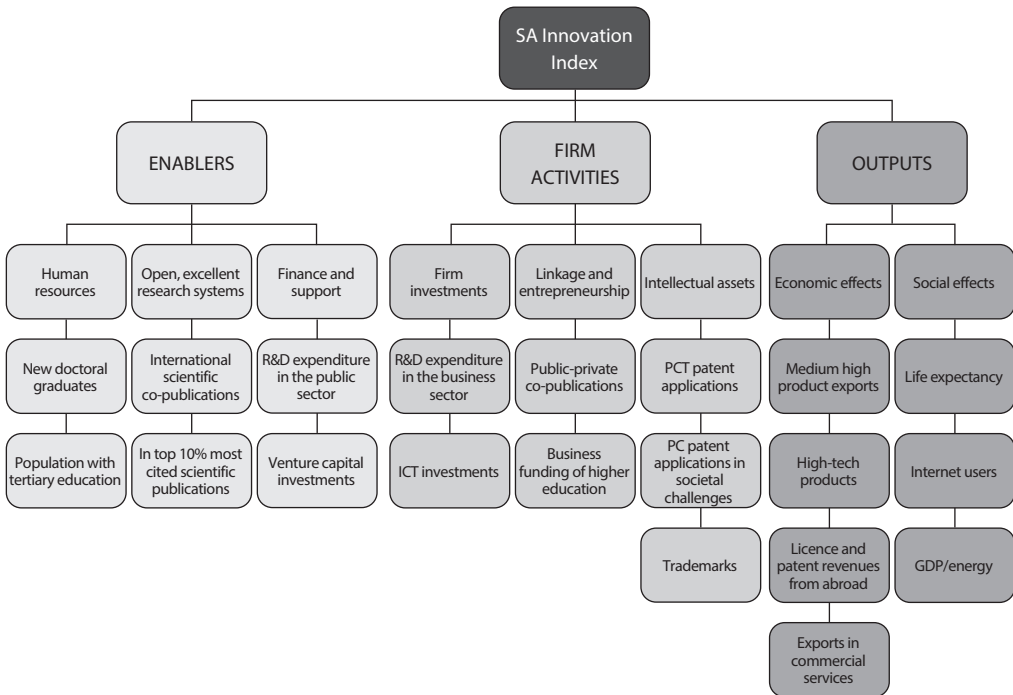


FIGURE 7.1: SA Innovation Index
Source: Adapted from Pouris (2013: 58)

is improving but is losing ground in comparison with the EU countries. A number of additional partial indicators can improve the current information available related to the national system of innovation. Furthermore, it has been suggested that the development of leading indicators can provide a warning to decision-makers about future states of the system and the development of appropriate actions.

Conclusion

This chapter aimed to provide a short description of the measurement activities related to science and technology in South Africa and of its evolution. It is interesting to note that the approach used in the country is one of institutionalisation. The establishment of NACI, CeSTII, and the DSI-NRF Centre of Excellence in Scientometrics and STI Policy aimed at maintaining a minimum level of expertise in the field of science and technology measurement and monitoring and providing the relevant stakeholders with advice.

It is interesting to discuss the possible effects of the used approach. While a proper assessment may be required, there are a number of examples indicating that the measurements of STI are used in the political environment and for the management of the national innovation system. The ratio of gross expenditures for research and development (GERD) to gross domestic product (GDP) has found recognition in the political arena in the country and a number of ministers set relevant targets (for example GERD/GDP equal 1.5%).

Similarly, having identified the weakness of the innovation side of the system, the DSI established the National Intellectual Property Management Office (NIPMO). NIPMO provides support (including financial support) to capacitate technology transfer and secure intellectual property rights to organisations using public funds for research. The above approaches are in accordance with international good practice and they can provide models to be followed in other African countries.

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Measuring National Innovation Performance: The Case of Austria

Hannes Androsch, Johannes Gadner and Jürgen Janger

Innovation performance has become increasingly important for governments as they search for ways to stimulate the economy and to address pressing societal challenges (Androsch & Gadner 2015). Thus, in recent years, a variety of innovation performance rankings have been applied to measure performance levels in relation to other countries. These are, thus, closely watched by policy makers and are frequently perceived as a neutral gauge of a country's innovation performance (Schibany & Streicher 2008). However, standard rankings such as the European Innovation Scoreboard (EIS) or the Global Innovation Index (GII) in general apply a standardised set of indicators to all countries ranked without regard of country-specific weaknesses or strengths. For example, the Austrian government has been using the benchmark defined by the EIS to compare the Austrian innovation performance in relation to leading countries in Europe. Yet, the EIS should not be regarded as the only way of assessing the effects of innovation efforts due to evident and well-known shortcomings (for example Edquist et al. 2018; Janger et al. 2017).¹

In this chapter, we sketch the framework applied by the Austrian Council for Research and Technology Development – the central advisory body of the Austrian Government for education, science, research and innovation policy affairs – for measuring and evaluating the performance of Austria's national innovation system in international comparison. The chapter aims to present an overview of the development of the framework in cooperation with the Austrian Institute of Economic Research and in accordance with the responsible ministries. The chapter also intends to describe its application in the context of the Council's annual reports on Austria's scientific and technological capability.

The applied measurement framework for innovation performance takes into account country-specific conditions and provides information on both the current distance to strategic benchmarks as well as information on the distance to the benchmark at a given time horizon, based on extrapolating past growth trends. A matrix composed of the juxtaposition of current and future distance to targets provides information to guide the setting of policy priorities, in terms of a measure of the effort required to reach targets (or the likelihood of reaching them). Using this approach, the Austrian Council has been providing a sound source of evidence for international comparison of Austria's innovation performance which supports evidence-based policy-making.

Note: A similar version of this chapter will also be published in the July 2020 issue of the *fteval* Journal for Research and Technology Policy Evaluation.

¹ For example, it underestimates the effects of innovation activities because it does not include indicators for improvement in the existing sectors, for example intra-sectoral structural change or sectoral upgrading; see also the more detailed explanations further below in this chapter. The EIS also aggregates input and output indicators, so that ample inputs can compensate for weak outputs.

Towards a framework to measure innovation performance

On 31 August 2009, the Austrian cabinet ministers agreed to set up an interdepartmental working group to devise a strategy for research, technology and innovation (RTI strategy). The aim was to define strategic goals and measures for Austrian RTI policy for the period up to 2020. The RTI strategy, with the title *Becoming an Innovation Leader*, was adopted in March 2011. In its title, the document reflects the priority goal to be reached by 2020.² The government has commissioned the Austrian Council for Research and Technology Development with the task of measuring the progress of the implementation of the strategy and monitoring Austria's performance in RTI compared to that of the leading countries in Europe and the world. Since then, the council has been drawing up a yearly *Report on Austria's Scientific and Technological Capability*,³ to present the main findings of its monitoring activities. The first report was presented in June 2012.

The reports apply a framework to measure innovation performance that relies upon a thorough analysis of the RTI system, strategic goals set by the government and standardised indicators to operationalise target achievement. Thus, in a first step, a detailed country-specific analysis of strengths and weaknesses of Austria's innovation performance was conducted, which was intended as groundwork for the subsequent definition of strategic goals compiled in a comprehensive RTI strategy. This multi-year process of discussions and analyses consisted of three pillars:

1. The *Austrian Research Dialogue*⁴ (2007–2008) (Ministry of Science and Research 2008) was designed to be a broad, nationwide process of discourse and consultations with Austrian stakeholders for the purpose of further developing the innovation system and our knowledge-based society.
2. The evaluation of Austrian research funding⁵ (Ministry of Transport, Technology and Innovation 2009) provided a profound assessment of the entire system, along with recommendations for improvement by experts.
3. The Council for Research and Technology Development (2009) discussed evidence-based strategic proposals and recommendations for further development of the Austrian research and innovation system.⁶

Based upon the results of these analytical processes, strategic goals for improving the Austrian innovation system were adopted in the aforementioned RTI strategy. In a next step, a set of crucial performance areas to be monitored by indicators had to be defined. Basically, the size of this set could be unlimited, but an analysis focusing on weaknesses or bottlenecks would address only a restricted number of specific performance areas. Then target values were set for each performance area. Some of

2 Austrian Federal Government (2011): *Becoming an Innovation Leader*. Strategy for research, technology and innovation. Vienna, MEV-Verlag publishers. The priority goal of the strategy to become an Innovation Leader by 2020 is informed by the European Innovation Scoreboard (EIS). As a Strong Innovator, Austria currently ranks among the top 10 member states of the European Union. Austria's score amounted to 120 points according to EIS 2018, while the group of Innovation Leaders reached an average score of 135. For details see https://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

3 All reports can be downloaded from <https://www.rat-fte.at/performance-reports.html>

4 The Research Dialogue was initiated by the Ministry of Science and Research. A synopsis (in German) can be downloaded here: <https://bmbwf.gv.at/forschung/national/standortpolitik-fuer-wissenschaft-forschung/oesterreichischer-forschungsdialog/>

5 The 'Evaluation of Government Funding in RTDI from a Systems Perspective in Austria' was commissioned by the Ministry of Transport, Technology and Innovation. The Synthesis Report (in English) can be downloaded here: https://www.bmvit.gv.at/service/publikationen/innovation/forschungspolitik/downloads/systemevaluierung/synthesis_report.pdf

6 The *Strategy 2020* was elaborated by the Austrian Council with the support of a Web-based discussion platform in order to deepen and intensify the process through virtual interaction with all relevant stakeholders and the RTI community. For the community-based innovation approach for strategy development see Gadner & Leo (2010). The *Strategy 2020* (in English) can be downloaded here: <https://www.rat-fte.at/strategy-2020.html>

them were derived directly from the RTI strategy, for example, the goal to reach a research and development (R&D) quota of 3.76% by 2020. Others were constructed from the average values of the group of Innovation Leaders (according to the EIS at which the RTI strategy is oriented).⁷ In fact, any target value can be used; while an absolute value will be static, the average of a number of freely chosen peer countries will be dynamic in the sense that the target value changes according to the performance of the peer countries. This is similar to standardised rankings, with the exception that for our tailor-made approach, peer countries can be chosen freely, presumably from a set of countries whose structures and performances are not too different from the country to be monitored.

Once performance areas and target values were set, appropriate indicators had to be selected, in terms of relevance and reliability, but also data availability. For the purpose of measuring Austria's innovation performance, a set of 75 indicators were developed in cooperation with the Austrian Institute of Economic Research and discussed with the responsible ministries.⁸ The selected indicators are based on internationally used classifications of the OECD, Eurostat and others, and corresponding data portfolios. These are accessible to the public and are collected on a regular basis on a national as well as on an international level.⁹ Every indicator corresponds to a strategic target of the RTI strategy to operationalise goal achievement.¹⁰

For the development of the set, it was important to focus on indicators suitable for better representing the conditions of the Austrian RTI system than, for example, those used by the EIS or other standardised rankings. This was deemed to be important by the Council since the EIS strongly focuses on inter-sectoral structural change and captures the economic effects of innovation mainly by the growth of high-tech sectors; in contrast to this, the EIS underestimates effects of innovation activities on medium-tech-sectors, as intra-sectoral upgrading – improving innovation within a sector, rather than growing the share of innovation-intensive sectors – is seldom captured (Janger et al. 2017).

In fact, the EIS does not show sensible indicators for improvement across all existing sectors, for example intra-sectoral structural change or sectoral upgrading in less R&D-intensive sectors such as steel or automobile parts. Austria performs very well in less R&D-intensive sectors, which is why a picture that does not take this aspect into account is somewhat incomplete. Moreover, the respective EIS indicators are based on the *Community Innovation Survey* (CIS).¹¹ As the CIS indicators are very volatile, their

7 The term Innovation Leader refers to those EU countries in the top group in the annual *European Innovation Scoreboard* (EIS) of the European Commission. Today, the group comprises Denmark, Germany, Finland, Luxembourg, the Netherlands and Sweden. For the calculations, the 'innovation leaders' actual value' is used for every performance area.

8 It must be mentioned that the processes of country analysis, target-setting and indicator choice enable collective learning and discussion processes at the national level, something which is completely absent from standardised innovation rankings but fosters the legitimacy of S&T indicators (Barré 2010). In our case, six ministries were involved in the process: the Federal Chancellery (BKA), the Ministry of Finance (BMF), the Ministry of Education, Art and Culture (BMUKK), the Ministry of Transport, Innovation and Technology (BMVIT), the Ministry of Science and Research (BMWF) and the Ministry of Economic Affairs, Family and Youth (BMWFJ).

9 A detailed explanation of the indicators (including the strategic goals which they operationalise) as well as the underlying data and the calculations can be found in the Appendices of every *Report on Austria's Scientific and Technological Capability*.

10 It has to be noted that quantitative indicators cannot display all the objectives of the RTI strategy. This particularly applies to the performance area of governance structures of the RTI system. Thus, the indicator-based analysis has always been complemented with a qualitative evaluation of implemented measures and goal achievement.

11 The *Community Innovation Survey* (CIS) is a survey of innovation activity in enterprises. It is carried out with two years' frequency by EU member states and a number of ESS member countries. Although it is designed to provide information on the innovativeness of sectors by type of enterprises, on the different types of innovation and on various aspects of the development of an innovation, such as the objectives, the sources of information, the public funding, the innovation expenditures, etc., the compiling of the data is voluntary for the countries. This therefore means that in different surveys or years different countries are involved. For details see <https://ec.europa.eu/eurostat/web/microdata/community-innovation-survey>

explanatory power is limited. Statistically, more stable indicators, for example the export quality in technology-oriented sectors or R&D intensity adjusted for the structural composition of an economy, demonstrate only a relatively low shortfall compared to the leading innovation countries (for details see Austrian Council for Research and Technology Development 2014: 10ff). Consequently, the indicators used within the framework adopted by the Austrian Council rely on more suitable indicators representing the country-specific characteristics. This does not prevent international comparison as these indicators are also available for other countries and in fact, the whole framework rests on international comparison with leading countries.

Visualising innovation performance

The applied framework focuses on the degree to which the goals set out in the strategy have been achieved (static component, current distance to the goal) and on the degree to which the goals may be achieved in the future (dynamic component, probability of achieving the goal). While the current distance to the target simply reflects Austria's current performance relative to the target value (either as set by the RTI strategy or as the average level of the Innovation Leaders), the probability of achieving the goal extrapolates past growth trends to indicate where Austria's performance might be by the time horizon 2020. This can be graphically displayed as the example in Figure 8.1 shows. Figure 8.1 provides a comprehensive overview of the performance within the analysed areas of the RTI system in relation to the selected peer countries. The goal distance on the horizontal axis in Figure 8.1 illustrates the current Austrian value and the distance to the respective target. It shows the ratio and the distance of the last available Austrian value to the national set target according to the RTI strategy and the *European Education and Training 2020 Strategy* (Council of the European Union 2009).¹² If there is no national goal, the target is constructed out of the last available average value of the current Innovation Leaders according to EIS. This is because catching up with the group of Innovation Leaders is a priority goal for Austria, as established in the RTI strategy.

The distance to the goal exhibits Austria's current performance level and reveals some information on the difference between where Austria is compared to the goal, but it says nothing about the changes or dynamics that are required for the goal to be achieved. Thus, an indicator which currently lies just below the target level could therefore deteriorate again due to a negative dynamic. To put it another way, the exclusive comparison of the goal distances does not allow any conclusions on the prospect of goal achievement. For this reason, the probability of reaching the target on the vertical axis was selected as the second dimension. It shows whether or not the past growth of the indicator is sufficient for goal achievement. It indicates the ratio of the average annual growth rate of the respective data series in the past and the projected value for Austria in 2020 to the target value for 2020 (under a business-as-usual assumption). As a target value for the calculation of growth (if no national goal is set) the projected value for 2020 will be used and not the actual value of the Innovation Leaders. This, in turn, is determined on the basis of the average growth rates of the comparison countries in the past.

¹² Following the suggestion of the Federal Ministry of Education, Arts and Culture at the time, target values of the *European Education and Training 2020 Strategy* have been used for some indicators operationalising targets within the education system.

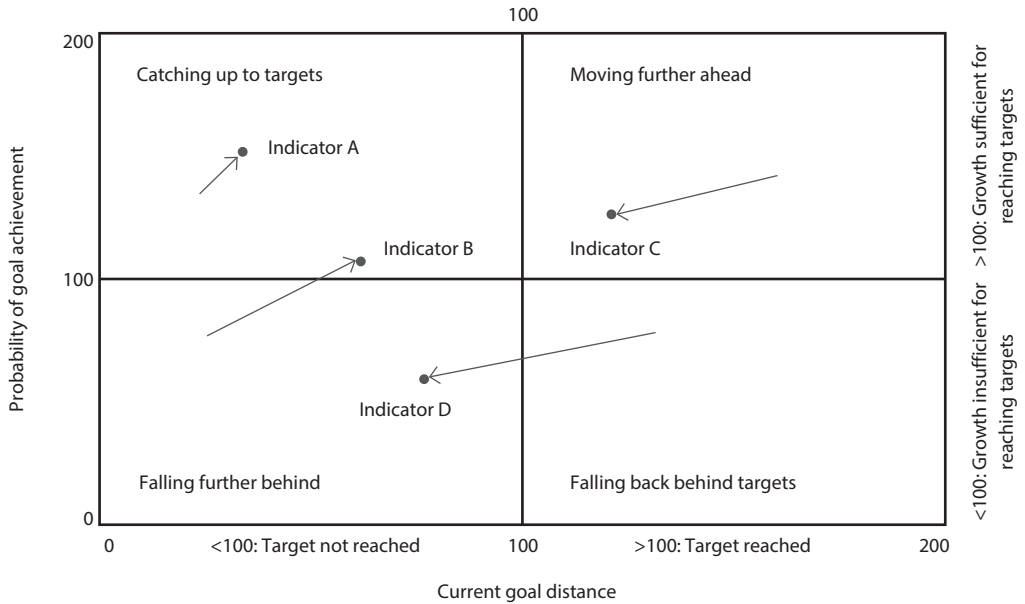


FIGURE 8.1: *Visualising innovation performance: Outcomes over time based on the combinations of current and future goal distance*

Source: Austrian Council for Research and Technology Development (2018: 103)

All indicators can be interpreted in the same direction, that is, values above 100 signal goal achievement; values below 100 a corresponding distance to the goal. Indicators with a probability of reaching the goal below 100 – below the horizontal line at 100 – are based on past growth trends that are unlikely to reach the target by the end of the time horizon; indicators with a value above 100 – above the horizontal line – are likely to reach the target value. The standardisation of the values is achieved as follows: the Austrian value is divided by the respective target value and multiplied by 100. If performance improvements are accompanied by a decline in the indicator values, such as with the unemployment rate, for example, the values would be inverted (that is, target value in the numerator, Austrian value in the denominator), in order to retain the interpretation of ‘greater equal to 100 = goal achievement’. Values above 200 are limited in the figures to 200.

If an indicator is located in one of the two quadrants on the left side, this means that Austria has not yet achieved the set goal. For indicators in the bottom left corner, this will most probably also remain unchanged. Hence, due to the weak growth rate in these performance areas, Austria will not achieve the goal by 2020. Consequently, without additional measures, the Innovation Leaders are very likely to remain out of reach. Measures that are suitable to increase performance in these areas should therefore be handled as a special priority. Indicators in the top left area are catching up, which could result in achieving the goal by 2020, as the Austrian development dynamic is greater than that of the comparison countries. In these performance areas, no further measures would be required, always assuming that trends continue as in the past.

Indicators located in the two right-hand quadrants show that the corresponding goals have already been achieved. Indicators in the top right corner signify that Austria has achieved the goal and, in all likelihood, will also remain ahead until 2020 due to the high growth rates, provided the growth of the

comparison countries remains within the expected range. Thus, there is currently no need for further action. For indicators in the quadrant on the bottom right, Austria's growth is insufficient to maintain its edge ahead of the Innovation Leaders in the long term. Accordingly, the development should be observed very closely here, either to counteract or adjust the indicators in good time where required.

Illustrating the use of the framework with a practical example

To illustrate how the sketched framework is used in practice, an example from the *Report on Austria's Scientific and Technological Capability 2015* is presented below.¹³ Figure 8.2 shows the indicator-based results of the described approach for the area of research and innovation in the corporate sector for the current distance to the target and the probability of reaching the target. The tail of each indicator depicts the past development from 2010 until 2015.

At a glance, the figure reveals the developments of both the current distance to the goal and the probability of reaching the goal by 2020 in the performance area of research and innovation in the corporate sector within the Austrian RTI system. It becomes clear that in 2015 there was still considerable potential to optimise performance and increase efficiency in the corporate sector. While the six green indicators in the right upper quadrant had indeed already reached their target or the level of Innovation Leaders, the majority of indicators continued to be within the bottom left quadrant, indicating a performance below the average level of comparison countries and were expected to fall

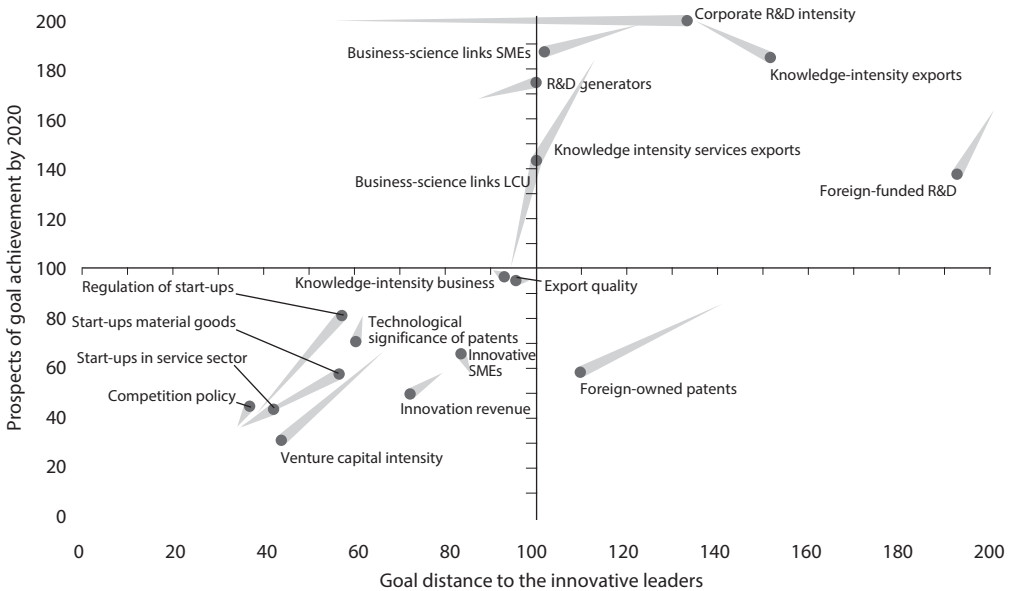


FIGURE 8.2: *Development of distance to targets and probability to reach the target in the area of research and innovation in the corporate sector, 2010–2015*

Source: Austrian Council for Research and Technology Development (2015: 47)

¹³ This figure has been chosen as an example because it contains indicators in all four quadrants.

further behind. Judging by the current trends, and with no additional measures taken, the indicator in the bottom right corner will deteriorate and fall below the target level by 2020. The yellow coloured indicators in the top right quadrant display dynamic developments and will most likely continue catching up and reach the target level by the year 2020.

In sum, the performance area of research and innovation in the corporate sector at the given time had the third smallest goal distance of the six areas analysed and the highest probability of achieving the goal. Overall, goal distance was deemed to be within reach by 2020 – providing the trends continued to develop as they had in the past. However, many indicators, such as ‘Competition policy’ or ‘Venture capital intensity’, were well below the target level and displayed insufficient or retrogressive dynamics to catch up with the group of leading countries. Furthermore, performance in key sub-areas, such as start-up dynamics and growth of innovation-intensive early-stage businesses, remained extremely weak in comparison to the Innovation Leaders. Based on this picture, the relevant fields of action were addressed in the Council’s report – including concrete policy recommendations for improving Austria’s innovation performance within the specific areas.

It is important to mention that the Council of Ministers commissioned the Council for Research and Technology Development to provide the annual *Reports on Austria’s Scientific and Technological Capability* in order to send them to the Austrian Parliament. There they are debated in the parliamentary committee on RTI. They are also presented publicly and published on the Council’s website. With this approach, it was intended to put the political and public debate of education, science, research and innovation policy affairs on a sound evidence-based footing.

It would be straightforward to adapt this measurement framework to other countries, although it requires more work than using standard indicators as outlined above. First, goals have to be set, possibly within a strategy-building exercise which requires an analysis of the strengths and weaknesses of a country. Once goals are set, suitable indicators can be drawn from available sources, such as OECD data; when no ready-made indicators exist, new indicators would have to be built, which needs more effort. Once goals and indicators are in place, progress over time can be monitored, assessing the impact of any policies implemented to reach the goals.

Concluding remarks

As we have demonstrated, the outlined framework for measuring innovation performance not only refers to Austria’s country-specific conditions but also facilitates a dynamic view of past and future developments. While standard rankings merely give a static snapshot of one performance point in time, the presented approach makes it possible to show where the current dynamics of innovation performance may lead to in future. Growth trends of single indicators may be positive or negative so that a yearly snapshot on its own is of little use to policy makers. Different policy priorities are needed to address the performance of areas where a country lags behind but can catch up quickly compared to those where a country lags behind with an indication that it will continue to do so. In the first case, no further action is needed; in the second, alarm bells should be ringing.

The limitations of the proposed framework for policy makers are that the framework needs to be custom-made for national content and it requires more resources, first for the analysis of national performance and then for national target-setting or strategy-building. Like a tailor-made suit, the framework fits better but is more expensive and time-consuming. The benefits of appropriately reflecting country strengths and weaknesses may however outweigh the costs of not only relying on standardised indicator frameworks. Moreover, common to all indicator-based measurement

frameworks, it is a quantitative framework, meaning that international benchmarking relies on available data for indicator-building. Country-specific challenges lacking internationally comparable data can only be addressed in a qualitative way.

For the Austrian Council, the described framework and the indicator-based measurement of innovation performance has been a basis from which to draw conclusions about Austria's scientific and technological capability in relation to leading innovation nations. With this evidence-based analysis of strength and weaknesses of the Austrian RTI system, the most urgent fields of action were identified and dealt with in the Council's annual reports and policy recommendations. Additionally, the Council uses the described approach for the strategic monitoring of the realisation of the Federal Government's RTI strategy as well as the assessment of efficiency and effectiveness of the implemented measures. A similar approach by other advisory boards or policy makers is strongly recommended.

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The Impact of Swedish Innovation Policies on Firm Growth: Some Insights from Evaluations

Enrico Deiacò

In this chapter we survey and discuss experiences drawn from a series of Swedish subsidy programmes on innovation and growth, targeting small and medium-sized firms. Two measures applied to stimulate innovation and growth are direct research, development and innovation subsidies (RD&I) through grants and indirect government support through tax incentives. The focus here is on the former.

Sweden is of particular interest since it is somewhat of an outlier among Organisation for Economic Co-operation and Development (OECD) countries with a high focus on direct government funding (OECD 2015), and the numbers are significant. In 2011, 3.1% of the Swedish government budget (Swedish Kroner [SEK] 27bn) was allocated to various forms of direct policies targeting trade and industry (Tillväxtanalys 2015). The amount going to support for entrepreneurship and innovation was around 11 billion SEK.¹ These measures include policies targeting innovation and growth, network building, various forms of collaboration, employment and investment subsidies and a set of regional support and innovation programmes.²

In many countries, the importance of innovation as a key driver of economic growth is a top priority on the political agenda. However, existing empirical evidence suggests that there is no guarantee for a subsidy programme to generate growth and jobs; sometimes a positive result is found, but insignificant and negative growth effects are also found (Deiacò & Tingvall 2017). The mixed evidence suggests that learning from past experiences can be important for improved programme design, which gives impact evaluations a central role.

While there are good arguments both for and against the use of direct (selective) policies, the question of how to make existing research, development and innovation (RD&I) programmes efficient remains an open question. There is no consensus regarding how best to design the subsidy programme and how to target those firms with strong innovative potential (Tillväxtanalys 2015; Veugelers 2016).

However, the situation may be improving. Increased access to detailed micro data and the capacity of analysis has improved considerably. The development of large register-based databases, such as the Swedish MISS database administered by The Swedish Agency for Growth Policy Analysis (Growth Analysis), with detailed information on different support programmes, therefore becomes instrumental as a tool for increasing our knowledge about the scale of the impact of various programmes.

¹ 10 SEK was equivalent to about 1.04 Euro (June 2019).

² Sweden, Finland, Germany and Denmark have a larger share of funding than other EU member states directed at collaborative research and development (R&D) programmes.

When evaluating a policy intervention, the question to ask is: what would have been the outcome for the treated firms/individuals if they had not been treated? Another way to frame this question is to seek the counterfactual outcome. The first thing to consider is what causal effects and counterfactual evaluations really are. This may seem a trivial task, but both 'impact' and 'evaluations' are terms that are used in a wide range of contexts and have tended to become semantic magnets with different meanings depending on who the sender of the message is. In other words, to identify an impact or an effect caused by an intervention, it is insufficient to simply detect a change; the change must also be shown to stem from the actual measure. This is difficult because there may be many other circumstances and factors that contribute to the change.

The purpose of this chapter is to give a broad overview of the measured impact of various programmes in Sweden. There are plenty of studies looking at the impact of subsidies for private investment in research and development (R&D) (Hall 2019), but there are few analysing the impact on growth and jobs in companies since, ultimately, the extra injection of R&D and innovation needs to translate into social welfare, growth and jobs in companies and in the aggregate.

We start with a short overview of some key features of the Swedish innovation system. Then we describe the data used for impact evaluation in Sweden followed by a presentation of results from the evaluation of various support programmes. These include an analysis of government bank loans to credit-constrained small and medium-sized enterprises (SMEs); an innovation support programme for SMEs; the impact of a national incubator funding programme on the growth and innovation of incubated companies; and the impact on growth for SMEs in participating in a programme advancing collaboration between business, public activities and universities. We end with a summary of the main findings across these different types of programmes.

Innovation policy and evaluation in Sweden

In the 1970s, the focus of state support was rescuing companies in the crisis-ridden Swedish steel and shipbuilding industries.³ The aim was to decrease negative effects on employment and to bridge crises. During the 1980s, this rescue-driven trend lost ground, and the new direction was to rely on the market and reduce governmental influence. When Sweden joined the European Union (EU) in 1995, regional support schemes again became the focus. During the 2000s, the direction of support changed again and focused on selective RD&I programmes for innovation and growth. The idea was to stimulate collaboration between the business and academic communities. The Swedish Innovation Agency, Vinnova, was then established in 2001 to formulate various programmes for stimulating R&D, innovation and growth.

The current forms of Swedish business and innovation policy measures have emerged from the idea that a well-functioning innovation system is needed to promote innovation and growth. Figure 9.1 shows the most important public stakeholders in the Swedish innovation system and identifies four different levels of activity: 1) Government and Parliament; 2) Government agencies that finance research and innovation; 3) Universities and higher education institutions; and 4) Stakeholders that help to commercialise new knowledge by supporting business development and the funding of new enterprises. Thus, a complex national innovation system has emerged with many actors and various selective programmes at each level.

The route to the current policy focus has been anything but linear. Business support is viewed as something to avoid during some periods, only to be followed by other periods, during which attitudes to selective policies have been positive.

3 This section is drawn from Tillväxtanalys (2015), especially Chapter 3 and Chapter 4.

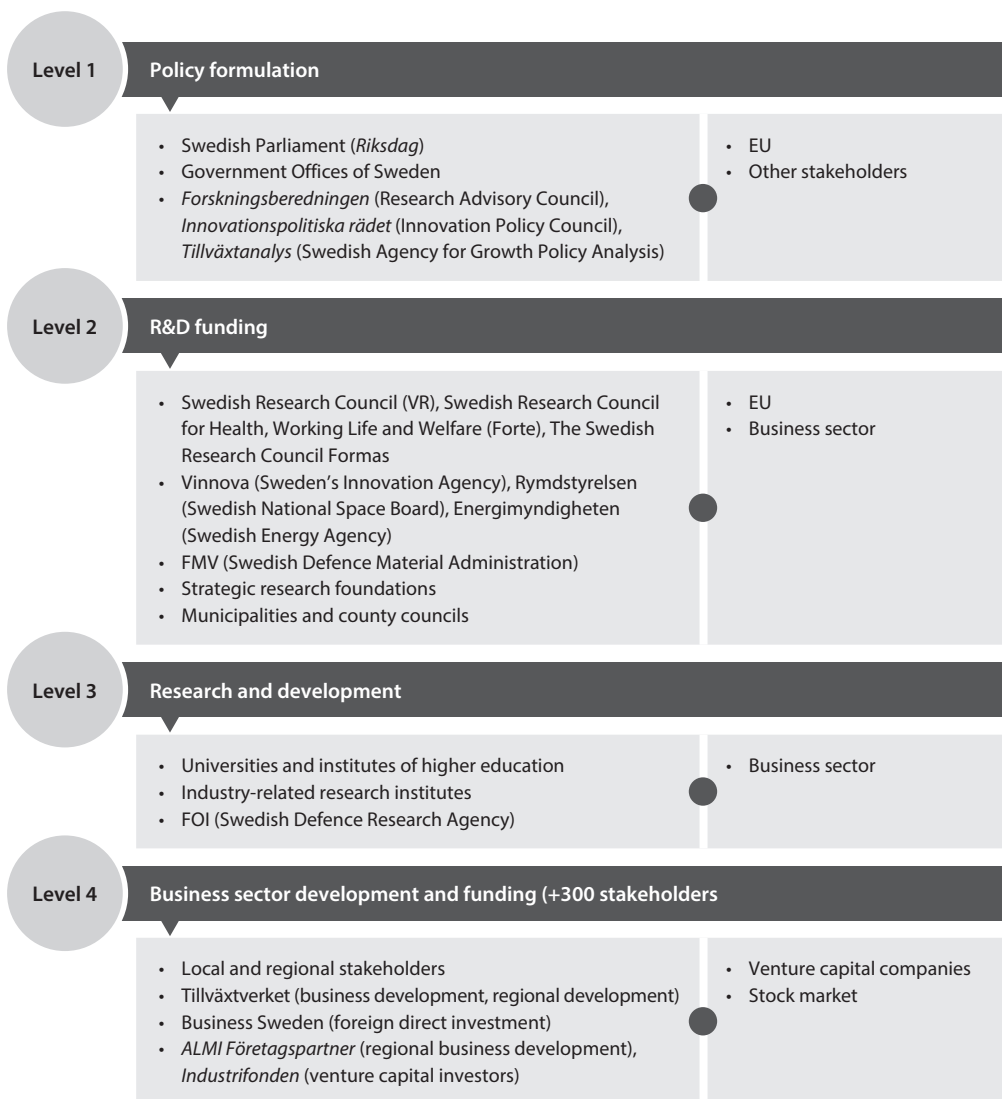


FIGURE 9.1: *The Swedish innovation system*

Source: Tillväxtanalys (2015: 24)

The importance of good data for evaluation

A common observation in the international literature on the evaluation of direct innovation support schemes is that there is a lack of (relevant and quality) data (Deiaco & Tingvall 2017).⁴ Critical views on data include the risk of arbitrariness in reported figures, a lack of relevant information, insufficient coverage and aggregated data. But improved access to detailed firm-level data and new methods have made impact studies considerably more precise and more useful than in the past, improving the

⁴ This section is drawn from Tillväxtanalys (2015), especially Chapter 6.

possibility of achieving new knowledge from evaluation studies. To estimate the causal effect, information is needed, for instance on which businesses receive support, what types of support they receive and the amount of money involved. In addition, it must be possible to link this information with other information about the specific firms. Until recently, this information was not available in Sweden, making it difficult to conduct extensive studies of the effects of support schemes.

To rectify this deficiency, since 2012, the Swedish Agency for Growth Policy Analysis has gathered data on the MISS database, which contains information of various types of state support to trade and industry (dating further back than 2012). The database includes information on business support that has been paid out by four large government agencies: the Swedish Innovation Agency (Vinnova), the Swedish Agency for Economic and Regional Growth, the Swedish Energy Agency and Almi.

To the best of our knowledge, this type of centrally-collected micro data is relatively rare from an international perspective (albeit that similar databases exist in Norway, Denmark and Finland). For example, with information on a series of programmes not only can one analyse individual support measures but one can also study the assisted entrepreneurs and potential synergy effects between various forms of support. In addition, the Agency for Growth Policy Analysis has linked data on support measures to other company-specific information, and firm inputs and outputs such as sales, exports, imports and investments results. The latter data includes all firms in the economy which allows well-defined control groups to be designed. Information on individuals' ages, education, earnings, locations and family status is also incorporated. The broad trends are determined from surveys conducted in terms of the Official Statistics Act.

Evaluation methods

The stated objectives of the relevant programme description are the point of departure for a counterfactual evaluation. In general, this might be difficult as government often has vague and multiple goals, which might well be mutually exclusive. This problem could be somewhat alleviated in the Swedish case as the government issues a briefing note on the overarching purpose of a particular programme. For example, in the appropriation to the Vinnova for the year 2013 it is explicitly stated that the agency is to report changes in turnover, number of employees and value added for the companies which the agency supports, all of which are figures readily collected and reported to the tax authority by all Swedish firms.

The various studies presented here all rely on designing a counterfactual analysis. The counterfactual state can be seen as an ideal state – and so it is. The approach has been to create a control group that is as similar as possible to those that participated in the programme, namely the treatment group. Once a control group is created, the outcomes for employment, productivity and profit, for example, are compared for the two groups. Next, any differences are interpreted as an effect of the programme. This approach also implies that the impact of a programme can be attributed to observable characteristics that we use as matching variables (see Blackwell et al. 2009; Iacus, King & Porro 2011, 2012).

There are two popular methods of creating control groups: propensity score matching and coarsened exact matching (CEM). Regardless of the choice of method, limitations of the data at hand are an issue that in many cases hinders sophisticated studies from being performed. As indicated below, this has to some extent been alleviated in Sweden in recent years.

The impact of public bank loans on SMEs

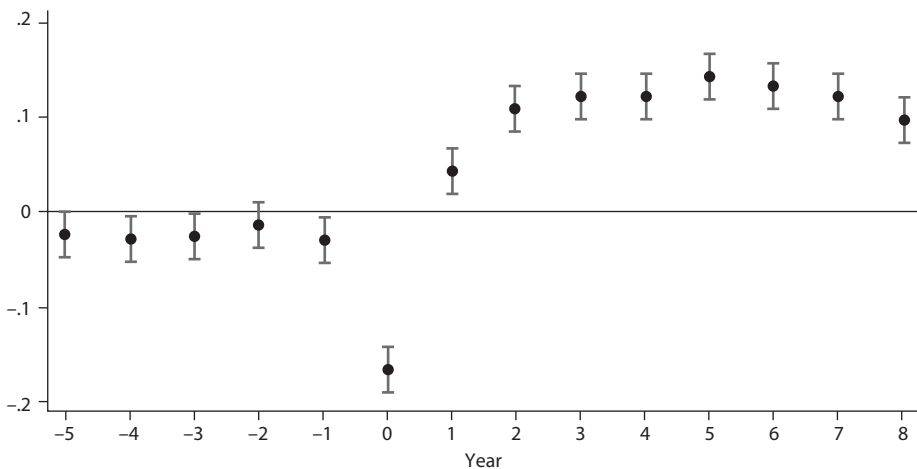
Credit constraints for SMEs are obstacles to economic growth due to incomplete capital markets and motivating government interventions.⁵ In Sweden, Almi, a wholly state-owned company, provides government bank loans targeting credit-constrained SMEs through 16 regional subsidiaries responsible for loans and counselling. The loan fund was valued at 5 482 million SEK in 2018. It approved loans for around 4 400 companies in 2015 and about 700 000 SEK on average, per firm. Almi offers a variety of loans but mostly for innovation and growth to SMEs with fewer than 250 employees that have problems obtaining financing on the market. Thus, they provide financing with a higher risk profile than private lenders. Due to higher risk, they charge an interest rate that is above the market average.

Using data on loans, and complemented with micro and register data, the report shows how these loans impact the targeted firms. The sample is not random since firms self-select lending. No data exists on firms that apply for loans that are rejected. The CEM-method is used in order to reduce selection bias. Difference-in-difference regressions estimate the effects on net sales, gross investment, labour productivity and number of employees. The pre-treatment period is five years and the post-treatment period, where data is available, is eight years.

Results

The results indicate that firms with low productivity and large amounts of debt choose expensive Almi loans along with commercial loans. The impacts of the loans are positive but modest, increasing sales and productivity for firms with 10 or fewer employees while no evidence is found of employment effects.

Figure 9.2 illustrates the treatment effect for sales and how it has evolved over time. The timing is normalised so that the loan is received by the firm in year 0, and the pre-treatment is coded -1, -2 and so on. Post-treatment is coded as 1, 2 and so on.



Notes: Regression results based on many-to-one matching fixed effects regressions. The firms receive their loans in Year 0. Points show regression results with 95% confidence intervals.

FIGURE 9.2: Effects on sales of Almi loan

Source: Gustafsson (2018: 02)

⁵ The section draws on Gustafsson (2018).

The modest but positive results for sales and productivity seem reasonable since SMEs are more credit-constrained than other firms. It could also be caused by the fact that small firms grow, in percentage terms, faster than larger firms. New firms can increase their sales by several hundred per cent per year, which is not as frequent for more mature firms.

The lack of an increase in the number of individuals employed is surprising, since increasing the number of employees in the targeted firms is one of Almi's explicit goals. There are several possible explanations for the observed lack of growth in employee numbers. Firms may lack a desire to grow, which requires the firm owner to become a manager. There may be a lack of individuals with the correct skills to hire, making it difficult to find a good match. Sweden's strict labour protection laws may make firms reluctant to hire.

The lack of positive results may also be due to inefficient targeting of Almi funds to credit-constrained firms with good projects, either due to self-selection or for some other reason. New research has indicated the importance of programme design (Veugelers 2018). Finding firms with valuable ideas is difficult because it is difficult to evaluate projects.

Innovation subsidies to small and medium-sized enterprises

Researchers and policy makers have argued that industrial policy should focus more on stimulating innovation and growth in small and medium-sized enterprises (SMEs).⁶ However, few studies in Sweden have evaluated whether direct firm support is effective due to limited availability of data on firm support. Here the effects of two government support schemes that target innovative SMEs in Sweden were analysed. Both programmes were developed and administered by Vinnova.

The two programmes distribute grants to selected small and medium-sized firms to support innovation and growth. The process by which firms are accepted into the programmes is complex and includes selection of both the firms that apply for grants in the first place and those that are eventually selected by the government agency.

The purpose of the VINN NU programme is to increase survival rates among young, innovative companies in order for them to commercialise their products and attract external capital. To be eligible for the programme, the company must have a finished product or service that is not yet on the market. There were 1 309 applicants between 2002 and 2011, and of these 125 were ultimately granted subsidies.

The purpose of the second programme, Forska&Väx, is to support innovation-driven growth. In order to receive support, the company must finance 50% of the R&D costs and develop new or improve existing products that would help the company grow. The maximum size of the subsidy is 5 million SEK (approx. 500 000 Euro) and the company must not be too small (above 1 million SEK in sales or equity) and below 250 employees.

While VINN NU targets small start-ups, Forska&Väx is focused on traditional SMEs. The difference in size between the two programmes is emphasised by their total budget. The total amount of funds paid out in the relatively small VINN NU programme was about 36 million SEK, whereas the total amount paid out by Forska&Väx was about 490 million SEK.

⁶ The section draws on the studies of Edling et al. (2007) and Gustafsson et al. (2016).

This report used the micro database compiled by the Swedish Agency for Growth Policy Analysis. The information from the database is used to match firms that received support from Vinnova against similar firms that did not receive support. Similar firms (twin firms) were identified using CEM. The post-treatment effect is analysed 4–5 years after the injection of the subsidy.

Results

The impact analysis is based on the number of employees, labour productivity, sales, sales growth, and the share of workers with higher education or research positions. The results of the regressions are summarised in Table 9.1 to indicate the significance and size of elasticities.

Overall, the analysis does not indicate any statistically significant effects of the support programmes during the period studied in terms of the number of employees, labour productivity, the share of highly skilled workers or the proportion of researchers in the firm. The only positive effect is limited to firms with at most six employees that, after the support programmes ended, increased sales by 20% compared to similar firms that did not receive any support. For larger firms, no positive and statistically significant effect is found. To be precise, with regard to employment effects, there is no evidence of positive effects. The estimated coefficient actually points to a negative relationship between employment and innovation grants, although we observe a small increase in the demand for post-graduate employees after receiving the grant. The estimate of the post-treatment effect on employment is positive, yet insignificant. Moreover, when comparing the impact of the subsidy on the recipient companies themselves, we actually see a negative estimate of the post-treatment dummy. Hence, the overall impression when it comes to employment effects is more on the negative side than on the positive side.

TABLE 9.1 *The impact of participation in any selective support programme on firms' competitiveness*

| | <i>Log labour costs per employee</i> | <i>Log gross investments</i> | <i>Log value added per labour</i> | <i>Log gross operating surplus</i> |
|-----------------------------------|--|------------------------------|---------------------------------------|--|
| Treatment effect | 0.017*** (0.0064) | 0.22*** (0.022) | 0.0076 (0.0063) | -0.017*** (0.0060) |
| Post-treatment dummy | 0.0042 (0.0058) | -0.082*** (0.019) | 0.019*** (0.0058) | 0.0026 (0.0051) |
| Share of high-skill labour | 0.014*** (0.0040) | 0.0083*** (0.0031) | 0.014*** (0.0038) | -0.0036*** (0.0012) |
| Log sales per employee | 0.28*** (0.0054) | | | |
| Log capital stock per employee | 0.028*** (0.0033) | 0.85*** (0.016) | 0.34*** (0.0034) | 0.17*** (0.0023) |
| Log employees | | 0.16*** (0.016) | | |
| Log sales | | -0.058*** (0.011) | | |
| Constant | 2.60*** (0.11) | -1.25* (0.70) | 3.73*** (0.10) | -1.04*** (0.14) |
| Observations | 1 517 379 | 1 077 132 | 1 494 407 | 1 469 326 |
| Adjusted R2 | 0.119 | 0.095 | 0.151 | 0.061 |

Note: *, **, *** respectively denote significance at the 10%, 5% and 1% levels. Period dummies and industry controls are included. Cluster robust standard errors (firm level) are in parentheses.

Source: Deiaci & Tingvall (2017: 17)

The data allowed us also to identify which companies were selected. It is shown that innovation potential appears to increase the probability of receiving subsidies. There is no evidence of fast-growing companies enjoying a higher probability of being selected. It is also found that companies with lower profit margins more often tend to be selected for programmes. This might be because such companies may find it more difficult to raise capital elsewhere.

Do business incubators enhance entrepreneurial growth?

Science parks, incubators and accelerators are established with the hope of stimulating new firm formation.⁷ The rationale behind this is the existence of 'liability of newness' which means that the new technology-based firms have a challenge in convincing markets to take on their firm's products. Incubators are established to shelter such firms from the immediate pressures to enter the market by providing coaching, management and legal advice. In 2015, around 7 000 incubators existed worldwide (Mian, Lamine & Fayolle 2016).

Sweden established its first incubators in the 1990s. The Swedish National Incubator Programme (NIP) took off in the early 2000s due to the launch of national funding channelled through Vinnova from the Swedish government. The turnover of the programme amounted to 1.2 billion SEK between 2003 and 2014, where 800 million SEK was financed by government. This led to a large increase in the number of incubators (39 in 2018) and to a large increase in the number of incubated firms. Over the period 2011 to 2015 some 1 320 new incubated companies were established.

The dataset allows analysis on the impact of the programme and contains data on both growth and innovation, measured by the number of patents registered. The analysis uses economic performance as an outcome and compares NIP-participants with non-NIP firms up to five years after exit. The control group is similar in characteristics to those of incubator firms.

The data on innovation has some new features. Using individual-level data on CEOs and employees and whether they are inventors (who have patented innovations), one can link these individuals to incubator firms and the general population of individuals and firms. Thus, a matched sample of treated and control groups is created, allowing us to contrast the effects on individuals in the treated group with those in the matched control group, and comparing their performance after incubation with that before incubation by means of difference-in-differences regressions. The individuals are tracked before and after incubation. This allowed us to understand how their inventive capacity changes during incubation, both compared to themselves and to the control group. Another advantage of the data is that there is no firm size threshold. Surveys to collect innovation data are often sent to firms with a certain size threshold in terms of employees or sales value with the idea of creating representative samples. By contrast, the inventor dataset includes small firm inventors in the sample, and this is advantageous because incubator firms are typically quite small.

Results

The early incubator programmes emphasised a bridging role between academia and industry and their potential to deliver new technology-based growth. This stemmed from a perceived need to increase efforts to commercialise Swedish research as some observers had suggested that the Swedish system was underperforming as formulated in the notion of 'the Swedish paradox' (Ejermeo & Kander 2011).

⁷ The section is drawn from Tillväxtanalys (2018a & b).

The objective of the early programme was to focus on commercialising research-based ideas from academia. This changed during the period where it was emphasised to foster rapid scale and growth of the incubated firms. This change in government objectives allows us to compare the relative impact on growth versus innovation.

The performance of incubator firms is generally worse than that of the control group. Incubator firms clearly have poorer turnover, productivity and own-capital performance after incubation than firms in the control group. However, the firms from NIP incubators have better economic performance than non-NIP incubated firms, even though their performance remains below that of the control group. Incubator firms in general also have lower prospects of surviving, although the short period under investigation after incubation makes this result somewhat uncertain.

The data makes two further analyses possible. The direction of incubator programmes has been debated regarding whether they should be oriented more towards research-based ideas or to being more growth-oriented, adapting ideas originating from the business sector. The report found that ideas from individuals with a background in academia or the public sector were driving the main results, for instance, due to a better growth in employees among incubator firms. Incubator firms with ideas from the business sector performed more like firms in the control group.

The report shows that incubation has a positive innovation effect on some individuals that participate in incubation (Figure 9.1). This effect is very clear for CEOs who increase their patenting by 300% compared to themselves and a carefully matched control group. The results for employees are somewhat less clear.

In summary, two key results emerge: 1) incubation does not foster economic performance, at least not in the short run following incubation; and 2) incubation does foster innovativeness. These results contradict the aims of the programmes, where the possibility to scale activities has been the primary objective over the last decade.

The results suggest that this aim has not been achieved. The aim to raise innovativeness, however, seems to have been reached. Such an aim is much more in line with a possible objective for policy to complement market efforts.

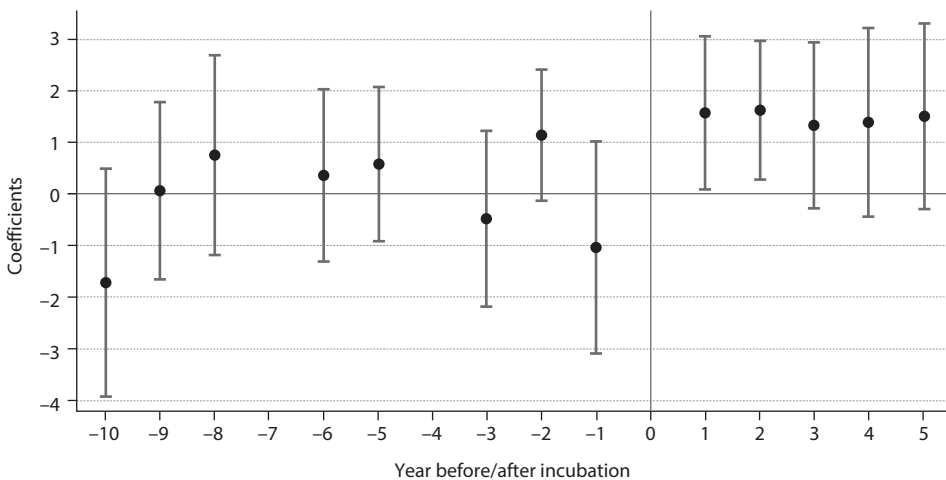


FIGURE 9.3: Trend dummy coefficients of CEOs before and after incubation (95% confidence intervals)
Source: Tillväxtanalys (2018b: 21)

Impact of cooperation on SMEs' economic performance

Collaboration and interaction among industry, academia and government is regarded as a key component in fostering innovation and growth.⁸ The importance of cooperation between research and surrounding actors was mentioned over 200 times in the last Swedish research Bill (prop. 2016/17:50, 53). It is also an important objective of Vinnova's remit to 'enable different forms of collaboration between business, public activities and the academic world within collaborative programmes'.

There has been considerable research analysing the pro and cons of cooperation between businesses as well as between companies and academia (Deiaco, Hughes & McKelvey 2012). However, there have been fewer studies analysing the impact of specific programmes with an objective of stimulating cooperation. This was possible in a study evaluating the growth effects on small Swedish companies (maximum 50 employees) participating in a number of Vinnova's R&D support programmes, where collaboration among the public sector, academia and business is a central component of the programmes' organisation and formulation.

An important feature of the data was that we could follow the main applicants and determine with whom they cooperated in the programme. This means that we could analyse in detail whether the project group's composition modulated the effects of the support measures. Did it make any difference to the small companies if universities or research institutes participated? What significance did the participation of a large private company have? How did single applicant companies fare, and what significance did the programmes' aims and focus have?

The dependent variables analysed in the study were the number of employees, sales and capital stock. A control group with CEM was created and the impact of participating in a collaborative programme was estimated by means of difference-in-differences analysis. Large R&D programmes typically have multiple objectives, but we limited the analysis to growth-related outcomes. The study focused on subsidies allocated during the period 2010–2012. The data provided information on 1 300 small firms that participated in 65 publicly funded innovation programmes.

Results

The results suggest that the companies receiving subsidies increased their sales during the duration of the project by an average of about 3% in relation to the control group. In the years following the end of the project, this figure increased to about 6%. The growth effect was greatest for the smaller companies (10 to 50 employees). It was not statistically significant for micro companies with one to nine employees.

The development in sales among companies that participated in just one project was significantly inferior to companies that participated in several projects. There are signs that companies that participate in several projects have relatively weak employment growth and strong sales growth. When it came to employment, there were mostly no significant employment effects.

The data allowed us also to study the impact of different cooperation patterns on growth performance. One result was that, upon completion of the project, companies that consistently participated in projects with universities or research institutes had experienced weaker development of their capital stock than other companies. One explanation for this might be that companies that applied for collaboration with universities and research institutes were trying to strengthen their human capital rather than their physical capital.

⁸ The section draws on Halvarsson, Tingvall and Engberg (2018).

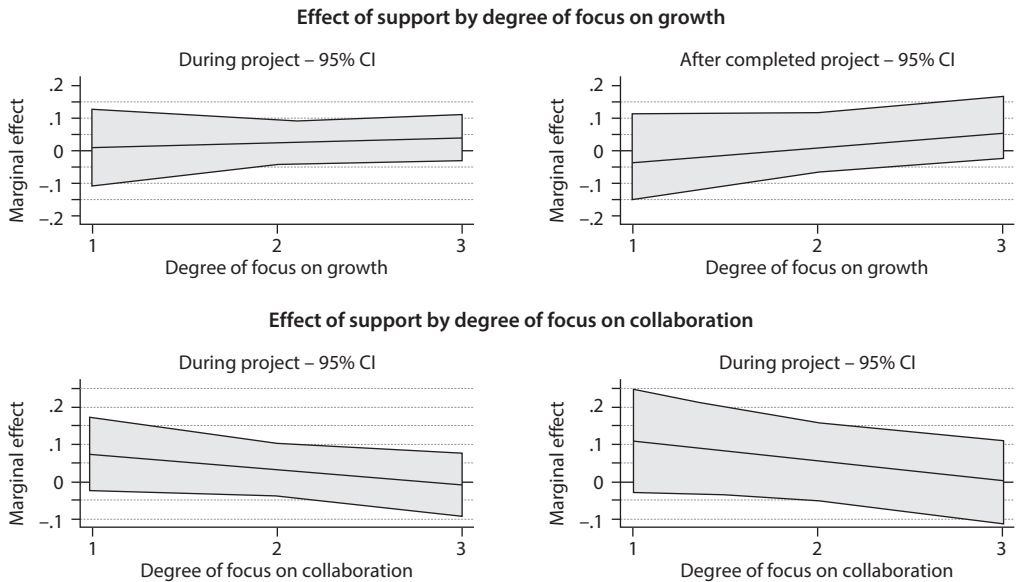


FIGURE 9.4: *Effect of support on growth with respect to the programme's focus*

Note: CI = confidence interval.

Source: Halvarsson, Tingvall and Engberg (2018: 31)

As was mentioned, the programme had multilevel objectives. Thus, it was possible to split the data by the degree of focus of the programme on growth and on cooperation. Figure 9.4 shows the effect of support by the degree of focus on growth and by degree of focus on collaboration. The overall observation is that the growth in the companies appears to be due to participation in a programme rather than the particular focus of the programme.

In summary, the analysis provides support for the conclusion that companies that participated in a project enjoyed faster growth than other similar companies that did not participate in a support programme. But the positive effects were limited to companies with 10–50 employees. It should be emphasised that wider and deeper knowledge of how different types of collaboration affect the companies' competitiveness (with particular sensitivity to the size of companies) is not available. This is a problem that Sweden shares with many other countries; however, today, we can use quantitative methods to begin to address the issue.

Discussion

Government-funded research and innovation programmes require that public spending ultimately leads to social welfare gains that sufficiently cover the opportunity costs of using public funds. Therefore, there is a need for systematic and quantitative evaluations in this area. The use of impact evaluations has increased but is still hampered by a lack of good micro data on those businesses that received support and others that were rejected; on the type of support granted; and on the amount of money involved. This has been rectified in Sweden where this type of data has been developed by the Swedish Agency for Growth Policy Analysis since 2012, having been commissioned accordingly by government.

This chapter has surveyed and presented some of the main results from a series of Swedish subsidy programmes on innovation and growth targeting small and medium size firms. The empirical evidence suggests that there is no guarantee for a subsidy programme to generate growth. Positive results are sometimes found, but, more commonly observed, are insignificant and even negative growth effects. Thus, the Swedish studies are similar to a growing body of evidence that indicates modest and ambivalent effects that are more on the negative side. It is therefore difficult to draw general conclusions about the impact of direct and selective types of interventions, although recent research tends to indicate that programme design as well as context matter (Hall, 2019; Veugelers, 2016). Our argument is that improved access to detailed firm-level data and new studies can make impact studies considerably more precise and more useful than they have been in the past (Deiaco & Tingvall 2017).

One challenge is to develop better programme design and lessons-learned processes. As noted in Tillväxtanalys (2015: 59–60), this would include amongst others that: 1) the goals of the various innovation policy measures must be made explicit to ensure that the schemes can be followed up and evaluated; 2) the possibility of conducting more randomised field experiments for ex-ante analysis should be examined; 3) independent reviewers should perform an analysis of causal effects, whereas people who have been closely involved in the programme can conduct process evaluations; and 4) a well-functioning cycle, in which lessons learnt provide feedback to both decision-makers and programme designers, is essential to ensure that the learning process will result in improved policy and a higher impact from various support schemes.

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Legislation

Swedish Research Bill (prop. 2016/17:50, 53)

PART THREE

**NATIONAL STI
ORGANISATIONS**

Ambiguities in Financing Innovation: A Case of Rio de Janeiro

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At the turn of the millennium, innovation emerged as one of the main objectives of the formulators of public policies for the promotion of socioeconomic development. Social perceptions of the role of science changed as a result of World War I and II in which the use of technologies such as radar, computers to break encrypted codes, or the very invention of the atomic bomb demonstrated the decisive role played by science in the competitiveness of countries. From this initial experience emerged what was later called the linear model of innovation (Bush 1945). The logic behind this approach is that the state's consistent investment in scientific activities is beneficial to society as such knowledge forms a stock that is naturally appropriated by the business sector in generating economic development.

In the 1970s and 1980s, the issue of technology emerged as one of the central points for the conversion of scientific knowledge into inputs for the economy and for the increase of competitiveness. Researchers who studied this process were concerned with the incorporation of scientific knowledge into technologies that could then be adopted by the business sector. This linear approach was criticised by several authors from the 1990s onwards. From this critical approach comes the concept of innovation systems (Edquist 1997; Freeman & Soete 1997; Lundvall 1992; Nelson 1993) as a counterpoint to a linear approach (Bush, 1945). For these authors innovation is not a linear phenomenon; investment in science and technology may not have the expected effect if the business sector lacks capacity for absorption and the appetite for such activities.

Our study finds a home in this context because, as will be shown in the next section, the innovation policy in Brazil was conceived from the science and technology (S&T) environment and adopts a linear profile since it positions the scientific environment as the main supplier of the inputs (for example patents, human resources, equipment) needed for innovation to take place. The purpose of this chapter is to analyse the process of incorporating the mission of financing innovation activities by a state research council, Foundation of Support to Science, Technology and Innovation in the state of Rio de Janeiro (FAPERJ). We present the historical evolution of Science, Technology and Innovation (STI) policies in Brazil and the state of Rio de Janeiro. We then highlight and analyse the ambiguities and nuances related to the incorporation of financing of innovation activities in addition to the activities of S&T in a governmental agency.

In the Brazilian case, in the late 1990s, legislation intended to stimulate the STI environment began to be implemented. Intellectual property laws and rules for distribution of royalties to public servants were drafted and a new funding system was designed for STI activities, called sectoral funds. Already in the 2000s, legislation was drafted specifically for the interface between public universities/research

institutes and the business environment. This Innovation Law was approved in 2004. In 2016, this legislation was deepened, culminating in the legal framework for STI and its regulations in 2018.

In spite of the enormous investments made in the 21st century in STI in Brazil, the results have been far below expectations. The law regulating innovation activities was enacted in 2004. Until then, public policy was mainly focused on S&T activities, the latter being mistakenly treated as synonymous with innovation. Thus, this environment in Brazil is dominated by the paradox that frequently affects countries adopting policies adhering to the linear model of the innovation process, leading the development agencies and other institutions to privilege technical aspects to the detriment of market aspects.

The Brazilian gross domestic product (GDP) is the 9th highest in the world, totalling around USD 1.8 trillion (World Bank 2019). Regarding scientific production, it is the 13th in the world rankings of the Institute of Scientific Information (2011–2016) (Web of Science Group 2019). On the other hand, there is very little debate about the scientific information produced and its impact on the market. Only 1% of publications in the period from 2011 to 2016 had at least one author who worked in a company, 10% of which were attributed to Petrobrás. Recent studies show that more than 80% of the country's doctoral graduates performing research activities are linked to universities, mainly public ones (Centro de Gestão e Estudos Estratégicos 2015). The data is reflected in its low innovation rate, where its position in the world ranking is 66th out of 129 (Dutta, Lanvin & Wunsch-Vincent 2019).

Statistics on innovation activities in Brazil have been developed by the Brazilian Institute of Geography and Statistics (IBGE) since 2000. The latest survey conducted between 2012 and 2014 shows that the national innovation rate is around 36%, that is, about one-third of Brazilian companies introduced innovations in those three years. However, only 3.8% of the total number of companies that engaged in innovation activities developed new products/services for the national market. Therefore, a very low percentage of companies mobilised to innovate processes in the industrial sector or to bring new products to the Brazilian market. In addition, the research and development (R&D) activities among the companies that innovated were very limited, comprising only 5% of these companies (IBGE 2016). In this scenario, it can be seen that STI is minimal, with no more than 1.8% of all Brazilian companies being involved in innovative activity.

The FAPERJ is the agency responsible for financing STI activities in the state of Rio de Janeiro. It was created in 1983, initially focusing on the financing of scientific activities. At the end of the 1980s, with the mobilisation around the country's redemocratisation, scientists were able to lobby to claim a constitutional quota of 2% of the state's tax revenue to finance the state's scientific activities. The agency worked by funding only scientific activities in its first 20 years of existence whereafter, in 2003, a board of technology was established at the agency (FAPERJ 2013).

Currently, the agency has an annual budget of approximately R\$ 380 million (1 USD = R\$ 3.89). About 90% of this budget is applied to activities of the Scientific Board while the rest is allocated to the activities of the Technology Board. The very fact that the word innovation does not appear in the name of the board already demonstrates that it was created under the paradigm of the linear model of innovation. Moreover, the nexus between research and innovation activities is not clear to the scientific community at large. This study shows that there is ambiguity in the process of financing STI. Only a few of the funded innovation projects actually use scientific inputs.

In the next section, we describe the STI environment in Brazil and Rio de Janeiro with the purpose of contextualising the case of FAPERJ. Methodological aspects that guided the research are presented thereafter. In this section, we explain the criteria used to select the 50 calls¹ and 2 217 innovation

¹ This means calls for proposals.

projects financed from almost 400 calls and more than 20 000 projects. Then, we present the case of FAPERJ in the incorporation of the mission to finance innovation activities. From the profile of the projects financed, it is possible to analyse the level of innovation adopted and to bring to light some strategic decisions that were taken implicitly as there were no documents indicating the goals of the agency for the decade analysed. In the conclusion, we analyse the consequences of adopting an ambiguous concept of innovation, highlighting some paradoxes faced by the agency and implicit strategic choices that have been made.

Science, technology and innovation in Brazil and Rio de Janeiro

This section aims to provide an overview of the evolution of the Brazilian institutional environment and the state of Rio de Janeiro so that we can better contextualise FAPERJ's experience in adopting the financing of innovation activities in its institutional mission.

Evolution of the institutional environment of STI in Brazil

According to Longo (2009), the evolution of the national system of science and technology in Brazil can be divided into four stages: (i) random nucleation; (ii) programmed nucleation; (iii) mutual interaction; and (iv) maturation and expansion. The first stage is characterised by the absence of S&T public policies, with a random nucleation of competencies occurring. Research and technical and scientific bodies are created without a systemic vision to meet national peculiarities and short-term emergencies, especially in health, agriculture, sanitation and defence. Few researchers are trained, and they are usually trained abroad and on their own initiative.

In the second stage, there is a governmental political disposition that encourages a programmed nucleation. In it, the necessary components are created for the formation of an S&T system, with the employment of highly qualified human resources, establishment of physical infrastructure (state and private), creation of development institutions and public funds to finance research and organisation of researchers in scientific associations.

In the third stage, there is the growth and mutual interaction of the components of the system, which still functions in a disarticulated way. Gradually, the policies are adapted and perfected and the systems are strengthened, completed and expanded. Financial, fiscal and market incentives are created. In the fourth stage, the system matures and expands. The formulation of S&T policies and strategies is aligned with industrial, agricultural, foreign policy and defence policies. Demand for technology and related services is increasingly served on a national basis. Strategies are formulated for the continuous improvement of the system, focusing now on cutting-edge scientific production and the generation of innovations in products, processes and services.

Brazil's STI evolution followed these four stages. The first stage of random nucleation can be traced to the beginning of the 1950s. Examples of the establishment of disparate organisations that were in place long before that included the Botanical Garden of Rio de Janeiro (1808), the National Museum (1818), the National Observatory (1827), (1876), Instituto Agronômico de Campinas (1887), Instituto Butantã (1901) and Instituto Vital Brazil (1919). The programmed nucleation phase began in the 1950s, with the creation, in 1951, of the National Research Council (CNPQ) and the Coordination of Improvement of Higher Education Personnel (Capes) and, in 1952, the National Bank for Economic Development (BNDE).

In 1967, FINEP (the current Brazilian innovation agency) was created to institutionalise the Fund for Financing Studies and Projects, created in 1965 at BNDE. In 1969, the National Fund for Scientific and

Technological Development (FNDCT) was established to provide financial support to the priority programmes and projects for scientific and technological development, notably for the implementation of the basic plan for S&T development. In 1971, FINEP became the executive secretariat of this fund (Ferrari 2002). During the 1970s and 1980s, three plans were developed for national scientific and technological development: PBDCT I (1973–1974); PBDCT II (1976) and PBDCT III (1980–1985). During this period, there was an abundance of funding for the S&T segment. FINEP experienced significant growth.

In the 1980s, the Brazilian economy was in crisis: the process of transition from military government to civilian government began. The national and international political and economic conjuncture was not favourable for investments in S&T. There was a significant reduction in resources allocated to these activities. However, in the 1980s, two major milestones of the national S&T system were reached. In 1985, the Ministry of Science and Technology was created and in 1988, the new Brazilian constitution included a specific chapter for the theme. Despite the enduring crisis that the country experienced throughout the 1980s and 1990s, in the early 1980s, the S&T system entered a stage of increased interaction among its actors. But during this period, the resources of the FNDCT were decreasing. There was great institutional instability; while the number of projects increased, S&T institutions struggled to sustain themselves (Longo 2009).

Throughout the 1990s, some tax incentives were approved for S&T activities that impacted the system as a whole. Also in the 1990s, laws regulating intellectual property rights were passed. Among these laws were: (i) Law 8974/95, Genetic Engineering Law, which establishes standards for the use of genetic engineering techniques and the release of genetically modified organisms into the environment; (ii) Law 9279/96 Industrial Property Law which established rights and obligations related to intellectual property in the country; and (iii) Law 9609/98, Intellectual Property Law of Computer Programs.

At the end of the 1990s, the government started to implement a new financing system for R&D activities. Public policy makers, at that time, identified the need to ‘build a new financing standard’ and sought to ‘consolidate a pool of sectoral funds, especially those linked to public concessions and with significant impacts on the generation and diffusion of new technologies’ (Pacheco 2007: 191). This change began with the allocation of a percentage of the royalties on oil production to the then Ministry of Science and Technology (MCT), through Law No. 9478 of 16 August 1997. In November 1998, said royalties due to the MCT were given to the FNDCT. With this decision, new prospects for the revitalisation of the funds were opened up using resources not dependent on the Union’s budget and were allocated without barriers on a regular basis. The country thus entered a phase of maturation and expansion of its national system of S&T.

Sectoral funds were established as an innovative financing instrument for S&T activities. The management mechanism adopted in these funds is based on a steering committee, responsible for outlining the direction of investments, in accordance with the demands of companies, universities, government and society as a whole. These actors have representatives on the fund management committee. There are currently 16 sectoral funds, of which 14 are related to specific sectors (aeronautics, agribusiness, the Amazon, water, biotechnology, energy, space, water, computer, mineral, oil and gas, health, transport and telecommunications) and two general funds aimed at university-business interaction and at supporting the improvement of the infrastructure of S&T institutions.

Since the creation of sectoral funds in 1999, FNDCT’s budget allocation has been growing until 2014, when the country began experiencing severe political and economic crises, leading to a reduction in the resources available for STI. According to data from the Brazilian Academy of Sciences (ABC.org 2019), the budget available for the year 2018 was equal to that of 2005, causing the country to retreat in the process of expansion of these activities. It is worth noting that in the work of Longo (2009), he analyses 30 years of evolution of the fund and shows that, in 2005, the resources allocated to STI activities were similar to the budget of the year 1976, showing the unstable character of these investments.

In 2004, the Innovation Law was approved (Law No. 10.973 of 12/02/2004). This law regulates the relationship between research laboratories financed with public resources and the private appropriation of the results of these researches. The law has three components: (i) it authorises and regulates the relationship between private companies and publicly funded research laboratories, allowing the use of shared physical infrastructure, the establishment of companies on the campus of universities and the participation of researchers of private companies through the temporary licensing of their functions; (ii) it determines that all federal universities must have a Technological Innovation Centre (NIT) to manage intellectual property in the academic context; and (iii) it authorises the granting of non-reimbursable public financing to private companies for the development of research and development activities.

As stated by Longo (2009: 6), from 1999, a major conceptual change occurred, from the 'national system of scientific and technological development' to the 'national innovation system'. The approval of the Innovation Law in 2004 was decisive for accelerating the interactions between the actors of this system and fast-tracking its phase of maturation and expansion. Despite the approval of the Innovation Law, a number of points mentioned in the law were not regulated and its application was limited. In 2016, the new legal framework for STI (Law No. 13.243) was approved. Its main points were the expansion of the role of technological innovation centres, the involvement of professors from public universities in private companies and the purchasing process of governmental organisations with regard to technological products.

The evolution of the STI support environment in the state of Rio de Janeiro

The research foundations (FAPs in Portuguese), are responsible at the state level for the financing of the activities of STI. Currently, only one of the 26 Brazilian states does not have a FAP (State of Roraima). As they act at a regional level, the FAPs have the advantage of knowing the particularities of each state, thereby enhancing their performance.

The research council of the Rio de Janeiro state, FAPERJ, was the third to be created in the country in 1980, through Decree No. 3.290/80. Its creation came from the merger of two state public bodies, the Foundation of Economic and Social Development of Rio de Janeiro, and the Foundation Centre of Human Resources of Education and Culture. Since its creation, its mission has been to promote and support research and scientific and technological training necessary for the socio-cultural and economic development of the State (FAPERJ, 2013). However, its role remained the same as that of previous institutions: staff training for the State and the publishing of documents such as maps and textbooks. This difficulty was mainly due to the fact that FAPERJ was linked to the Secretary of Planning and General Coordination of the State Government. Only in 1983 was it linked to the Extraordinary Secretariat of Science and Culture, being transformed into the State Secretariat of Science and Technology in 1987 (FAPERJ 2013).

Thus, in addition to the needs of the academic community for S&T policies on the state level, changes had begun in the Foundation. The initial kick-off of these changes was Bill 153, which gave rise to the new FAPERJ, and Law No. 1.175, of 21 July 1987, known as the legal framework for structuring the foundation. The law defined the functions of FAPERJ as follows, namely to:

1. promote and finance research programmes and projects, individual or institutional, carried out in public or private institutions in the State of Rio de Janeiro;
2. collaborate, including financially, in the reinforcement, modernisation and creation of the necessary infrastructure for the development of research projects, in public or private institutions in the State of Rio de Janeiro;
3. promote the exchange and training of researchers through the granting of scholarships and research in Brazil and abroad;

4. promote studies on the research situation in the state, identifying the fields that should receive priority of support;
5. monitor the implementation of the aid granted;
6. maintain a register of research units located in the state and of its personnel and facilities;
7. keep a register of the surveys carried out in the state, especially those carried out under its support;
8. promote and support the publication and exchange of research results; and
9. advise the state government on the formulation of its S&T policy.

However, the financial transfers to the foundation were not sufficient to carry out their mission and were often uncertain. With the support of the state's scientific community in 1989 (established in 1991), in the State Constitution, the allocation of 2% of the net state taxes to FAPERJ was promulgated. This was a very important milestone because it established at the state level a secure and stable source of financial resources for S&T activities.

In 1990, there was a very strong drive from the then Ministry of Science and Technology (MCT) to create sectoral funds for research funding. This movement was consolidated by the creation of sectoral funds in 1999. As presented in the previous section, the creation of sectoral funds marked the beginning of a systemic approach in the national S&T environment and the beginning of an explicit effort to promote the increase of competitiveness of specific sectors through the incorporation of scientific knowledge in their productive chains. It was the beginning of the innovation policy associated with S&T policy in Brazil.

As a reflection of these movements, in 2002, FAPERJ created the Technology Board, being the first FAP of Brazil to have a board specifically focused on technology and innovation activities. In that same year, the word 'innovation' was added to the name of the Secretariat of Science and Technology (SECT in Portuguese), becoming the Secretariat of Science, Technology and Innovation (SECTI in Portuguese). Among its missions, was the promotion of state-based innovative companies, boosting their development and acting to strengthen the relationships between universities, government and companies. Today, FAPERJ operates mainly through two financing modalities: scholarships and grants. Its themes, aims and objectives are defined by the Scientific and Technology Directorates.

The scholarship programmes exist as a form of payment to the scholarship holder and are not necessarily applied in the execution of the project. The major programmes are those of Scientific and Technological Initiation (IC and IT, respectively), masters and doctorates. The grants are financial assistance granted to the institution, individual or company to perform scientific or innovation projects. These open project calls are divided between the two boards (scientific and technological), with different objectives, selection criteria and evaluation processes. The scientific directories are evaluated by area coordinators and by ad hoc reviewers who are researchers who have already received support from FAPERJ. The main target audience for these calls are Institution of Science and Technology (IST) researchers. The technology board's allocations are more connected with companies, incubators, accelerators, technology parks, technological innovation centres and other mechanisms to encourage the development of innovations.

TABLE 10.1 *Open calls according to the directorate of origin*

| <i>Board of Directors</i> | <i>Open calls</i> | <i>Projects</i> | <i>Amount in R\$ 2018 (Million)*</i> |
|---------------------------|-------------------|-----------------|--------------------------------------|
| Scientific | 301 | 19 528 | 2 017 |
| Technology | 76 | 2 651 | 698 |
| Total | 377 | 22 179 | 2 715 |

Notes: * Amounts brought to present value in 2018.

Source: Author's own elaboration

These initial data demonstrate a greater volume of projects in the Scientific Board, which has a longer track record in FAPERJ. Another relevant point is that not all of the open calls of the Technology Board have a focus on innovation and/or companies. Rather, a good part of this investment was used in infrastructure projects of incubators, accelerators, technological parks and technological innovation centres, among others.

Open calls and innovation projects funded by FAPERJ: Methodological aspects

We began our analysis based on a selection of open calls aimed at financing innovation activities. In the period from 2007 to 2017, FAPERJ initiated almost 400 open calls that financed more than 20 000 projects with an overall value of approximately R\$ 3 billion (USD 1 = R\$3.89).

For the analysis of the calls for proposals, we analysed the projects financed with an explicit focus on innovation activities, totalling 2 217 projects. We sought to classify and identify essential items for innovation in the proposals submitted by reading the summaries of the projects submitted to the foundation, expected results, requested budget, information of the companies and researchers involved, company/IST relationship and, in some cases, partial and/or final technical reports, as well as a history of projects previously completed with the agency. In this way it was possible to identify characteristics of the projects that link them to innovation activities in companies, which is one of the missions of FAPERJ.

Open calls for innovation funding from 2007 to 2017

In order to choose the calls that were studied, the first criterion was that the objective of the call must involve innovation activities. The following aspects were analysed: (i) the use of financing companies; (ii) profit-making enterprises; and (iii) expected financial returns on the project. These criteria excluded calls aimed at addressing the creation, reinforcement and modernisation of infrastructure of institutions linked to the State Government and competitions for popularisation of S&T and non-profit programmes. After the analysis, 50 calls were selected which had as their main focus the financing of companies and innovation.

TABLE 10.2 *Open calls involving innovation*

| <i>Board of Directors</i> | <i>Open calls</i> | <i>Projects</i> | <i>Amount in R\$ 2018 (Million)*</i> |
|---------------------------|-------------------|-----------------|--------------------------------------|
| Scientific | 5 | 308 | 49,7 |
| Technology | 45 | 1 909 | 570,5 |
| Total | 50 | 2 217 | 620,2 |

Notes: * Amounts brought to present value in 2018.

Source: Own elaboration

Initially, only the notices of the Technology Board were considered, believing that only its calls would involve relationships with companies. However, during the analysis, five calls issued by the Scientific Board were identified that had the necessary requirements to fit this analysis. These calls were released by both the Technology Board and the Scientific Board. The boundary of 'science, technology and/or innovation' notices is complex, and it creates confusion both in the community, which may not know where it fits best, and in FAPERJ itself, which has difficulties in setting objectives related to its mission.

Innovation projects financed by FAPERJ from 2007 to 2017

In the initiation of the study, prior exploration of the data available at FAPERJ was required. It is important to point out that the agency does not finance companies, but projects. The proposers may be companies or universities/research institutes, but what is analysed, in large part, is the submitted project. However, when it comes to innovation, companies' information is relevant, for example, the number of employees, total revenue, industry, description of the value chain, description of the innovation strategy and reporting of the main R&D projects and technological competencies developed.

The absence of this type of information, which was evident in the FAPERJ database, limited the research because it required a deeper documentary analysis of the projects in order to identify such information. This could only be done if the proposer presented such information in the proposal even though it had not been explicitly requested. Thus, all projects were read to identify aspects such as the profile of the proposers, their objectives, the presence or not of R&D activities, the interaction between universities and the business environment, the budget requested, the expected impacts and the level of maturity of the proposed innovation. Projects that include R&D in at least one of the stages have the greatest potential to generate technological innovations of great impact. Projects with this profile involve uncertainties and require specific financing. On the other hand, innovation projects that do not involve R&D are often projects focused on incremental advances, which generally seek to update infrastructure in general. These projects generate relevant impacts but are structurally different from the technological innovation projects that involve R&D because they are projects that do not involve uncertainties. Both situations may result in innovations, but with different expected impacts.

To identify projects involving R&D, in one of the stages, the Organisation for Economic Co-operation and Development (OECD) research criteria (2015) were used. This analysis identifies whether there are systematic research activities (for example partnership with ISTs), human resource development (training, academic training of masters and doctoral level staff and professional history) and intellectual property, a large part of R&D projects. The R&D activities involved in the projects analysed were categorised according to their origin and could be internal to the company or contracted externally with the ISTs located in the state of Rio de Janeiro.

The objectives of the requested budgets may involve updating the available infrastructure in the company or university/research institute and consumables to carry out R&D activities. These awards are not intended to be working capital, for example to pay for personnel, nor resources for commercial activities that must be funded by the proposer of the requested project. Projects where the objective primarily involves the incremental infrastructure of the company or a university/research institute proposer should not automatically be classified as incremental innovation projects. According to the Oslo Manual (OECD 2005: 37), 'the purchase of more machines of a model already installed, even if extremely sophisticated, is not a technological process innovation'. If they do not involve significant improvements in their specifications or are not new to the group of companies that are included, these activities are not considered innovations.

The expected impact of the contemplated projects was analysed, when possible. Closely linked to the degree of novelty, this analysis followed the definitions of the Oslo Manual (OECD 2005). The expected

impacts can be within the company or locally, regionally, nationally or globally. However, projects that involve R&D, but are not yet in the market, have an uncertain acceptance. Therefore, these projects were classified with non-measurable impact. We also took into account the stage of maturity of the proposed innovation. In order for an innovation to occur, it must be placed in the market (OECD 2005), and the level of readiness of the technology/product to be developed indicates how close to the market application a particular technology is.

Results and discussion

In our analysis of the projects financed, the first item analysed was the profile of the proposer and the participants in each project. From this initial analysis, it was then possible to identify the interactions between companies, ISTs, researchers, and other members of the innovation environment that interact with FAPERJ.

This first analysis revealed data about the origin of the projects, with the main proposers being universities/research institutes and/or companies. In total, there were four categories of proposers: (i) company in partnership with university/research institute; (ii) company only; (iii) university/research institute; and (iv) independent inventor (does not involve company or university). This information is presented in Table 10.3 below.

TABLE 10.3 *Open calls issued by FAPERJ from 2007 to 2017 according to the proposer*

| <i>Proponent</i> | <i>Involves enterprises</i> | <i>Involves IST</i> | <i>Total of projects</i> | <i>Amount in R\$ (Million)*</i> |
|--------------------------------------|-----------------------------|---------------------|--------------------------|---------------------------------|
| Business and university relationship | Yes | Yes | 132 (6%) | 36,4 |
| Business enterprise | Yes | No | 1 097 (49%) | 214,9 |
| University | No | Yes | 923 (42%) | 361,6 |
| Independent inventor | No | No | 65 (3%) | 7,3 |

Notes: * Amounts brought to present value in 2018.

Source: The authors

It can be seen that most of the projects submitted involve only the participation of companies (49%) or only the participation of universities/research institutes (42%). Projects that involve a partnership between universities/research institutes and companies are 6% of the total and 3% are projects of independent inventors who have no relations with companies or research institutions. The ability of a university/research institute or an independent inventor to carry out an innovation is questionable since these actors are not in the market and do not have the ability to market their inventions. Analysed by proposer, 45% of the projects financed by FAPERJ in the last decade in open calls aimed at innovation were not projects of de facto innovation. These projects that have universities/research institutes and independent inventors as proposers are projects of invention and not innovation because the marketing component is absent. These projects run the risk of remaining 'on the shelf'. A great problem of interpretation occurs at that moment where an invention is seen as something so unique that, when it happens, it is imagined that the innovation process will subsequently occur, which is not the truth. Maurya (2012: 7), in his book, *Running Lean* which is focused on developing start-ups but is also applicable in this case states: 'when an idea is not validated, it is very likely that you are developing something that no one wants'.

When the proposer of a project is a company, the chances of an innovation occurring are greater. In the case in question, 6% were projects whose proposers were companies involved in partnerships with universities/research institutes and aimed at the development of technological innovations. Approximately half of the projects analysed (49%) were projects whose proposers were companies but only a small fraction actually involved R&D activities that could indicate the potential for a technological innovation. These projects were mostly focused on infrastructure improvements, or simply the purchase of machines and equipment, and cannot thus be characterised as innovation, according to the Oslo Manual (OECD 2005).

Table 10.4 below presents a summary of the categorisation of projects highlighting the proposer's profile (company, research institution, partnership of companies and research institution and independent inventor), the project objective (if R&D is involved) and the budget profile.

TABLE 10.4 *Innovation projects financed between 2007 and 2017*

| <i>Project profile</i> | <i>No. of projects</i> | <i>Total amount*</i> |
|--|------------------------|----------------------|
| Projects proposed by companies do not involve R&D activities. Projects focused on updating infrastructure. | 874 (39.4%) | 272.3 (44.7%) |
| Projects proposed by research institutions whose focus does not involve R&D activities. Projects focused on updating infrastructure. | 559 (25.2%) | 130.5 (21.4%) |
| Projects proposed by research institutions involving R&D activities. | 353 (15.9%) | 86.8 (14.3%) |
| Partnership projects, research institutions and companies involving R&D activities. | 116 (5.2%) | 34.5 (14.7%) |
| Projects proposed by companies with R&D activity whose products/services were in commercialisation or in the testing phase. | 63 (2.8%) | 16.7 (2.7%) |
| Projects proposed by companies with R&D activity whose products/services were in the conception phase. | 132 (5.9%) | 39.1 (6.4%) |
| Other: Independent inventors and specific government demands. | 120 (5.4%) | 29.3 (4.9%) |
| Total | 2217 | 609.2 |

Notes: * (R\$ million in 2018).

Source: The authors

Table 10.4 presents information that allows us to make interesting analyses about the profile of the innovation projects that FAPERJ has been financing in the last decade. Surprisingly, even applying several filters to focus our analysis on innovation projects only (we selected 2 217 projects from a database of more than 20 000), two-thirds of the projects we analysed (64.6%) were simple projects to upgrade companies' or research institutions' infrastructure, and R&D activities were not explicit in the projects. Among the projects involving R&D activities, most (15.9%) were proposed by research institutions and another 5.2% of the projects involved partnerships between research institutions and companies. It is interesting to note that although these cooperative projects represent 5.2% of total projects, when we analysed their participation in the total volume of resources, we realised that this amounted to 14.7%, which indicates that these are projects with a greater volume of resources. Projects proposed by companies that carry out R&D activities account for only 8.7% of the projects financed in the last decade. On analysing the projects that were supposed to involve innovations (2 217 among more than 20 000 projects), it was surprising to discover that only 195 projects were projects proposed by companies that carried out R&D. Innovation projects carried out by companies that carry out R&D do not comprise even 1% of the total number of projects financed by FAPERJ in the last decade.

Conclusion

Our research began with a contextualisation of the national and state environment of STI. This contextualisation shows that the constitution of this environment was gradual and that the innovation theme only entered the agenda from the year 2000. The innovation policy in the Brazilian case is generated from a linear approach, that is, it is a policy developed from the support of the S&T environment with little connection to the business environment.

The main focus of our research was the study of the case of FAPERJ in the actualisation of the mission to finance innovation activities. For this, we analysed a decade of financing of innovation projects to reflect on the profile of innovations that had been financed by FAPERJ. Our analysis took into account the open calls and financed projects in the period 2007 to 2017. With this information, project profiles were illustrated according to their objectives, proposers involved, stage of development and involvement of R&D. It is worth noting that after the application of filters to define calls and projects that were focused on innovation, we selected 50 open calls from almost 400, and 2 217 projects from more than 20 000. The projects we analysed were essentially projects of simple infrastructure replacement without R&D activities (64.6%) or inventions (21.3%), which cannot be classified as innovation projects. Only 14.1% of the projects involved R&D activities with the participation of companies potentially capable of taking research results to market.

In this conclusion, we offer a more in-depth reflection on the reasons why an STI financing agency that has as its official mission the financing of innovations and is governed by a board of directors, even after a decade of operations, still has difficulties in financing projects with the appropriate profile. Firstly, it is interesting to note that national innovation statistics point to a national innovation rate of 36% (IBGE 2019), but that among companies that innovated, fewer than 5% performed R&D activities. It is reasonable to say that an agency that has functioned as a research council for 20 years should have the skills to evaluate S&T projects and should adhere to the financing of innovation projects that involve R&D and clearly use inputs (human resources, equipment and patents) from the S&T environment. However, this was not the path chosen by the agency: the vast majority of projects submitted by companies or research institutions (85.9%) were simple infrastructure replacement projects, without the performance of R&D activities. One possible explanation for this choice is that the agency did not develop the skills to analyse marketing and business issues, which led it to focus on infrastructure upgrade projects.

Another interpretation, perhaps more realistic, is that very few companies are undertaking technological innovation, but this cannot justify the performance of a board approving only 195 projects in a decade (these were the projects that actually constituted technological innovation among the 2 217 that were analysed). That is, a public agency linked to the S&T environment has the competency to focus its action on technological innovation projects, but this universe is so small that politically, it becomes unfeasible. In the effort to increase achievement of the goals of the policies of FAPERJ's technology department, it is necessary to broaden the concept of innovation to reach a larger number of beneficiaries. This process of extending the concept of innovation requires a shift away from the scientific activities required by the FAPERJ technology board. When FAPERJ abandons the strict concept of innovation in favour of a broader concept, the synergies between the actions of the scientific and technological board are dissipated. On the other hand, adopting the concept in the strictest sense of the word, would see the synergies between the two boards increasing, but the scale of projects is so small that it may not justify the existence of a specific board to deal with the topic.

In this sense, the adoption of an ambiguous concept of innovation is forged in this trade-off which, on the one hand, seeks to establish a relationship with the scientific community and on the other

hand, seeks legitimacy with society by ensuring the implementation of the policies. Interestingly, this discussion does not appear in FAPERJ's planning documents: it is an implicit decision that can only be revealed from the kind of research work we did. Our work brings into focus important elements for a future analysis of the impact of the projects financed by FAPERJ. From the categories we found, we were able to identify expected results and the potential impact of the different project profiles and could verify them from a survey of companies and laboratories that had been supplied with resources over the last decade.

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Legislation

Innovation Law (Law no. 13.243)

The Science and Technology Advisory Forum and the Mexican Experience in Technology Assessment

Liliana Estrada Galindo and José Franco

The Mexican system of science, technology and innovation (STI) is relatively young and has been steadily growing for the last few decades. This growth, however, is fairly slow mainly because the STI budget is very small compared to the size of the economy, or even the size of the population. The investment has been irregular and it has been oscillating between 0.2% and 0.5% of the gross national product (GNP) for the last 40 years. About 70% of this budget comes from the federal government, about 20% comes from the private sector and the rest from other sources (universities, state departments and international grants). This distribution is opposite to that of the leading innovation countries, in which 70–80% of the research and development budgets corresponds to investments from their private sectors. Thus, despite the fact that Mexico is ranked as the 14th largest economy in the world, its R&D investment is far below the 2.4% average value already reached by the Organisation for Economic Co-operation and Development (OECD) countries (Office of Science and Technology Advice for the Mexican Congress [INCyTUa] 2018).

The structure of the STI system is defined in the Law of Science and Technology (LST), whose present version was created in 2002. Prior to this, in 1970, the National Council of Science and Technology (CONACyT) had been established by a presidential decree. This event, together with a first version of an LST in 1985, marked the foundation of an ambitious and integrated science and technology policy for the country that has shaped the present state of the scientific infrastructure in Mexico. The 1985 Law to Coordinate and Promote Scientific and Technological Development laid the foundations for the operation of the system, making the Mexican State responsible for supporting scientific and technological research, while the 1999 Law for the Promotion of Scientific and Technological Research sought the promotion of scientific and technological development in a more proactive way.

One of the most important aspects of the 2002 Law was the ring-fencing of a minimum percentage of the national budget for allocation to scientific and technological development activities, this being fixed at no less than 1% of gross domestic product (GDP) (Ley de Ciencia y Tecnología [Ley de CyT] 2002). This goal, unfortunately, has not been achieved after 17 years. The largest percentage reported to date (reached in 2015) was approximately 0.5% of GDP (INCyTUa 2018).

Governance structure

Another important aspect of the LST of 2002 was the creation of three new organisations, each of which has a specific purpose in order to improve and articulate the relationship among the different

stakeholders of the science and technology (S&T) sector (Ley de CyT 2002).

1. The General Council for Scientific Research, Technological Development and Innovation
2. The National Conference on Science, Technology and Innovation
3. The Science and Technology Advisory Forum (Foro Consultivo Científico y Tecnológico – referred to as Foro from here on)

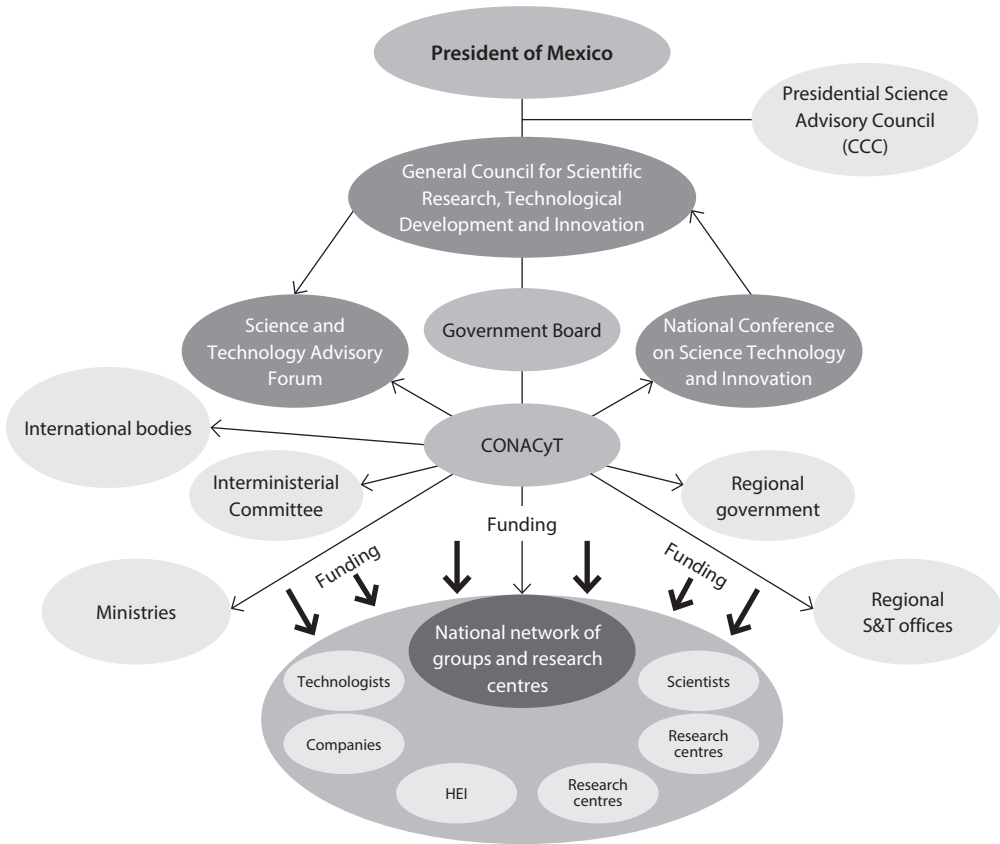


FIGURE 11.1: S&T system in Mexico
Source: CONACyT (2008: 15)

The General Council for Scientific Research, Technological Development and Innovation was established to coordinate the government’s policy on STI in Mexico and to define priorities and criteria for the allocation of public expenditure in this area. It is the highest authority of the government on S&T issues. It is chaired by the President of Mexico and is constituted by the ministries related to S&T activities, by representatives of CONACyT, the Science and Technology Advisory Forum and the Mexican Academy of Sciences, among others. By law, this council must be convened ordinarily twice a year, although in practice, this has not been the case. The President may also call for extraordinary meetings (Ley de CyT 2002).

The National Conference on Science, Technology and Innovation was created to establish a permanent link between CONACyT and the regional S&T offices in the country. One of its objectives is to facilitate the decentralisation of policies and support collaborative programmes.

Mandate and vision

The Foro is an autonomous, permanent consultative body reporting to the President of Mexico, the General Council and the Governing Board of CONACyT. At the request of the Federal Legislative Power, the Foro may formulate questions or issue opinions on matters of general interest in the field of S&T. One of its objectives is to make suggestions concerning national and sectoral policies, and to provide advice on special programmes to support scientific research, technological development and innovation. Specifically, the Foro was established to:

1. promote and disseminate scientific, technological and innovation research;
2. promote the expression of ideas from the scientific, academic, technological and business communities for the formulation of proposals regarding policies and programmes of scientific research, technological development and innovation; and
3. disseminate the previous activities and link the academy, the government and the industry.

In addition, the 2002 Law establishes that the Foro is responsible for convening the scientific, academic, technological and productive sector communities to gather their opinions and contribute to the preparation of the National Plan of Science, Technology and Innovation (or PECiTI after its initials in Spanish), that is prepared by CONACyT. The Foro is considered to be a unique entity in Mexico, due to the multidisciplinary composition of its board of directors, providing it with a convening power that facilitates open and transparent dialogue and that seeks to contribute to the creation of informed and inclusive public policies.

This inclusive and multidisciplinary team has transformed the Foro into a dependable organisation that supports actors across the STI sector, with a powerful ability to facilitate and coordinate efforts across institutions. This has allowed the Foro to act as spokesperson for the scientific, technological and business communities, representing their positions to the bodies responsible for decision-making on national STI policies. Examples of these cases are presented in the following sections.

Successful cases of cross-sector collaboration promoted by the Foro Consultivo

Importation of scientific and technological research goods

In recent years, the scientific community has stressed the need to make the importation of research inputs more agile. In 2012, for example, with the collaboration of 120 representatives from 64 institutions (from academia, social, public and private sectors), the National Autonomous University of Mexico (2012) led a study aimed at addressing the best way to promote science and technology in order to boost Mexico's development. One of the study's recommendations was to reduce restrictions on equipment and research inputs, including reagents, animals, cells and tissues, for example.

In 2015, this topic was taken up again by the S&T Commission of the Senate of the Republic, who, with the support of the Foro, ensured public consultation on the importation of inputs for research. During this process, almost 7 000 researchers from higher education institutions, public and private research

centres, government bodies, companies and other non-governmental organisations were consulted about their experience related to importing. Of these, about 5 000 had encountered a range of problems when importing the products needed for research (INCyTU 2018b: 2), as highlighted below.

The main concern of the scientific and technological community, as detailed in the study, is that 30.9% of importers had lost a proportion of inputs during the importation process, in addition to suffering restrictions, conflicts in customs, lack of information, arbitrariness and billing problems, among others.

One of the most significant recommendations of the consultation was that perishable inputs, such as certain reagents and animals, should not be detained for more than 24 hours. Inadequate handling and storage conditions, as well as delays in delivery, can cause irreparable damage to these products, and this translates into losses of time and money. In fact, 30% of the total budget that CONACyT allocates to scientific research projects, technological development and innovation is allocated to import costs of inputs. When imports are unsuccessful, the accumulated costs can result in losses of hundreds of thousands of pesos per year.

The results of the consultation carried out by the Foro were used to support the modification of the LST, aiming at eliminating the administrative procedures that delay investigation processes and make them more expensive. Although this particular modification did not become law, as a result of the discussion generated by this process, a group of regulators led by the Ministry of Economy was convened to continue the work.

From the discussion, in which the Foro had an active role, it was concluded that considerable improvements could be made to the regulations of each of the ministries involved. An agreement to modify the rules and criteria for the importation of scientific inputs has been proposed. This proposal seeks to expedite the importation of inputs to encourage scientific research and proposes that the importation of research supplies be exempt from previously required permits. The inputs selected by the Ministry of Economy and other federal agencies involved, would be imported expeditiously, once the amendment to the agreement is approved and published in the official gazette of the Federation (INCyTU 2018b).

Vive Conciencia

Vive Conciencia is a contest for university students that can be considered as a second stage of a previous project called the S&T Citizen Consultation (Agenda Ciudadana). The purpose of the Citizen Consultation was to allow the Mexican society to give an opinion and contribute to the identification and prioritisation of the most pressing problems in the country that should be addressed with the aid of scientific knowledge. It was done twice at a national level, in 2013 and in 2018. The Vive Conciencia initiative uses the results of the consultation and challenges young university students to identify specific problems in their communities and, by applying their knowledge of S&T, to design innovative projects to solve them. It is organised annually with the first contest held in 2014. This contest fulfils two main functions. First, it helps young people to be aware that scientific knowledge can lead to useful, tangible and immediate applications. Secondly, the analyses they need to carry out in their communities help to create a sense of social responsibility (Vive Conciencia 2018).

In 2017, there were 579 projects presented on such topics as clean water and sanitation, climate change, quality education, affordable and non-polluting energy, life and the ecosystem, public health, mental health, the fight against hunger, the reduction of inequalities, and industry innovation. Among the winning projects in 2018 were projects to manufacture bioplastics from shrimp waste, the encap-

sulation of bio-fertilisers, and increasing efficiency in integrated water management for crops (Vive Conciencia 2018).

Social innovation network (RedIS-MX)

Social innovation refers to the development and implementation of new ideas, products, services and/or models that meet social needs, in addition to creating new partnerships and social relationships. This requires the mobilisation of the necessary resources and partners. Today, technological innovation alone is insufficient; the current reality requires improving the quality of life in society, including working towards sustainability and inclusiveness (Foro 2019).

The RedIS-MX emerged to contribute to the strengthening of the Social Innovation Ecosystem in Mexico, since it links diverse actors from the governmental, academic, civil society and financial sectors. It contemplates the promotion of a culture of social innovation, training towards democratisation and the provision of specialised tools to those who need it, as well as highlighting the participation of higher education institutions to teach entrepreneurship as an exercise in professional life. The aim of the project is to promote public-private partnerships and sustainable impact over time, as well as to compile best practice for social innovation from educational institutions in a repository of social innovation, and, finally, to encourage the appropriate use of digital technologies to generate mass open-courses online (Foro 2019).

Three seminars have been held annually since 2016: 1) Young People in Social Innovation; 2) Social Innovation in Mexico: Conforming Networks; and 3) Consolidating Networks for Inclusion and Sustainability. Their main results are published respectively in the following publications: Theory and Cases of Social Innovation in Mexico; New Approaches to Innovation; and Proposals for Social Innovation in Mexico (Foro 2019).

Science and technology assessment in Mexico: INCyTU

Since its creation, the Foro has enjoyed a solid relationship with the Mexican Congress, providing it with information and advice on a number of different topics such as health, computer sciences and trends in S&T. It was in this context that the Office of Scientific and Technological Information for the Mexican Congress (INCyTU) was created, with the goal of working more closely and regularly with Congress.

INCyTU is an office of Technology Assessment (TA) and its goal is to provide legislators with balanced, precise and evidence-based information on topics related to S&T, relevant for policy and decision-making in Mexico. The office arose from the collaboration agreement signed in 2015 by the Foro, the Senate of the Republic and the Parliamentary Office of Science and Technology of the United Kingdom (POST), providing the basis for INCyTU methodology.

Technology assessment: Definition and history

In 1972, the Office of Technology Assessment (OTA) from the United States (US) the term 'technology assessment' for the first time. This office sought to give advice to the US Congress on technology-related topics in order to help the members of the Congress make decisions about support for new projects.

Although the OTA was closed in 1995, the importance of having such advice offices spread during the ensuing years, mostly in Europe. Since then, offices with different characteristics and approaches have been created, for example, France created the Parliamentary Office for Evaluation of Scientific and Technological Options in 1983; the United Kingdom created the POST in 1989; and Sweden created the Evaluation and Research Secretariat in 2007.

During these decades, the connotation of TA has broadened. Currently TA is not only focused on technology, but on more diverse topics. For example, European Parliamentary Technology Assessment (EPTA) describes TA as follows:

TA explores the relationship between science, technology and society. It is a concept which brings together researchers from different disciplines such as business, economics, sociology or biology, to name but a few. The common goal is to explore how current technological developments affect the world we live in (EPTA 2019).

Additionally, a report from the Institute for Technology Assessment mentions that:

while most projects of parliamentary TA institutions revolve around technologies, such as security technologies, energy issues, genetic engineering, nanotechnologies or the Internet, TA is not interpreted everywhere in the narrower sense as focusing solely on technological issues. In a number of cases, interdisciplinary topics that have a relatively small technology component may be addressed under this label or in this connection (Nentwich 2016: 13).

In 2017, the INCyTU Office was established and started operations. As a guest institution, it is currently a member of the EPTA network. INCyTU's objectives are:

- to interpret, analyse, and anticipate S&T issues of interest for legislative work;
- to assess evidence objectively and identify where agreements and disagreements exist on relevant issues;
- to analyse current trends and identify emerging issues on S&T that may impact on public policy in the future;
- to build capacity in Mexico and train professionals in policy analysis at the intersection with S&T; and
- to write reports, policy briefs and related documents on aspects of S&T.

One of its main products is the generation of *INCyTU Notes* which discuss social issues, innovation, science, technology and health in the light of scientific evidence. In addition, they present the ethical and bioethical context of these issues as well as national and international regulations.

INCyTU structure

INCyTU's structure includes the following three areas (see Figure 11.1):

1. Research: This area is constituted by seven researchers who are responsible for drafting *INCyTU Notes* (policy briefs) on the S&T topics that are relevant to the work of Congress. These researchers recruit external analysts, mostly graduate students in Mexico and abroad, who work for a few months and write these briefs under the researchers' supervision. At the time of writing this chapter (May 2018), there were 30 external analysts working with INCyTU.
2. Science Communication: There are two science communication experts who revise the final version of the briefs to make sure that they are presented in a clear manner. They also produce short videos based on the information contained in the *INCyTU Notes*. This is done in collaboration with TV UNAM (the University's TV channel).

3. Legislative Affairs: The liaison coordinates the work of the office with the agendas of the legislative bodies, including organising presentations and meetings to shape and define the relevant topics for future INCyTU briefs. Furthermore, INCyTU has a Senior Advisory Board comprised of three prestigious professors, who work with the office continuously on an honorary basis.

During 2018, INCyTU's work focused on developing its operations manual, setting key performance indicators (KPIs) to improve the delivery timescales for *INCyTU Notes* and also standardising all the office's processes. This was done with the aim of improving its capacity to respond to the requests and requirements of Congress.

Conclusions: Challenges and results

During its first years, INCyTU was affected by a number of issues which were largely due to the time required to define INCyTU's standard methodology and to adapt it to the specific conditions of Mexico. Financial issues also needed to be addressed. For example, the UK-POST receives grants from the science funding agencies to pay the doctoral students that perform most of the work required to finish each of their publications. This is not possible to replicate in Mexico, because most doctoral students already receive scholarships from the CONACyT, and the regulations do not allow them to receive any additional payments. Therefore, INCyTU had to explore other sources of recruitment and now focuses mainly on volunteer work.

Furthermore, the Mexican political scenario and its actors change frequently (for example, there was a completely new Senate and Congress in 2018) and it takes a long time for the Mexican scientific community and legislators to become aware of the office.

In spite of these shortcomings, INCyTU has progressed significantly, and has already produced important results, some of them being:

- the definition of Mexico's own standards and methodology, now clearly described in INCyTU's Operations Manual;
- the production of 30 *INCyTU Notes* (February 2019) covering a variety of different topics, including basic sciences, new technologies, health, energy, environment, economy and innovation. Some twenty *Notes* are currently in progress;
- a new and well-documented INCyTU web page;
- a number of courses provided by the INCyTU team on scientific topics at several Mexican institutions. The UNAM-INCyTU course is now part of the Biomedical Science PhD Programme; and
- the provision of *INCyTU Notes* to legislators, these having already been used in legislative work for economic and financial matters, such as financial technology, supply chain management and S&T budgets.

Mexico needs to implement efficient mechanisms to address, in the shortest possible time, the most pressing problems in a more effective manner. In this sense, the scientific community has a very important role to play but it requires a stronger link with decision-makers as well as with the private sector. This, in principle, will allow experts with the best available knowledge to have an impact on the way to solve these major problems. The Foro is one of the very few players with the potential to achieve this goal and has taken a decisive step forward with the creation of INCyTU, but it needs to be more assertive in order to have greater convening power. Experts that know both worlds, science and politics, are needed to work on strengthening the collaboration between scientists and decision-makers. In this sense then, INCyTU is the best candidate to be such a bridge. However, INCyTU is still an emerging organisation and requires protection from political changes and the provision of resources to guarantee its freedom of action and neutrality in the generation of information. INCyTU should

be constituted as a scientific advisory office that will contribute to the development of informed public policies.

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CHAPTER 12

The Profile of the National Advisory Council on Science, Technology and Innovation in Iran: An Overview

Akram Ghadimi, Naser Bagheri Moghaddam, Sahar Kousari and Vahid Zahedi Rad

The role of the scientific sector is essential to the realisation of the Islamic Republic of Iran's 20-Year Vision. This requires establishing organisations to improve and expand the borders of science; to educate and provide skilled manpower to prepare the ground for the expansion of technology; to facilitate research and technology; to guide, direct and supply financial sources; and to produce, transfer, absorb, localise and improve technology. It also needs to build a system for making research achievements implementable in business; to promote entrepreneurship; to increase productivity of the Iranian specialists inside and outside the country to produce science-based technology for use by the country; to establish, develop and use new technologies; to draft policies; to manage and supervise the development of science and technology (S&T); to establish an information society; to improve and develop recognition of the country and global community; and to remove the barriers in the path of development (National Research Institute for Science Policy [NRISP] 2007; Department of Research, Ministry of Science, Research and Technology [MSRT] 2007).

Within a 20-year horizon from 2004, the goals of the country are to ensure that Iranian society is the most advanced technologically developed society in Western South Asia with continuous economic growth, relative growth of per capita income level and achievement of full employment in the region (Ministry of the Economy and Financial Affairs [MEFA]).

Many research units and centres have been developed in Iran to attain these objectives. First, a brief description of these research centres is presented.

Mandate and vision

Research is an activity that ultimately leads to production and generation of science and production and application of technology. It strengthens and reinforces the socioeconomic and cultural foundations of a country and is therefore essential to a country's development. The Iranian authorities believe that there should be a nationally coordinated research plan that will guide the research sector (Da Wan et al. 2016). The research plan in Iran was prepared for the first time in 1989 and was approved by the budget and planning commission of Islamic Legislative Assembly. This plan paved the way for a series of five-year development plans in which considerable attention has been given to research and science and technology. A specific place was allocated to research in the national development plan. Thus, budgetary resources were allocated for the establishment of the research programme (Yahyaei 1994). Supporting open and free research and reinforcing and establishing

non-governmental research centres were core aims of the first development plan. Publicising the research and efforts in establishing Iran's place within the science and technology research community was included as one of the aims for this sector (Yahyaee 1994).

In the second development plan (Islamic Republic of Iran 1995), special attention was paid to research as a key component of the drive to expand the sector and enhance its impact both nationally and internationally. One of the main aims was to achieve self-reliance which would support the 20-Year Vision of full employment in the sector (Ebrahimian 2003). The third development plan (The Islamic Republic of Iran 1999) was aimed at upskilling staff and involving the non-governmental sector in research and technology activities (Amuzegar 1999). In the fourth development plan (The Islamic Republic of Iran 2005), the Ministry of Science, Research and Technology (MSRT) aimed to ensure that government policy would become research-based and thus better address the needs of the country. The protection of the intellectual property of the scientific community was a key focus area in this development plan. This was followed by the fifth development plan (The Islamic Republic of Iran 2011) whose main focus was to achieve a fundamental transformation in higher education together with a qualitative improvement in knowledge, skills and Islamic education realms, based on the foundations of the Islamic belief system (Ghasimi 2012). The sixth development plan of (The Islamic Republic of Iran 2016) intended to build on and consolidate the gains made in the previous five plans, namely to establish a knowledge-based economy; to increase productivity; to establish an interrelationship between education and employment; to extend international collaboration; and to increase the role of people in the S&T management of the country.

Clearly these plans are broad and far-reaching and require commitment and drive from universities and research centres in promoting the productivity of the country and the quality goals of scientific development (Ghazavi et al. 2016). This should start with the re-envisioning of universities and research institutes who need to define their missions and mandates to develop research units and improve scientific endeavour in the country both in terms of productivity, efficiency and effectiveness (Litvak 2017). The focus of such institutions will need to become less insular but, for this to happen, there is a need to develop human and social science research, Islamic studies, arts and inter-disciplinary and trans-disciplinary majors. According to Rahmanpour, Liaghatdar, Sharifian and Rezaee (2016), Iranian research also needs to be properly supervised, assessed and evaluated in order to gain the recognition of the international scientific community.

In the next section, we provide a critical reflection on the extent to which the goals of the development plans have been achieved to date (that is, 2019) (see Table 12.1).

Table 12.1 provides a brief overview of developments in science, technology and innovation in Iran in the first five development plans. The table shows that in every area there has been improvement in Iran's science, technology and innovation profile.

TABLE 12.1: Science and technology and innovation in Iran at a glance

| <i>Enrolment and graduation from tertiary education in Iran</i> | | | <i>Knowledge-based firms</i> | | <i>Rank in innovation indicator</i> | |
|---|-----------|-----------|--|------|---|------|
| | 2005–2006 | 2012–2013 | 2014 | 2016 | 2013 | 2017 |
| Students | 2 389 867 | 4 367 901 | 52 | 2732 | 113 | 75 |
| Graduates | 340 246 | 718 901 | <i>Number of science and technology parks in Iran</i> | | <i>Rank in innovation input indicator</i> | |
| PhD students | 19 237 | 58 683 | 2002 | 2016 | 2013 | 2017 |
| <i>Scientific publications</i> | | | 1 | 39 | 107 | 98 |
| | 2005 | 2015 | <i>Number of incubators in Iran</i> | | <i>Rank in innovation output indicator</i> | |
| Iran's share in scientific publication in the Middle East | 14.8% | 28.6% | 2013 | 2016 | 2013 | 2017 |
| Rank in the Middle East | 3 | 1 | 136 | 170 | 120 | 57 |
| Iran's share in scientific publications in the world | 0.4% | 1.5% | <i>Companies that are located in the S&T parks</i> | | <i>Rank in innovation effectiveness indicator</i> | |
| Rank in the world | 34 | 16 | 2012 | 2015 | 2013 | 2017 |
| <i>Number of universities in Iran in 2016</i> | | | 2518 | 3650 | 107 | 16 |
| Public universities | 154 | | <i>Museums of Science and Technology</i> | | <i>Number of Iranian paper in 1% higher paper</i> | |
| Public medical universities | 58 | | 2010 | 2019 | 2012 | 2017 |
| Islamic Azad universities | 567 | | 23 | 60 | 100 | 350 |
| Private universities | 354 | | | | | |

Source: Data supplied by authors

Structures at the operational level

It should be noted that the information in all the following sections is based largely on the science, technology and innovation policy review of the Islamic Republic of Iran by UNCTAD (2016). In this regard we have divided the institutions into two parts. Some institutions are oriented to technological development while other institutions are oriented to science development.

Institutions oriented to science development

The research academic units are defined as organisation research structures (affiliated to a university) that conduct research in a specialised form in a specific field such as energy, education and agriculture. The range of research in these structures consists of basic, applied and development research projects and research activities for industries in the form of consultancies and contract research.

Independent governmental and private research units

Independent governmental and private research units are specialised and professional units that conduct research in a specific area in a specialised form. The range of activities in these units is mostly focused on applied and development research and semi-industrial research. The governmental and public non-governmental research units usually conduct their basic research through joint ventures with the universities or by assigning projects to the latter.

Research units affiliated to industries, production units and executive bodies

Research units affiliated to industries, production units and executive bodies are units that, in organisational terms, are affiliated to industries, production units and executive bodies and, after obtaining permits from the council for improvement of higher education, conduct research in a specialised form in a certain area. The activities of these units include performing applied and development research, reverse engineering and, in some cases, semi-industrial research to respond to the short-term, mid-term and long-term needs of relevant bodies or organisations. In fact, most established consumer goods companies dedicate a significant part of their resources to developing new versions of their products or improving existing product designs because, according to Mazzacuto and Perez (2015), this enhances growth particularly in the pharmaceutical industry or software or high technology companies where constant innovation is needed to counter competition.

National research institutes

National research institutes are research units established with the permission of the Ministry of Science, Research and Technology for national initiatives. These research institutes perform research activities in certain areas and have specific goals based on national priorities. They can obtain permits to establish regional units or collaborate with existing research units at the national level to fulfil their missions (Asemi 2006; Da Wan et al. 2016).

Networks

Networks are a series of research and technological units with parallel missions and they coordinate, interact and collaborate in a specific field of specialisation in organised and defined forms. The networks are not permitted to employ researchers and perform research directly (MRST 2006).

Think tanks

Think tanks are non-governmental, not-for-profit or for-profit organisations that act totally independently in offering views and perspectives (Katirai 2005). They generate ideas and conduct research for decision-making and policy formulation in the cultural, social, political, economic and defence sectors. A think tank aims to provide ideas and solutions for national problems and challenges, provide views on future perspectives for managers and policy makers (governmental or private sectors), and contribute to decision-making (MRST 2004).

Scientific associations

Scientific associations are organisations that are developed and based on agreement and voluntary participation of a group of specialists in a particular scientific discipline. Scientific associations are not affiliated to the government and are independent companies in organisational terms (Commission of Scientific Association and NRISP 2002).

Institutions oriented to technology development

Research and technology staff units at executive levels

Research and technology staff units in the executive departments of companies are units that work in the executive bodies (for example as deputy officers or officers) with the responsibility of dealing with research and technology, including policy-making, planning, supervision and assessment. They identify the short-, medium- and long-term research needs of their respective organisations in order to assign projects, conclude contracts with qualified research units, receive the results, cooperate and collaborate, and use the results in carrying out organisational strategies.

Research and development units affiliated to state-run industries and companies

Research and development (R&D) units affiliated to state-run industries and companies are mission-based R&D units within specific fields of specialisation. They are an important means of achieving future growth and maintaining relevant products in the market (Namdarian & Naimi-Sadigh 2018). There is a misconception that R&D is the domain of high-tech firms or big pharmaceutical companies. However, governments also invest large sums in R&D (Alaedini & Razavi 2018) as they seek greater efficiencies in industries needed to meet the needs of their growing populations in fields such as electrification and transport.

Private technology development and engineering services companies

Private technology development and engineering services companies are companies that mainly aim at the development, transfer and localising of technology. The range of activities of these companies is to perform applicable, developmental, semi-industrial design and engineering research with more emphasis on design, reverse engineering and semi-industrial research (Soofi & Goodarzi 2016).

Growth centres

Growth centres are centres that are formed under the administration of professional specialists. They provide supporting services (including the establishment and development of new professions by entrepreneurs) created in the form of newly developed active units in various areas that lead to technology, and they follow economic goals based on knowledge and technology (Banadkouki et al. 2018). These centres are not permitted to employ researchers but, according to Aghajani and Talebnejad (2011), they carry out direct research mainly to support and grow the units already established as a nucleus as well as assisting newly developed companies with relevant research activities.

Science and technology parks

Science and technology parks are organisations established to encourage and promote a culture of innovation (Davodi et al. 2013). These parks also improve the competition potential among companies and institutes that rely on science and knowledge developed in the parks (Fazizadeh & Moshiri 2010). In order to create a knowledge and technology flow among universities, R&D centres, private companies and the market, the science and technology parks facilitate the process of generating companies and growth centres. They also provide services with high added value work environments and suitable and quality support for established bodies and institutes. These parks may not employ researchers but perform direct research. Their duties are not of the same nature as research institutes; instead, they provide overall support and back-up for the small and medium-size companies established in the park. The improvement of technology in the agricultural sector is a specific area of research of these parks (Davodi et al. 2013)

Centres of excellence

A centre of excellence is a 'scientific pole', that is, an academic (educational or research) centre that performs scientific activities with significant specialisation in education, research and academic international collaboration (Nazarzadeh et al. 2016).

Museums of science and technology

According to Yousefi, Nabipour, Raesi, Mosleh, Azin and Assadi (2015), museums of science and technology are places that collect and protect the various work, samples and information related to scientific, cultural and technological activities and achievements as representative of society. They also publicly exhibit these in the form of collections together with necessary explanations. By employing different methods of informatics and archiving of scientific data, visitors can benefit from the information according to their needs, their interests and their scientific/professional backgrounds. In addition, the museums conduct various scientific and educational programmes and facilitate the establishment and popularisation of scientific knowledge in society. There has been considerable growth in the number of such museums in Iran since 2010 as shown in Table 12.1. According to Qarehgozlou (2017), these museums are not simply places where historical events and old artefacts are displayed, but are platforms 'to create a culture of developing science and innovation to build a quality life for mankind' and showcase developments in the 'sciences, technology, health, education, entertainment, design and arts'.

Conclusion

Since 2004 Iran has developed a multifaceted and multipronged approach to scientific and technological research for the enhancement of the nation's economic development. To achieve its ambitions to become an innovative nation, Iran has enacted many laws and adopted a variety of policies. Government should place continued emphasis on the supply side of the national system of innovation by providing a well-developed scientific and educational infrastructure for the development of technology.

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The Evolution and Functioning of South Africa's National Advisory Council on Innovation

Mlungisi B.G. Cele

This chapter focuses on the National Advisory Council on Innovation (NACI) by drawing on its contribution to the post-apartheid science, technology and innovation (STI) policy as articulated, first, through the 1996 White Paper on Science and Technology (S&T), and second, through the 2019 White Paper on Science, Technology and Innovation. NACI's contribution has served a dual purpose, namely policy reflection and renewal. In its recent review of the 1996 White Paper on Science and Technology, NACI identified aspects of the post-apartheid STI policy that worked and those that did not work or areas where there was progress and where there was limited or no progress. One such key area of weakness related to the persistent neglect or limited attention given to social responsiveness/societal challenges or needs of the majority of South Africans. South Africa is one of the most inequitable societies in the world and there are growing demands for development and a better life for the underprivileged sectors of society. Consequently, the 2019 White Paper set out a long-term programme that seeks to utilise STI to address societal challenges and to strengthen the role and functions of NACI that are essential to the well-coordinated, coherent and functioning National System of Innovation (NSI) (DSI 2019).¹

Therefore, the structure of this chapter consists of five sections: (i) a description of the broader South African context; (ii) the relationship between the National Development Plan (NDP) and STI policy; (iii) the post-apartheid STI policy trajectory; (iv) the 2019 White Paper on STI; and (v) the expanded role and functions of NACI.

Socioeconomic and political context of South Africa

South Africa is estimated to currently host a population of approximately 58 million people, with approximately 51% (approximately 29,5 million) of the population being female (StatsSA 2019). By 2018, life expectancy at birth was estimated at 61.1 years for males and 67.3 years for females (StatsSA, 2018). In 2015, the size of the South African economy was estimated at R3 055.2 billion (measured in constant 2010 prices, seasonally adjusted and annualised) (StatsSA 2016). Figure 13.1 shows how the gross domestic product (GDP) of the country has nearly doubled since the transition from apartheid in 1994 to its current institutional form as a constitutional democracy (NACI 2016b: 32).

¹ Note that the Department of Science and Innovation (DSI) was previously known as the Department of Science and Technology (DST).

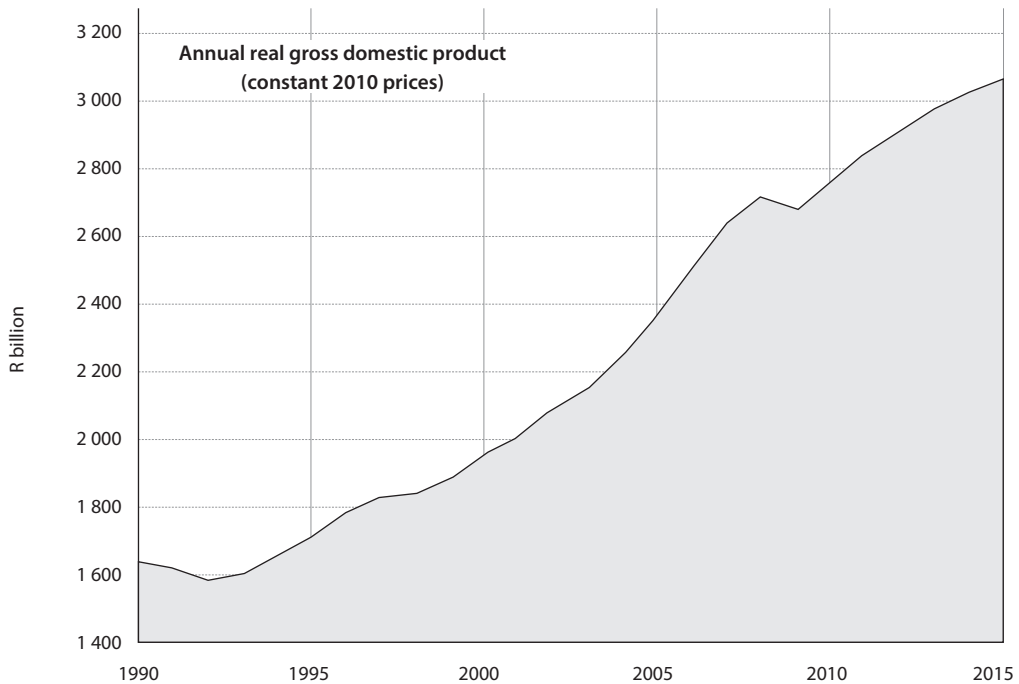


FIGURE 13.1: South African GDP (1990–2015) at constant 2010 prices

Source: NACI (2016b: 32)

In the context of world systems, South Africa contributes only 0.46% of the global economy's total output. Emergent in the context of international and intra-national inequalities is the ascension of BRICS as a new geopolitical bloc on the semi-periphery of the world system, comprising Brazil (3.15% of total world output), Russia (2.49% of total world output), India (2.74% of total world output), China (13.9% of total world output) and South Africa. The BRICS countries are home to 42% of the world's population and collectively contributed 22.74% of the world's GDP in 2015. This share is marginally lower than that of the USA alone, which generated 23.32% of world output (NACI 2016b: 32).

The United Nations Development Programme (UNDP) Human Development Report argues that '...work can enhance human development when policies expand productive, remunerative and satisfying work opportunities, enhance workers' skills and potential, and ensure their rights, safety and wellbeing' (UNDP 2015 cited in NACI 2016b: 33).

According to Borhat (2015 cited in NACI 2016b: 33), South Africa is '...one of the most consistently unequal countries in the world'. South Africa is home to the most unequal distribution of incomes and wealth, which is consistent with its history and the persistence of market-oriented fundamentalist approaches which continue to exclude the majority of the country's population from access to economic resources.

South Africa's current situation reflects its past and contemporary challenges and obscures progressive possibilities in its emergent future. At the same time, globalisation has brought about an integrated, interdependent, hierarchical and capitalistic international economic order which has done little to address the problems of poverty, underdevelopment, unemployment and inequality that constitute

major inherited and embedded structural legacies. The minerals-energy complex which underpinned apartheid has been unbundled and de-concentrated but its impacts include increased ecological constraints and environmental degradation. State capacities and capabilities are displaying evidence of being 'hollowed-out' through the local variation of new public management (NPM), also known as *Batho Pele* (RSA 1995). This has perversely allowed continuities with the legacy of apartheid (Van Vuuren 2006 cited in NACI 2016b: 35).

The national development plan and STI

The NDP, published in 2011, highlights the centrality of STI in creating sustainable socioeconomic development and addressing societal challenges such as education, health, food security, water shortages and climate change. The difference between countries that are able to tackle poverty effectively by growing and developing their economies, and those that cannot, is the extent of their ability to grasp and apply insights from STI and use them creatively (National Planning Commission [NPC] 2011: 71).

The NDP is clear that achieving a competitive and sustainable economy will require a strong and effective NSI, which must contribute to transformation. It views the NSI as the principal tool for creating new knowledge, applying knowledge in production processes and disseminating knowledge through teaching and research collaboration. The plan further acknowledges that advances in technological innovation and the production of new knowledge are critical to growth and development.

Having identified the potential contribution of the NSI to socioeconomic development, the NDP proposes two actions for the NSI. First, a common overarching framework should be created to address pressing challenges in the NSI (involving the higher and further education systems, state-owned enterprises and private industries). The NSI should function in a coordinated manner with objectives that are aligned to national priorities. Second, the size and effectiveness of the NSI should be increased.

The post-apartheid STI policy trajectory

The post-apartheid government inherited a S&T system designed to serve the interests of the white minority. Some of the system features were aptly summarised in the 2002 National Research and Development Strategy. They included the financial consequences of the termination of technology missions (such as military dominance on the subcontinent and energy self-sufficiency) by the apartheid government between 1990 and 1994. Second, the Southern Africa Development Community (SADC) and sub-Saharan Africa faced strategic risks from a human, economic and security perspective. Other challenges included inadequate intellectual property legislation, fragmented governance structures, reduced levels of local private sector investment in research and development (R&D), the unrepresentative demographics of the S&T system, inadequate access and employment of the majority of citizens (black people in general and black African women in particular), and skewed human resource patterns, research capabilities and STI infrastructures.

South Africa has developed numerous policies, strategies and plans as part of its STI policy mix (see Table 13.1). The 1996 *White Paper on Science and Technology* (Department of Arts, Culture, Science and Technology [DACST] 1996) introduced the concept of the NSI – a set of functioning institutions, organisations and policies that interact constructively and optimally in the pursuit of a common set of social and economic goals and objectives, seeking to promote change through the introduction of innovations.

The White Paper highlighted that such a system, in its broadest conception, is the means through which a country seeks to create, acquire, diffuse and put into practice new knowledge that will help that country and its people achieve their individual and collective goals. A well-functioning, coordinated and efficient NSI that assists in the achievement of national development priorities remains an ideal towards which South Africa continues to strive. Since the publication of the White Paper, the NSI approach has become more accepted in South Africa in line with its wide adoption in many countries and international organisations.

TABLE 13.1: *Recent periodisation of South Africa's STI*

| | ~1989 | ~1990 | ~1994 |
|------------------------------------|--|--|---|
| Political economy | Racial capitalism | Siege economy | Mixed |
| Dominant ideology | Apartheid | Dual power | Post-Keynesian |
| Governance framework | Authoritarian: military | Negotiations | Democratic developmental |
| Macro-economic policies | Normative Economic Model | Normative Economic Model | Reconstruction and Development Programme |
| Micro-economic policies | Subregional industrialisation | Deregulation and GATT | WTO |
| Science, technology and innovation | Science and technology discrete and stratified | International mission review and contestation | Green Paper on Science and Technology |
| Higher education and training | National Education Crisis Committee | Post-secondary Education Report of the National Education Policy Investigation | Policy Framework for Education and Training (ANC and National Commission on Higher Education) |

Source: Based on Maharajh (2011: 20) with substantial additions and changes by the author

In 2002, the National Research and Development Strategy (NRDS) was published (DSI 2002). The NRDS sought to contribute towards socioeconomic development by focusing on a set of 'technology platforms' and 'science missions'. The technology platforms were for biotechnology, information technology, technology for advanced manufacturing, technology for and from natural resource sectors and technology for poverty reduction. The missions were in areas in which South Africa had an obvious geographic advantage, such as astronomy, human palaeontology, and biodiversity, as well as in other areas in which South Africa had a clear knowledge advantage, such as indigenous knowledge and deep mining (DSI 2002).

These missions and platforms were expanded under the Ten-Year Innovation Plan (TYIP) (2008–2018) under five 'grand challenges', in the bioeconomy, space science and technology, energy security, human and social dynamics, and global change (with a focus on climate change) (DSI 2008).

| ~1997 | ~2001 | ~2007 | 2012+ |
|---|---|--|--|
| Mixed market-led | Mixed market-led | Mixed state-led | Mixed market-led |
| Structural adjustment | Neoliberal | Second radical phase of the national democratic revolution | Neoliberal |
| NPM | NPM | NPM | NPM |
| Growth, Employment and Redistribution Strategy | Accelerated and Shared Growth Initiative for South Africa | New Growth Plan | National Development Plan |
| Privatisation and structural adjustment | Reducing costs of doing business | Industrial Policy Action Plans | Infrastructure and sector strategies |
| White Paper on Science and Technology (NSI-perspective) | National Research and Development Strategy (DSI 2002) & the DSI (2004) | The 10-year Innovation Plan | Ministerial Review of the Science, Technology and Innovation Landscape & White Paper on STI (2019) |
| White Paper on Higher Education Transformation and a new Higher Education Act | Towards a New Higher Education Landscape (Council for Higher Education) | Department of Higher Education and Training (2009) | Green Paper on Post-school Education and Training (2012) and White Paper (2014) |

The TYIP articulated a path to innovation in support of South Africa’s transformation to a knowledge-based economy, in which the production and dissemination of knowledge leads to economic benefits and enriches all fields of human endeavour. The TYIP identified the ability of STI to play a driving role in enhancing productivity, sustainable economic growth and inclusive socioeconomic development as a measure of the plan’s success. Long-term goals based on the grand challenges were set. These included: South Africa becoming one of the top three emerging economies in the global pharmaceutical industry, based on the innovative use of South Africa’s indigenous knowledge and rich biodiversity; deploying satellites that provide a range of scientific, security and specialised services for all spheres of government, the public and the private sector; achieving a 25% share of the global hydrogen and fuel cell market with novel platinum group metal catalysts; and becoming a world leader in climate science, able to respond effectively to the multiple challenges associated with global and climate change (DSI 2008).

The TYIP emphasised the importance of human capital development and knowledge generation and exploitation as important elements of a knowledge-based economy. It identified international partnerships as important given that knowledge-based economies are connected through a growing international research and cooperation network (DSI 2008). The TYIP also sought to bridge the 'innovation chasm' (the divide between research and the translation of research results into innovative commercial products and services) through, among other things, the establishment of the Technology Innovation Agency (DSI 2008).

Since 2015, NACI has participated in the review of the NSI policy. It completed the review of 1996 White Paper on Science and Technology and performance analysis of the NSI in 2016 and 2017 respectively. These reviews contributed to the development of the new White Paper for STI in 2019. In addition, the council is undertaking a comprehensive review of the NRDS and TYIP, the outcomes of which will contribute towards the crafting of the new decadal plan.

The 2016 and 2017 NACI-led reviews noted that progress towards the attainment of the high-level goals and requirements (as set out in the 1996 White Paper on Science and Technology), including the important issues of reducing unemployment, providing safety and security and working towards environmental sustainability, has been limited. (For specific findings on NSI performance see the section below.) Important indicators across a range of components, including life expectancy, employment and standard of education, remain at low levels (World Bank 2015 cited in NACI 2016a: 2).

The 2016 review further noted that although economic growth may have been consistent, it had certainly not been remarkable, with the GDP increasing between 2% to 3% annually over this period. Furthermore, based on per capita data, economic growth had been minimal and highly exclusive. The labour market had been characterised by a shrinking of low-wage formal employment opportunities and higher earnings/better working conditions for white- and blue-collar workers. This divergence between conditions for unskilled vs. skilled labour is an enduring feature of apartheid policies which specifically sought to establish and preserve high wages and protected incomes for the white minority. Furthermore, post-1994 policies such as trade liberalisation and the promotion of a high-productivity growth path have favoured capital-intensive over labour-intensive firms, resulting in rising real wages for the employed but higher levels of unemployment in 2014 compared to 1994.

One important mitigating factor has been the increased payments of social grants, which have trebled in real terms since 1994 and now reach an estimated 17 million recipients from about 4 million in 1994. This development is recognised in the 2015 Organisation of Economic Co-operation and Development (OECD) report on the South African economy, which notes that:

Since 1994, South Africa has made great progress in reducing absolute poverty by rolling out social grants for pensioners, the disabled and children. Access to education, housing, water, electricity and other services has been greatly broadened. As a result, wellbeing has increased substantially. (OECD 2015: 2)

The 2016 NACI review recognised that path-goal dependence remains a key determinant in the economy with relatively little change in several aspects. The post-apartheid state acquired a system of actors, institutions and policies which had historically paid little attention to the needs of the poor (Mariotti & Fourie 2014 cited in NACI 2016a: 21). Although the new state has performed well in several respects, including the management of knowledge, the ability to collect taxes and the operation of a substantial welfare state, it has been deficient in development planning and implementation, and, consequently, has been largely ineffective as a developmental state. It has sustained a strong S&T system, including several world-class universities, but has failed to prevent the erosion of its

manufacturing sector or develop new medium- and high-technology industries, with the result that the potential of innovation-led growth has been under-realised. Moreover, key actors, such as the economic elite, have retained a powerful influence over policy to the extent that few changes to the distributional patterns of income have been possible.

The latter factor is central to this review and the proposed revision of innovation policy. Despite rising public investment in research and development, and, by implication, STI, outputs have been disappointing with limited growth in the key indicators such as patents and high-technology exports. At a general level, this weak performance can be explained as a manifestation of the conflict between the demands of various constituencies, and, in particular, the fiscal tension between longer-term policies/expenditure and shorter-term welfare state programmes. The need to manage this tension was identified in the 2007 OECD review of the NSI which noted the imperative for the NSI to deliver tangible benefits to the poor in order to secure sustained political support for STI (OECD 2007 cited in NACI 2016a: 22).

Although innovation-led growth as a development strategy remains valid and is indeed a central principle of the NDP, its implementation has been largely hindered by under-resourcing of business innovation, adverse labour market conditions, low levels of entrepreneurship and the slow response of the educational system to deliver human resources for a high-technology economy. All these issues will need to be resolved in the short term if significant progress towards a progressive and full employment economy is to be realised.

Synopsis of NSI performance between 1996 and 2016

In respect of specific initiatives, the NACI (2016, 2017) reviews noted the following progress:

- The implementation of the White Paper has been successful in several areas, namely, first, the introduction of the NSI framework that scoped a host of policy instruments and organisations that would contribute to the goal of harnessing STI to sustainable socioeconomic development.
- The establishment, building and strengthening of NSI actors and institutions such as the DSI, NACI, National Research Fund (NRF), Technology Innovation Agency (TIA), National Intellectual Property Management Office (NIPMO), South African Agency for Science and Technology Advancement (SAASTA), South African National Space Agency (SANSA), the South African National Research Network (SANReN) roll out, the Microscopy Centre at Nelson Mandela University (NMU), university centres of excellence and centres of competence, a pilot plant to produce foot and mouth disease vaccine, and facilities such as the Institute of Infectious Disease and Molecular Medicine (IIDMM) at the University of Cape Town, Doris Duke Medical Research Institute (DDMRI) at the University of KwaZulu-Natal, the Wits Reproductive Health and HIV Institute, Southern African Large Telescope (SALT), Telescope Array (KAT-7) and MeerKAT (NACI 2017, 2016).
- The incorporation of STI policies and goals within other policies, strategies and plans (the NDP and Industrial Policy Action Plan).
- The broadening of participation in all sectors of the NSI (mainly through transformation).
- The re-direction and improvement of R&D within the universities/science councils.
- Small but measurable progress in human resource development (NACI 2016, 2017). In particular, the number of degrees awarded to black African students has shown phenomenal increase and significant demographic shifts are occurring, though output is still short of employment equity goals (NACI 2016, 2017).
- The public funding for STI activities has risen substantially in real terms since 1994, with funding in 2014 almost double the level twenty years previously, led by the DSI whose funding level has increased 900% since 2005/6. This funding has been instrumental in maintaining the quality

(in some cases the excellence) of the country's S&T institutions, including its top universities and science councils.

- Knowledge outputs, international collaboration and university participation rates (enrolments) have all increased substantially, suggesting that the knowledge creation aspect of the NSI is intact (NACI 2016, 2017).
- South Africa's research system has done relatively well in areas such as palaeontology, astronomy, mathematics, theoretical physics projects and health science (and established very strong international links to governmental and multilateral donors and philanthropies). In climate change, South Africa has a voice in the structures of the Intergovernmental Panel on Climate Change, thereby recognising expertise in the fields of ecology, environmental science, water resources and modelling (NACI 2017).
- Public sector innovation has yielded positive results, including the development of the new portal for educator support, the system of social grants, and online tax collection. These innovations are essentially non-technological in character, with their execution depending upon the supply of skills from higher education in general (NACI 2017).
- Space science and technology enjoy the successes associated with KAT-7 radio telescope and the first light event of MeerKAT (a radio telescope that was a precursor to the Square Kilometre Array (SKA) telescope). These projects demonstrate significant local expertise in signal detection and processing and speak to the resilience of the telemetry sectoral system of innovation (SSI). DSI support has been pivotal to this work (NACI 2017).
- Considerable organisational innovation and change have taken place. For example, the Innovation Fund (IF) began life inside DACST. It then migrated to the NRF where it remained for a decade and grew an expert team, after which it was merged into the TIA, there to be joined with the four BRICs. The IF had initially functioned through the mode of competitive thematic calls but became less focused with time. In its later phase, the IF also backed the Joule electric vehicle project into which some R450 million was invested before the project was abandoned. While the IF pioneered the concept of the 'living evaluator,' namely an expert who worked with each funded project during its lifecycle, no authoritative post hoc evaluation of the value gained from the close to R2 billion invested in the IF is in the public domain. Much organisational development occurred but the associated learning is in danger of being lost (NACI 2017).
- Modest funding for pre-commercial stage R&D projects is available from the Department of Trade and Industry (the DTI) through the Technological Human Resources for Industry Programme (THRIP) and the Support Programme for Industrial Innovation (SPII). Both programmes have been subjected to recent external evaluation, with SPII receiving strong praise despite some observed inefficiencies in the drawdown of funding. The THRIP has a long track record of bringing industry and the universities closer together and has served an important secondary role of easing the recruitment of promising researchers into the private sector.

The 2019 White Paper, social challenges and the fourth industrial revolution

The new White Paper of 2019 was informed and shaped by the NDP which identifies STI as critical for the creation of a competitive and sustainable economy and for addressing societal challenges such as education and health. It advocates a strong, coordinated, coherent and effective STI system that promotes networks and partnerships between different actors in the public and private sectors, and that contributes to transformation and recognises a multiplicity of knowledge production sites beyond higher education. It promotes the idea that knowledge should be shared as widely as possible across society and calls for the expansion of STI outputs by increasing government expenditure on R&D and encouraging increased expenditure by the private sector.

Building on previous successes and adopting new approaches where required, the 2019 White Paper sets out a long-term policy approach for the South African government to ensure a growing role for STI in a more prosperous and inclusive society. It identifies inclusivity, transformation and partnerships as core themes, and proposes a range of actions to address policy coherence, the development of human capacity, knowledge expansion, innovation performance and increased investment.

South Africa has embraced the fourth industrial revolution by establishing the Presidential Commission on the fourth industrial revolution and ensuring that it features prominently in the White Paper on STI. The fourth industrial revolution is seen as a radical and disruptive technological change that will have an impact on production and quality of life across the world. Human beings have always identified and developed tools to augment their constraints or limitations. In this regard, the fourth industrial revolution represents such tools. The fourth industrial revolution will have both positives and negatives. It will create new kinds of jobs and, at the same time, destroy and alter existing jobs. Technological change demands better management of the transition to ensure that old institutions are not ruined while new institutions are established.

Since the White Paper is explicit about artificial intelligence (AI), the issue of principles will be an important consideration in the decadal plan. The G20 countries (of which South Africa is a member) adopted human-centred AI principles that draw from the OECD AI principles, which are as follows:

- AI should benefit people and the planet by driving inclusive growth, sustainable development and wellbeing.
- AI systems should be designed in a way that respects the rule of law, human rights, democratic values and diversity, and they should include appropriate safeguards, for example, enabling human intervention where necessary to ensure a fair and just society.
- There should be transparency and responsible disclosure around AI systems to ensure that people understand AI-based outcomes and can challenge them.
- AI systems must function in a robust, secure and safe way throughout their life cycles and potential risks should be continually assessed and managed.
- Organisations and individuals developing, deploying or operating AI systems should be held accountable for their proper functioning in line with the above principles (OECD 2019: 1).

The 2019 White Paper on science, technology and innovation and its implications for NACI

The White Paper on STI (DSI 2019) proposes an expanded mandate and role for NACI, which is to perform advisory, monitoring and evaluation, planning and coordination functions. To carry out this mandate effectively, NACI will have to align its work to broad government priorities, ensure that the council is representative and be given enhanced organisational capacity. In particular, the White Paper notes:

- NACI will be reconfigured to act as the national STI monitoring and evaluation (M&E) institution, charged with analysing STI information and undertaking work to inform government planning on STI. [...] NACI will convene a high-level forum to develop a framework of indicators to monitor South Africa's NSI performance (DSI 2019: 28).
- To support the Ministerial STI Structure in carrying out its mandate, government recognises that, in addition to the STI Plenary [...], there is a need for ongoing stakeholder engagement. NACI will be strengthened to facilitate such engagement, for example by following up on matters discussed at the STI Plenary. Policy advice from relevant NSI institutions and think tanks, for instance, the Academy of Science of South Africa, the Human Sciences Research Council (HSRC) and the Centres of Excellence will also be used (DSI 2019: 25).
- Furthermore, the Ministerial STI Structure will require expert studies and up-to-date performance and environmental information to support its decisions. To advise the Ministerial STI Structure, a strengthened NACI will undertake such studies [...] (DSI 2019: 25).

- NACI will [...] implement knowledge management systems to enhance the analysis of NSI performance and support evaluation work that informs strategies. In this, NACI will draw on the work of existing specialist centres that collect STI-related information. Existing institutional arrangements for data collection (for example innovation and R&D surveys) will be maintained and strengthened and, where necessary, expanded (DSI 2019: 28).
- The DSI, working with NACI, will develop a public STI investment framework (DSI 2019: 66). This will be done to support the commitment of public resources for STI by the Ministerial STI Structure (DSI 2019: 25).
- NACI's role will be to undertake foresight studies and provide an independent STI M&E function (including regular analysis of public STI spending). The framework will be based on an analysis of STI funding requirements in line with strategic and sovereign priorities, as well as consultation across government through an interdepartmental STI Budget Committee at the level of Director-General, including national and provincial governments with significant STI mandates (DSI 2019: 66).
- The DSI will work with NACI, the Department of Planning, Monitoring and Evaluation (DPME) and National Treasury to ensure that the framework delivers actionable and comparable information that can inform the management and funding of the NSI initiatives (DSI 2019: 28).
- Appropriate links will also be established between NACI and the DPME to help integrate STI into transversal government planning by the DPME, and to support funding prioritisation by the DPME and National Treasury (for example via the annual Budget Mandate Paper). For instance, based on its new M&E function and on regular environmental scanning, NACI will prepare reports on the implications of geopolitical and demographic shifts, technological changes, environmental sustainability imperatives and other megatrends for government STI planning (DSI 2019: 26).

Conclusion: Influence, impact, challenges

Science and innovation advisory bodies the world over face the issue of the influence they have. The Global Forum of National Advisory Councils (of which NACI is a member) deliberated this matter at its third meeting, hosted in 2017 by NACI. Studies have also identified influence/impact as a challenge. According to Schwaag Segger, Wise and Arnold (2015: 6) 'international comparison shows that a national council's influence or impact is not only determined by its mandate or its composition [...] Rather, there are many factors – acting in combination with one another – that contribute to councils' impact on innovation policy'. These factors include:

- A mandate, composition and anchoring at top political level to give legitimacy; in order to be able to have an impact on policy-making, an innovation council must have a combination of relevant, recognised and sought-after expertise and anchoring at top political level. The latter could mean that the council reports to or is chaired by the President.
- A focus that is relevant and anchored in the national context – taking a broad (instead of a narrow) perspective on innovation and a systemic approach, including aspects such as education, sustainability, etc. While it is not realistic to expect the council members to possess all expertise necessary for a broad-based innovation policy, it is important that its composition does not lead to a limited or narrow perspective on innovation – and that the council's mandate and working practices allow it to access competence and examine issues that are outside 'traditional' fields of innovation policy.
- A mandate, governmental anchoring and composition that foster receptiveness and willingness on behalf of government to receive and act upon suggestions put forward or decisions made in the council.
- A focus/approach and composition which both acknowledge the increasing internationalisation of research and innovation in order to avoid the council (and innovation policy) becoming inward-looking, for example through the inclusion of foreign experts in the council or the establishment of an advisory group consisting of foreign experts who are connected to the council.

- Resources (budget and staff) that allow the council to produce and/or commission relevant analysis and work with forward-looking activities, which are necessary in order to work proactively and promote broader visibility (Schwaag Segger et al. 2015: 7).

NACI is no different. It continues to confront the question of influence/impact despite its high output. The 2018 review panel (NACI 2018) identified a range of systemic and organisational factors that, in combination, have limited NACI's efficiency and impact within the NSI. These include NACI's structural location and reporting arrangements; its conception of innovation; the composition of its council; its choice of advice themes; its staff capacity; the use made of its advice by the Minister of Science and Technology and other ministries; and the failure to publish/disseminate advice-related documents timeously. The review panel found that NACI's profile in the business sector is low; that its mandate and work are not well-known even among senior staff at higher education institutions; and that it is hardly known in the civil society sector.

There remains much to be done, but it is hoped that the White Paper approved by Cabinet in 2019 has raised awareness of the value NACI can add to policy-making, and that action will be taken to empower it. As with any advisory council, NACI's success and survival depend to a great extent on political will.

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Legislation

National Advisory Council on Innovation Act 55 of 1997.

Appendix: NACI mandate, role, function and structures

Mandate, role and functions

The National Advisory Council on Innovation (NACI) derives its mandate from an Act of Parliament, promulgated in 1997 and amended in 2011. The legislation requires NACI to offer advice to government on the role and contribution of science, technology and innovation (STI) in meeting national imperatives such as the creation of sustainable quality of life, sustainable development and economic growth and developing human capital for STI. The Act sets out a number of specific areas in which NACI is expected to provide advice. These include (a) the coordination and stimulation of the NSI; (b) strategies for the promotion of technology innovation, development, acquisition, transfer and implementation in all sectors; (c) the coordination of science and technology policy and strategies with policies and strategies in other environments; (d) the identification of research and development (R&D) priorities, and their incorporation in the process of government funding of R&D; (e) the promotion of mathematics, the natural sciences and technology in the education sector; (f) the establishment and maintenance of information systems that support the monitoring and evaluation of the management and functioning of the National System of Innovation (NSI); (g) international liaison and cooperation in STI; and (h) developments in STI that might require new legislation.

The issue of mandate is one of the factors that affect the influence and effectiveness of advisory councils. The areas indicated above span the policy concerns of Cabinet as a whole, as well as the work and jurisdictions of various government departments. This is one of the reasons for repeated questions about whether NACI is able to fulfil its mandate in its current form and location. Although the Minister of Science and Technology or Department of Science and Innovation (DSI) officials occasionally refer NACI's advice to other government departments to which the advice might be relevant, the 2018 Institutional Review found that NACI's advice was primarily associated with the priorities and jurisdictions of the DSI and did not appear to have a Cabinet reach.

NACI's ability to fulfil its mandate and perform some of its functions has been hampered for several reasons. The Ministerial Review Committee on the STI Landscape in South Africa and other experts² argue that NACI is 'hamstrung by the fact that it reports[s] to the DSI and thus ha[s] no structural location that ... afford[s] it the authority needed for effective coordination of a national system'. There has been a general call for NACI to be established as an independent entity responsible for its own resources, both human and financial. The idea is for the secretariat to be removed from government and be appointed under terms to be determined by NACI. This has not yet been achieved, although NACI's founding legislation was amended to allow NACI to have its own Chief Executive Officer, where previously the Director-General of Science and Technology was the CEO.

Composition of NACI Council

The composition of national advisory councils is a key factor in their efficacy. The NACI Act provides for between 16 and 20 NACI Council members to be appointed by the Minister of Science and Technology.

² These include the 2007 OECD Review of the South African NSI, and institutional reviews of NACI carried out in 2008 and 2018.

These should all be people who have (a) achieved distinction in any field of science and technology in their own right or in the context of innovation; (b) special knowledge or experience in relation to the management of science and technology, or innovation; (c) special insight into the role and contribution of innovation in promoting and achieving national and provincial objectives; or (d) special knowledge and experience of the functioning of the NSI within which the science and technology system operates, the science and technology system, or any other aspect of NACI'S domain of responsibility.

The NACI Council should be broadly representative of all sectors and be constituted in such a way that ensures a spread of expertise and experience regarding (a) national and provincial interests; (b) scientific and technological disciplines; (c) innovation; (d) needs and opportunities in different socioeconomic fields; and (e) R&D in all sectors.

The NACI Act sets out the tenure of members, who hold office for a period determined at the time of a member's appointment. The period may not exceed four years. If the office of a member becomes vacant for any reason, the Minister may appoint a replacement for the remainder of the member's term of office. Members may resign, or have their appointment terminated on the grounds of misconduct, incapacity or incompetence. A member whose period of office has expired may be reappointed, but not for more than two consecutive terms.

The NACI CEO and a representative of the Department of Trade and Industry nominated by the Minister of Trade and Industry also serve on the council in their official capacities.

Involving the private sector and civil society continues to be a challenge. Part of this relates to the difficulty of reconciling and mediating between different cultures and interests to enable effective participation. NACI has tended to draw its members from the public sector and higher education institutions; the civil society conundrum stems from systemic bias towards R&D actors. However, it is now globally recognised that, for STI policy to be seen as inclusive, civil society must be involved.

The South African NSI and NACI can learn much from other countries about involving the private sector and civil society in a meaningful way.

NACI Secretariat

The NACI Secretariat is the administrative and operational arm of NACI. It is smaller than similar structures elsewhere in the world, consisting of 13 full-time staff (including the CEO), all employed by the DSI. Structurally, the NACI Secretariat is located within the DSI, which provides the secretariat with corporate services (human resource management, information technology systems and financial – including procurement – management). There has been concern about how this administrative support and NACI's structural location and reporting lines may affect its independence and efficacy. This was noted most recently in the 2018 institutional review, which also pointed out that the lack of seniority and capacity in the NACI Secretariat limited networking and relationship-building across the different sectors of the NSI.

The panel that carried out the latest review is of the opinion that the statutory position of NACI bears investigation. A statutory arrangement that makes NACI an autonomous advisory body that is not located in a single line-function department (as proposed, for example, in the new White Paper on STI) will help to facilitate greater independence and reach for the advice produced by NACI. However, if NACI remains within the DSI under the current arrangement, additional steps will need to be taken to strengthen NACI's independence.

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Index

A

- advisory bodies 7
- ageing societies 4
- artificial intelligence (AI) 35, 145
- Austria 85
 - indicators 87
 - innovation performance 86
 - monitoring and evaluation 7
 - research, technology and innovation strategy (RTI strategy) 86, 87, 90–91
- Austrian Council for Research and Technology Development 85

B

- Bayh-Dole Act 34
- Brazil
 - advisory bodies 7
 - innovation policies 109
 - scientific associations 111
 - STI environment 109–110
 - STI evolution 109–111
- business incubators 7, 69, 70
 - entrepreneurship 65, 100–101
 - small and medium-sized enterprises (SMEs) 57, 100–101
 - universities 56

C

- case-study countries 15–21
 - evaluation criteria 19
 - experimentation 17–18
 - frame 3 16–17
 - fundors 18, 20–21
- Centre of Excellence 54, 81, 83, 134
- Citizen Consultation 124
- climate change 4
- Coega 35
- collaboration model 69
- collaborative programmes 102–103
- commercialisation 32, 44, 45
- composite indicators 80
- counterfactual evaluations 94, 96

D

- data importance 95–96
- double diamond model
 - global competitiveness 38–40
- dynamic interactive capabilities 49–52, 58
 - case study 53–55
 - Square Kilometre Array (SKA) 55–56
 - universities 56–57

E

- economic policies
 - inclusive growth 44–45
- ecosystems *see* innovation ecosystems
- entrepreneurship
 - business incubators 65, 100–101
- environmental needs 14
- European Commission (EC) 79
- European Innovation Scoreboard (EIS) 81, 85
 - South Africa 82
- evaluation methods 96
- evidence-based policy-making 7, 103–104

F

- FAPERJ 109
 - analysis of projects financed 117–118
 - challenges with funding 119–120
 - creation 110, 113
 - financing of innovation projects 7, 110
 - functions 113–114
 - innovation projects funded 115–118
- financing of innovation projects 7, 109
 - small and medium-sized enterprises (SMEs) 97
- Foro
 - Mexico 7
 - objectives 123
 - cross-sector collaboration 123–124
- Foro Consultivo Científico y Tecnológico *see* Foro Foundation of Support to Science, Technology and Innovation in the state of Rio de Janeiro *see* FAPERJ
- fourth industrial revolution (4IR) 3
 - challenges and opportunities 3–4
 - impact 35–37
 - South Africa 39–40
 - White Paper on Science, Technology and Innovation, 2019 144–145
- frame 1 5
 - market failure 11–12
 - research and development (R&D) 11–12
- frame 2 5
 - national systems of innovation 12
 - stimulation of innovation 13–14
- frame 3 5
 - case-study countries 16–17
 - environmental needs 14
 - evaluation criteria 19
 - societal challenges 13
 - sustainability transitions 13, 14, 16
 - transformative innovation policy 12–13
- frames *see* three frames; *see also* frame 1; frame 2; frame 3
- fundors 18

- G
- Germany
 - innovation policies 34
- global competitiveness 33
 - double diamond model 38–40
 - South Africa 38–40
 - Switzerland 33–34
- Global Innovation Index (GII) 85
- government-funded research 45
 - small and medium-sized enterprises (SMEs) 45, 103–104
 - Sweden 103–104
- gross domestic product (GDP) 137–138
- I
- inclusive growth 44–45
 - economic policies 44–45
 - implementation 46–47
 - innovation policies 45–46
- inclusive innovation policies
 - objectives 6, 40
- inclusiveness 6
 - industrial 33
 - social 33
 - territorial 33
- incubators *see* business incubators
- INCyTU 125
 - challenges 127
 - objectives 126
 - structure 126–127
- indicator-based measurement 87–92
- Industrial Development Zones (IDZs) 35
- inequality
 - South Africa 31, 138–139
- informal business sector 38
- innovation
 - definition 31
- innovation capabilities 45, 50, 58, 63
- innovation ecosystems
 - see also* regional/sectoral innovation ecosystems
 - construct 60–62
 - definition 61
 - Mexico 125
- innovation instruments 70
- innovation performance 86
 - Austria, strengths and weaknesses 86
 - indicators 87
 - research, technology and innovation strategy (RTI strategy) 86
 - visualising 88–90
- innovation policies
 - Brazil 109
 - challenges to implementation 32
 - Germany 34
 - implementation challenges 35
 - inclusive growth 45–46
 - objectives 33
 - OECD member countries 33
 - South Africa 34–35
 - Sweden 94–95
 - three frames 4
- innovation projects funded 7, 110
 - collaboration 67
 - FAPERJ 115–118, 119
- innovation rankings 85, 110
 - standardised 87, 91
- innovation strategies 72, 116
 - monitoring 71
- innovation subsidies 98–100
- Innovation Voucher Programmes 33
- interactive capabilities framework 51
- Iran 7
 - 20-Year Vision 129
 - advisory bodies 7
 - Centre of Excellence 134
 - growth centres 133
 - museums of science and technology 134
 - research and development (R&D) 133
 - research units 131–132
 - science and technology parks 133
 - scientific associations 132
 - socioeconomic context 129
 - STI environment 129–131
 - think tanks 132
 - universities 131
- J
- Japan
 - science indicator system 78
- K
- Korea 43
 - inclusive growth 44–46
 - innovation policies 45–46
 - societal challenges 43–45
 - socioeconomic challenges 43–44
- L
- linear model of innovation 109
- M
- market failure 12, 28, 29
 - frame 1 11–12
- measurement frameworks 4
- measurements *see* STI measurements
- Mexico 7
 - advisory bodies 7
 - Citizen Consultation 124
 - Foro 7
 - innovation ecosystems 125
 - RedIS-MX 125
 - STI environment 121–123
 - Vive Conciencia 124
 - monitoring and evaluation 6
 - regional innovation ecosystems 71
 - museums of science and technology 134

N

National Advisory Council on Innovation (NACI)
7–8, 137
composition of council 149–150
impact 146–147
indicator reports 81
mandate 149
secretariat 150
White Paper on Science, Technology and
Innovation, 2019 145–146

National Development Plan (NDP) 139
National System of Innovation (NSI) 139
National Research and Development Strategy 34,
139, 140

National Research Institute for Science Policy (Iran) *see*
NRISP

National Science Board (NSB) 79
National System of Innovation (NSI) 12, 139
frame 2 12
National Development Plan (NDP) 139
performance review 143–144
network alignment 49–52
Square Kilometre Array (SKA) 55–56

NRISP 7

O

OECD member countries
innovation policies 33
OECD methodologies 6, 79
Office of Science and Technology Advice for the
Mexican Congress *see* INCyTU

P

partnerships 69
policy frames *see* three frames
policy makers 72
policy models 69–70
political context
South Africa 7, 137–139
post-apartheid government
STI policies 139–143

R

RedIS-MX 125
regional innovation ecosystems 62–63
see also innovation ecosystems
actors 70
building 63–67
collaboration 69
critical success factors 67–70
innovation instruments 70
monitoring and evaluation 71
partnerships 69
physical infrastructure 69
policy makers 72
policy models 69–70
resources 69
role of government 70–71

stakeholders 71
Triple Helix Model 63–67
vision 67
research and development (R&D)
frame 1 5, 11–12
Iran 133
research, technology and innovation strategy
(RTI strategy)
Austria 86, 87, 90–91
indicators 87, 90–91
innovation performance 86
limitations 91
research units 131–132
Rio de Janeiro
STI environment 113–115
Route 128 63, 67, 72

S

Science & Engineering Indicators 78
science and technology parks 70, 133
scientific associations 111, 132
scientometrics 6, 77, 81
scorecards 81–82
sector development zones (SEZs) 35
sectoral innovation ecosystems 62–63
see also innovation ecosystems
critical success factors 67–70
sectoral upgrading 87
Silicon Valley 63, 67, 72
skills development 35, 40, 53
small and medium-sized enterprises (SMEs) 7, 94
business incubators 57, 100–101
collaborative programmes 102–103
financing of innovation projects 97
government bank loans 97–98
government-funded research 45, 103–104
innovation subsidies 98–100
social capital
definition 70
social grants 142
social innovation 4, 7, 9, 46, 125
social skills 51–52
societal challenges 3
frame 3 13
Korea 43–45
South Africa 137
STI policies 4
systemic nature 4
White Paper on Science, Technology and
Innovation, 2019 137
socioeconomic challenges 31
Korea 43–44
socioeconomic context 7, 137–139
Iran 129
South Africa 7, 137–139
socioeconomic inclusion 52–53
South Africa 31
European Innovation Scoreboard (EIS) 82

- fourth industrial revolution (4IR) 39–40
 - global competitiveness 38–40
 - gross domestic product (GDP) 137–138
 - inequality 31, 138–139
 - innovation policies 34–35
 - National Development Plan (NDP) 139
 - network alignment 52–53
 - political context 7, 137–139
 - scientometrics 81
 - societal challenges 137
 - socioeconomic context 7, 137–139
 - socioeconomic inclusion 52–53
 - STI measurements 80–83
 - STI policies, periodisation of 140–141
 - Ten-Year Innovation Plan (TYIP) 140–142
 - South African innovation index 6, 82
 - Square Kilometre Array (SKA) 6, 55–56
 - stakeholders 71
 - STI environment
 - Brazil 111–113
 - Iran 129–131
 - Mexico 121–123
 - Rio de Janeiro 113–115
 - STI measurements
 - history 77
 - Japan 78
 - South Africa 80–83
 - Sweden 7
 - universities 80
 - STI policies 4, 8
 - post-apartheid government 139–143
 - societal challenges 4
 - three frames 5, 14
 - White Paper on Science and Technology, 1996 137
 - White Paper on Science, Technology and Innovation, 2019 137
 - structural change 87
 - subsidy programmes 7, 93
 - sugar industry 53–55
 - supply chain enterprises 39
 - sustainability transitions 5, 10
 - frame 3 13, 14, 16
 - sustainable development goals 3, 9, 31
 - sustainable policy interventions 56–57
 - Sweden 7
 - collaborative programmes 102–103
 - data 95–96
 - government funding 93
 - government-funded research 103–104
 - innovation policies 94–95
 - innovation subsidies 98–100
 - monitoring and evaluation 7
 - STI measurements 7
 - Switzerland
 - global competitiveness 33–34
- T
- tax incentives 10, 33, 81, 93, 112
 - technology assessment
 - definition and history 125–126
 - Ten-Year Innovation Plan (TYIP) 140–141
 - theoretical perspectives 4
 - think tanks 7, 132
 - three frames 11, 14, 24–29
 - see also* frame 1; frame 2; frame 3
 - case-study countries 20–21
 - description and summary 24–29
 - STI policies 5, 14
 - transformative change 5, 9
 - transformative innovation policy 12
 - criteria 15
 - frame 3 12–13
 - Transformative Innovation Policy Consortium (TIPC)
 - evaluation and accountability 19
 - goals 10
 - theory 10
 - transitions *see* sustainability transitions
 - Triple Helix Model 63, 66, 67, 69
 - TVET Colleges 53–55
- U
- United States of America
 - National Science Board (NSB) 79
 - Science & Engineering Indicators 79
 - universal standards 4
 - universities 56–57
 - business incubators 56
 - Iran 131
 - rankings 80
 - STI measurements 80
- V
- visualisation
 - innovation performance 88–90
 - Vive Conciencia 124
- W
- White Paper on Science and Technology, 1996 34, 52, 139
 - review 142
 - STI policies 137
 - White Paper on Science, Technology and Innovation, 2019 52, 71
 - fourth industrial revolution (4IR) 144–145
 - National Advisory Council on Innovation (NACI) 145–146
 - societal challenges 137
 - STI policies 137