Making Innovation Policy Work

LEARNING FROM EXPERIMENTATION

Edited by Mark A. Dutz, Yevgeny Kuznetsov, Esperanza Lasagabaster and Dirk Pilat

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BETTER POLICIES FOR BETTER LIVES

THE WORLD BANK

ISBN 978-92-64-18387-2 (print)
ISBN 978-92-64-18573-9 (PDF)

Corrigenda to OECD publications may be found on line at: *www.oecd.org/about/publishing/corrigenda.htm.*

Foreword

Policy makers and development professionals around the world feel a common sense of urgency to reduce inequality and address the needs of the most vulnerable in society, notably the over one billion people who live in extreme poverty. We must have a clear and unforgiving focus on the results that we seek: to end extreme poverty, build shared prosperity, and improve living standards for the world's poorest people, through inclusive and sustainable growth.

We are all searching for the best global knowledge to solve local problems. We must engage in a rigorous and systematic focus on outcomes and how to achieve them, using the best evidence, data and methods. Yet, if we discover an innovative approach that works in one place, we must adapt it and scale it up in other places, learning from both successes and failures. Our knowledge must be accessible, useable, and relevant to policymakers and development practitioners. This focus on impact and delivery of policy advice is what some are calling a "science of delivery".

Most importantly, sharing our knowledge and results on a website or through reports isn't enough. We must embed innovation and adaptation in our organizational culture, making it a vigorous part of our work ethic, staff and managerial incentives, and common purpose.

This volume draws on the conclusions from the conference "Innovation Policy for Inclusive Growth", which took place in Rio de Janeiro in October 2011, and was co-hosted by the OECD, the World Bank Group and Brazil's National Development Bank (BNDES).

The report focuses on the important role of "experimentation" in boosting innovation. Experimentation involves designing a portfolio of policies to solve problems step-by-step; monitoring and evaluating intermediate outcomes as rapidly as possible; and constant learning, feedback and adjustment. Critical to the experimentation process is the recognition that policymakers can and should learn from failure. This report also supports multidisciplinary approaches to designing and implementing innovation policy.

Three new policy domains are examined in detail: inclusive innovation, which can improve the lives of the poor; high-growth entrepreneurship, including its application to health care and nutrition; and green innovation. Experimentation in these three critical areas is under way.

The report recommends that we embed monitoring and evaluation in projects, beginning at the design stage in order to improve the quality and efficiency of public expenditures supporting innovation policy. It proposes that we cooperate closely with private and non-governmental actors, who are often better placed than governments to identify barriers and areas for productive investment or policy action. It suggests involving agencies and actors on the periphery of policy making to limit capture by vested interests, and to enable more creative and cooperative policies than those emerging from central agencies. Finally, it recommends that we share lessons early and periodically at the global level, as well as collect and deploy more data through rapid feedback and decision support.

We are pleased to present this report as a joint initiative of the OECD and the World Bank. Together, we can scale up innovative policies that contribute to more inclusive and sustainable growth, and that serve the aspirations of the most vulnerable in society, including the more than 1 billion people in extreme poverty who seek an opportunity for a better life.

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Acknowledgements

This volume was inspired by a technical conference of the World Bank, OECD and Brazil's National Development Bank (BNDES) on Innovation Policy for Inclusive Growth, held in Rio de Janeiro on 24-25 October 2011. The editors wish to thank Janine Treves and Justin Dupré-Harbord for editorial support; Julia Gregory, Joseph Loux and Martine Zaïda for their support in the publication process; and Sarah Ferguson and Florence Hourtouat for technical support.

Abbreviations and acronyms

3F	Friends, family and fools
ABLE	Association of Biotechnology-Led Enterprises
AMC	Advance market commitment
APOC	African Programme for Onchocerciasis
AIIMS	All India Institute of Medical Sciences
AEA	American Evaluation Association
ARPA-E	US Applied Research Projects Agency for Energy
AT	Appropriate technology
AUTM	Association of University Technology Managers
BIG	Biotechnology Ignition Grants
BIPP	Biotechnology Industry Partnership Programme
BIRAC	Biotechnology Industry Research Assistance Council
BIRD	United States-Israel Binational Industrial Research and Development Foundation
BMVSS	Bahwan Mahaveer Viklang Sahayate Samiti
BOP	Base of the pyramid, bottom of the pyramid
BPU	Bio-processing unit
BRICs	Brazil, Russia, India and China
CGIAR	Consultative Group on International Agricultural Research
CIRCE	Canada-India Research Center of Excellence
CGMP	Current good manufacturing practices
ComDT	Community-directed treatment
CRS	Contract research scheme
CSIR	Council of Scientific and Industrial Research
DARPA	Defense Advanced Research Projects Agency
DFID	Department for International Development
DBT	Department of Biotechnology
DSIR	Department of Scientific and Industrial Research
EMBRAPA	Brazilian Agricultural Research Cooperation

ETRI	Electronic Technology Research Institute
EU	European Union
EU15	Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden, United Kingdom
FII	Finnish Industry Investment
FITs	Feed-in-tariffs
FAO	Food and Agriculture Organisation
FDI	Foreign direct investment
GAO	United States General Accountability Office
GDP	Gross domestic product
GE	General Electric
GPT	General purpose technology
GSK	GlaxoSmithKline
GAIN	Global Alliance for Improved Nutrition
GAVI	Global Alliance for Vaccines and Immunization
GPS	Global positioning system
GPRA	Government Performance and Results Act of 1993
HM-HST	Harvard-MIT Health Sciences and Technology
HACCP	Hazard Analysis of Critical Control Points
HEIs	Higher education institutions
HTP	Horizontal technology policies
IAVI	International AIDS Vaccine Initiative
IBM	International Business Machines
ICAR	Indian Council of Agricultural Research
ICGEB	International Center for Genetic Engineering and Biotechnology
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
ICT	Information and communications technologies
IEA	International Energy Agency
IIT	Indian Institute of Technology
ICT	Information and communication technology
ILRAD	International Laboratory on Research for Animal Diseases
INTA	National Agricultural Technology Institute (Argentina)
IP	Intellectual property
IPO	Initial public offering
IPP	Innovation Policy Platform
IPRs	Intellectual property rights

ITDG	Intermediate Technology Development Group in the United Kingdom (now Practical Action)
ISO	Indian Space Research Organisation
ISCB	Indo-Swiss Collaboration in Biotechnology
ITRI	Industrial Technology Research Institute
IT	Information technology
kWh	Kilowatt-hours
MFI	Microfinance institutions
MDG1	Millennium Development Goals
MNCs	Multinational corporations
MNEs	Multinational enterprises
MOTECH	Mobile Technology for Community Health programme (Ghana)
MW	Megawatt
NASA	National Aeronautics and Space Administration
NABI	National Agri-Food Biotechnology Institute
NGOs	Non-governmental organisations
NMEICT	National Mission of Education through Information Technology
NMTILI	New Millennium Indian Technology Leadership Initiative
NTBF	New technology-based firms
OCP	Onchocerciasis Control Programme
OCS	Office of the Chief Scientist
OMB	Office of Management and Budget
PART	Programme Assessment Rating Tool
PATH	Programme for Appropriate Technologies in Health
PRIs	Public research institutions
PPP	Public/private partnership
PTTC	Platform for Translational Research on Transgenic Crops
PV	Photovoltaic
RCT	Randomised clinical trials
RCT	Randomised control trial
SA	South America
SBIR	Small business innovation research
SBIRI	Small Business Innovation Research Initiative
SDAs	Schumpeterian development agencies
SDC	Swiss Agency for Development and Cooperation
SIB	Stanford-India Biodesign
SIDA	Swedish International Development Cooperation Agency

Sitra	Finnish National Fund for Research and Development
SMEs	Small and medium-sized enterprises
SOEs	State-owned enterprises
SPV	Special purpose vehicle
S&T	Science and technology
STI	Science, technology and innovation
STEM	Society for Technology Management
Tekes	Finnish Funding Agency for Technology and Innovation
TPP	Target product profile
TTC	Technology transfer and commercialisation
TTOs	Technology transfer organisations
THSTI	Translational Health Science and Technology Institute
UNDP	United Nations Development Programme
UTEN	University Technology Enterprise Network
UAV	Unmanned air vehicles
VAP	Indo-US Vaccine Action Programme
VC	Venture capital
WFP	World Food Programme
WHO	World Health Organisation
WTO	World Trade Organisation

Table of contents

Figures

Tables

Boxes

Executive summary

Building on concrete examples, this book explores a number of emerging topics in innovation policy for sustainable growth and shared prosperity and develops the concept of experimental innovation policy, which integrates monitoring and evaluation at the policy design stage and throughout implementation. This approach can help improve the quality and efficiency of public expenditures supporting innovation policy.

The report also calls attention to the need for a more open approach to innovation and industrial policies that differs from traditional industrial policies. Open-economy policies focus on linking the better-performing segments of the private and public sectors, which helps to alleviate existing institutional constraints and helps develop new solutions. These policies often start at the periphery of policy making and are therefore less susceptible to rent seeking. In many cases, they do not have a large budget, as they rely on other policies and programmes. Also, by linking the better-performing segments of an existing institutional framework and searching for out-of-the-box solutions to familiar problems, they can help reshape the existing institutional framework. This approach shifts the debate on government activism in support of globally competitive industries from picking winners to a process of step-by-step transformation of the private and public sectors. Open economy innovation policies emphasise strategic collaboration with the private sector to ensure that interventions work as expected.

Key findings

Industrial and innovation policies characterised by top-down government interventions are not the right approach to development. The reasons for the failures of such policies are well known, and include the risks of capture by vested interests, lack of information on the economy and strong information asymmetry with private actors, and a lack of capability in the public sector for effective policy making. Another, more appropriate approach to innovation (and industrial) policy, involves search, experimentation, monitoring, learning and adaptation, all of which need to occur in a context of international openness to knowledge, trade, investment and competition. This new approach also rests on close co-operation with private and non-governmental actors, who are often better placed than governments to identify barriers to innovation, and point to areas for productive investment or policy action.

This new approach also rests on a much stronger focus on (diagnostic) monitoring and evaluation, which need to be embodied in programmes and policies from the outset. This is particularly important for new and emerging areas of policy, such as policies for bottom-of-the-pyramid innovation, high-growth entrepreneurship and green innovation, where there is significant experimentation underway and where the scope for learning and identification of good practices is the largest. Such learning should benefit from early and periodic sharing of lessons from policy experimentation at the global level, which will require strengthened mechanisms to identify and diffuse good practices, including through specific knowledge platforms and networks.

A number of other conclusions emerge from the various chapters. One of these is that some very successful new innovation policies have emerged from agencies and actors on the periphery of policy making. Such a peripheral position typically implies restricted room for large budgetary interventions, but can limit capture by vested interests and may enable more creative and co-operative policies than those emerging from more central agencies. The success of these agencies with smaller budgets also suggests that governments can achieve results in the innovation area in other ways than through public financial support alone.

Moreover, the development of new approaches and policies is not limited to governments alone. Non-governmental actors, such as private and social enterprises, foundations and other civil society organisations, play a key role in specific areas, such as health, and can be instrumental in developing new actions and scaling them up.

Finally, the chapters raise a number of issues for further research and policy experimentation. First, they raise questions on how policy makers learn from experience and mistakes that are made, how to encourage more entrepreneurial experimentation and appropriate risk-taking not only by enterprises but in policy making, how not only success but failure can be openly discussed and built upon, and how such learning can be organised, embedded and institutionalised in the policy-making process. Second, they point to a need to better understand systems and their behaviour, and how policy can influence the behaviour of (increasingly) complex systems to achieve more sustainable growth and shared prosperity.

More broadly, the book is intended to help launch a series of conversations together with further exploration, experimentation and learning into how to make innovation policy, its implementation and its measurement—including the measurement of investments in innovation capabilities by enterprises—work for better development impact in different domains and different country contexts.

Key policy recommendations

- Modern approaches to innovation (and industrial) policy require search, experimentation, monitoring, learning and adaptation, all of which need to occur in a context of international openness to knowledge, trade, investment and competition.
- These new policy approaches also require close co-operation with private and non-governmental actors, who are often better placed than governments to identify barriers to innovation, and point to areas for productive investment or policy action.
- Policy makers should incorporate monitoring and evaluation already at the design stage to improve the quality and efficiency of public expenditures supporting innovation policy.
- Governments can achieve results in the innovation area by involving agencies and actors on the periphery of policy making, which can limit capture by vested interests and may enable more creative and co-operative policies than those emerging from more central agencies. Such agencies may also be able to achieve more with less.
- Learning about innovation policies would benefit from early and periodic sharing of lessons from policy experimentation at the global level, which will require strengthened mechanisms to identify and diffuse good practices, including through specific knowledge platforms and networks.

Chapter 1

Making innovation policy work: The benefits and lessons of experimental innovation policy

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Building on concrete examples, this volume explores a number of emerging topics in innovation policy for sustainable growth and shared prosperity. The book develops the concept of experimental innovation policy, which integrates monitoring and evaluation at the policy design stage and throughout the process of policy implementation. This approach can help improve the quality and efficiency of public expenditures supporting innovation policy. Policy making based on experimentation is particularly important for new and emerging innovation domains, where the scope for learning and improvement is the greatest.

This volume is organised in three parts. **Part 1 (Chapters 1-2)** outlines the motivation for the book and sets out some key conceptual issues. To make the discussion on experimental innovation policies as specific and relevant as possible for practitioners and policy makers, **Part 2 (Chapters 3-7)** focuses on specific design and implementation issues in three selected emerging domains of innovation policy: pro-poor or base-of-the-pyramid (BOP) innovation, innovative entrepreneurship, and green innovation. **Part 3 (Chapters 8-9)** focuses on cross-cutting issues of experimental innovation policy, namely on how to institutionalise policy design and implementation as a continuous process of policy learning, error-detection and correction.

Chapter 2 (by Yevgeny Kuznetsov and Charles Sabel) focuses on the concept of new open economy industrial policy and provides the foundation for several other chapters in the book. The chapter explores how policy makers – operating under pressures from politicians and vested interests, and with only a partial view of the economy – can make accountable choices on public investments and policy measures aimed at specific economic activities. It focuses on three challenges that governments face, namely the power of vested interests, a lack of information on the economy and a lack of capability for successful policy making.

Open economy industrial policy focuses on establishing connections among domestic firms and between firms and the world market. In contrast to import substitution policies, the objective of these policies is to increase economic openness, enhance knowledge flows, foster productive innovation and strengthen non-traditional exports. An example of such a policy is the development of a venture capital (VC) programme that allowed engineers, born in Chinese Taipei and trained both at home and abroad, to deploy their skills in start-up firms whose activities complemented and facilitated the reorganisation of US leaders in the computer and semi-conductor industries. VC therefore became an instrument to orient and reorient the direction of the economy's development in rapidly shifting and highly demanding markets. Another example is Ireland, which, starting in the 1950s, created a method for identifying and developing growth-enhancing connections. As Chinese Taipei used VC to connect its expatriate engineers to each other and world markets, Ireland used selective foreign direct investment (FDI). The result in both cases was cumulative capacity building, evident in Chinese Taipei in the creation and evolution of firms, and in Ireland, at least through the mid-1990s, principally in the growing responsibilities of local managers rising through the professional networks of particular sectors.

There are three reasons why these policies are different from traditional industrial policies. First, by linking the better-performing segments of the private and public sectors, they alleviate existing institutional constraints and help develop new solutions. Second, these policies often start at the periphery of policy making and are therefore less susceptible to rent seeking. In many cases, they do not have a large budget, as they rely on other policies and programmes. Third, by linking the better-performing segments of an existing institutional framework and searching for out-of-the-box solutions to familiar problems, they can help reshape the existing institutional framework. The chapter therefore shifts the debate on government activism in support of globally competitive industries from picking winners to a process of step-by-step transformation of the private and public sectors. Open economy industrial policy emphasises strategic collaboration with the private sector to ensure that interventions work as expected. Very little can be said *ex ante* about either the instruments to be used or the economic activities to be promoted. Instead, the discussion focuses on the processes and procedures for selecting and correcting selections of both, rather than on specific policy instruments or sectors.

One such procedure is diagnostic monitoring: the systematic evaluation of a portfolio of projects or programmes to detect and correct errors as each project evolves (including the weeding out of inefficient ones) in light of experience and new information. Fundación Chile provides a good example of how diagnostic monitoring is conducted: staff members, hired on the basis of demonstrated technical knowledge and familiarity with the markets and business practices in a particular sector, apply for grants to develop a case for launching a new venture in some general area. The best of these preliminary plans can be used to apply for a second, longer-term grant to develop a business plan for a new venture, typically in partnership with outsiders. This process continues until the early stage venture becomes a candidate for seed capital and enters the familiar sequence of VC financing. At every stage, projects are benchmarked against internal and external alternatives, and the start-ups that result are the institutionalised expression of the efforts provoked by that benchmarking. The operation of the start-ups in turn relaxes constraints on the development of the clusters whose growth propels the Chilean economy.

Open economy industrial policy facilitates the search process and the connections among domestic firms, and between them and world market actors. This is not automatic. The chapter concludes that developing countries that want to encourage capacity-building connections with the world economy must devise novel institutions—search networks—to connect domestic and foreign actors, overcome constraints and provide complementary public inputs.

Chapter 3 (by Rafael Kaplinsky) is the first of two chapters focusing on base-of-the-pyramid (BoP) innovation, which is one of the important emerging areas of innovation policy. The chapter notes that outside China, despite rapid economic growth in many low and middle income countries, there has been little progress in meeting the Millennium Development Goal target of halving the incidence of global poverty by 2015. Part of the explanation for this weak poverty-reducing performance has been the historic trajectory of innovation. During the 20th century, most global innovation had its origins in the north, producing products for high-income consumers, developing technologies that excluded poor producers and that were energy-intensive and polluting.

This innovation trajectory gave rise to the not-for-profit appropriate technology (AT) movement after the 1970s. But many of the technologies developed were inefficient in that they made greater use of both capital and labour per unit of output. Moreover, the appropriateness of technology is inherently contextual, and involves trade-offs between objectives. For example, many labour-intensive and small-scale technologies are relatively energy-intensive. The AT movement often failed to recognise these trade-offs and was guilty of over-promise, undermining the credibility of the technologies it was promoting. Finally, the social context of innovation was often not conducive to the diffusion of ATs. The dominant innovators in the global economy were located in advanced economies and had no or little incentive in meeting the needs of the income-less global poor, or of incorporating the poor in global value chains.

A series of disruptive factors – the growing importance of low-income consumers in the context of the global economic slowdown, the development of radical technologies (such as mobile telephony and renewable power), the development of new capabilities in low-income economies and the emergence of new types of innovation actors – have begun to transform the potential of AT to support pro-poor growth. While this new vintage of ATs will be largely market-driven – since it provides the potential for profitable production – there are important dimensions in which this market-driven process can be supported by policy. The chapter identifies five such actions, namely:

- *The removal of market imperfections that are intrinsic to pro-poor innovation*, notably imperfections in the market for knowledge. Users of innovation often lack knowledge of the nature and extent of pro-poor innovations, while producers of innovations often lack knowledge of relevant markets, particularly those that are not geographically close. At-the-border distortions are important too, as they often affect imports from low-income economies more than those from high-income economies. Moreover, regulatory barriers affect the market for pro-poor innovation.

- *A realignment of actors in the innovation system* (and in the related value chains) to focus on pro-poor technologies. If there is market demand, private firms may respond relatively well to the growing potential of AT. But there is also a need to re-orient other institutions. For example, standards need to be adjusted to respond to the needs and capabilities of the poor.
- *Strengthening the role of non-market actors.* Non-market actors have already played a key role in the provision of innovative public goods in some areas, such as innovations aimed at neglected diseases or diseases disproportionally affecting the poor. But in other markets, such as infrastructure provision, their role should be strengthened.
- *A stronger connection between BOP policies* aimed at mass markets, often served by private firms, and the poorest groups, where non-market actors play a larger role. The poorest groups in low-income economies have little or no cash income and are therefore not a market for private firms. Yet, there are important interconnections between this group and the mass market, and policy needs to consider how it can ensure the greatest complementarity of approaches focused on the two groups.
- *A redistribution of income to the poorest groups*, which has substantially strengthened the markets for pro-poor growth, and thus positively influences pro-poor innovation and the development of a pro-poor growth path.

Chapter 4 (by Carl Dahlman and Yevgeny Kuznetsov) deepens the discussion on BOP innovation and explores specific policy approaches and experiments. It suggests that different BOP innovations can be distinguished on two principles. First, whether the returns to such innovation can be appropriated by the private sector or whether there are significant externalities (including public good aspects). Second, the magnitude of the start-up costs to develop a new business of innovation. These could be significant, in which case there may be need for critical mass, and there is a possibility for disruptive innovation. In other cases, start-up costs may be small, and the resulting innovation is likely to be more incremental.

Recognition of the poor as a major market opportunity has led to a new type of innovation, sometimes known as "Ghandian innovation" or "piggyfrogging": a combination of piggybacking (which involves adopting and adapting global knowledge) and leapfrogging (which involves leveraging the local context to skip certain steps in the process of economic development to move directly to a more advanced stage). This approach is one example of a shifting approach by multinationals and other global actors from "design globally, execute locally" to "design locally, execute globally". The resulting BOP innovation involves the co-development of new solutions by the poor and global knowledge agents that leverages local tacit knowledge and social capital, and that enables the poor to transform from being passive beneficiaries to crucial collaborators in the innovation process.

This transformation also has practical ramifications for the design of public policies to promote BOP innovation. Since local context and co-development with local agents is showing growing promise, it is necessary to develop new practices. This needs to involve a search for relevant technologies as well as experimentation and learning of public policies and emerging good practices. One approach to do this is to assemble a portfolio of promising projects and programmes that can be implemented, financed and scaled up once they show promise. At the same time, policy makers will need to monitor the projects, revising or eliminating poorly performing initiatives. A critical element here is how policy makers learn from success and failure: how for instance, information on the performance of one programme can inform the design of similar programmes.

The chapter provides a framework to structure this process of search, experimentation and learning, which involves three steps. First, it is important to document the diversity of experimentation efforts in BOP innovation. The chapter shows a wide range of efforts in both technological and organisational innovation, such as advanced market commitments or crowd-sourcing in the health domain. Second, this diversity needs to be made more amenable to policy makers, e.g. in establishing taxonomies of policies and approaches. For example, the US Defence Advanced Research Projects Agency's (DARPA) experience can provide a useful approach for radical BOP innovations, whereas early stage venture capital (VC) funds and agricultural extension agencies may be relevant approaches for more incremental BOP innovations. Third, policy will need to establish a procedure for *diagnostic monitoring* – as described in Chapter 2, the detection and correction of each portfolio of projects and programmes as they evolve. This is particularly important since BOP innovation is still emerging gradually, with significant scope for experimentation and learning, also at the global level. The chapter therefore also recommends that mechanisms be developed and investments made to develop the capability for *diagnostic monitoring* at the global level, involving a range of public and private (including non-governmental) actors.

Chapters 5 and 6 turn to another important emerging dimension of innovation policies, namely support for innovative entrepreneurship. Chapter 5 (by Bob Hodgson and Yevgeny Kuznetsov) explores how countries can increase the rate at which new technology-based businesses are generated, improve their rate of survival and assist them to grow quickly. The promotion of technology-based start-ups and innovation clusters has been a concern of government for many decades. In most middle-income economies, a variety of support instruments have been put in place: technology incubators, science parks and initiatives based on the US Small Business Innovation Research (SBIR) programme. These programmes appear to be of two types: on the one hand, predominantly public-sector and grant-based support to early stages of the incubation cycle (support for research and development and seed funds for commercialisation) and, on the other hand, predominantly private-equity and later-stage VC investment in companies that have proven to be successful.

The chapter proposes an approach based on the management of the incubation cycle, which focuses on the creation of early-stage private sector capabilities. It builds on and connects existing programmes, projects and initiatives (technology incubators, technology transfer offices in universities, science parks and other programmes) by institutionalising search networks composed of diverse players that rarely work together. This approach contrasts with existing, more administrative approaches such as: SBIR-type grant-based programmes that are popular because they are easy to administer, relatively transparent and result in tangible outcomes such as technical prototypes. However, there are reasons to be sceptical regarding their impact. If there is no involvement of early-stage VC or other appropriate forms of financing, the technical prototypes that are funded may not go beyond this stage, even if they have commercial promise.

The emerging proactive search approach proposed in the chapter is less straightforward as it aims to achieve synergy among players and capabilities that previously did not interact. This approach reveals that the deal flow, namely the co-existence of many promising ideas yet few structured deals, is often the binding constraint for the development of innovation clusters and a VC industry. This contradicts the finding of most studies which focus on the shortage of VC finance as the major problem.

Instead, the chapter regards the VC industry as a search network for identifying and combining finance, technical expertise, marketing know-how, business models, standard-setting capacity, etc. Once integrated, these components become nodes in a new set of search networks for designing and building products. By supporting a diverse portfolio of ventures and combining hands-on monitoring and mentoring with market selection, private-public search deal generation networks organise a process of continuous economic restructuring and also learn about how to improve restructuring itself. Also, there is a sharp distinction between early- and later-stage VC in this process.

The chapter concludes that this proactive search approach is only emerging. The chapter offers a diverse portfolio of examples to illustrate this approach, along with an analytical and conceptual underpinning of the approach, with the intention that this will help to improve the design of relevant public sector programmes and policies.

Chapter 6 (by Mark Dutz and Vijay Vijayaraghavan) explores policy initiatives by India's Department of Biotechnology (DBT) for the adaptation and commercialisation of existing global biotechnologies to provide quality affordable solutions for local needs in healthcare, agriculture, industry and the environment. Accelerated technology adaptation has been implemented through actions in six complementary policy areas: 1) translational research; 2) global consortia; 3) skills development; 4) regulation; 5) institutional governance; and 6) public/private partnerships. A notable outcome of these programmes to-date is India's first indigenously-developed oral vaccine to prevent high infant mortality from rotavirus-caused diarrhea, supported by a global public/private partnership (PPP) consortium. It is the first time that an Indian company has brought a vaccine successfully through phase III trials, India's first community clinical trial conducted directly through doctors and clinics, with the licensed vaccine to be sold to governments worldwide including UN procurement agencies at a price of USD 1.

Among the six policy areas, India's promotion of translational research through global consortia between local and foreign firms, universities and public research entities, complemented by support of domestic PPPs, appears to have been critical in spurring learning, including about structured research protocols that lead to commercialisable products. The impact of such learning is suggested, among others, in 78% of surveyed biotech firms indicating that they collaborate with other firms or academia for co-development, and with 86% of these firms collaboratively monitoring progress and results via milestones and joint review processes.

The chapter points to a key outstanding challenge for improved implementation, namely the adoption of more rigorous performance measurement by the Biotechnology Industry Research Assistance Council (BIRAC), the DBT new interface agency with the private sector. This includes both the incorporation of impact evaluation into programme design that allows learning from comparing the results of firms benefiting from support with a similar group of firms not benefiting from the same support, and the institutionalisation into programme implementation of *diagnostic monitoring* routines for more continuous monitoring, learning and improvement. Such performance evaluation based on both impact evaluation and continuous experimentation with feedback would help to assess and improve the cost effectiveness of policies and outcomes relative to alternative solutions, to provide accountability, and to inform and build support from new prospective enterprise applicants and from society at large for any demonstrated (and not just presumed) positive benefits relative to costs of existing and future support initiatives in this area. It also would facilitate joint learning of how to best address emerging challenges through successive modifications of programme design features driven by evidence-based analysis and debate, thereby improving the quality of public expenditures supporting innovation policy and providing a more solid foundation for future funding decisions.

The chapter also suggests that the BIRAC should consider applying to its initiatives an even more systematic set of the *diagnostic monitoring* principles of error detection and correction for continuous improvement – going from: 1) helping programme recipients to detect and better deal with their own deficiencies early on, to 2) helping the programme implementers themselves detect and better manage deficiencies in the programmes, strengthening the range of support initiatives in response to this continuous learning.

The key recommendation from the chapter is for firms and governments to learn from evolving local experience based on more rigorous performance measurement, including from the more systematic incorporation of the lessons from impact evaluation into project and programme design (with explicit metrics to report and learn from failure) and the institutionalisation into project and programme implementation of diagnostic monitoring routines for continuous improvement through redesign.

Chapter 7 (by Mark Dutz and Dirk Pilat) discusses the final new dimension of innovation policies, namely green innovation policies. The chapter explores the role that innovation can play in achieving a greener economy, with a focus on radical innovations that may help move from "business as usual" to a green growth path. It reviews the role of different types of innovation for green growth, the rationale for innovation policies in a green growth strategy and experience to date with policies that favour more radical green innovation. In practice, countries will use a combination of supply- and demand-side policy instruments to achieve policy goals that may differ from country to country. The appropriate policy settings and policy tools will depend on each industry's capacity for innovation, and notably on whether it is involved in innovation at the frontier, in fostering incremental innovation and adopting technologies from abroad, or in building its local capabilities for innovation.

Even when countries have similar policy goals, their instrument mixes can be expected to differ, as these need to be adapted to the specific environments in which they are intended to work. These environments vary in terms of the structure of the industrial productive base, existing local institutions, and prevailing preferences. For instance, without the institutional ability to implement complex tax policies effectively, tax incentives for research and development (R&D) may be ruled out as a policy instrument. Different countries also exhibit different degrees of acceptance of regulation. Moreover, the efficacy of various demand-side instruments can be highly sensitive to industry-specific characteristics. To help policy makers better understand which policies best foster green innovation, more systematic compilation, global sharing and learning about the effectiveness of different policies in different contexts are needed.

The chapter concludes by discussing mechanisms that could facilitate the sharing of what works in the area of green innovation. This learning can usefully distinguish three areas:

- *Existing green innovation policies*. There is an urgent need for well-designed performance measurement of specific policy interventions in the area of green innovation. Both experimental impact evaluation with randomised controlled trials and quasi-experimental evaluation of existing interventions are needed, particularly to learn about the effectiveness of different policies to promote both radical innovation and the broader absorption of existing green technologies. Arguably even more important is understanding how to improve existing programmes' performance through ongoing experimentation during programme implementation, with continuous feedback aimed at evidence-based iterative learning and improvements built into programme design and implementation. Moreover, the effectiveness of all existing green innovation policies should ideally be evaluated in the context of a national wealth accounting framework that explicitly incorporates the value of natural capital.

- *Relevant experience from related innovation policy fields*. There is also much scope for policy learning from related domains. For example, the unmet health needs of poor populations across the world have posed a variety of related innovation challenges, such as developing business models with R&D costs at levels that do not require high-priced blockbuster products. Policy initiatives such as specific prize funds, advance market commitments, patent buy-outs, compulsory licenses, patent pools, patent commons and open source approaches can provide useful insights. The experience of non-profit private foundations, such as the Bill and Melinda Gates Foundation, could also provide relevant lessons for green innovation.

- *New as-yet-untried innovation policies*. A major challenge in the area of green innovation involves fostering effective global consortia to address priorities for public goods by building on existing bilateral consortia. As an illustration, Canada awarded in 2012 its first bilateral Canada-India Research Center of Excellence (CIRCE) initiative.

> Once the fixed costs of setting up initiatives like this are incurred, it would require relatively little additional cost to enrich and globalise such bilateral consortia by including other appropriate participants in the Canada-India platform. The policy challenge is how best to fund such add-on initiatives, how best to identify and bring in the most appropriate complementary global talent, and how best to assist in the dissemination and commercialisation of the research findings. Learning about such new initiatives and policies is a major challenge.

The final part and last two chapters of the book focus on the design and implementation of experimental innovation policies. **Chapter 8** (by Eric Oldsman) explores the role of monitoring and evaluation and its influence on policy design. Recognising the importance of innovation, governments around the world have launched policies aimed at accelerating the development and application of technology. In many instances, the allocation of resources has been accompanied by calls for meaningful measurement of results and greater accountability. This is particularly true in an era of tight budgets and fiscal austerity.

Organisations are therefore placing greater emphasis on trying to measure their performance. Reciting the mantra – "what gets measured gets done" – more and more organisations are picking particular aspects of performance to measure and then devote significant resources to collecting data and reporting results. However, there is evidence that much of this effort may be wasted. To be useful, the right things need to be measured in the right way. As importantly, data need to be turned into information, information into insights, and insights into action. This implies that performance measurement should be embedded in a broader evaluation system, which fosters critical thinking and continuous improvement as part of a policy cycle.

The chapter concludes that organisations need to make sure to count what is important and count it correctly. In this regard, indicators need to be selected and defined with care; requisite data need to be collected and analysed in a suitable manner. Done properly, performance measurement can provide a clear picture of what particular programmes have been able to achieve in terms of measurable results. However, while necessary, organisations need to go well beyond simply measuring performance. They need to focus attention on determining the factors that underlie performance, diagnosing the root cause of any identified deficiencies, in order to take appropriate corrective action. They also need to consider a broad range of issues that do not lend themselves easily to measurement. More generally, critical thinking – an ability to state questions clearly, marshal valid and reliable information, weigh evidence, assess the strength of arguments, recognise implicit assumptions and values, and draw reasoned conclusions – needs to be encouraged throughout the organisation. In this respect, formative evaluations are critically important. They provide an opportunity for organisations to examine accepted truths, questioning the justification for specific claims and calling attention to unstated assumptions.

Clearly, organisations need to establish the technical capacity to undertake evaluations successfully. As importantly, to realise the full promise of using evaluations to inform policy, senior managers must actively support the process and cultivate a culture of learning. While evaluations can be required by legislative mandate or outside funders, managers within institutions must be fully committed to using evaluations to help drive their organisations forward.

Chapter 9 (by Dan Breznitz and Darius Ornston) focuses on learning and experimentation within innovation agencies. It examines how two historically low-technology economies, Finland and Israel, assumed leadership in new and rapidly evolving innovation-based industries. It argues that "Schumpeterian development agencies" (SDAs), such as the Finnish Fund for Research and Development (SITRA) and the Israeli Office of the Chief Scientist (OCS) in the Ministry of Trade and Industry, played a transformative role, by introducing new science and technology policies and facilitating industrial restructuring. In contrast to standard practice, however, these agencies were located on the periphery of the public sector and had few hard resources.

While the analysis in the chapter focuses on Finland and Israel, there are similar developments in Ireland, where the decision to split the Industrial Development Authority permitted the development of new industrial policies targeted at domestic software entrepreneurs. In Denmark, steep cuts to the Ministry of Trade and Industry paradoxically created space for a new generation of policy makers to promote restructuring through sectoral dialogue and reliance on local inter-firm networks. Outside of Europe, Chinese Taipei's Industrial Technology Research Institute (ITRI) introduced the innovation policies that made it a leading semiconductor manufacturer.

In each case, reform-oriented policy makers relied on similar instruments to scale and monitor new science, technology and innovation (STI) policies. For example, SDAs used formal and informal inter-personal networks to bring experimental STI policies rapidly to the centre of national discourse. Irish policy makers formed industry organisations, such as the Irish Software Association, to raise awareness about new policies, while Danish policy makers leveraged local, inter-firm networks to implement new labor market initiatives. At the same time, policy makers in small open economies relied on international openness to challenge established industrial policies and monitor new ones.

This is not to suggest that peripheral public agencies will successfully scale and monitor new STI policies everywhere. In identifying the specific mechanisms that permit scaling and monitoring, the chapter also explains why some countries may be less innovative than others. For example, they may lack effective co-ordinating and consensus-building institutions. They may be fragmented along ethnic, religious or ideological lines, or power may be concentrated in ways that inhibit effective private-public and inter-sectoral dialogue. Alternatively, they may be less vulnerable to external pressure, either because of domestic policy choices that reduce international openness or their location in a region with less geopolitical competition. Some states may suffer doubly, from a fragmented society and limited international exposure, making it more difficult to scale and monitor new innovation policies.

At the same time, policy makers can mitigate these disadvantages. First, policy makers seeking to promote experimentation are better off providing small agencies with a mandate to engage in radical policy experimentation rather than concentrating power in a high-profile, centrally located developmental agency. This finding is as true for large countries as it is for smaller states, as comparatively marginal agencies such as DARPA spearheaded experimentation in new information and communication technologies in the United States. Second, the chapter suggests that the success of SDAs is shaped less by their financial resources than their informal networks. The SITRA and OCS managers surmounted fiscal constraints by leveraging both formal and personal networks to engage other policy makers and private sector representatives. National governments can actively facilitate this process by promoting closer co-operation among public and private sector actors.

At the same time, reform-oriented policy makers should remain sensitive to the limitations associated with these strategies. Co-ordination and consensus-building can stifle experimentation by mobilising resources around institutionally entrenched actors, reinforcing existing prejudices and blinding actors to new ideas. As a result, this chapter also underscores the benefits of economic openness for both large and small states. SDAs increased monitoring capacity by linking STI policies like Finland's new technology policies and Israel's Yozma programme to international economic competition. International organisations and external evaluations also played an important role in ameliorating the deficiencies associated with co-ordination and consensus-building. While small states are uniquely "advantaged" in their reliance on international trade and institutions, there is no reason why policy makers in larger states cannot replicate this strategy by deepening economic integration and linking new STI policies to international economic competition.

A number of messages connect the various chapters, in particular as regards the role of government in innovation and industrial policies. Throughout the book there is an understanding that industrial and innovation policies characterised by top-down government interventions are not the right approach to development. The reasons for the failures of such policies are well known, and include the risks of capture by vested interests, lack of information on the economy and strong information asymmetry with private actors, and a lack of capability in the public sector for effective policy making.

Instead, the book points to another approach to innovation (and industrial) policy, characterised by search, experimentation, monitoring, learning and adaptation, all of which need to occur in a context of international openness to knowledge, trade, investment and competition. This new approach also rests on close co-operation with private and non-governmental actors, who are often better placed to identify barriers to innovation, and areas for productive investment or policy action.

This approach rests on a much stronger focus on (diagnostic) monitoring and evaluation, which need to be embodied in programmes and policies from the outset. This is particularly important for new and emerging areas of policy, such as policies for BOP innovation, high-growth entrepreneurship and green innovation, where there is significant experimentation underway and where the scope for learning and identification of good practices is the largest. Such learning should benefit from policy experimentation at the global level, which will require strengthened mechanisms to identify and diffuse good practices, including through specific knowledge platforms and networks.

A number of other interesting conclusions emerge from the various chapters:

- Some very successful innovation policies have emerged from agencies and actors on the periphery of policy making. Such a peripheral position typically implies limited room for large budgetary interventions, but can limit capture by vested interests and may enable more creative and co-operative policies than those emerging from more central agencies. The success of these agencies with limited budgets also suggests that governments can achieve results in the innovation area in other ways than through public financial support alone.

- The development of new approaches and policies is not limited to governments alone. Non-governmental actors, such as private and social enterprises, foundations and other civil society organisations, play a key role in specific areas, such as health, and can be instrumental in developing new actions and scaling them up.

Finally, the chapters raise a number of issues for further research. First, they raise questions on how policy makers learn from experience and mistakes that are made, how to encourage more entrepreneurial experimentation and appropriate risk-taking not only by enterprises but in policy making, how not only success but failure can be openly discussed and built upon, and how such learning can be organised, embedded and institutionalised in the policy-making process. Second, they point to a need to better understand systems and their behaviour, and how policy can influence the behaviour of (increasingly) complex systems to achieve more sustainable growth and shared prosperity. More broadly, it is hoped that the chapters of the book will help launch a series of conversations together with further exploration and learning into how to make innovation policy, its implementation and its measurement—including the measurement of investments in innovation capabilities by enterprises—work for better development impact in different domains and different country contexts.

Chapter 2

New open economy industrial policy: Making choices without picking winners

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This chapter discusses open economy industrial policy, which focuses on connections among domestic firms and between firms and the world market. In contrast to import substitution policies, the objective of such policies is to increase economic openness in order to enhance flows of knowledge, foster productive innovation and strengthen non-traditional exports. This chapter shifts the debate on government activism in support of globally competitive industries from picking winners to a process of step-by-step transformation of the private and public sectors.

How can policy makers set priorities or provide public inputs to suit the needs of particular areas of economic activity rather than others? The assumption of this chapter is that policy makers invariably make mistakes. They therefore need to shift the focus from a single choice of winners (sectors, industries, firms, other organisations) to the process of detecting and correcting errors (with careful attention to governance).In addition, obstacles to informed choices (influence of entrenched interests, insufficient public-sector capabilities, and the like) require particular attention. Three are particularly important. The first is the *power of vested interests,* which are likely to shift attention from the provision of public goods to self-dealing and rent seeking. Notably, disengagement of the public sector proves to be much more difficult than its engagement, even in successful and promising cases of industrial policy. The second is a *necessarily partial view of the economy.* No actor has a panoramic view of the economy or full knowledge of the distortions the public sector is expected to correct. The third is the *insufficient capability of governments and other economic agents to undertake industrial policy tasks.* In low-income economies in particular, public support for connections to the world economy can be self-defeating, because the capabilities to make these connections do not exist. The issue is how to generate them.

The hypothesis of this chapter is that agents with new capabilities, such as a new private sector (which learns to innovate by connecting to the world economy) and a new public sector (capable of providing complementary public inputs for private-sector research), should develop together as they are two sides of the same collaborative process. This process can begin even if many parts of the government are weak, and many firms are rent-seeking because the public and private sectors are highly heterogeneous. Moreover, as research on new exports shows (Sabel, 2010), some firms will prefer to seek high but uncertain quasi-rents (contingent on research and innovation) rather than the lower but more certain rents accruing from the position of privilege.

The approach taken here shifts the debate from the one-time choice of "picking winners" or "letting losers go" to creating institutions to support private-sector connections with the world economy. If no agent has a panoramic view of the economy, then all views are partial and political economy considerations are central, and mistake-proof industrial policy is impossible. The solution is to design a process that can—through a variety of private-public partnerships—detect and correct mistakes (including those instigated by special interests).

Examples of new industrial policy

There is evidence for the new open economy industrial policy at both national and micro levels. At the national level, small, open economies—Chile, Chinese Taipei, Ireland—provide examples of how to build capacity-enhancing connections with the world. Chinese Taipei implemented an open economy industrial policy process through the development of a venture capital (VC) programme that allowed engineers, born in Chinese Taipei and trained both at home and abroad, to deploy their skills in start-up firms whose activities complemented and facilitated the reorganisation of US leaders in the computer and semiconductor industry. VC—even today diffusing slowly in the advanced economies, and virtually unknown in developing ones outside of Chinese Taipei and Israel—became in effect an instrument for orienting, and reorienting, the direction of the national economy's development in rapidly shifting and highly demanding markets.

Starting in the 1950s, Ireland created a method for identifying and developing growth-enhancing connections. Exemption from (later reduction of) the corporate profits tax attracted subsidiaries of multinational corporations (MNCs) from promising sectors such as chemicals, pharmaceuticals and software. While Chinese Taipei used VC to connect its expatriate engineers to each other and world markets, Ireland used selective foreign direct investment (FDI). The result in both cases was cumulative capacity building, evident in Chinese Taipei in the creation and evolution of firms, and in Ireland, at least through the mid-1990s, principally in the growing responsibilities of managers rising through the professional networks of particular sectors.

The chief vehicle for learning—for selecting the most promising collaborators from among those attracted by the incentives, and working with them to ensure incremental improvement of local supply networks, infrastructure, education, and the like—was at first the Irish Development Agency, and then, from the late 1980s, as domestic firms increased in importance, Enterprise Ireland. The Irish Development Agency's attention to the systemic or economy-wide implications of its collaboration with groups of firms is evident in the way it tracked and reacted to indications of possible skill shortages and in its efforts at supplier development (Box 2.1).

Between 1977 and 1979, the Irish Development Agency negotiated agreements with electronics firms that would create demand for some 600 electrical engineers a year, about four times the number that Irish universities and regional colleges were graduating at the time. Because it takes between two to five years to educate technicians and engineers, there was a need for a short-term remedy and a plan for a long-term expansion of the education system. The short-term solution was conversion of science graduates to electronics qualifications via one-year courses. The longer-term solution was expansion of existing courses and the addition of new ones. The rapid response of the Higher Education Authority reassured subsequent investors that Ireland could provide the skills needed and contributed to the renewal of the university and technical training systems.

The organisation best suited to perform a collaborative search for missing capabilities in firms is: an autonomous entity with a mandate to experiment by assembling and carefully monitoring a portfolio of projects for which it is accountable for. A typical project is a collaborative programme that seeks to alleviate a specific constraint, such as a skills shortage or a lack of qualified suppliers for electronic firms, as in the case of the Irish Development Agency. A project in the new industrial policy portfolio could be a private firm, incubated in collaboration with private partners.

In 1982 for instance, Fundación Chile, an autonomous private-public agency with a modest endowment, acquired the necessary technology at no cost from specialist public agencies in the United States and founded a firm to produce smelts, another to develop hatching and ranching technology for Chilean waters, and a third to smoke fish, thereby creating a foundation for the salmon cluster. Crucially, as the technologies it aimed to commercialise grew in complexity, Fundación Chile went from seeding firms on its own to co-venturing with external partners.

An enlightened sceptic would argue that even if Chile, Chinese Taipei and Ireland had the capacity to undertake these challenging tasks, this may not be the case of low-income economies with a dysfunctional public sector. However, the public sector in these economies may also increasingly provide customised and flexible public inputs. The emergence of a new public sector in Kenya as a result of institutional reforms responsible for ensuring hygiene and food safety at the Nile perch fishery on Kenya's portion of Lake Victoria is a prime example.

Perch exports, predominantly to the European Union, increased from just under USD 100 000 in 1985 to almost USD 44 million in 1996. However, in the same year, the European Union and various member states began to restrict perch imports from Kenya because of concerns about pathogens and pesticide residues, and that Kenyan producers did not meet EU regulations based on Hazard Analysis of Critical Control Points (HACCP) and therefore could not ensure food safety and hygiene. Under these regulations, producers identify the production steps at which pathogens are most likely to be introduced; devise remedial measures; test to verify that these measures produce outcomes within parametres set by the regulator for the relevant class of product; correct remaining shortfalls; and regularly verify, through routine tests, the effectiveness of the chosen methods. A competent public authority periodically verifies the reliability of this self-monitoring.

Box 2.1. Example of a framework programme: The Irish National Linkage Programme

In the wake of a highly successful FDI programme, Ireland faced the challenge of how to deepen FDI involvement and how to leverage the technology then being used to develop its domestic technological capability. In response, the Industrial Development Authority took a calculated risk by bringing together a group of multinational corporations (MNCs) and potential suppliers through a systematic search process that came to be known as the National Linkage Programme (1987–92). The key problem in developing potential suppliers is that one is "doomed to choose" among potential suppliers because developing large numbers is wasteful.

The three main groups involved in the programme were:

Government, which provided the political imperative and charged various state agencies to collaborate. Budget lines were established, and the Department of Industry took a close interest in the programme's operation and effectiveness. Input at this level was essential to maintain political visibility and support for the programme. A total of eight agencies contributed staff and assistance, in part to help small and medium-sized enterprises (SMEs) navigate the bureaucracy when seeking assistance. Staff members from each agency had to shed familiar bureaucratic routines and behave entrepreneurially to make it possible to fast track applications for assistance and to fine-tune the services offered to meet the specific needs of both the customers and their suppliers.

Industry (primarily MNCs through FDI). The principal sector targeted was electronics, since it was the largest and most dynamic and had the greatest propensity to source locally. Industry co-operation was sought, and the MNCs, through the Federation of Electronic Industries, contributed to programme costs in the first two years. Companies were lobbied at high levels by senior agency executives and government ministers. Incoming companies were introduced to the Linkage Promotion Programme's executives so that local sourcing opportunities could be discussed and developed. MNCs were also asked to provide technical assistance in association with state technical agencies.

SMEs. A rigorous assessment procedure was used to select participating companies. It included an analysis of existing or potential capabilities against perceived supply opportunities; a detailed examination of financial management; and an assessment of existing management and of the firms' potential. An essential part of the programme was the close relationships developed by the Linkage Programme with key MNCs. Because of the number of agencies involved in the programme, a well-balanced and multifaceted team of experts in management, business development, technical issues, accounting and banking was key for its success. The wide range of skills allowed the team to conduct the initial assessment and select suppliers (in close co-operation with the MNCs), and also to carry out early-stage development workshops with the SMEs.

During the five years of programme operation, locally sourced materials in electronics increased from 9% to 19% of MNC purchases. While there were some 900 MNCs in Ireland, approximately 200 proved to be effective participants in the programme, both through purchases and their willingness to support it.

Source: Authors' compilation.

The European Union inspected the fishery with Kenyan counterparts and documented problems such as unhygienic storage of fish on the fishing vessels; inconsistent record keeping, especially of "own checks"; inadequate vermin control at processing facilities; insufficient training of fishery inspectors; and a wide variety of deficiencies in the organisation, maintenance and equipment of the testing laboratory. In response, the Kenyan government combined into one the oversight authority of three fishery industry entities, and the fisheries producers formed themselves into a single association to work with the government. A World Bank study (Henson and Mitullah, 2004) notes substantial improvements not just in compliance with HACCP regulations, but also in the organisation of many links in the supply chain and the public sector infrastructure. During the period covered by these reforms, Kenya ranked around 80 out of 117 countries on the World Economic Forum's competitiveness index: a place in the league tables of institutional adequacy poor enough to cast doubt on its ability to accomplish any reform, let alone to effect, in a short period, a co-ordinated series of demanding changes in the public sector and between it and private firms. Despite its marginal economic significance—in good years Nile perch accounts for only 2.5% of Kenyan exports—the regulatory reform of the fisheries reflects broad trends in the provision of customised public services and just-in-time regulation. In effect, the regulatory authorities are requiring firms to demonstrate the same general capacities to detect and correct problems that the firms' customers insist upon as a condition of doing business.

Partial reform, domain by domain or, as in this case, reform of one cluster at a time, also appears to be commonplace. The accounts of cluster development invariably involve discussion of the restructuring of firms and the relationship among them, as well as reorganisations of the public infrastructure related to that cluster, e.g. as regards compliance with standards set both by public authorities and private buyers of the cluster's products. A 2009 World Bank publication documents African success stories and confirms that the simultaneous emergence of new private and public sectors is relatively common in difficult environments, but that they remain small and fragile (World Bank, 2009).

The fragility of the fishing clusters in Chile and Kenya is illustrated by the collective action problem of overfishing. In Chile, notwithstanding certain dynamic parts of the government, the inadequate capabilities of government agencies were not improved as a result of the industry's rapid growth. Indeed, the dynamic segments may also have been weakened as companies lobbied to maintain short-term profitability and the emergence of an underground market for antibiotics led to the failure of collective action to combat the virus threat. A similar problem emerged in Kenya and the other countries producing Nile perch. Exports to the European Union fell dramatically because the industry grew without the necessary trade infrastructure and government regulation on product quality in accordance with European Commission food safety norms.[1]

Framework programmes that help scale up micro changes to the macro level

A key problem for scaling up and institutionalising such fragile new industrial policy episodes at the micro level to the national level is the gap between micro innovations and improvements in macro conditions. In principle, incremental changes can lead to wide and abiding transformations. However, strong constraints can remain if micro changes do not achieve critical mass. Framework programmes can provide an environment for micro level changes to continue and to scale up, thus reducing the risk. The Irish National Linkage Programme (Box 2.1) and the Chinese Taipei VC initiative are two examples.

By the end of the 1970s, Chinese Taipei had already developed significant research and development (R&D) capabilities, such as the Industrial Technology Research Institute (ITRI) and the Electronic Technology Research Institute (ETRI). Yet transforming technology into firm creation proved difficult. The large Hsinchu Science Park, which opened in 1980, was unable to find tenants in spite of aggressive efforts to lure MNCs.

The programme started with the efforts of Minister Li and his influential allies, who convinced the Ministry of Finance to introduce legislation to create, develop and regulate VC in Chinese Taipei, including comprehensive tax incentives and financial assistance. Institutions such as the Seed Fund provided matching capital contributions to private VC funds. Two American-style venture funds, H&Q Asia Pacific and Walden International Investment Group, were created and managed by US-educated Chinese living overseas who received invitations to relocate to Chinese Taipei. Once the first venture funds proved successful, domestic banks and large companies created their own VC funds. Once those started to pay off, even the conservative family groups decided to invest in VC funds and information technology businesses. In the late 1980s, when companies such as Acer and returnee company Microtek were publicly listed on the Chinese Taipei Stock Exchange, the VC industry in Chinese Taipei took off.

A search network (to identify constraints and people or institutions that can help mitigate them), consisting initially of dynamic and forward-looking members of the Chinese Taipei government and leading overseas Chinese engineers in Silicon Valley, was central to the emergence of the VC industry. This network did not have a blueprint, yet it had a role model (Silicon Valley) and a clear idea of "what to do next". By defining subsequent steps, the network broadened and eventually incorporated sceptics and opponents.

As the examples from Chinese Taipei and Ireland illustrate, framework programmes have three distinct features that distinguish them from typical government policies. First, they start with existing institutions and programmes, and reshape them. By linking the better-performing segments of the private and public sectors, they alleviate existing institutional constraints and develop new solutions. They link exceptions to the general rule and allow them to institutionalise their agendas. Both Chinese Taipei's VC programme and the Irish linkage efforts were initially viewed with scepticism; yet, by drawing on existing organisations and programmes, they created sustained dynamics (in backward linkages with VC development) and won over the sceptics.

Second, framework programmes start at the organisational periphery and are therefore less susceptible to rent seeking. Public programmes and policies have three constituencies: users and clients, public-sector bureaucrats, and politicians. All three rely on government programmes as a source of rent seeking: visible political payoffs in the case of politicians, kickbacks in the case of public-sector servants, and subsidies to maintain current business practices in the case of users. By design, framework programmes do not have a large budget: they rely on other programmes. In economic parlance, the motivational effect is transformation from rents to quasi-rents that are contingent on performance and effort. Despite starting small and only needing a small amount of public money, framework programmes require a substantial effort. As a result, and as the Chinese Taipei example illustrates, they are not taken seriously by established interests because they are contingent on the articulation of quasi-rents (which by definition require creativity and effort) rather than on the simple capture of rents (Kuznetsov, 2009).

Third, by linking the better performing segments of an existing institutional framework and searching for out-of-the-box solutions to familiar problems, the institutional framework is also reshaped. There appeared to be no institutional space for the VC industry in Chinese Taipei in the 1980s owing to the tight grip of established agents (large firms and banks). The institutional framework for the VC industry emerged through a dynamic virtuous cycle.

Framework programmes allow public and private actors to respond to current needs without having to feel locked in by their initial choices. Moreover, and crucially, they help these actors deal with the governance questions that their openness creates.

Contrasts with previous generations of industrial policy

The instruments of traditional industrial policy are easy to list: tariff protection, tax rebates, R&D subsidies, directed credit, industrial zones, etc. These instruments serve priority sectors, such as autos, call centres and biotechnology. The priority sectors at any moment are those thought to have, by their nature, certain promising developmental features and to be hindered by significant market failures. For instance, investments in these sectors are held to induce important complementary investments, to represent the next step in the developmental sequence appropriate to an economy of a particular type, or to facilitate the climb of domestic industry up global supply chains. In contrast, the approach presented here emphasises strategic collaboration with the private sector to ensure that interventions work as expected. Very little can be said *ex ante* about either the instruments to be used or the economic activities to be promoted. Recommendations are therefore for the processes and procedures for selecting and correcting selections of both, rather than for specific policy instruments or sectors.

One such procedure is *diagnostic monitoring:* the systematic evaluation of a portfolio of projects or programmes to detect and correct errors as each project evolves (including the weeding out of inefficient ones) in light of experience and new information. Fundación Chile provides a good example of how diagnostic monitoring is conducted: staff members, hired on the basis of demonstrated technical knowledge and familiarity with the markets and business practices in a particular sector, apply for grants to develop a case for launching a new venture in some general area. The best of these preliminary plans can be used to apply for a second, longer-term grant to develop a business plan for a new venture, typically in partnership with outsiders. This process continues until the proto-venture becomes a candidate for seed capital and enters the familiar sequence of VC financing. At every stage, projects are benchmarked against internal and external alternatives, and the start-ups that result are the institutionalised expression of the efforts provoked by that benchmarking. The operation of the start-ups in turn relaxes constraints on the creation of the clusters whose growth propels the Chilean economy.

Fundación Chile's style of diagnostic monitoring is far from error-proof: it failed to introduce vaccines to prevent the propagation of disease that devastated the salmon cluster. But so far, at least, the transparency inherent in the broad and continual benchmarking of projects at every stage has also functioned as an effective governance mechanism, ensuring that public funds are indeed directed toward public purposes. Table 2.1 summarises and juxtaposes three generations of industrial policy: vertical ("picking winners"), horizontal (ensuring adequate background conditions) and new (open economy) policy.

Conclusion: Hayek meets List

International organisations are familiar with economies which have been "studied to death". For instance, by conservative count, during 2007–10 in countries as diverse as the Russian Federation and Tanzania, there were 43 studies on constraints on the investment climate, innovation and competitiveness in Tanzania[2] and 18 studies on constraints on innovation and the investment climate with the participation of international organisations in Russia. While international observers involved in these studies do learn, each additional study may provide diminishing, if not outright negative, value added for the client: they already know the constraints and what to do, the issue is how to put the recommendations into practice, a topic on which the studies are usually mute. Countries would like to see implementation capabilities as endogenous variables of the analytical work.

Austrian thinkers such as Hayek (1949-2002) would have been surprised by such a flurry of studies. For them, understanding reality implies engaging with it through micro-level experiments and projects. Arm's-length information from micro- and aggregate-level constraints is no substitute for the real-time knowledge of micro-level details and constraints revealed in projects and experiments. Hayek himself was not interested in the study of policies. This does not mean there can be no Hayekian perspective on policy making and implementation.

In the German and Austrian historical traditions, List (1841) and Hayek are usually perceived as the two sides of the state intervention–free market continuum. The aim here is to bring together List's concerns with industrial growth and transformation and the attendant microeconomic constraints with Hayek's insight that economic phenomena emerge spontaneously and are experimental, with a focus on tacit and easily accessible knowledge. A Hayekian perspective on industrial policy is long overdue.

The Hayekian approach presented here emphasises ensuring that strategic collaboration with the private sector, which directs interventions, works effectively. Little can be said *ex ante* about either the instruments to be used or the economic activities to be promoted. What is important is the processes and procedures of selecting and correcting the selections, rather than specific policy instruments or sectors. Open economy industrial policy facilitates the search process and the connections among domestic firms, and between them and world market actors. This is not automatic. Developing countries that want to encourage capacity-building connections with the world economy must devise novel institutions—search networks—to connect domestic and foreign actors, to overcome constraints and provide complementary public inputs. The issue is to shift the debate to how to design appropriate governance institutions.

Table 2.1. Generations of industrial policy

	Vertical industrial policy: Backward linkages	Horizontal industrial policy: Market failures	Open economy industrial policy: Missing connections
Incentives for private agents	Rents (in the form of infant industry protection or other price distortions)	Subsidies (when private returns are believed to be lower than social returns)	Quasi-rents—rent opportunities that are contingent on effort or performance
How capabilities of private agents are enhanced	Rents are invested in firm-level learning	Background conditions are improved: improvement of investment climate	To capture rent opportunities, the firm and the government jointly engage in root cause analysis: identification of bottlenecks to progressively relax the binding constraints
Focus	**Micro level** and sectoral ("picking winners")	**National level**: institutional infrastructure—financial markets and regulatory environment ("backing winners")	**Mezzo level**: connections between agents ("matching winners")
Main conceptual axis	Unusually strong **government capabilities** enable and monitor firm-level learning	**Background conditions:** reduction of market failures and distortions; ensuring balance of macro-aggregations and eliminating, in the aggregate, the many micro-impediments to growth	**Search network**—to identify successive constraints and people or institutions that can help mitigate (in part) the difficulties associated with them
Main problem	State capture: development of capabilities subverted by entrenched interests; lock-in of link between macro and micro	Absence of a link between macro changes in various senses and increase in micro-potential	Gap between micro innovations and improvements in macro conditions. Strong constraints remain binding; micro changes do not necessarily achieve critical mass
Examples	Infant industry protection	Reduction of regulatory burden; creation of VC funds	Supplier development programme; development of VC networks

Source: Authors' compilation.

This chapter shifts the debate on government activism in support of globally competitive industries from picking winners to a process of step-by-step transformation of the private and public sectors. In such a process, open industrial policy creates its own context for efficient design and implementation in two ways. First, this shifts the focus of analysis and institutional design from the specific industries that the private sector should pursue to a new public sector capable of providing customised and flexible public goods, and enabling private agents to compete globally. New public and private sectors emerge simultaneously. The key concept is the heterogeneity (discretionary differences) of institutions: it is almost always possible to find some that work. The issue is to use the ones that work to improve those that do not. This assumes that there are nearly always opportunities for development in a given economy, and that some actors, private and public, begin to take advantage of them.

Second, this approach turns obstacles (corrupt and dysfunctional governments, clientelistic networks, etc.) into variables. Errors and entrenched interests that subvert the public good are assumed to be normal and in fact are invited to speak out. Error-proof institutions are replaced by continuous error detection and correction. In this view, a developing economy resembles a vast, continuously improving Toyota-style production system, in which it is presumed that no actor can have a sufficiently panoramic view to be able to identify obstacles ex ante (vertical industrial policy is naïve and unrealistic). The chief problem is to devise search networks (with governance mechanisms to check opportunism) to detect and help facilitate the relaxation of constraints to growth as they emerge.

Notes

1. The authors are grateful to Juan Gabriel Goddard (World Bank) for articulating this point.
2. For Tanzania, the estimate was provided in December 2010 by Josaphat Paul Kweka, World Bank Country Economist based in Tanzania.

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Chapter 3

"Bottom of the pyramid" innovation and pro-poor growth

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Outside of China, despite rapid economic growth in many low- and middle-income countries, there has been relatively little progress in meeting the Millennium Development Goals (MDG1) target of halving the incidence of global poverty by 2015. Part of the explanation for this has been the historic trajectory of innovation. During the 20th century, most global innovation had its origins in the north, producing products for high-income consumers, developing technologies that excluded poor producers and were energy-intensive and polluting. This innovation trajectory gave rise to the not-for-profit appropriate technology (AT) movement after the 1970s. But many of the technologies which it sought to diffuse were inefficient and scorned by both producers and consumers. However, a series of disruptive factors – the growth of low-income consumers during the global economic slowdown, the development of radical technologies (such as mobile telephony and renewable power), the development of capabilities in low-income economies and the emergence of new types of innovation actors – have begun to transform the AT's potential to support pro-poor growth. While the new AT movement will be largely market-driven (since it provides the potential for profitable production), important dimensions of this market-driven process can be supported by policy.

The need for a pro-poor growth agenda

Much of the developing world experienced a "lost decade" during the 1980s, and in some cases the years of slow growth extended well into the 1990s. Then, economic growth revived in many low- and middle-income countries. One of the consequences of this renewed growth was that the number of people living below the Millennium Development Goal (MDG1) benchmark (USD 1.25 per day) fell from 1.8 billion in 1990 to 1.3 billion in 2008 (Chen and Ravallion, 2013). Yet, despite progress on the growth front, poverty numbers remain a cause for considerable concern, and it is clear that the 2015 MDG1 target (fewer than 900 million people living below USD 1.25 per day) will not be met.

Table 3.1. Gross domestic product (GDP) growth rates and numbers living below MDG1, 1990-2008

	GDP growth p.a. (%)		**Living below USD 1.25 per day (MDG1)** (2005 USD PPP) Millions of persons	
	1990-2000	**2000-08**	**1988-90**	**2007-08**
World	2.9	3.1	1 668	1 329
China	9.9	10.4	724	208
India	5.5	7.0	414	456
Sub-Saharan Africa (SSA)	2.2	4.9	224	355

Source: Poverty numbers from Chen and Ravallion (2013), "More Relatively-Poor in a Less Absolutely-Poor World", Policy Research Working Paper 6114, Development Research Group, World Bank, Washington; and Sumner (2010), "Global Poverty and the New Bottom Billion: What if Three-Quarters of the World's Poor Live in Middle Income Countries?", mimeo, Institute of Development Studies, Brighton. Growth rates from World Development Institute (WDI), accessed October 2011.

Progress in reducing the number of people living below the MDG1 target has been almost entirely a reflection of poverty reduction in the People's Republic of China (Table 3.1). In most other parts of the developing world, the absolute number remained static or increased. This is particularly evident in India and Sub-Saharan Africa. In India, which is home to almost half of the world's poor living below the MDG1 target, there was no reduction in the absolute poverty number. In Sub-Saharan Africa, the annual growth rate increased from 2.2% during 1990-99 to 4.9% during 2000-08, yet the population living below the MDG1 threshold increased from 224 million in 1988-90 to 355 million in 2007-08 (Sumner, 2010). India's annual growth rate over the same periods rose from 5.5 to 7%, yet the numbers living below the MDG1 target rose from 414 million to 456 million. Significantly, as Sumner observes, the bulk of the global absolute poor do not live in countries with an average income below MDG1 (Collier’s “bottom billion”; Collier, 2007). Three-quarters live in middle income economies, many of which benefited from the post-1995 growth spurt.[2]

Poverty is not just a measure of absolute living standards. It also reflects relative living standards, and there is growing evidence that inequality in itself makes it difficult to reach many of the other development and MDG targets, such as infant health, education and life expectancy (Wilkinson and Pickert, 2009). With the exception of continental Europe and a few Latin American economies, intra-country distribution of income has generally grown markedly more unequal over the past two decades. However, as Cornia (2011) notes, recent years have seen a reduction of inequality in some economies which have introduced social welfare policies.

China’s progress in reducing absolute poverty in a context of rapidly growing inequality shows the contribution growth can make to poverty reduction. It is clear that low-income economies in particular cannot meet the MDG1 target without continuing and increasing financial transfers either from richer economies or from sustained economic growth (or from both). Yet, it is also abundantly clear from the numbers cited above that growth in itself will not adequately solve either the absolute or the relative poverty agenda. In fact, under some circumstances, the conditions that promote rapid economic growth (e.g. deepening financial integration, competitive devaluation) may exacerbate the problems of absolute poverty, as sections of the population may be excluded from the benefits of growth owing to unemployment or reduced real wages.[3]

Consequently, to reduce poverty, it is necessary, beyond the promotion of economic growth *per se*, to consider the nature of growth. This means moving from an “exclusive” to an “inclusive” pro-poor growth strategy, one in which better distributional patterns are endogenous to the growth process and in which the social and political constellations underpinning growth reinforce more equal distributional outcomes.

A number of factors determine the distributional outcomes of economic growth. These include globalisation, which allows high-income earners who possess various forms of rent (such as natural resources, skills, entrepreneurship and patents) to commercialise these over a larger market. At the same time it exposes those with low incomes and without rents to intensified competition (as in the case of unskilled labour when the global labour pool doubled after liberalisation in China, India and the former Soviet Union from the mid-1990s). Fiscal and welfare policy also affect the distributional outcome of growth. For example, in many European economies the distribution of consumption is much less unequal than the distribution of income. In recent years, Latin American economies, such as Brazil, have seen reduced inequality as a consequence of fiscal transfers (Cornia, 2011). The character of innovation is another determinant of the distributional outcome of growth and is the subject of this chapter. How does innovation affect distributional outcomes, and what policies might be adopted to improve them? While innovation is only a partial contributor to the persistence of global poverty it is an important one, and one which is largely neglected in the theorisation of the causes of poverty and inequality (Cozzens and Kaplinsky, 2009).

Insofar as innovation has contributed to adverse outcomes for poverty reduction, the first challenge is to understand how and why this has occurred. The chapter therefore first considers these questions. It then looks at the Appropriate Technology (AT) movement as a way to respond to the links between innovation and exclusive growth, while recognising its limited carrying power in both public- and private-sector policies. However, while the AT movement is largely scorned as a suitable policy response and has been relegated to non-governmental organisations (NGOs), disruptive forces are emerging that may change the prospects for pro-poor innovation and are discussed next. If they evolve in the way suggested here, the AT movement will shift from an NGO-driven diffusion path to a market-driven diffusion path. Even if this occurs, there are important issues for policy support which are briefly outlined.

What do we mean by innovation?

Innovation is the process which occurs when a new idea is applied to meet the needs of a user. It may be new to a particular producer, to a particular sector, to a particular economy or to the world. It provides a different good or service (product innovation), or applies new methods in the production of a good or service (process innovation) or combines a change in both a product and a process. Seen in this light, an innovation represents a change in technology. As the knowledge-content in production has increased, and as global value chains have continued to fragment (Kaplinsky and Morris, 2001; Gereffi et al., 2005), technological change has become increasingly intangible. That is, it affects the configuration of production systems as much as physical products and equipment. In the context of the value chain framework, innovation can be classed into four categories: product innovation, process innovation, functional innovation (changing business models and the division of labour within a value chain) and chain innovation (moving from one product chain to another).

In what way has innovation contributed to exclusive growth?

Joseph Schumpeter, writing in the 1930s, defined entrepreneurship as the act of innovation, that is, the application of a new idea to meet the needs of consumers. His primary focus was on entrepreneurs' search for new combinations that would enable them to escape, at least temporarily, from competition and thereby earn higher profits ("entrepreneurial rents").

With a view to developing pro-poor innovation policies, three lessons can be drawn from this Schumpeterian perspective. First, while a profit-driven agenda explains the bulk of innovation in the global economy, there is no intrinsic reason why innovation should always involve commercial activity. Social innovation, for example by national health services, is an important area of technological change. Second, the Schumpeterian perspective highlights the role of social actors in the innovation cycle. Among other things, this helps to understand that technologies are predominantly shaped by their social context rather than a result of unfolding "natural laws." Third, as a consequence of the social context of innovation, it highlights the limits to interventions that are confined to physical technologies and do not take into account the social and economic context of innovation. As will be seen, these three insights have important implications for the trajectory of innovation and for pro-poor innovation policies.

Drawing on the Schumpeterian framework and on the fourfold classification of innovation and technological change in value chain theory, it becomes clear why the trajectory of innovation over the 20th century led to an exclusive rather than an inclusive growth path. As a general rule, the consumers whose needs the global innovation system (product innovation) has historically targeted have been higher-income consumers located in the relatively rapidly growing northern economies. The physical "embodied" technologies that have been developed (process innovation) have generally been increasingly large-scale and have depended on reliable, high-quality and network-driven infrastructure (such as electricity grids, fixed telecommunications, integrated water and sanitation systems). They have also generally been labour-saving (increasingly reliant on skilled labour) and capital-intensive. The widespread availability of relatively cheap energy sources has also meant that they have been energy-intensive and often heavily polluting. The organisation of value chains, which have become increasingly fragmented and global (functional innovation), has led to clusters of producers in low-income economies in highly competitive niches of the value chains, often confined to simple labour-intensive assembly and subject to intense wage competition. Moreover, meeting the needs of high-income consumers in high-income northern economies has also led to a situation in which value chains are increasingly standards-intensive (Kaplinsky, 2010), thereby raising barriers to entry for small-scale informal and often illiterate producers. Finally, moving to new lines of activity (chain upgrading) in an increasingly knowledge-driven economy has required a range of complex capabilities which are beyond the reach of poor producers and low-income economies.

Of course, not all innovations during this period have excluded the poor. Some have directly addressed their needs (e.g. elements of the Green Revolution) and others have indirectly addressed them (e.g. improved infrastructure has provided access to wider markets and reduced the costs of goods imported from other localities). However, as a general rule, innovation has been directed toward meeting the needs of rich consumers and producers in high-income economies and in high-income pockets of low- and middle-income economies. It is important to keep in mind that this trajectory was not inevitable and that innovation must be seen in a social context in which it has only partially contributed to the "exclusive" growth trajectory which dominates the global economy.

Why has innovation been exclusive?

The theory of induced innovation provides a framework for understanding how this technological trajectory has evolved. It identifies three factors that determine the nature and trajectory of technological progress (Ruttan, 2001). The first is the nature of demand, with innovators responding to the effective demand of consumers with disposable cash incomes. The large and growing markets of the post-war era were those of high-income consumers in developed economies rather than low-income consumers in developing economies. The second is factor prices and the quality, nature and price of infrastructure. Innovation in high-income economies reflects these operating conditions and has been capital-intensive, large-scale and dependent on reliable, widely diffused and centralised infrastructure. The third factor identified by Ruttan, based on insights from institutional economics (Dosi, 1982), reflects the path dependencies of innovating firms. This means that northern-based firms innovated in areas closely related to their past success. This reinforced a trajectory of innovation largely focused on meeting the needs of high-income consumers and on operating conditions in high-income economies. The role of regulatory systems can also be added to Ruttan's three-fold induced innovation framework. An increasingly tight and enduring system of global intellectual property rights has created major barriers to the entry of new innovators. The underpricing of the real cost of energy and environmental externalities (an effect of regulatory systems) has led to the development of energy-intensive and polluting innovation streams.

Therefore, until very recently, the overwhelming proportion of resources for innovation has gone to high-income economies. The Sussex Manifesto of 1970 (Singer et al., 1970) estimated that around 98% of global research and development (R&D) expenditure occurred in high-income economies, and that much of the 2% spent in the developing world was directed to the needs of high-income consumers and the formal sector. Although R&D is only one source of technological change, a very large proportion of non-R&D-based incremental change in production processes also took place in high-income economies. Much of the incremental innovation in low-income economies has been due to multinational enterprises (MNEs) originating in high-income economies and geared to the routines of their global operations (Teece et al., 1997).

It is not surprising, then, that the path followed by innovation has contributed in important ways to the persistence of global poverty and to a widespread increase in global inequality. The most marked indicator of this impact has been the marginalisation of much of the world's population from formal-sector employment owing in large part to the diffusion of labour-saving innovations. In 2009, for the first time in human history, more than half of the global population lived in cities (UN-HABITAT, 2010). But unlike the cities of the nineteenth century and the first half of the twentieth century, these cities are inhabited by the marginalised and excluded who live in a "planet of slums" (Davis, 2006).

A response to marginalisation: The rise (and fall) of the AT movement

One response to this northern-focused innovation trajectory was the development of the AT movement. It is composed of a growing spread of NGOs, often with global reach, such as the Intermediate Technology Development Group in the United Kingdom (ITDG, now Practical Action) and Appropriate Technology International in the United States. In spirit, many of these AT NGOs drew their inspiration from the values promoted by Ghandi's Swadeshi Movement in India and globally by Schumacher (Schumacher, 1973). They supported the development of new ATs, which often blended traditional and new technologies (Bhalla, 1984) and diffused existing ATs both within and across national boundaries.

In principle, the AT movement offers the prospect of providing the underpinnings of a more inclusive and less environmentally damaging growth path. However, three problems have beset the AT movement. First, empirical studies have shown that many of the ATs disseminated were "economically inefficient" (i.e. they made greater use of capital and labour per unit of output), a criticism that was widely recognised in the literature (Eckaus, 1955, 1987; Stewart, 1979; Bhalla, 1975; Emmanuel, 1982). Second, "appropriateness" is inherently contextual and involves trade-offs between objectives (Kaplinsky, 1990). Many labour-intensive and small-scale technologies are relatively energy-intensive. The AT movement often failed to recognise these trade-offs and made unrealistic promises, thereby undermining the technologies it promoted. Third, the social context of innovation was not conducive to the diffusion of ATs. The dominant innovators in the global economy were located in northern economies and had little or no interest in meeting the needs of the global poor or of incorporating the poor in global value chains.

As a consequence, the diffusion of ATs has generally been undertaken by not-for-profit NGOs such as ITDG and the AT movement. They have been widely scorned in many low-income countries, particularly by the urban elite who model their consumption patterns and life trajectories on those of their peers in high-income countries. The AT movement may have grown rapidly in the 1970s and early 1980s, but its growth was truncated, and it was consigned to the margins of economic growth.

The world is changing: Forces of disruption

In recent years a number of emerging factors have threatened the dominance of a global innovation system which targets the needs of high-income consumers and which utilises capital-, scale- and standards-intensive technologies which are sensitive to the quality, reliability and ubiquity of infrastructure. They open opportunities for innovative ATs that are efficient and can be profitable. Four of these emerging disruptive factors are: the dynamism of low-income markets, the availability of radical new technologies, the global diffusion of innovative capabilities and the emergence of new innovation actors.

The dynamism of low-income markets

In spite of the revival of economic growth in the United States and other northern economies after the financial crisis of 2008, most high-income markets continue to be burdened with two structural deficits. The first is debt. While deficits in the private sector have narrowed, sovereign debt remains high and continues to grow. The second, less widely recognised but equally germane deficit, is the level and persistence of balance of payments deficits. The structural rebalancing required to meet these deficits will necessarily lead to a decline in demand in high-income markets (Farooki and Kaplinsky, 2011). Increasingly, observers refer to the likelihood of a "lost decade" in the United States and parts of Europe, like those of Latin America and Africa in the 1980s and of Japan in the 1990s. By contrast, China, India, Brazil and other emerging economies seem unlikely to suffer to the same extent. Growth in these low-income economies is likely to remain high and robust, at least in comparison with the northern economies. The Africa-Asia-Central Europe head of Unilever estimated in 2010 that by 2020, nearly 80% of incremental growth in consumption will come from emerging economies.

These growing low-income economy markets are distinctive. On the one hand, there is rapid growth in demand from an urban middle class which is not very different from most consumer markets in the north. They want globally branded, differentiated and high-quality positional goods. For example, in 2010 China was the most rapidly growing market for Mercedes Benz and Rolls Royce cars. On the other hand, there is a rapidly expanding and very large market of poor consumers. In particular, 56% of all households in China had a total annual income of less than USD 5 000 in 2009, and 71% of all households in India (www.portal.euromonitor.com). Although poor relative to the elite in these economies and to consumers in high-income economies, these consumers represent a dynamic and growing market. According to McKinsey calculations, the number of Indian households with an annual income between USD 7 000 and USD 10 000 will catapult from 14 million to 200 million between 2010 and 2015 (*Financial Times*, 2011).

It would appear likely (drawing on Ruttan's induced innovation framework) that consumption by low-income households will induce a set of products different from those induced by high-income earners in northern economies. These product innovations are also likely to be differentiated to suit the environments in which they are developed. According to McKinsey, these innovations will be distinctively different from those produced for high-income global consumers and somewhere between the positional goods of high-income consumers and the basic functions and low-cost goods of those at the "bottom of the pyramid" (Prahalad, 2005). This "bottom of the pyramid" market has begun to draw the attention of many of the world's largest MNEs, particularly those that sell final consumer goods such as Unilever, Proctor and Gamble, and Nestlé. Low-income consumers may prefer "high-quality" branded goods but lack the income necessary to acquire and consume them. They will make do with what they can afford rather than what they would prefer.

A shift of the final market from high-income to low-income countries has had important implications for the role of standards in global value chains. Products destined for high-income consumers and countries have tended to involve the extensive use of product and process standards. There is considerable evidence that these standards have excluded low-income producers from global value chains. By comparison, as such standards have affected products destined for low-income markets relatively little (Kaplinsky et al., 2011), some of the barriers to entry for small-scale producers of such products have fallen. However, insofar as standards have protected the environment and the exploitation of vulnerable labour, there has been some trade-off in terms of the consequences of production processes and products for poor producers and consumers.

The emergence of radically new technologies

The literature on long-wave cycles and innovation distinguishes a spectrum that runs from incremental changes on the shop floor and farm to the revolutionary technologies that sweep across sectors rapidly in disruptive waves of creative destruction (Freeman and Perez, 1988). Somewhere in between these extremes a series of radical technologies provide opportunities for new, higher-quality, multi-functional products produced with different technologies and delivered through new business models. Historically, synthetic textiles and nuclear power are examples of this form of radical technical progress.

Today, four radically new technologies have potentially widespread significance for producing products for poor consumers or for including poor producers in efficient production processes. The first of these is the rapid growth and diffusion of information and communication technologies (ICTs). Perhaps the most pro-poor innovation-relevant outcome has been the use of mobile telecommunications for low-cost and distributed information diffusion. Farmers and distributed producers in other sectors now have greater access to market information and increasingly to knowledge-intensive extension and business services. The second set of emerging technologies is renewable energy production, such as solar and wind power and biomass. These new technologies enhance consumer welfare and provide the potential for low-cost and distributed energy supply to small-scale consumers and producers, particularly those living in rural areas. The final two families of emerging pro-poor relevant technologies are nanotechnology and biotechnology (Singer and Daar, 2001). They have important potential applications for meeting the needs of poor people and for small-scale applications such as new diagnostic kits and new water purification systems.

Each of these technological developments provides possibilities for shaping technological progress in particular directions. In the northern economies, the feed-in tariffs designed to promote the adoption of solar photovoltaic and other renewable forms of energy supply have led to a system in which the energy generated is fed into the national energy grid, and new energy producers do not consume the energy they produce. However, these new sources of energy production can also be consumed directly at the source by producers, and thereby lead to distributed production and use.

The global diffusion of innovative capabilities

Recent decades have seen a substantial increase in the share of global manufacturing value added in low-income countries (particularly in China) and in some knowledge-intensive services (particularly in India). The global diffusion of value added in these sectors has been associated with an increase in capabilities in many low-income economies. These capabilities have been built on a number of strands of activity. The first has been the relatively passive process of "learning by doing" and the more active processes of "learning by adaptation" and "learning by capacity expansion" (Katz, 1987; Bell, 2007). These firm- and farm-level activities – generally associated with efforts to make maximum use of purchased, and often imported technologies – arise from incremental changes in the operation of equipment. They are often also acquired through participation in global value chains (Kaplinsky and Morris, 2001; Gereffi et al., 2005). Formal R&D is another important component of innovation (although its importance is often overestimated). By 2000, more than one-fifth of global R&D was located in the developing world (Hollanders and Soete, 2010), an increase of major significance given an estimated share in 1970 of only 2% (Singer et al., 1970). An increasing share of this dispersed R&D occurs as a result of outsourcing by global MNEs, particularly to China and India (Bruche, 2009). The diffusion of capabilities to countries with large populations of low-income consumers provides the scope for a new source of innovation that is potentially disruptive to the dominance of northern technological change.

Disruptive entrepreneurs

However, the existence of capabilities, the availability of radically new technologies and the growth of effective demand from poor people do not in themselves result in innovation. Instead, as Schumpeter highlighted, innovations arise as a consequence of purposive action by entrepreneurs who develop and use inventions in product, process and organisation in the search for profit.

Different categories of entrepreneurs might play a role in the innovation of pro-poor products and services, and process technologies. One is established global MNEs seeking to capture the "fortune at the bottom of the pyramid", particularly in the FMCG (fast-moving consumer-goods) sectors, but also in medical instruments (e.g. General Electric increasingly uses India and China as sources of low-cost innovation; Immelt et al., 2009). Prahalad was one of the first to spot the potential for profitable production offered by growth in these low-income markets and by this new class of consumers (Prahalad and Hammond, 2002). He observed that there were 4 billion people living at per capita incomes below GBP 2 000 a year and described their growing consumption power as a "fortune at the bottom of the pyramid". Crucially, and perhaps not surprisingly given that he worked in northern business schools, Prahalad believed that this provided a profitable market opportunity for MNEs rather than for the small-scale, locally owned firms long identified in the AT and informal sector literature as key providers for low-income consumers. He argued that:

> "[b]y stimulating commerce and development at the bottom of the economic pyramid, [northern-based] MN[E]s could radically improve the lives of billions of people… Achieving this goal does not require multinationals to spearhead global social development initiatives for charitable purposes. They need only act in their own self-interest, for there are enormous business benefits to be gained by entering developing markets." (Prahalad and Hammond, 2002)

The belief that northern MNEs would be able to obtain this market is an untested assertion. As Christenson's (1997) widely cited work has pointed out, large firms that dominate in their industry are often extremely good at hearing the demands of existing customers but very poor at hearing those of new customers such as low-income consumers in low-income economies.

If the leading northern MNEs are unable to exploit this emerging low-income market effectively, a variety of domestic firms in low-income economies recognise the potential for profit in targeting the needs of low-income consumers and the scope for addressing these needs through innovations in basic, labour-intensive technologies. A widely cited example (which is not without its teething problems) is the Tata Nano in India, a basic car priced at less than USD 2 500 and aimed at low-income consumers moving up from a two-wheeled scooter. One idea is to produce the car in kit form so that consumers can tailor the body to meet their needs (adding trailers, for example) so that the car becomes a capital good. In China, Haier (now the world's second largest producer of white goods) discovered that some rural consumers used their washing machines both for clothes and to wash potatoes, so they redesigned their machines to make them more robust and to serve both consumer needs effectively.

Less visible, and below the radar, are a plethora of small- and medium-scale entrepreneurs in the South who are introducing small-scale innovations without inputs of formal R&D and with little attention to intellectual property rights or product and process standards. For example, DMT Mobile Toilets is a commercial enterprise that produces, rents and maintains safe, sanitary portable toilets in West Africa. Lifeline Energy conducts extensive end-user research and develops and distributes clean energy products, including radios, a range of lights, solar panels and MP3-enabled Lifeplayers that allow for pre-loaded educational content as well as Internet access. In Uganda, low-cost sanitary towels made from reeds growing near Kampala have led to lower product prices and reduced the tendency for teenage girls to miss school.

Another relatively new set of carriers of innovation are the public/private partnerships (PPPs) constructed by international organisations such as the Bill and Melinda Gates Foundation, the Global Alliance for Vaccines and Immunisation (GAVI) and the International AIDS Vaccine Initiative (IAVI) to deal with global health problems. These involve building innovation consortia combining northern and southern research institutions, universities and firms. Unlike private-sector entrepreneurs who seek to tap into growing bottom-of-the-pyramid cash markets of private consumption, these PPPs tend to focus on innovation in sectors where poor consumers either do not have the income that would allow private entrepreneurs to capture the fortune at the bottom of the pyramid or where the public-good nature of the product and service would not allow private entrepreneurs to appropriate their innovations.

Promoting pro-poor innovation: Market or state and policy implications

The single most important conclusion which emerges from the above analysis is that there has been a sea of change in the underlying determinants of pro-poor innovation. In the past pro-poor innovations were often inefficient, were promoted by civil-society organisations and were scorned by both consumers and formal-sector producers. Now, as a result of the disruptive factors discussed above, ATs are beginning to move in from the economic margin. They are now increasingly efficient and a source of corporate profit. There is widespread evidence that this is occurring and has resulted in pro-poor outcomes in many countries, Cameroon being one example (Khan and Baye, 2011). Another example is Chinese motorcycles, which are less durable than Japanese motorcycles and require more repairs. However, they are one-third of the cost and have provided low-income school leavers the opportunity to enter the market as taxi drivers and logistics providers. Similarly, Chinese-produced batteries have half the operating life of northern-branded products, but cost only one-third as much. In both cases, the Chinese products lower the costs of purchase for consumers and firms, creating new markets that support pro-poor growth.

A recent edition of *The Economist* focuses on the development and diffusion of a range of pro-poor innovations in South Africa, and through South African firms in Sub-Saharan Africa:

> “South Africa is being shaken up by the rise of the emerging world, as its champions invade South Africa and South African champions return the compliment. The Industrial and Commercial Bank of China bought 20% of Standard Bank in 2007, in what was the country’s biggest foreign investment. Indian conglomerates such as Tata and drugs firms such as Ranbaxy are hyperactive in South Africa. South Africa’s FirstRand is bringing its banking skills to India. SABMiller has bought one of Colombia’s largest brewers, Bavaria. This growing “south-south” trade is forcing South African companies to think about costs as never before: Tata’s trucks, which use parts made in India, are 15-20% cheaper than other locally assembled models. South Africa is littered with Chinese wholesalers selling cheap Chinese brands. And it is opening minds to the huge opportunities that lie in the emerging world.
>
> “South African companies are paying much more attention to the rest of the continent, which some once made a habit of ignoring. MTN controls half of the Nigerian telecoms market, which is doubling in size every year. Shoprite is Africa’s largest food retailer, operating in 18 African countries. South African companies are also discovering the “bottom of the pyramid” in their own country. Several companies have pioneered the art of using cell phones to map the distribution of informal shops (spaza) and truck stops. Blue Label Telecoms, which sells pre-paid tokens, has blazed a trail in forming relationships with tribal chiefs and popular gospel singers to help sell its products. Knowledge of the bottom of the pyramid is now being used to expand in emerging markets. SABMiller produces beer for Uganda using cheap local ingredients rather than expensive imported malt. MTN provides solar-powered phones to fishermen.” (Economist, 10 September 2011)

Beyond this diffusion of emerging-country technologies in low- and middle-income economies, many of the world’s largest northern-based MNEs are all too aware of the slowdown in consumption in many high-income markets and of the vibrant growth of demand in low-income economies and, within these, of low-income consumers. They are reorienting their innovation systems to take advantage of the profit potential opened up by the dynamic markets of low-income consumers. The most widely cited example is Unilever in India which repackaged its shampoos into small containers to make them available to low-income consumers with limited budgets (Prahalad, 2005).

If the market is now becoming a primary driver of ATs, policy still has a role in the promotion of pro-poor innovation. Five areas of policy action can increase the breadth and depth of diffusion of pro-poor innovation. Since the development and diffusion of efficient pro-poor ATs is a relatively recent and rapidly evolving phenomenon, the policy issues sketched out below are embryonic and will require further development. Many of these innovation-focused policies need to complement existing policies (such as agricultural extension, policies to promote SMEs, investment promotion agencies) that are relevant to meeting the needs of the poor.

Removing market imperfections

All markets are characterised by imperfections of one sort or another, and much economic policy in recent decades has sought to weed out the imperfections that hinder growth without creating too high a cost for the consumer, the producer or the environment. Although some degree of trade-off between growth and other development objectives is widespread and unavoidable, the task is to identify those market imperfections which are intrinsic to pro-poor innovation.

Since poor producers and consumers are often illiterate or lack access to the Internet and print media they are particularly prone to knowledge imperfections. One involves users who lack knowledge about the nature and extent of pro-poor innovations. Mirroring this are producers of innovations who lack knowledge of final markets, particularly those which are not geographically proximate. This imperfect knowledge is especially problematic in the case of pro-poor innovations since many are produced by SMEs in rural areas that lack links to high-quality infrastructure. Consequently, for these and other reasons, many pro-poor innovations are "below the radar." A mechanism is needed to fill these knowledge gaps within countries and in trade between countries. Governments in both producing and using economies are important actors, but so are the World Bank, the IMF and other International Financial Institutions, the UN family and global NGOs. Unlike the existing policy trajectory, which seeks to connect poor producers to rich buyers, the task is to connect poor producers to poor buyers outside of their region.

A second market imperfection is distortions at the border, which often place relatively higher barriers to imports from low- and middle-income countries than to products, technologies and services from traditional northern economies. In addition, the transport and communications infrastructure in many low-income countries is disproportionately geared to links with the industrial north rather than to other low- and middle-income countries, even in the same region. (It is still often easier to get from one African country to another by flying through a European airport.)

A third set of imperfections is due to inappropriate regulatory mechanisms. A review of the regulatory structure is needed to determine the extent to which regulations may adversely affect poor producers and consumers. This is not to suggest that regulations should be abolished. Many regulations exist to protect the public interest. But it is important to determine whether the regulations that affect the development and diffusion of innovations are weighted against poor producers and consumers. For example, a regulation that specifies the minimum weight of a loaf of bread may either be determined by the weight of an average loaf (allowing for variable loaf size with manual, labour-intensive manufacturing) or the minimum weight of an individual loaf (favouring mechanised mixing and dividing).

Reorienting national, regional and sectoral innovation systems

Although innovations tend to be marketed by individual firms, they are produced in value chains that involve a series of producers of inputs. These individual producers are often connected to institutions in the national, regional and sectoral systems of innovation such as public research institutes, universities, technical colleges, testing and calibration service providers and various providers of business services, including those provided by government to support industrial and agricultural development.

Optimising the flow of pro-poor technologies therefore requires an alignment of the relevant actors in the innovation system. This recommendation slips off the tongue easily, but is a more daunting task than is often recognised. Connecting private-sector firms in the innovation value chain is relatively easy and generally occurs as an outcome of market forces. But getting institutions aligned to meet the needs of poor producers and to develop products and services for poor consumers is more difficult. Often standards and curricula, let alone the direction of research, reflect connections in the system of innovation with the global community of peers rather than with the needs and capabilities of marginalised domestic populations. This gap appears frequently in relation to the perception of quality. “Fit-for-purpose” quality reflects the operating environment of the users, their income and their budget. Often these only allow for the purchase and use of technically “inferior” products, as in the case of batteries and motorcycles discussed above. It is also evident in the Consultative Group on International Agricultural Research (CGIAR) system where the selection of problems for investigation often ignores the needs of poor and marginalised producers. For example, following the successful development of Green Revolution seeds, the International Laboratory on Research for Animal Diseases (ILRAD) sought for more than 20 years to find a “high science” vaccine for trypanosomiasis. It failed, but in the interim a low-technology approach to vector control was largely ignored, and veterinary services were wound down, with severe consequences for poor livestock farmers (Clark and Smith, 2010).

Strengthening the role of non-market actors

The growing role of the market as an environment for inducing and diffusing pro-poor innovations has been a central concern in the preceding discussion. However, this role is inappropriate for innovations that are public goods characterised by difficulties in appropriation and by non-exhaustibility. In such circumstances, the market is unlikely to serve the needs of poor consumers and producers. This is classically the case of health services, which are particularly important for meeting the needs of the poor. Networks are a related problem, as they involve high capital costs while unit costs decline sharply with large-scale provision, as in the case of infrastructure. In this case market failure is likely, poor and dispersed populations are likely to be particularly affected, and pro-poor innovations are unlikely to emerge without the active participation of non-market actors.

This does not necessarily mean that market actors will be excluded from participating in the development of pro-poor innovations, for example if governments compensate market actors for market failures (as in subsidies for training). However, there are cases of new non-market innovation actors entering the innovation cycle in collaboration with private-sector firms. They have played a particularly positive role in the provision of innovative public goods which have a direct bearing on the welfare of the very poor, such as innovations aimed at neglected diseases or diseases that disproportionately affect the poor. This has been an important development and needs to be sustained. There has been less presence of non-market actors in the development and diffusion of pro-poor innovations with regard to infrastructure. The positive impact of infrastructure on poor producers is often underestimated.

Linking BOP1 and BOP2 populations

Many of the absolutely poor – the 1.3 billion people living below the USD 1.25 a day MDG threshold – live in close proximity to the additional 1.2 billion people living with more than USD 1.25, but less than USD 2.50 a day. The two groups are here referred to as BOP1 (bottom of the pyramid 1) and BOP2, respectively. The BOP1 group has little cash income and is unlikely to be a significant market for MNEs and other private-sector actors. The BOP2 group does have cash income, albeit very little, and represents an inducement to innovation for profit-seeking entrepreneurs. Although Prahalad did not distinguish between BOP1 and BOP2, the examples he provides (shampoo-packaging, eye-care services, etc.) more clearly target BOP2 than BOP1 consumers.

There is an articulation between incomes in the BOP1 and BOP2 target groups, so that rising incomes in BOP1 may be linked to those in BOP2. Some examples are as follows: 1) BOP1 provide cheap wage goods and services for BOP2 workers, thereby contributing to welfare in BOP2 but also keeping down wage rates and fostering growth; 2) BOP1 characteristically use what is discarded by BOP2; 3) BOP2 consumers with cash incomes may be important consumers for BOP1 products; 4) BOP2 income recipients often provide transfers to BOP1 relatives; 5) there will be externalities in network-intensive sectors when the costs of the network are covered by meeting the needs of BOP2 and the benefits spill over to BOP1; and 6) there is extensive evidence that because BOP2 live above the subsistence level, they are more open to adopting riskier and innovative entrepreneurial behavior than BOP1 and provide role models for BOP1 (Sonne, 2010).

Since the BOP2 poor possess incomes, they are the major target for Prahalad's profit-seeking MNEs and for much market-driven pro-poor innovation. The BOP1 poor are much less likely to provide a market for the private sector. There are two consequences which arise for the stimulation of pro-poor innovation. First, non-market actors are more likely to play a role in meeting the needs of BOP1. Second, because of the articulation between the BOP1 and BOP2 populations, it may well be that innovations that affect the very poorest segments of society are those that aim to meet the needs of the BOP2 population. This conclusion fits awkwardly with some pro-poor policy agendas, as does the recognition that meeting the MDG1 target may require a focus on middle income countries (where 72% of the global poor live) than on countries with an average per capita income below the MDG1 target level.

Redistributing income

The market is a major factor in the trajectory of innovation. Historically the global innovation system has met the needs of high-income consumers. However, in recent years, the growing market power of low-income consumers has led to the development of a growing number of products and services designed to profit from poor consumers and production technologies aimed at poor producers. It stands to reason that the faster the market of poor consumers grows, and the larger the market, the greater the inducement for pro-poor innovation. It is therefore possible to look towards a self-reinforcing virtuous circle in which pro-poor growth stimulates pro-poor innovation which in turn reinforces pro-poor growth.

It is probable that this is the single most important factor underlying the development of a pro-poor growth path. It also makes it abundantly clear that innovation is merely one factor – albeit an important and largely neglected one – in a development strategy which can rapidly erode absolute and perhaps also relative poverty in the global economy.

Notes

1. I am grateful to Esperanza Lasagabaster and Yevgeny Kusnetsov for constructive comments on an earlier draft.
2. In recent years progress has been made in reducing absolute poverty in some low-and middle-income economies, particularly in Latin American economies that have introduced social welfare policies (Cornia, 2011). However, there has been little progress in reducing the overall number of the global poor, particularly in light of the (as yet largely unmeasured) increase in global poverty following the 2008 global economic crisis.
3. These outcomes are widely referred to in the literature as "immiserising growth" (Kaplinsky, 2005).

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Chapter 4

Innovation for the "base of the pyramid": Developing a framework for policy experimentation

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There is increased interest in innovation for people at the base of the pyramid (BOP innovation). The term is used loosely and there are various definitions. This chapter offers a broad definition of BOP innovation and gives a rationale for BOP innovation. It provides a framework for thinking about BOP innovation and presents some case studies. It discusses policy instruments for promoting BOP innovation and suggests some policy approaches, contrasting those of India and China. Finally it proposes some ideas about what more could be done.

Definitions and rationale for BOP innovation

A working definition of BOP innovation

The working definition of bottom-of-the-pyramid (BOP) innovation adopted here is: an organisational and or technical novelty that is likely to be broadly diffused and have an impact on welfare and living standards of low-income households. It is also sometimes called inclusive innovation. The definition used in this chapter focuses exclusively on consumption. It does not discuss how innovation helps the BOP population through its impact on income earners through employment or as grassroots entrepreneurs and low-income informal or formal enterprise managers, or as owners of even small amounts of capital (although inclusive innovation could contribute to all of the above). In addition this chapter does not address how innovation can help handicapped or other excluded groups. For greater clarity, it is useful first to define innovation, then to identify the population at the bottom of the pyramid, and then to develop the concept of BOP innovation.

Innovation, as distinct from invention, which is the conception of an idea, is the concrete application of that idea in a new product or new way of doing things. The narrow definition of innovation is the initial application of that idea anywhere in the world. Because this chapter focuses on developing countries, it adopts a broader definition of innovation as the first use in a country, whether or not it already exists elsewhere in the world. This is because much existing knowledge is not being used in developing countries. Another important dimension is the dissemination of a new product or new way of doing things within a country. This is important because an innovation has greater social benefits if it is used broadly rather than by a single firm, organisation or individual. Dissemination is therefore considered here as part of the innovation process. In this chapter innovation is broadly defined to include new products, processes, services, or ways of organising and delivering goods and services (including the dissemination of the new product, process or service).

An important distinction is between incremental and radical or "disruptive" innovation. Incremental innovation is defined as small improvements in products, processes, services or ways of organising and delivering services. These are often the result of experience over time and often come from production operations, customers or suppliers. They may also be the result of formal research and development (R&D) efforts to improve products. Moreover, they are generally developed by firms or by those directly engaged in production and delivery of services. Radical innovations instead involve fundamental changes in products, processes, services or ways of delivering them. Radical innovations are often the result of major formal research efforts sustained over a period of time, although they may also result from serendipity (such as Fleming’s discovery of penicillin). Radical new business models or ways of delivering goods and services may not require formal R&D, although they generally require some experimentation and testing before scale-up and commercialisation.

Most innovations are incremental and developed by firms. In addition, most combine or recombine existing technologies rather than develop new technologies. An innovation can be based either on advanced technology, such as the development or recombination of electronics or new materials, or on more conventional or traditional technologies, as in the case of most grassroots innovations. Many new business models simply create a better way of delivering traditional services. A good example is containerisation of cargo for shipping. This essentially mundane innovation, when combined with sophisticated electronics-based advanced logistics, has radically reduced shipping costs.

The population referred to as the bottom of the pyramid generally includes those who live on less than USD 2 a day in purchasing power parity (PPP) terms. Table 4.1 shows the numbers of persons worldwide living below the international poverty line of USD 1.25 PPP a day as well as those below USD 2.00 PPP a day. The good news is that the share of the world population living below USD 1.25 PPP a day has been cut from 52% in 1981 to 22% in 2008. The share living below USD 2.00 PPP a day has also fallen but only by 4%. By 2008, 43% of the world population was still living below USD 2.00 PPP a day. The number of poor has fallen most dramatically in China, but has not fallen in absolute terms in India. Part of the reason has been China’s faster growth. China has also tapped global knowledge more effectively than India and has focused more on the poor.

BOP innovation is innovation that serves the needs of this low-income population. Obviously, poor people use and benefit from many goods and services that have been developed over time. These include everything from new synthetic materials used in low-cost shoes, tools, construction materials, clothing and other basic household items; new vaccines and basic healthcare services, education, and basic infrastructure; and new goods and services, such as low-cost electrical and electronic products and services, including cell phone services. The use of cell phones has spread remarkably quickly around the world, including to low-income populations. Access to cell phones has reduced transactions costs for communicating for social or business reasons and has made it possible for poor people to have access to many kinds of information, such as the price of agricultural goods in different markets, or basic health and financial information and services.

Table 4.1. Number of poor and world poverty rates, 1981-2005

Millions

	1981	1987	1993	1999	2005	2008
Below USD 1.25 PPP/day						
Total persons	1 938	1 768	1 910	1 743	1 389	1 289
As percentage of world population	52.2	42.3	41.0	34.1	25.1	22.4
China	835	586	633	446	212	173
India	429	443	462	473	466	445
Below USD 2.00/day						
Total persons	2 585	2 710	2 941	2 937	2 596	2 471
As percentage of world population	69.6	64.8	63.1	57.4	46.9	43.0
China	972	907	926	770	482	395
India	621	689	760	818	857	862

Source: World Bank (2012), *World Development Indicators 2012*, The World Bank, Washington, DC, p. 72.

The rationale for BOP innovation

There are various reasons for interest in BOP innovation. The first is a concern that many of the innovations that the poor could use are beyond their reach and that too little effort has been made to develop goods and services to meet their needs. The reasons are many. Innovation is largely driven by two forces. One is the government, which funds most basic research and applications for defense as well as health and education. The other is the market, which is driven essentially by the profit motive, and is the most powerful driver of innovation. While the government led in funding R&D through the 1980s, the private sector has taken the lead in funding and carrying out R&D. Currently almost two-thirds of the world's R&D is conducted by the productive sector (Jaruzelski and Dehoff, 2008).

The second reason is the realisation that the landscape of innovation is changing and that developing countries now have much more innovation capability.[1] Between 2002 and 2009 the percentage of total R&D conducted in non-OECD countries has increased from 15% to 25%.[2] The bulk of this increase has been in the People's Republic of China and Korea, and to a lesser extent in India and some other large emerging economies. It includes not only inputs, such as R&D and scientists and engineers, but also intermediate outputs such as scientific and technical publications and patents. It also encompasses the emergence and growth of innovative domestic firms in these emerging markets, many of which not only export products developed for their home markets but also invest in other developing countries and even in developed countries. They include firms such as Korea's Hyundai, Kia, LG and Samsung; India's Bajaj, Cipla, Dr. Reddy, Infosys, Lupin, Mahindra and Mahindra, Ranbaxy, Reliance, Suzlon, Tata, and Wipro; China's Cherry, COSCO, Goldwing, Haier, Legend/Lenovo, Shanghai Electric and ZTE; Brazil's Embraer and Sandia; and Mexico's Cemex and Telefonos de Mexico.[3]

The third is that developing countries are becoming the most attractive markets. Since the 2008-09 financial and economic crisis, gross domestic product (GDP) in developing countries overall has grown at an average of 6-7% a year, while growth has been negative or very low in developed countries. With the continuing economic instability in the developed world (especially in the EU), growth prospects are much higher in developing countries, especially the BRICs (Brazil, Russia, India and China), but also in other large growing economies such as Indonesia, Mexico, Nigeria, Turkey and Vietnam. These emerging economies are now a powerful magnet for innovations that cater to the needs of the hundreds of millions of persons who are entering the middle class and demanding more goods and services but also of those at the bottom of the pyramid.[4]

Some examples of BOP innovation

The definition of BOP innovation adopted here emphasises scale and impact. These can be achieved in a variety of ways. New opportunities can be created by a new business model based on well-known technical solutions or achieved through new technical designs.

The ***M (mobile)-Pesa Mobile Phone Payment System*** in Kenya is an illustration of the radical opportunities arising from a new business model that fits local circumstances. It was developed for Vodafone by Sagentia (a Cambridge Network Company) with financial assistance from the United Kingdom's Department for International Development (DFID). It was launched in Kenya by Safaricom, a mobile telephone operator and an affiliate of Vodafone. Although it was initially developed to help microfinance borrowers receive and reimburse loans over the network of Safaricom airtime resellers, it was soon refocused as a way to send remittances in Kenya (Hughes and Lonie, 2007).

M-PESA was launched in March 2007. The software application resides on the SIM card, which identifies the subscriber's phone number and allows users to access various functions. The M-PESA application connects to the Safaricom network and uses the SMS protocol to communicate with the central servers (which record transactions) and other phones (such as for peer-to-peer value transfer). A user registers for M-PESA at any one of 20 000 licensed agents. The process is free and only requires the customer's name, government ID number, date of birth, occupation and mobile phone number. If the customer has an older SIM card, it is swapped for one that supports M-PESA, but the phone number remains the same. As part of the process, the customer chooses a secret PIN and the retail agent explains how to use the application and the cost structure. Once registered, users have a variety of options. When M-PESA is launched, users can deposit or withdraw cash at agents, transfer money to another M-PESA account, or buy prepaid airtime. Deposited cash is also denominated in its digital, M-PESA equivalent, "e-float", and customers can check their balance on the mobile phone. M-PESA charges for cash withdrawals and for sending money to another user (via SMS); the fee increases with the value of the transactions. Additionally, users can send value to non-users who can withdraw the amount received without charge; however, the sender is charged a significantly higher fee if the recipient is not a registered user (Donovan, 2011: 8-9).

By November 2010 M-PESA had over 13 million customers, roughly 60% of the Kenyan population over 15 years of age (Donovan, 2011: 47). The system has expanded to allow employers to pay their workers and for customers to pay for purchases in retail stores. It has also expanded to provide banking and saving accounts to customers. In early 2011 M-PESA linked up with Visa to develop a pre-paid credit card that can be used worldwide at any retailer that accepts Visa.[5]

General Electric's (GE) hand-held electrocardiogram for the Indian market and ***PC-based ultrasound machine*** for the Chinese market, priced at USD 1 000 and USD 15 000, respectively, are examples of new technical designs for emerging markets. GE announced in 2009 that it would spend USD 3 billion over the next six years to create at least 100 innovations that would substantially lower costs and increase the quality of health-care delivery. GE is concerned about changing its model from "glocalisation" – developing products for its rich home market and then producing them worldwide with some adaptation to local conditions – to reverse innovation (the technology created for the developing country market is then exported to developed countries markets). This involves innovating for low-income, rapidly growing developing country markets such as those of China and India, and then bringing these lower-cost innovations to rich-country markets. The reason for the change in strategy is to pre-empt local companies in developing countries from creating products for their domestic markets and then using them to enter and disrupt GE's rich country markets. The CEO of GE published a very revealing article on this topic in the October 2009 issue of the *Harvard Business*

Review (Immelt et al., 2009). GE's example is interesting as a response to the shift in the focus of innovation.

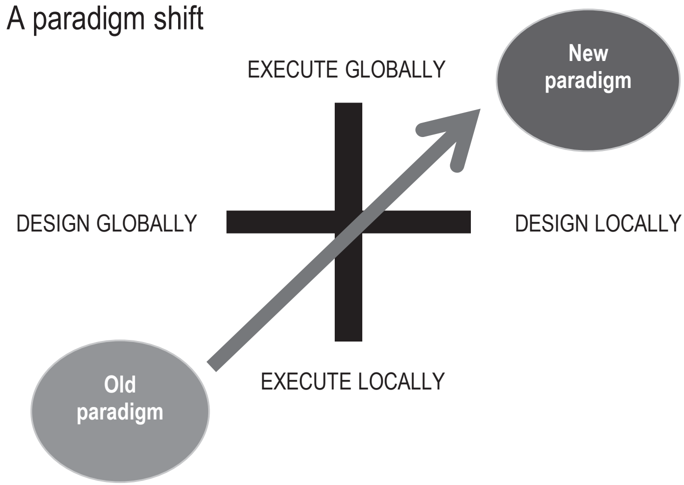
The changing sources of innovation and new challenges

These two examples illustrate leapfrogging opportunities due to a so-called "disruptive" technology (a concept introduced by Clayton Christensen in 1997). A disruptive technology is a superior alternative to the currently dominant know-how in a particular domain. As the GE example illustrates, disruptive technologies can get footholds in secondary or peripheral markets of no interest to the dominant players. Proven there by "outsider" firms, they are generalised to core domains of application, dislodging the incumbents.[6] Examples include disruption of integrated steel making by electric-arc or mini-mill steel production; of wire-activated by hydraulically activated earth-moving equipment; or, more recently, of magnetic-tape or CD-ROM-based portable music players by devices based on semiconductor flash memories. Christensen argues – apparently unchallenged – that all established technologies are in principle disruptable in this way.

The policy issue is accommodation of "disruptive" alternatives to the current trajectory of development. The focus on perfecting the current trajectory blinds both companies and policy makers to solutions from unlikely sources that could ultimately prove superior to the currently dominant one.

A search for disruptive BOP innovation (of which the GE medical devices offer one example) is just one manifestation of an emerging paradigm shift from a familiar "design globally, execute locally", which was a linchpin for every multinational, to an emerging "design locally, execute globally" paradigm (Figure 4.1). BOP innovation happens to be an entry point into this emerging paradigm owing to a confluence of forces and circumstances, the key to which is the emergence of China, India and other countries as powerhouses, both on the demand side (a critical mass of low-income consumers) and on the supply side (a critical mass of relevant local R&D and other search efforts to design indigenous solutions to articulate and respond to the needs of the poor).

Figure 4.1. Towards a paradigm shift: Design locally, execute globally



Source: Adapted from Hang Chang Chieh (2011), “Singapore Innovation Challenge”, presentation at Chile Innovation Workshop, Santiago, Chile.

To illustrate further the novelty of an emerging generation of BOP technologies, it would be helpful to compare it with the appropriate technology agenda (see also Chapter 3). The novelty of emerging solutions appears to be two-fold. First, although the technology agenda articulated in the 1960s and 1970s in the context of import substitution also endeavoured to develop technologies to fit local circumstances, the goal of import-substituting industrialisation was to create in each developing economy a functioning copy of the advanced industrial economies of the 20th century. As a result, the technologies, at least those suggested by foreign advisors, tended to be slightly cheaper and simpler replicas of technical solutions of advanced economies, rather than the new solutions that are now emerging. Second, a home-grown R&D and technology adaptation effort did produce a number of “piggyfrogging” solutions[7] – local design and adaptation (leapfrogging) by building on (piggybacking) global knowledge – yet these solutions tended to remain at a prototype stage, because of the lack of actors, both private and public, to facilitate and finance technology diffusion in the market. The novelty of the current second generation of BOP innovation is that it is pioneered by private actors – either by emerging multinationals from developing economies (see the example of Tata below) or start-up entrepreneurs. It is not surprising that most examples come from India as since the gradual opening at the beginning of the 1990s, Indian big business and start-up entrepreneurs have acquired self-confidence and the capability to undertake a global search to articulate innovative solutions for local problems (Table 4.2).[8]

Table 4.2. BOP innovation: Then and now

	Traditional approach	Current approach
Nature of innovation	Simplified replicas of the developed world	Indigenous solutions informed by global knowledge Significant improvement in performance
Actors	NGOs, philanthropy, donors, informal entrepreneurs	Entrepreneurs, multinationals and (third-world) multinationals
Goals of development	Catching up: imitate economies at the technological frontier	Innovation for self-discovery: global search for home–grown solutions

Role of the public sector in promoting BOP innovation

This section discusses the role of government in promoting BOP innovation. Because what is needed to take an innovation from conception to dissemination and use is not always clear, it first discusses the different steps involved and then summarises the role played by different actors in the various steps. This is followed by a discussion of market failures. The following section then sets out policy options for promoting BOP innovation.

The main steps in producing an innovation are: basic and applied research, development, scale-up or engineering, production and commercialisation, and dissemination and use.[9] These are not necessarily sequential as the idea for an innovation may come, for example, from consumers or from experience acquired in production and delivery of goods and services. The main actors are: the government, state-owned enterprises (SOEs), private firms, individuals, grassroots innovators, universities and non-governmental organisations (NGOs). These actors play different roles at different stages (Table 4.3).

Table 4.3. Main actors and stages of innovation

Innovation value chain/ main actors	Research	Development	Scale-up	Production and commer-cialisation	Dissemination and use
Government	Government research institutes Government funding of university and private sector research (mostly basic)	Government research institutes Government funding of private sector development	Government research institutes Some govern-ment funding of scale up by private sector	Some support of private firms mostly in military area, but mostly through SOEs	Work of own ministries through use of new technolo-gies plus explicit dissemination efforts by ministries
SOEs	Important performers of own research, and some funding by universities and others	Development work for own technologies	Scale-up of own technologies	May be important producers of goods and services, especially in developing countries	Through own growth, licensing and strategic alliances
Private firms	Main perform-ers and funders of all research in world	Main actors in development	Main actors in scaling up	Main actors in production	Through own growth, licensing or other strategic alliances
Individuals	Inventors	Very little development work by individual inventors	Very little scale-up by individual inventors	Through licensing of technology to productive enterprises or own start-ups	Ultimate users of innovations
Grassroots innovators	Non-formal if any	Non-formal if any	Very rarely	Usually limited to own use	Very little dissemination
Universities	Important performers of R&D, particular-ly basic research	Some develop-ment work	Little scale-up	University spin–offs Licensing of technologies to productive sectors	Key actors in dissemination of knowledge: teaching, papers, conferences, consulting
NGOs	Funding research (mostly by foundations)			Not very common, though some engage in production	Dissemination of appropriate technologies, through advocacy, demonstrating projects, finance

As the table shows, the principal actor is the private company across all stages of the chain from research to dissemination and use. The main role of government is in funding and performing basic R&D, and in its dissemination and use. The main role of universities is also in basic research and dissemination of knowledge. Poor people are sometimes inventors and entrepreneurs, but their main role here is as end users of innovations. Grassroots innovators are also little involved in dissemination. NGOs, particularly foundations, can be important funders of research and can be active in dissemination, but are not usually involved in production (although exceptions exist).

Market failures at the different stages of the innovation chain

Innovation efforts are driven primarily by governments and companies. Governments tend to finance basic research that advances general knowledge, as well as more applied knowledge that is relevant for military purposes, social welfare (such as public health), and, to some extent, for increasing industry competiveness. Private innovative efforts are mostly driven by the prospect of profit. The problem for BOP innovation is two-fold. On the government side, not enough emphasis has been put on stimulating the production of goods and services relevant to the low-income population except in the areas of general health and security (military). On the private-sector side, the needs of the BOP population have not appeared to be an attractive market segment because of low incomes.

There are many potential market failures along the chain from R&D to use, and they differ across the five stages listed above. The most traditional market failure is the private sector’s underinvestment in research, particularly basic research, because of the problem of appropriability of the research results.[10] Intellectual property rights (IPRs) offer a partial solution to this problem by rewarding those who undertake the creative effort. These may take the form of patents, trade secrets, copyrights or trademarks and can be sold. In the case of patents, the innovator obtains a monopoly on the innovation of 20 years. However, the basic information behind the patent must be made public so that the knowledge is disseminated. A patent is thus an imperfect compromise between the need to provide an incentive for inventors to innovate and the social value of making the information available so that others know what is possible and can seek further innovations. However, the implementation of intellectual property rights raises many problems because of weak legislation, weak enforcement and low penalties, particularly in developing countries. Moreover, there are concerns that overly strict patent regimes as well as abuse by patent trolls are leading to high costs and inefficiencies, especially in advanced countries where IPR is increasingly implicated in unproductive patent wars.

Another market failure occurs when companies lack adequate information about the potential market for products and services at the bottom of the pyramid. This is the result of the tradition of focusing on the needs of wealthier consumers. The broader economic and institutional regime also plays an important role. In the absence of competition or of sufficient macroeconomic stability the incentive to innovate is greatly reduced.

Many potentially useful innovations die in the stage between the initial prototype application and actual production because of difficulties in finding funding for the intermediate stages (further research, development, scale-up). This gap is known in the literature as the "valley of death" and the underlying market failure concerns financing. In development and scale-up the concern is mostly with the technical risk. In production and commercialisation, the concern is commercial risk: whether the innovation will find a market that more than covers the necessary investments. Banks will not fund activities if there is no collateral, which innovators generally do not have unless they are already established companies. Venture capitalists are not willing to come in until the technical risks have been solved and there are good prospects for successful commercialisation. To deal with this market failure governments provide grants or low-cost finance until the project is of interest to venture capitalists.

A major problem for grassroots innovators is that they do not have the funds to patent their innovations. This is particularly problematic because most of their product and process innovations are relatively straightforward and easily replicable. Also they have trouble finding companies that are able or willing to develop, scale-up and produce their products and services.

University researchers tend to stop at the production of new knowledge. They tend not to patent it, let alone take it through scale-up and production. Most knowledge produced by universities is not commercialised and simply remains as scientific and technical papers.

Market failures in dissemination and use may include the fact that consumers may lack information about the existence of the innovation or its value over existing products or ways of doing things. The consumer may not be able to adopt the innovation because he or she lacks the means to buy it. Here the solution is to produce lower-cost goods and services which the low-income population can afford. This is the essence of the argument for promoting BOP innovation. Other means of solving the problem include faster growth which raises incomes, as in China, or significant income redistribution to increase the purchasing power of the BOP population. However this has generally not been done except very marginally, as in Brazil's Fundo Familia Programme. Another reason for lack of adoption of an innovation by the BOP population may be that they do not have skills or complementary assets needed to use it. The solution is to increase educational levels and access to the skills required to use more demanding innovations.

Table 4.4. Actors, their key interests, and possible policy interventions

Actors	Key interest	Possible policy intervention
Government research labs	Military Security Competitiveness Welfare	Make the focus on BOP innovation explicit Include promotion and salary incentive schemes to reward BOP innovation
Government ministries	Providing the services they are supposed to perform	Foster use of more cost-effective BOP products and services in internal processes and delivery systems (such as vaccines, ICT for e-government services, etc.)
SOE	Making profits, often combined with some public service function	Direct these to give more focus to developing, producing and delivering goods and services for the BOP population
Private firms	Making profits and therefore looking for areas in which they think returns on R&D investments are possible Going beyond the profit motive for corporate social responsibility reasons	Supply side: • Remove policy constraints on tapping global knowledge • Grants • Fiscal incentives • Financial incentives Demand side: • Information on business opportunities • Procurement • Prizes • Global challenges
Grassroots innovators	Improvising to solve problems Contributing to their community Obtaining extra income	Focus on the further development, scale-up and commercialisation of BOP innovations so that they can be diffused and used more broadly. Specialized financing such as the Indian Government Innovation Fund
Universities	Primary function of education and training Knowledge creation-public good, recognition Income-generating opportunities from developing and disseminating knowledge	Give university researchers (and government and NGO researchers) funded with federal money the IPRs to their innovation as by the US Bayh-Dole Act of 1980[1] Provide greater incentives to focus on BOP by allocating some funding explicitly for BOP innovations. Provide financial and other rewards for BOP innovations
NGOs Gates Foundation	Social welfare	Partner with foundations and NGOs that focus on BOP innovation Special tax incentives for foundations that support BOP innovation

1. For an analysis of the impact of the Bayh-Dole Act, see Mowery et al. (2001), "The growth of patenting and licensing by US universities: An assessment of the effects of the Bayh-Dole Act of 1980", *Research Policy,* Vol. 30/1, pp. 99-119.

Government failures are also an issue and can be of several types. Already mentioned is the fact that governments have generally not given sufficient attention to BOP innovation in funding research. The second is misallocation of funds spent on R&D. A third is excessive focus on the R&D element of the innovation chain; as already noted, other elements of the innovation chain are also very important and are subject to various market failures. A fourth is that government failures are often the main obstacle to better investment environments owing to macroeconomic instability stemming from poor revenue and expenditure policies, overly cumbersome taxation and regulatory regimes, weak rule of law, tariff and non-tariff barriers to international trade, etc. Table 4.4 summarises the main interests of the different innovation actors and some possible policy interventions to spur BOP innovations.

The different categories of BOP innovation

Private-sector BOP innovations[11]

Emerging evidence suggests that it would be useful to think about BOP innovation in two ways. First, in terms of whether returns can be appropriated by the private sector (private-sector innovation) or whether there are significant externalities (public good aspects). Second, in terms of whether BOP innovation is incremental or radical, i.e. allows for breakthroughs in products and in service delivery. Of course the distinction between radical and incremental innovation is somewhat arbitrary and many innovations can be considered as both. The reason for contrasting them here was to draw on Christensen's (1997) insight on disruptive technology: a superior alternative to the currently dominant know-how in a particular domain. Radical innovation is often a disruptive technology, although it can develop gradually as a series of incremental innovations. The following presentation of a wide variety of examples is organised on this basis.

Incremental BOP innovations

Most BOP innovations are incremental private-sector innovations. Many grassroots innovations are developed by farmers and rural populations to make ordinary tasks easier to perform. In India an NGO, the Honey Bee Network, has collected and catalogued more than 100 000 such innovations.[12] These include improvements in simple agricultural tools, such as special plows or better simple hand- or foot-powered irrigation pumps, and simple processes for drying or preserving foods. The main challenge is that although the Indian government has made efforts to support further refinement and scale-up of these innovations, there are few examples of successful scale-up and mass commercialisation. One concern has been protection of intellectual property since many of the innovations are easy to replicate. Another has been access to finance and a support infrastructure for distribution and sales. Also, even when innovators get assistance from the government to patent their innovation and prepare it for industrialisation, the products may not be competitive because they are too expensive to compete with standard industrial products.[13]

The Chotokool, an energy-efficient portable refrigerator priced at USD 69, is an incremental product innovation for rural India of the Indian conglomerate Godrej and Boyce. The Chotokool has only 20 parts instead of the 200 typically used in refrigerators; it uses a cooling chip and fan similar to those on computers and high-end insulation rather than a compressor, and runs on batteries since most rural households do not have electricity. The company had the idea after a class on "disruptive" innovation with Professor Christian Anderson at the Harvard Business School in 2006. It developed the product in consultation with women in rural India. To reach its rural markets, Godrej and Boyce also had to develop a distribution system using low-cost financing and community networks.[14]

However, it is likely that multinationals' strongest competition will come from the many low-cost Chinese firms that manufacture products which have been adapted or created for the Chinese market and are now being exported and even produced abroad. Haier, a former Chinese township and village enterprise, is now the world's largest white goods producer.[15] It has developed small-scale household appliances for the low-income Chinese market and has also moved upstream to compete with large appliance producers in the US market. In 2010 it had revenues of USD 20 billion and sales in over 100 countries. It has production facilities in Algeria, Egypt, India, Indonesia, Italy, Jordan, Malaysia, Nigeria, Pakistan, the Philippines, South Africa, Tunisia and the United States. It also has the largest number of patents in China (more than 10 000 as of 2010) and has been actively involved in developing national and international standards. Haier's advantages are its large domestic market, its innovation capacity, its effective use of the Internet and its ability to leverage these advantages. In Haier's own words:

> "Haier has enormous marketing network advantages in China. In full combination with the Internet, it developed the competitiveness of catering to the demand of consumers in the quickest time via 'zero-distance virtual and practical network combination'. 'Virtual network' refers to the Internet, which forms customer loyalty through online communities; "Practical network" refers to the marketing network, logistic network and service network, which helps realise the quickest delivery. Therefore, a lot of world-noted brands commission Haier to manage part or all of their sales in China. In the

meantime, Haier utilises their channels overseas to sell its products. With resource exchanges, Haier speeds up the pace of entering the world market."[16]

Radical BOP innovations

There are also many examples of radical private-sector BOP innovations. Many come from companies in developing countries and are business organisation innovations. Examples include Tata's Nano car and Lupin's psoriasis treatment. GE's electrocardiogram and ultrasound, and M-Pesa are discussed above.

The ***Nano Car*** was developed by Tata Motors after Ratan Tata, the chairman of the Tata conglomerate decided that it was important to provide lower-income Indians an alternative to the scooter, which often carried a family of four or more. The project started in 2003. The objective was to produce a car that cost no more than INR 100 000 (roughly USD 2 000 at the time). To achieve this required radically rethinking both the design and the production process. The Nano's design is modular. It consists of components that can be produced and shipped for easy assembly by local mechanics at destination. This allows local entrepreneurs to distribute, assemble and service the vehicles. In addition, Tata allowed suppliers to innovate in the design and manufacture of the parts and components for the car. Suppliers included multinational as well as local companies. The car was designed in Italy. Bosch provided the fuel injection, braking system and car electronics as well as many of the plastics through its Indian subsidiary. Continental provided the fuel pump through its Indian subsidiary. To reduce the cost, the basic model has no radio, power windows, remote locks, power steering or air bags. However it has a fuel-efficient engine that passes Indian Bharat Stage III and Euro IV emissions standards. The car was successfully launched for USD 2 500 in 2009, half the price of the next cheapest Indian car, the Maruti 800. The Nano had 21% more interior space, and 8% less exterior space than the Maruti owing to its innovative design (the wheels at the extremes of the body).[17]

The production and sale of the Nano had teething problems. Tata was unable to get approval to build a plant outside of Calcutta because local farmers did not want to sell their land. Tata therefore had to move its operations to another state. It also had to rethink its distribution model, because the customers it aimed at did not have a credit record in order to make such a large purchase. It therefore devised a distribution model that leveraged third-party non-commercial institutions in order to reach potential customers. In addition, some early cars had engine fires and this dampened demand, but the problems were resolved and the Nano has been successful. It has also moved up-market, with more expensive models that have air conditioning and diesel engine options. It is now developing an electric model. In short the Nano is a radical innovation which has made the global auto industry take notice and begin to rethink its target audience and pricing strategies.

Lupin's USD 100 psoriasis treatment is an example of reverse drug discovery.[18] In response to the Indian government's New Millennium Indian Technology Leadership Initiative (NMTILI), launched in 2000 to fund drug development programmes on psoriasis, osteoarthritis, hepatitis and diabetes, Lupin, one of India's largest pharmaceutical companies, announced an interest in developing herbal-based medicines. A practitioner of herbal medicines approached Lupin with a cure based on an herb (*Argemone mexicana*) handed down by his family for generations. Working with the practitioner, Lupin isolated the active ingredient and tested it in patients. It found that patients were cured and suffered no relapse for three years. In 2003 the government funded the next stages and arranged partnerships with two government research labs, the Central Drug Research Institute and the National Institute of Pharmaceutical Education and Research. Clinical trials were completed by the end of 2010 and the drug was planned for launch in 2011. Using this reverse pharmacology process, Lupin developed the drug at a cost of USD 10 million rather than the USD 1 billion plus, normally needed to develop a new drug. In addition, treating psoriasis with the new drug is expected to cost just USD 100 per patient instead of USD 15 000 in the United States.[19]

Bharati Air Tel is one of the world's top four mobile providers. The company was founded in India by Sunil Bharati Mittal in 1983. It initially produced pushbutton telephone units. In 1992 it won a bid to provide cellular telephone service to New Delhi. It continued to bid on and win cellular contracts and expanded rapidly as India liberalised the telephone market. Cellular telephony became its main market.

By the early 2000s it realised that to continue its rapid expansion it had to change its business model. It switched from a model focused on average revenue per user to a model focused on increasing gross revenues by reaching more customers through low cost. In order reduce costs, save on investments and increase efficiency, it decided to outsource all its business operations except marketing and sales, financial management, regulatory affairs and strategy. In 2004 it outsourced its information technology (IT) services to International Business Machines (IBM). It guaranteed a minimum payment but structured the contract as a percentage of sales, with the provision that when sales exceeded a predetermined number the percentage would decrease and the savings would be passed on to customers, thereby reducing prices. It also structured contracts with its equipment suppliers (Ericsson and Nokia) as service contracts per unit of capacity, thereby converting fixed costs into variable costs. It developed an Airtel Open Developer Community to make its application platform available to a large number of developers. Then it paid developers a percentage of sales rather than buying the applications outright. In addition, to save on the costs of setting up its own distributors it piggybacked on the distribution systems of companies such Godrej and Unilever which had large distribution centres and many decades of experience operating in India. It teamed up with India's largest microfinance company to extend credit to customers to buy cell phones on instalment plans. It even collaborated with competitors to set up cell phone towers in sparsely populated areas and save on costs (Prahalad and Mashelkar, 2010: 136).

As a result Airtel was able to reduce airtime costs to USD 0.01 per minute and to become the world's lowest-cost airtime provider. Airtel is credited with having pioneered this new business strategy by outsourcing all of its business operations but the core and by motivating all partners to work to improve efficiency and reduce costs to the benefit of consumers. As of 30 September 2012, it operated in 20 countries in South Asia and Africa and had 252 million mobile subscribers (193 million in India and South Asia, 59 million in Africa).[20] The business model it pioneered is being copied by several other telecom companies.

BOP innovations and public goods

Incremental innovations

There are many examples of incremental innovations of public goods for the BOP. They include the Jaipur Foot, the Grameen Bank and the Grameen Village Phone. The Jaipur artificial foot was developed by an Indian master craftsman, Ram Chander, under the supervision of Dr. P.K. Sethi, an orthopaedic surgeon, in 1968. The innovation is the flexibility and very low cost of producing this artificial limb: roughly USD 30 compared to USD 3 000 typically in developed countries. However, only 50 feet had been fitted until 1975 when D.R. Mehta (an India civil servant who had been in a serious car crash and nearly lost a leg) set up an NGO, Bahwan Mahaveer Viklang Sahayate Samiti (BMVSS) Jaipur to industrialise production of the artificial limb. Today, the NGO fits 17 000-20 000 artificial limbs a year for free. The NGO receives funding from the Indian Ministry of Social Justice and Empowerment and from donor contributions. The original technology for the foot has evolved over time from vulcanised rubber and aluminum to high-density polyethylene. Production also evolved from handicraft to industrialised processes, including laser alignment and modern casting techniques.[21] A researcher at Stanford University also developed a nylon knee joint,[22] which is now used by BMVSS to make artificial legs for legs amputated above the knee. The Indian Space Research Organisation (ISO) has transferred the technology for making a polyurethane foot to BMVSS. BMVSS also receives support from Dow India, as well as from various Indian companies, including a shoe manufacturer.[23] As this example shows, this simple indigenous innovation was not widely disseminated until it was industrialised many years later. It is interesting that an NGO was established to industrialise and disseminate the innovation and that the NGO has received funding from the government and technology, and technical assistance from various private companies (including a multinational), a foreign research university and a high-technology government research lab.

The ***Grameen Bank*** developed from a research project. In 1976 Muhammed Yunis (an economist trained at Vanderbilt University) started to explore the possibility of designing a credit system to lend money to the poor based on trust. It initially operated as an NGO in several districts close to the capital city. It was formally incorporated in Bangladesh in 1983 as a financial institution that made very small loans to very poor people. The clients are mostly women. The innovation is that the bank makes small loans to a group of five persons without collateral or a loan instrument. Although there is no group liability, members of the group apply peer pressure to make sure that loans are repaid. The bank's policy is that if anyone in the group defaults, then no one in the group can borrow. Grameen Bank has been very successful. By 2011 it had made loans of USD 11.3 billion, had more than 2 500 branches and 8.3 million members, 97% of whom were women.[24] The bank is owned 95% by its borrowers and 5% by the Government of Pakistan. In 2006 Grameen Bank, and its founder, Mohamed Yunis were awarded the Nobel Peace Prize, the only financial institution to receive such a prize. Its success has spawned many similar types of microfinance organisations around the world.

Among various other innovative programmes, Grameen Bank developed a Village Phone programme because phone penetration in Bangladesh was very low. Through this programme, also known as the village ladies, Grameen Bank has lent the money to buy cell phones to nearly half a million women who provide cell phone service in their villages. They receive some training and technical assistance and are responsible for collecting the phone fees from their customers and repaying their loans.

A separate entity, the ***Grameen Foundation***, was established to help the poor in other countries to improve their lives through access to finance, new ways to generate income and information on health, agriculture and finances. The Grameen Foundation operates in 36 countries. It does not engage directly in microfinance. Instead it helps local microfinance institutions (MFI) access finance. It provides information platforms to help MFIs manage their operations and their clients. It also focuses on improving livelihood opportunities, such as a village phone operator programme for women to sell airtime in Indonesia like the one in Bangladesh. It also includes delivering products, tools and services over mobile phones. In health, for example, through its Mobile Technology for Community Health (MOTECH) programme in Ghana, community health-care providers use cell phones to collect vital information and to provide information to expectant mother and their new infants. In India, with finance from Johnson & Johnson, the HIV/AIDS programme uses mobile phones to provide patients with information about options and to send reminders on medications. In agriculture, their "Community Knowledge Worker programme uses mobile phone applications and human networks … to provide poor farmers with relevant, timely agricultural information, including caring for animals, planting crops, treating pests and diseases, and getting fair market prices for produce and livestock."[25]

Both the Grameen Bank and the Grameen Foundation are actors in areas that until recently were considered the purview of government. These innovations use redesigned business processes to provide affordable services to the BOP and make extensive use of cell phone technology to create business opportunities such as the village phone operator and to deliver information on health and agriculture to improve welfare. It is noteworthy that in 2010 the Government of Bangladesh brought a lawsuit against Muhammed Yunis and forced him out of the Grameen Bank. Although many issues were raised, some have argued that the government felt that the NGO intruded too much in areas it wished to control (*e.g.* Bornstein, 2011). This suggests that tensions may arise between the government and new organisations that provide goods or services with a strong social dimension.

Radical innovations of public goods

Radical BOP innovations of public goods provide a dramatic demonstration of what can be achieved. The ***Green Revolution*** is one of the first and best-known examples of such an innovation and will not be discussed here. This was a large international effort supported by the Ford and Rockefeller Foundations and involved government research institutes from around the world. Key elements were research and development to create and adapt seeds to the specific conditions of soil, weather, and climate of the different locations. International consortia composed of foundations, international institutions, public research institutes and governments worked in a global network to implement food security as a global public good.[26]

Three more recent innovations are here described in some detail: the Aakash Tablet Computer, the African River Blindness Eradication Programme and the Gates Foundation Global Health Challenge. The Defense Advanced Projects Agency of the US Department of Defense, discussed below, offers an even more dramatic example of very radical innovations.

The ***Aakash Tablet Computer*** is an example of the use of government procurement to stimulate the development of a low-cost tablet computer to take advantage of the potential of computers and the Internet to revolutionise education in India. The development of the Aakash tablet has encountered problems and delays, and the final outcome is still uncertain. The concept was excellent but execution has been poor. The key elements of this experience present important lessons for the use of government procurement.

The development of the Aakash tablet computer was the idea of India’s Ministry of Education and Human Development. The objective was to encourage the development of a low-cost tablet computer to be made available to millions of Indian students so that they could access knowledge via the Internet. It is part of India’s National Mission of Education through Information Technology (NMEICT) launched in 2009. It aims to increase enrolments in higher education, link 400 universities and almost 20 000 colleges across India, and deliver education to anyone over the Internet.[27] In 2010, Minister Kabil Sibil announced that the tablet would cost USD 35 initially and would eventually cost USD 10. By the launch date of January 2011, 100 000 tablets were to be available. The Indian Institute of Technology (IIT) of Rajasthan was charged with procuring the tablets. At that time producing such a computer with wireless connectivity at so low a cost for the education market was a radical idea. However, the government believed that the size of the order would interest suppliers in developing such a tablet computer. In addition, there was the prospect of procurement of millions more tablets if the product was successful. IIT Rajasthan evaluated various bids and initially chose HCL Infosystems, an Indian hardware and systems integrator. However HCL was not able to produce the tablets by January 2011 and the tender was cancelled.[28]

Datawind, a software firm based in the United Kingdom and Canada and run by Suneet Singh Tuli, an Indian American, won a new bid at the beginning of 2011. As a software firm, Datawind did not have experience in producing tablet computers and outsourced the manufacturing to Quad Electronics, based in Secunderabad, India.[29] In October 2011 the Minister of Education launched the Aakash tablet computer. The government was to buy the tablets at USD 50 but sell them to students at USD 35, and 650 tablets were initially given to students. The seven-inch tablet had an Android 2 operating system powered by a 366-megahertz processor, 256-megabite random access memory, and three-hour battery life. Testing by Rajasthan and students found that the product was poorly made (parts rattled inside 40% of the tablets when they were shaken) and performance was poor. Battery life was much shorter than three hours. In addition, applications stalled and the touch screen was not responsive in many of the computers. Because of this, IIT Rajasthan rejected them.[30]

Datawind also offered an upgraded commercial version to the general public for USD 60. There was a rush of commercial orders for the upgraded version. In November 2011 the Ministry of Education announced that the remaining tablets would be upgraded to deal with the problems and would sell for the same price. The Ministry of Education also said it was exploring other suppliers. The ministry was reportedly upset because Datawind had started selling the higher-priced commercial version before it fulfilled the order for the 100 000 tablets. By January 2012 there were 1 million orders for this commercial version.[31]

Datawind argued that IIT Rajasthan had rejected the orders to favour other suppliers and that the testing standards it had eventually established were very high military standards, including drop tests and water resistance, which could not be provided in a low-cost computer. The government reprimanded IIT Rajasthan for not setting the detailed specifications and tests in advance and transferred management of the procurement to IIT Mumbai.[32]

The second generation Aakash II was launched by President Pranab Mukherjee on 11 November 2012. It is an upgraded version with 512 RAM, a one gigahertz processor and an upgraded Android operating system. It costs the government USD 42 but is sold to students for half the price. Datawind has apparently provided only 10 000 tablets and was required to produce the rest by the end of the year. A major uproar and wounded national pride have resulted from revelations that the 10 000 tablets were actually sourced from China. *The New York Times* has obtained purchase orders from four Chinese companies. IIT Mumbai has confirmed that the first batch of the Aakash II were purchased from China to be in time for the President's launch in November. The CEO of Datawind has argued that the contract did not specify that procurement had to be from India. He also claims that four Indian suppliers and his company are on track to produce the tablets on time.[33]

Although the procurement process was bungled owing to unclear performance specifications and testing criteria, it has in fact led to the commercial production of very low-cost laptop computers which can now be produced by many manufacturers. The government had an important role in identifying a need and stimulating innovation in order to serve the millions of students who could benefit from low-cost tablets. These low-cost tablets, originally produced for the Indian market, are expected to be available worldwide. However, the history of the Aakash also demonstrates the importance of clear specifications and testing procedures and of transparency in the procurement process. It also shows that to stimulate innovation and to get a reliable product at the lowest cost it is necessary to open procurement to the global market.

River blindness (onchocerciasis). The programme to eliminate river blindness in Africa is an excellent example of the power of collaboration among countries and agencies; the importance of involving the local community and of very long-term donor funding; and "the benefits of public private partnerships to bring pharmaceutical innovation into large scale use in developing countries."[34] River blindness is the result of a parasitic infestation of the eye. The parasite is transferred by the bite of the blackfly. If a blackfly bites another person after biting a person carrying the parasite, it transmits the parasite to the second person. Therefore, eradicating the disease requires controlling the flies as well as treating infected people.

Various attempts were made to control the disease in the 1950s and 1960s. They were not very successful because they required a transnational effort since the flies crossed national boundaries. By the late 1960s there was consensus that a successful strategy would require a co-ordinated, international approach. In 1974 the World Health Organisation (WHO), the World Bank, the Food and Agriculture Organisation (FAO) and the United Nations Development Programme (UNDP) developed the Onchocerciasis Control Programme (OCP) to eradicate the disease in 11 West African countries. The World Bank mobilised funding from donor countries, multilateral organisations and private foundations. A key element of the programme was commitment to fund the insecticide spraying programme for 20 years because it was believed that it would take at least 18 years to eliminate the parasites in humans. This involved weekly spraying from airplanes and helicopters as well as by hand pumps.

The programme was successful in the 11 West African countries targeted. In 1974 almost 10% of the population of 30 million in these countries was infected, and approximately 100 000 were blind. By 2002 when the programme was officially completed, transmission of the disease had been stopped, the roughly 1.5 million persons who had been infected no longer experienced symptoms, 600 000 cases of blindness had been prevented, and 22 million children had been born free of the disease (Seymour et al., 2007:3).

However, the disease still affected 70 million people in 19 countries in Central and East Africa. Aerial spraying of insecticides was not considered technically feasible or cost-effective because of greater forest cover and longer distances. A major breakthrough came when Merck developed the drug Mectizan to treat parasites. It was originally developed for parasites in cattle, but it was discovered in 1978 that a single annual dose was very effective in treating the parasite that caused river blindness, as well as several other parasites in humans. Merck was ready to donate the drug but could not find a partner to manage its distribution. Finally, in 1987 Dr. William Foege, Director of the Carter Center, agreed to lead a programme at the Task Force for Child Development and Survival, an affiliate of Emory University. Merck committed to donate Mectizan "to anyone who needed it, for as long as it was needed."[35]

The initial programme was based on clinics. However it soon became clear that "a more cost-effective, sustainable approach…was necessary" (Seymour et al., 2007:5). The African Programme for Onchocerciasis (APOC) was launched in 1995. Its objective was to eliminate the disease in all of Africa. It was designed as a 15-year partnership led by the four institutions that had launched the OCP. The programme aimed to treat 86 million people a year by 2010 and 90 million a year when fully scaled up. The programme involved the governments of 19 African countries, 21 multilateral or bilateral donors, more than 30 NGOs, Merck, and more than 100 000 rural African communities. Unlike the OCP, which was a top-down programme, the APOC was integrated into the countries' national health system, and ultimate responsibility was given to the communities. The programme pioneered a community directed treatment (ComDT) through which hundreds of thousands of communities, trained by the public health systems and participating NGOs, organised and managed the Mectizan treatment, "thus enhancing prospects for long term sustainability of the programme after donor funding ends" (Seymour et al., 2007: 5). The ComDT programme was also used to deliver other drugs[36] with high coverage to other remote populations. By 2005, 41 million people were being treated and WHO estimated that the programme prevented 54 000 cases of blindness a year.

Merck's contribution of Mectizan is valued at USD 1.5 billion. The actual production costs were less and Merck offset some of the costs with tax benefits. Mectizan was also sold to fight parasites in animals (in 1987 it was Merck's second highest selling drug) and this also helped to offset the cost of its donations for human use. These were very important to the programme's success and served as a model for donations of drugs by other multinationals (Seymour et al., 2007: 5).

Estimated costs for the rest of the APOC were USD 180 million of which 75% financed by donors and 25% by African governments and NGOs. A preliminary analysis by the World Bank gave a rate of return on the programme of 17% in 1995 (Benton, 1998).

Bruce Benton, manager of the Onchocerciasis programme at the World Bank, attributes the programme's success to five factors: a comprehensive regional approach; effective long-term partnerships; community participation and grassroots empowerment; capacity building and Africanisation (in the 1970s 75% of the OCP's 30 professional staff were expatriates, but by the 2000s 99% of the staff of both the OCP and APOC were African); and a built-in operational research component. The last element (which represented 10% of the annual budget) made it possible to adjust the programme as it evolved. For example when monitoring showed that the blackfly became resistant to the original insecticide, seven back-up insecticides were use in rotation to break the resistance. Operational research was also critical in determining whether ComDT would be cost-effective and what level of participation would be necessary. It also mapped the disease throughout Africa so that APOC operations could be scaled up as necessary (Seymour et al., 2007, p. 7).

The eradication of river blindness in Sub-Saharan Africa is one of 20 examples collected in *Millions Saved: Proven Successes in Global Health* (Levine et al., 2007). While the technological innovation was an important element, it was not sufficient. Success also required managerial and logistical efforts "to ensure that the new technology reached the target population through the existing public health system or through a dedicated distribution system" (Levine et al., 2007) at a sustainable price. Other elements of its success were: predictable long-term funding from international and local sources; political leadership and champions; technical consensus about the appropriate bio-medical or public-health approach; good management on the ground; and effective use of information about the health problem and monitoring of the effectiveness of the treatment in order to make mid-course corrections.

The ***Bill and Melinda Gates Foundation*** Grand Challenges model is a good example of the use of crowd-sourcing to get the best minds from the private sector, academia, public or research institutes, or even individuals to find radical solutions to seemingly intractable problems. [37] The Foundation is a private foundation with an endowment of about USD 65 billion (with a matching grant from Warren Buffet). Its objective is "to help all people lead healthy, productive lives. In developing countries, it focuses on improving people's health and giving them the chance to lift themselves out of hunger and extreme poverty. In the United States, it seeks to ensure that all people—especially those with the fewest resources—have access to the opportunities they need to succeed in school and life."[38] As a result not only governments but also foundations allocate large resources for BOP innovations for public goods. Foundations such as the Wellcome Trust are also allocating more funds for BOP innovation.[39]

As of the end of 2011 the Gates Foundation had made grants totalling USD 26 billion in three main programme areas (global health, global development, the United States) and slightly more than USD 1 billion in non-programme areas. The global health area received 58% of the total (Gates Foundation, 2011).

In terms of promoting BOP innovation its most relevant experience is its Global Health Initiative. The main objective is better health care for the poor in developing countries. It includes work from discovery of new vaccines and drugs to product development and delivery partnerships as well as advocacy. The initiative has identified 16 grand challenges to inspire researchers to find solutions to health problems. These include single dose vaccines, vaccines that do not require refrigeration, needle-free vaccines, creation of bioavailable nutrients in single staple plant species, therapies and methods that can cure latent infections, assessment methodologies to assess multiple conditions and pathogens in populations, etc.[40]

Since the inception of the programme in 2003, 45 grants totalling USD 458 million have been awarded for research projects involving scientists in 33 countries.[41] To broaden the scope of the programme, the Gates Foundation launched in 2008 an additional grant programme called Grand Challenges Explorations. Grants are awarded to worthy projects on the basis of two-page online applications. Initial grants of USD 100 000 are awarded twice a year. Successful projects can receive a follow-on grant of up to USD 1 million. As of 2012 more than 700 exploration grants had been awarded to researchers from 45 countries. So far the programme has been more successful in stimulating research than in getting the results of the ideas into production. In December 2010 Bill Gates acknowledged that they had underestimated the challenge of going from laboratory results to factories and dissemination.[42]

Nevertheless there have been many concrete results. These include: vaccines for hundreds of millions of children through the Global Alliance for Vaccines and Immunization (GAVI);[43] fortified foods for hundred or millions of people in more than 26 countries through the Global Alliance for Improved Nutrition (GAIN)[44]; and antiretroviral and tuberculosis treatment for 6 million people and insect-treated bed nets for malaria for millions of people through the Global Fund.[45] New products include inexpensive cholera vaccine for Africa, meningococcal meningitis vaccine for Africa (discussed below), a vaccine against Japanese encephalitis and compounds for the control of mosquitoes carrying malaria or dengue.

Key elements of the Gates Foundation global health model that may be replicable to other areas of BOP innovation include applying global knowledge to address local needs and partnering with NGOs, university researchers, private companies and international organisations. The model is being replicated in areas such as education, sustainable livelihoods, green technology and drinkable water. For example, the X-Prize Foundation, famous for having awarded a prize for the successful development of a private spacecraft and a 100+ mile per gallon car, is developing similar challenges for an innovative game platform for education, a tuberculosis diagnostics prize, a cookstove prize, an African entrepreneurship development prize and a water desalination prize.[46]

PATH's meningitis vaccine, a good example of one of the Gates Foundation's successful health projects, is the development of the MenAfriVac vaccines by the Programme for Appropriate Technology in Health (PATH) and the WHO. PATH is an NGO established in Seattle, Washington. It focuses on improving health in developing countries. It has successfully developed and implemented many health innovations.[47] Part of the reason for its success is that it focuses on the needs of poor populations. After identifying a need, PATH explores what is available or could be developed to meet that need, whether it can be obtained at an affordable cost, and what is necessary to deliver it to the target population. Doing this successfully has involved working collaboratively with private companies, research institutes, other international NGOs, governments of developing countries and grassroots organisations. A particularly revealing example, which illustrates the process, is PATH's development of a meningitis vaccine for African countries.[48]

For decades 25 Sub-Saharan countries have suffered from meningitis. Among those who contract the disease one in ten die and one-quarter remain debilitated. The worst meningitis epidemic occurred in 1996 and 1997. It killed 25 000 people and debilitated 250 000.[49] Pharmaceutical companies had developed meningitis vaccines for developed country markets, but no vaccine existed for meningitis A, which was specific to Africa. In 2000 a meeting of African health ministers, the WHO, and medical and health experts determined that it would be possible to develop a vaccine against this disease. In 2001 the Bill and Melinda Gates Foundation gave a ten-year grant of USD 70 million for a PATH-WHO project to develop the vaccine.[50] PATH staff met with African health ministers and learned that the vaccine would have to cost less than USD 0.50 a dose to be used massively. No global pharmaceutical company was interested in developing a vaccine to be sold at that price. PATH funded research at an institute in the Netherlands and found a pharmaceutical company (the Indian Serum Institute in India) that was willing to produce the vaccine at that price point if it received the technology and support for building the production facility. The missing piece was a proprietary conjugation technology to join two critical raw materials. Such a technology had been developed by the Center for Biological Evaluation and Research at the US Department of Agriculture. PATH bought the technology and transferred it to the Indian Serum Institute. PATH worked with the company and the Indian Ministry of Health to get approval for the vaccine and for its export. It worked with the WHO and health ministries in India and African countries to train staff to carry out the clinical trials to test the effectiveness of the vaccine, and later with the WHO to obtain certification of the vaccine. It also funded some of the cost of the production facility and also provided training to health ministries in the target African countries for monitoring the spread of meningitis outbreaks and rolling out the vaccination programmes. It also worked with journalists, national health officials, health workers and communities to raise awareness of the disease and of measure to combat it.[51]

Massive vaccination campaigns based on the MenAfriVac vaccine started in Burkina Faso, Mali and Niger in the beginning of December 2010. By the end of the year 20 million persons had received the vaccine. In December 2011, the vaccine was launched in Cameroon, Chad and Nigeria. By the end of the year 54.5 million people had been vaccinated.[52] PATH and the WHO expect to have 300 million children and adults vaccinated in the next few years. The widespread use of the vaccine will reduce the rates of transmission, illness and death from the disease. One dose is expected to provide immunity for ten years. Widespread coverage will produce a "herd immunity" that will protect even those who have not received the vaccine. PATH and the WHO are now working on testing and approval of the vaccine for use on children less than a year old. PATH claims that the vaccine was developed at less than 10% of the typical USD 500 million cost of a new vaccine. It continues to work with the WHO to extend vaccination to other countries in Africa.[53]

Pneumococcus vaccine. Advance market commitment (AMC) is another approach to funding innovation for vaccines. The idea was originally proposed by an academic, Michael Kramer, and was supported by the Center for Global Development in a 2005 report (Levine et al., 2005). The basic idea is that to signal to the private sector that there is a market for neglected diseases in developing countries, there needs to be a commitment from governments or international development institutions to buy a specified amount of the new vaccine provided. A report to the G8 by the Italian Minister of Finance, with support from a World Bank team, endorsed the idea and identified six orphan diseases for an AMC pilot project: HIV/AIDS, malaria, tuberculosis, rotavirus (diarrheal disease), pneumococcal disease (pneumonia and meningitis) and cervical cancer (caused by human papillomavirus, HPV) (Tremonti, 2005). In February 2006, an Independent Advisory Committee concluded that an AMC mechanism could help address all six diseases and selected pneumococcal vaccines as the most promising for the pilot AMC trial.

In February 2007, the governments of Canada, Italy, the United Kingdom, Russia, and Norway, and the Bill and Melinda Gates Foundation pledged USD 1.5 billion for an AMC mechanism to support the development of a pneumococcus vaccine.

A target product profile (TPP) was developed to guide companies in developing and producing vaccines suitable for use in developing countries. The TPP defined threshold standards of efficacy, safety, dose scheduling, presentation and packaging for pneumococcus vaccines to be eligible for AMC financial support. A legal agreement setting up the AMC for the vaccine was signed in 2009 before the G20 meeting in Italy. The agreement established GAVI as the secretariat, the World Bank as provider of financial and fiduciary support, and UNICEF as the agency to launch the bids, evaluate the proposals and make the purchases (Cernuschi et al., 2011).

The first call for proposals was made in September 2009. Four were received. GlaxoSmithKline (GSK) and Pfizer were deemed to meet the TPP. The price for the vaccines in developed countries was EUR 40 in the European Union and USD 96 in the United States (GAVI White Paper, 2011: 42). Each company agreed to produce 30 million vaccines a year at USD 3.50 a dose for ten years starting in 2012/13. This price was a more than 90% reduction relative to developed country prices. To get the companies to produce the new vaccines for developing countries the AMC programme paid a supplement of USD 3.50 a dose for the first three years for 45% of the amount to be purchased. This was to encourage the companies to install the capacity needed to produce the drugs at the required scale for developing countries quickly.[54]

The AMC mechanism has proven effective in getting drug manufacturers to produce drugs for developing countries they would not otherwise have produced. This mechanism might be extended to other drugs and to other areas. There is already is a proposal to use it for low-carbon development.[55] However the programme has been criticised as being too expensive. Critics have compared the high cost of this approach to the supply-push approach used to develop the PATH meningitis vaccine for just USD 70 million, which also created capacity to produce the vaccine at much lower cost per dose in a developing country (*e.g.* Hargreaves et al., 2011). There is certainly a need for more pilots and more evaluation of the effectiveness of alternative mechanisms under different circumstances. In addition to traditional supply-push mechanisms and demand-pull mechanisms such as AMC, there are other demand-pull mechanisms such as milestone prizes, buying IPRs from companies that are not exploiting the technology for developing countries markets (as in the case of the PATH syringes), as well as forced technology transfer to developing countries. However, interventions that supplement what the market alone would have done can be an effective way to develop innovations for the BOP and merit more experimentation and research.

Relevant policy issues for BOP innovation

Policy agenda for private-sector BOP innovations

The rise in the innovative capabilities of emerging countries, combined with the growth of their markets, is restructuring innovation efforts. Firms from emerging countries are likely to make more inroads in developed country markets, and multinationals, as in the case of GE, are likely to respond strongly.

The policy agenda for private-sector innovation is essentially the same for incremental and radical innovations although there is scope for doing more for the latter, as will be seen. Since the private sector possesses most of the technological capabilities, it should be encouraged to focus more on inclusive innovation and the bottom of the pyramid. This is particularly important for multinationals, given their weight in the global R&D effort. One way to stimulate this is to provide more information on the needs of the BOP population and to publicize examples of companies that have begun to produce for this market profitably. More generally policy should address the following issues.

The first is to facilitate access to global knowledge. This includes removing policy and regulatory restrictions on tapping into global knowledge in all its forms: capital goods, FDI, technology licensing, foreign education and training, participation in knowledge networks, the Internet, technical publications, etc. For nearly all the cases studied, access to existing technology, much of it from abroad, was essential. In addition, technology acquired directly from foreign firms or knowledge from foreign firms or universities was important. There are many instances of adaptation and incremental innovation in the different examples. Many are business organisation innovations, particularly in the more radical innovations.

A second important issue is a well-developed technological infrastructure. This consists of technically qualified personnel as well as private, public and university research centres. It also consists of appropriate metrology, standards and quality-control infrastructure. A well-developed technological infrastructure is likely to be more important for radical technical innovations such as Tata's Nano car or the new psoriasis treatment, than for radical business organisation innovations such as the M-Pesa mobile money system, although both required developed telecom infrastructures.

A third policy issue is supply-side policies that reduce the cost of attempting innovation. These include grants, tax subsidies, low-interest loans, etc. Although these may not have been critical for all of the innovations discussed they probably helped. A critical policy failure has been to focus too closely on the R&D component of innovation. The problem is that R&D is not always necessary and it is not sufficient. There is big gap between innovation and the steps to reach commercial production and dissemination. More effort needs to be put into the downstream steps to get BOP products and services into production. A recent study by the Monitor Group has argued convincingly that those who try to develop business models to supply the BOP market face problems of fragmented supply and distribution chains. They propose that philanthropic institutions should provide grants to help offset learning costs as firms learn to develop appropriate supply and distribution chains (Koh et al., 2012).

A fourth policy issue is support for developing private-sector bridge institutions that can help innovators cross the "valley of death". As noted, many innovations do not get beyond the first prototypes. This is particularly true for grassroots innovators and for universities and government research institutes. Bridge institutions such as technology parks, business incubators, technology transfer offices, early-stage finance and venture capital companies help innovators cross the valley of death. They have been used with different degrees of success in various countries.

A fifth policy issue is to stimulate innovations that address the needs of the poor through demand-side policies such as prizes and contests for product and services that are not provided by the market, but which the market could support once the necessary supply and distribution channels are developed. The potential for this will be highlighted in more detailed discussion of certain examples.

A sixth policy issue is the importance of facilitating co-development. Nearly all the examples depended on interactions among different actors. These were not just other domestic or foreign private elements of the technological infrastructure, but also government institutions and NGOs.

Policy agenda for BOP innovation of public goods

The examples of BOP innovations of public goods range from incremental process innovations that are the purview of government to radical transnational, multi-partner collaborative efforts. Clearly, government is not the only provider of public goods. NGOs (the Jaipur Artificial Foot, the Grameen Bank), major foundations (the Gates Foundation), international agencies (the World Bank, WHO, FAO, UNDP) , the private sector and local community organisations (the Green Revolution, the Programme to Eradicate River Blindness) also are involved in producing and delivering public goods.

Among relevant policy issues, there are first those that can affect the supply of innovation from government institutes and government-related institutions such as public R&D centres and R&D in ministry institutes and in government-funded universities. Policy can mandate a more explicit focus on BOP innovations in government operational and research activities.

Second, government demand policies can be used to elicit a supply response from the private sector (as well as the government research infrastructure) in order to produce BOP innovations. This can be done through procurement, as in the case of the Aakash tablet computer. It can also be done by offering prizes or challenge grants as in the case of the Indian government's support for the development of medicines to treat specific diseases such as psoriasis (the Lupin example). However, as noted, these innovations are no longer the exclusive preserve of government as they can also be achieved by large, socially oriented foundations, such as the Gates Foundation with its global health challenges. They can also be facilitated by NGOs such as PATH.

Third, there is a need for more co-ordination across government and with other actors to the extent that innovation involves co-development efforts by many actors, both public and private. Examples presented in the following section will show the importance of this.

To summarise, Table 4.5 lists different policy agendas for private goods, services and business models, and for public goods, services and organisational models. Initially a main differentiator of the private good and the public good model is that the private model depends more on an appropriate innovation climate and supply-side incentives. The public good model, beyond the traditional public supply-side R&D effort, depends more on getting the private sector, or for that matter the public R&D infrastructure (government laboratories and public universities), to respond to demand-side incentives such as procurement, prizes and contests to produce particular types of goods and services.

Table 4.5. Policy instruments for private and public BOP innovations

	Private-sector innovation	Public-sector innovation
Emerging policy issues	How to induce profit-seeking private firms to undertake more inclusive innovation. How to support dissemination of promising BOP innovations developed by the private sector	How to induce R&D in areas that are not profitable in existing markets. How to foster co-ordination of a diversity of actors
Traditional instruments	Beyond improving the innovation environment, supply-side policies such as grants and tax incentives lower the cost of innovation	Public R&D programmes focus on BOP needs (the Green Revolution, River Blindness Eradication). These are essentially large supply-side efforts which require massive public/private co-ordination to ensure diffusion
Emerging new instruments and approaches	Subsidising the purchase of inclusive innovation products and services (Haier appliances for poor households, Lifestraw water filters) Advanced market commitment (low-cost pneumococcus vaccine) Prizes such as the Grand Health Challenges launched by the Gates Foundation, which led to the PATH meningitis vaccine	Demand-side policies such as public procurement (the Aakash computer) Proactive demand-side policies (the Defense Advanced Research Projects Agency (DARPA(development of applicable technologies from the science and research base, see below) Advanced market commitment Prizes and challenges such as those launched by the Canadian and US governments[1]

1. The Canadian government launched its Grand Challenges as a new form of development aid in 2010: “T*he bold ideas we support integrate science/technology, social and business innovation – we call this Integrated Innovation™. We focus on bringing successful innovation to scale, catalyzing sustainability and impact. We have a determined focus on results, and saving and improving lives.”* For more information see www.grandchallenges.ca.

A framework for BOP innovation

The preceding discussion of policy issues suggests that while there are clear principles and elements of policy response (solutions developed in close collaboration with BOP customers, reliance on policy instruments such as public procurement, etc.), it is not simple to combine them in a coherent and co-ordinated policy. A policy response should fit the required BOP innovation. For instance, the River Blindness consortium led by the World Bank involved an alliance with government and Merck and served as an institutional platform for further developing the policy response. The search for a solution needs to be organised so as to allow for piloting and experimentation, while avoiding pitfalls, i.e. it should combine an experimental approach with knowledge about relevant good practice. Drawing on relevant good practices and assessing the current situation in light of good practice is one approach (see Chapter 2). The limited number of policy-relevant benchmarks proposed here distinguishes between private and public goods, and between radical and incremental BOP innovation.

Table 4.6. BOP innovation: Emerging policy agendas and institutional benchmarks

	Private-sector innovation *Motivated primarily by desire to make a profit*	**Significant public good innovation** *Previously the purview of government but now achieved by non-governmental actors such as foundations and public/private partnerships*
Relatively small co-ordination problem: adaptation of knowledge from diverse domains	Incremental improvement in products and gradual transformation of value chains *Examples*: Many grassroots innovations Godrej and Boyce Chotokool refrigerator for rural India Haier home appliances in China *Institutional benchmark* Venture capital, particularly early-stage	Customised products or public services for the BOP population *Examples*: Jaipur artificial foot and knee Grameen Bank and Grameen Phone *Institutional benchmark*: Agricultural extension as an example of demand-driven customised public support (*e.g.* EMBRAPA in Brazil, INTA in Argentina)
Significant co-ordination problem and critical mass effect Possibility of radical innovation (new business and public sector dynamics)	Next big thing: creation of new products and new value chains *Examples*: Tata’s Nano car GE’s low-cost electrocardiogram for Indian market and ultrasound for Chinese market Lupin’s psoriasis treatment Bharti Airtel low-cost mobile phone service in India M-Pesa –Mobile phone, low transaction costs payment platform (started in Kenya) *Institutional benchmark*: Innovation by multinationals (e.g. GE, Tata)	Breakthrough in new products and in service delivery *Examples*: The Green Revolution Aakash tablet computer Eradication of river blindness Gates Foundation grants: Global Health Challenge Meningitis vaccine by PATH (NGO) and Indian Serum Institute Pneumococcus vaccine by GSK and Pfizer in response to advanced market commitment *Institutional benchmark*: DARPA (see below)

The examples of policy responses to develop radical BOP innovations suggest that co-ordination is a key issue. Indeed, the River Blindness and PATH meningitis vaccine initiatives demonstrate that the pooling of diverse capabilities requires the creation of a new actor able to pursue a long-term objective (often spanning a generation). For incremental innovation, instead, co-ordination is relatively easy and can be ensured by existing actors. Table 4.6 juxtaposes the private and public search for institutional solutions and the magnitude of the co-ordination challenge for the two types of innovation. Institutional models (benchmarks) discussed in what follows are chosen from the perspective of co-ordination, which is why they can be quite unexpected and counterintuitive. But that is the point of benchmarking: revealing similarities and relevance where they are not readily apparent.

Four institutional benchmarks, corresponding to the four policy situations outlined in Table 4.6, are discussed as examples of support for BOP innovation.

Incremental private BOP innovation benchmark: Early-stage venture funding

The diffusion of an incremental BOP innovation largely involves finding an appropriate business model rather than conducting formal R&D. Venture capital funding is a means of co-ordinating the aspirations of an entrepreneur with a promising idea with meeting the needs of customers. It can transform ideas into high-risk, high-return business ventures (see Chapter 5). Venture capital funding is not of course the only benchmark for incremental private BOP innovation. As the example of M-Pesa indicates, incubation and rapid diffusion of a relevant innovation can be also carried out by established firms. Yet diverse and flourishing private-sector innovation is constrained without early-stage venture capital and while this is not the only model it is the most promising benchmark. India is already experimenting with VC funding for BOP innovation.

Incremental public BOP innovation benchmark: Good national agricultural extension agencies

As the examples of incremental innovation indicate, the peculiar challenge of BOP is co-development, that is, innovating not just for the poor but with the poor and including them as customers in the design of the appropriate technical and business model. Agricultural extension is a good example of decentralised customer-oriented service. It is largely responsible for the success of the Green Revolution, when it provided customised bundles of services ranging from R&D to improved seed varieties more resistant to diseases, to training on how to cultivate these new varieties. Each bundle of services is designed to suit specific customer needs and assistance is provided over a long period of time. The Brazilian Agricultural Research Cooperation (EMBRAPA) (*www.embrapa.br)* and Argentina’s National Agricultural Technology Institute (INTA) (*inta.gob.ar)* are such decentralised demand-driven agencies with significant R&D portfolios.

The Grameen Bank also follows this decentralised customer-oriented model of close collaboration with customers to learn about their needs and to design business models to meet those needs in a cost-effective way. Agricultural extension and technology agencies do not offer the only means of meeting the challenge of co-ordinating the design and diffusion of a customised bundle of services but they do offer one which policy makers need to examine carefully.

Radical private BOP innovation benchmark: Multinational enterprise

A main challenge for radical BOP innovation is co-ordination of applied R&D, assembly of a prototype and creation of a new value chain. Tata, an Indian multinational – was able to handle the co-ordination challenge in a short span of time. Management of R&D and innovation by a multinational enterprise is a good benchmark for radical BOP innovation because multinationals have proved good at reaching scale with their R&D. The 1 000 multinationals that conduct R&D account for slightly over 50% of world R&D, and the 20 that conduct the most account for 13% of the world total (Jaruzelski and Dehoff, 2008). Multinationals are the most important R&D actor, particularly for applied R&D and development. In addition, they have the greatest capability to implement, scale up and disseminate innovation because of their global scope and extensive global networks of research, production and distribution.

Radical public BOP innovation benchmark: The US Defense Advanced Research Projects Agency (DARPA)

For radical technologies DARPA offers the example of an extremely efficient mediator between science and application. It promotes relevant science by co-ordinating specialists in different disciplines and moves from science to application. It is an intermediary between researchers, who create ideas and potential applications, which it takes to the point of proof of concept. DARPA then hands these over to specialised actors able to implement them.

DARPA’s role and accomplishments are aptly summarised on its website.

"DARPA is the principal agency within the Department of Defense for high-risk, high-payoff research, development and demonstration of new technologies and systems that serve the warfighter and the Nation's defense. DARPA's core mission is to prevent and create technological strategic surprise for the United States. The Agency has a rich 50-year history of successes ranging from the Internet to GPS, stealth, and UAVs, but these advances, now ubiquitous, were once the source of discomfort and unease. Such is the nature of work performed at the Agency. Many of the now ubiquitous technologies pioneered at DARPA were once considered impossibilities. And this progression—first impossible, then improbable, eventually inevitable—characterises many of the Agency's most important advances. We take on new, seemingly impossible challenges each year."[56]

The agency now known as DARPA was set up in 1958 by the United States in response to the success of the Soviet Union's Sputnik satellite programme. Its purpose from the beginning was to "assure that the United States maintained a lead in applying state-of-the art technology for military capabilities and to prevent technological surprise from adversaries" (Van Atta, 2008:20). The emphasis has been on advanced high-return and high pay-off research that leads to radical, rather than incremental innovations. At the same time it is outcome-oriented. Initially it focused on space and ballistic missile defense. The civilian space area was transferred to National Aeronautics and Space Administration (NASA) and the military space programmes to specialised military agencies. In the 1960s it focused on smaller exploratory research programmes. In 1972 it was renamed the Defense Advanced Research Projects Agency. In the 1970s it developed the Advanced Research Projects Agency Network (ARPANET) which was the beginning of what later became the Internet. In the late 1970s and early 1980s it worked on land, air and sea technology for the military. The space segment was later transferred to the Strategic Defense Initiative. In the 1980s it did work on advanced avionics and space, advanced computing, SEMATECH, and technologies connecting academia and industry. In the 1990s it developed greater inter organisational and international research linkages. Since 9 November 2001 it has focused more on anti-terrorism technologies and on increasing US competitiveness.[57]

Some of DARPA's key achievements include what eventually became the Internet, the stealth bomber, the global positioning system (GPS), unmanned air vehicles (UAV), precision bombs and many other technologies which have led to what is called a revolution in military affairs.

Key elements of its success have included:

- Independence from the R&D arms of other parts of the US armed services. It answers directly to the Secretary of Defense and the President of the United States.
- A flat organisation with little hierarchy.
- A lean and agile organisation. For example, although it has had an average annual budget of USD 3 billion, it has a staff of less than 300 persons, half of whom are technical staff (Shachtman, 2012).
- It does not do any research itself. Instead its programme manager seeks out and funds the best researchers in academia, private companies, government research institutes (though little is done at government labs), as well as individuals to work on projects.
- Initial short-term funding for seed efforts scale to significant funding for promising concepts, but it also has clear ability to close non-performing projects.
- It hires the staff necessary to run projects on a needs basis. Generally assignments are for three to five years, as are projects. Continuity can be assured by having different projects work on problems over time, and maintaining contact with persons who have worked with DARPA.
- Fosters “co-operation as well as competition among a group of forward looking researchers and operational experts” (Van Atta, 2008: 25).
- Most work is project-based management organised around a challenge model. DARPA foresees new innovation capabilities and works back to the fundamental breakthroughs required to make them possible.

There is some tension between the goals of supporting research and of providing proof of concept. Researchers often want to go on exploring the science, while DARPA turns to what can be done with the science. For its part, once DARPA has helped develop the technology sufficiently to proof of concept and some demonstration, it wants to hand it off to clients to refine and implement the technology, but clients often want DARPA to develop the concept further (Van Atta, 2008: 26). The delicate balance between funding and co-ordinating the upstream science and moving it to proof of concept and eventual application has changed under different administrations. DARPA has constantly reinvented itself and gone on to explore new areas rather than get stalled in expensive demonstration and scale-up of the finished technology.[58]

In spite of its very impressive achievements DARPA has some critics. Some want it to do more, in particular to move further down the road from ideation to implementation. Others want it to do less, particularly in these times of fiscal constraint (Hundley, 1999; Van Atta, 2003, 2008). In the end, DARPA is constrained by what top US policy makers want it to do. That depends on their understanding of what the key threats are. In the current rapidly changing global environment this is harder to discern than in the more stable bipolar world in which DARPA was created. However, DARPA has clearly been remarkably successful in many of the areas it has been asked to address. Moreover, some of the basic principles that help to explain its success are relevant and transferable to other innovative endeavours.

From the perspective of fostering BOP innovation there are two key lessons about the role of government arising from DARPA’s experience. The first is that beyond its support for basic science, it can be an effective bridge between science and specific challenges, in the present case producing innovations for the BOP. The second is that to do this well requires a very agile organisation that plays a co-ordinating and facilitating role, leveraging the capabilities of others rather than trying to do the work itself. This requires extremely able managers and strong discipline, both of which are hard to come by in government.

In sum, DARPA is an example of a radical approach that goes beyond providing supply- or demand-side incentives or collaboration under existing technology regimes. It offers the example of an aggressive effort to advance science to create breakthrough technologies. This more radical approach may be useful for dealing with very large challenges such as climate change. In fact, the United States has created a DARPA-type agency to try to develop radical technologies in the energy sector. It is called Advanced Research Projects Agency – Energy (ARPA-E) and was established in 2009 (Bonvillian and Van Atta, 2011). A similar type of agency could be conceived at an international level to deal with grand challenges such as climate change, global pandemics and other major needs for global public goods. The key point is to use the DARPA model to tackle very large global issues. While DARPA has focused more narrowly on military technologies it has also changed the underlying technological base for many non-military applications. There is no reason why an agency such as DARPA cannot be created to focus on positive global public goods rather than sophisticated weapons and surveillance systems.

It should be possible to set up an international DARPA-type organisation to stimulate the scientific base to produce radical game-changing technologies for global social welfare (the light side) rather than for military applications (the dark side). It could be argued that international development institutions and foundations such as the Gates Foundation could help orchestrate the global funding for such an effort. The main problem would be setting up the appropriate governance and management structure for such an organisation.

China's and India's strategies for BOP innovation

When looking at government policy options it is interesting to compare the policies of the two largest developing countries with the most capabilities, China and India.[59]

Initially both countries focused on BOP innovation as well as technological catch-up. Both have accorded great attention to defense, space, and agriculture. Both had a green revolution in the 1960s and 1970s, India with the help of the West, China on its own.

China began to open up to global knowledge in the late 1970s and has gone further than India. It has been very effective at tapping global knowledge through trade, FDI, technology licensing, foreign education and training, and copying and reverse engineering. Early on the government emphasised disseminating knowledge to the rural population through efforts such as the Spark and Torch programmes and other major initiatives to develop technology that would improve the quality of life of the poor. It also ramped up its innovation capability much faster and has a much larger and more developed technological infrastructure and capability. In 2011 China surpassed Japan to become the second largest investor in R&D in PPP terms.[60] China's productive sector does almost 70% of its R&D and is now developing many BOP innovations for use domestically as well as for export, such as Haier's white goods.

India began to tap into world knowledge only in the early 1990s and did so more tentatively than China. It has not made as extensive or effective use of global knowledge. India is the world's eighth largest spender on R&D. The government still does more than half of India's R&D. However, since 2000 India's private productive sector has been actively involved in BOP innovations. Indian government policy started focusing on BOP innovation (which it calls inclusive innovation) around 2005. This is largely because of concerns about increasing inequality and stability, as the absolute number of persons earning less than USD 2.00 PPP a day in India increased by 241 million between 1981 and 2008, while the number in China decreased by 577 million (see Table 4.1). The Prime Minister of India has announced the decade starting in 2010 as India's Innovation Decade. Inclusive innovation is a central element of this strategy.

China has focused on rapid catch-up and on development of its frontier technological capability, mostly oriented toward security and international competitiveness. In 2006, it launched its Medium and Long Term Science and Technology Plan which sets a goal of reaching parity with developed countries by 2025. It defines seven strategic high-technology areas (Cao and Simon, 2008). However, as inequality has recently been increasing rapidly, the Chinese government has again become interested in supporting BOP innovation. Thus there has been some convergence of the trajectories of BOP efforts in the two countries (Table 4.7). It is not surprising that they lead the global effort on BOP innovation because of their large R&D and innovation capabilities and the needs of their very large poor populations. As they put more emphasis on this area one can expect to see the results in these countries and in other developing countries, as many of the products, services and forms of organisation they develop will be relevant to other developing countries.

Table 4.7. Converging trajectories of BOP efforts in India and China

	China	India
Drivers	Government and state-owned enterprises	Private sector and its growing innovative capability
Dominant best practice	Innovative government programmes: Spark and Torch programmes	Firm-led examples
Emerging best practice	Innovation by local multinationals	Major government focus and investments in BOP innovation
Key company examples	Mindray (medical equipment) Haier (home appliances), ZTE (telecom hardware) Goldwind (wind power) Tsinghua Solar BYD (electric car)	Dr Reddy (T drugs) Infosys, TCS, Wipro (software) Zuzlon (wind power) Tata Nano (low-cost car) Lupin Indian Serum Institute Reva (electric car)

Conclusion

Recognition of the poor as a major market opportunity has recently produced a peculiar type of innovation, known as "Ghandian innovation" or "piggyfrogging", a combination of piggybacking (by adopting and adapting global knowledge) and leapfrogging (by leveraging the local context). Piggyfrogging is an example of an incipient shift from a "design globally, execute locally" to a "design locally, execute globally" paradigm. Put another way, BOP innovation involves the co-development of new solutions by the poor and global knowledge actors by leveraging local tacit knowledge and social capital, with the poor no longer passive beneficiaries but crucial collaborators.

This paradigm shift has practical implications for the design of public policies to promote BOP innovation. Given the promise of local contexts and co-development with local actors, it is necessary to seek relevant technologies and develop public policy and good practice through experimentation and learning. One plausible approach to experimentation and learning is for policy makers to assemble and monitor a portfolio of developmental policies, projects and programmes: an array of initiatives to promote BOP innovation. A portfolio-based approach eliminates the need to discover "silver bullets" – the perfect combination of policies for stimulating innovation. It enables policy makers to engage in experimentation, introducing and observing variations in the policy context, economic outcomes and the connection between them.

A portfolio-based approach has two aspects: the position of a specific project or programme in the portfolio and its position relative to the project portfolio as a whole. For the former, the tasks are to assemble a portfolio with an array of promising projects and programmes, implement them, arrange financing and scale them up once they show promise. For the latter, the tasks are to monitor the projects and to revise or eliminate poorly performing initiatives. A critical element here is for policy makers to learn from success and failure and to see how information on the performance of one programme can inform the design of a similar programme.

This chapter attempts to provide a framework for structuring a process of search, experimentation and learning about appropriate, locally informed government policies and programmes. It involves three steps. First, it is necessary to document diverse BOP innovation efforts. The examples provided show a wide range in terms of technological and organisational innovation. Their diversity reflects the richness of this emerging field, and the chapter has sought to reflect this diversity with the taxonomy developed in Table 4.6 as the guiding lens. In the area of health alone, for instance, organisational innovations include advance market commitment and crowd sourcing. Second, this diversity needs to be categorised for policy makers by establishing a taxonomy of BOP innovations. The taxonomy presented above introduces four programme and project portfolios and establishes a benchmark for each type. The discussion of China and India illustrate differences in such policy portfolios. Third, it is important to establish a procedure for diagnostic monitoring, i.e. for the systematic evaluation of each portfolio of projects and programmes to detect and correct errors as each project evolves (including the weeding out of inefficient ones) in light of experience and new information. The diagnostic monitoring procedures are crucial because they allow for putting disparate pieces into a coherent whole without specifying and constraining how such new radical solutions emerge over time (see Chapter 2 for more details on diagnostic monitoring). However, a system of indicators for making diagnostic monitoring procedures a reality does not yet exist. As the diagnostic monitoring procedure for BOP projects is a global public good, investments in it are as important as investments in individual projects.

As with every global public good, the procedure should be designed as a collaborative effort by global players. One global player can lead and become a first mover (for example, the Gates Foundation could design a diagnostic monitoring procedure in the health area) with others to follow. The logic of collective action (as illustrated by the River Blindness Consortium led by the World Bank) makes it possible to deliver a global public good incrementally.

Notes

1. See for example, *The Economist* (24 May 2012) on the spread of innovations from developing to developed countries.
2. See UNESCO Institute of Statistics database: http://stats.uis.unesco.org/unesco/ReportFolders/ReportFolders.aspx?IF_ActivePath=P,54&IF_Language=eng.
3. For an analysis of some of these firms see Sauvant (2008).
4. See Prahalad and Hammond (2002), and Prahalad (2005) for some early understanding that companies are able to make profits by selling basic products and services to the poor.
5. www.safaricom.co.ke/index.php?id=1229.
6. See Clayton M. Christensen, *The Innovator's Dilemma* (1997).
7. See the article on innovation from developing countries in *The Economist* 24 May 2012.
8. See Prahalad and Mashelkar (2010), Kumar and Puranam (2011), Radju, Pradhu and Ahuja (2012) and Govindadarajan and Trimble (2012) for many examples of how Indian entrepreneurs have developed innovative products and services for the poor.
9. Many intermediary steps can also be distinguished such as basic research, applied research, engineering, development, prototype, pilot-scale testing, scale-up, initial commercial production, further scale-up, initial adoption, further dissemination, general use, etc. For simplicity these have been compressed to the five stages discussed.
10. See Nelson (1959, 1993) for an analysis of market failure in the creation of knowledge and the basic institutions of a national innovation system.
11. For more examples of private BOP innovation by domestic firms and multinationals, see Radju et al. (2012) and Govindarajan and Trimble (2012), respectively.
12. See Honey Bee Network at www.sristi.org/hbnew/aboutus.php for an extensive catalogue of these innovations and efforts to scale up and disseminate them. Utz (2010) discusses other examples and challenges.

13. For a good example see the case of the pedal-powered washing machine at the following link. http://rahulbrown.wordpress.com/2008/05/23/indias-national-innovation-foundation-and-honeybee-network/.

14. www.innosight.com/impact-stories/chotokool-case-study.cfm.

15. Other very impressive Chinese manufacturers have considerable innovative capability and are aggressively moving beyond China to other developing countries and increasingly to developed countries. They include Mindray in health appliances, and Huawei and ZTE in communications.

16. www.haier.com/in/header/201110/t20111027_83001.shtml.

17. www.scribd.com/doc/26552806/Tata-Nano-Innovations-Approaches.

18. Another Indian example is Reddy Biotech’s development of the hepatitis B vaccine, which is similar in many respects. It started from an indigenous treatment and worked backwards to discover the active agent by running pharmacological studies. The project included co-operation between the company and government research labs and government funding. Presentation by Dr. Yamasaki at Indian Global Innovation Round Table. September 2011 in New Delhi.

19. Mashelkar (2010), p. 93, citing a forthcoming book by Mashelkar and Goel, *Inclusive Innovation: “More from Less for More.”*

20. www.airtel.in/QuarterlyResult/Press_release_Q2_N_13.pdf.

21. www.jaipurfoot.org.

22. D-Rev.org.

23. www.jaipurfoot.org. See also “The Jaipur Foot: The Real Story” at: www.goodnewsindia.com/index.php/Magazine/story/jaipur-foot/.

24. Grameen at a Glance, October 2011, www.grameen-info.org/index.php?option=com_content&task=view&id=26&Itemid=175. Accessed 2 March 2012.

25. www.grameenfoundation.org/what-we-do/mobile-phone-solutions/agriculture.

26. For more on the history, accomplishments and limitations of the green revolution, see Ruttan (1977) and Jain (2010).

27. http://govnext.in/case-study-description.php?case_study_id=1.

28. *The Economic Times*, “Tender for $35 Laptop Project Cancelled,” 18 January 2011, http://articles.economictimes.indiatimes.com/2011-01-18.

29. *The New York Times*, "The Tangled Tale of Aakash, the World's Cheapest Laptop," 27 April 2012, http://india.blogs.nytimes.com/2012/04/27/the-tangled-tale-of-aakash-the-worlds-cheapest-laptop/.

30. Govnext, "A Bitter Tablet," http://govnext.in/case-study-description.php?case_study_id=1.

31. "Is the Aakash Dream Over?", *Light Reading*, 19 January 2012, www.lightreading.in/document.asp?doc_id=216561.

32. "Datawind blames IIT-Rajasthan for Aakash Failure," *Tech 2*, 5 April 2012, http://tech2.in.com/news/tablets/datawind-blames-iitrajasthan-for-aakashs-failure/296002.

33. "India's 'Aakash' Now Made in China," *The New York Times*, http://india.blogs.nytimes.com/2012/11/26/india%E2%80%99s-super-cheap-tablet-now-made-in-china/.

34. Most of the information in this section is taken from Seymour et al. (2007) from which this quote is taken.

35. Ray Vagelos, CEO of Merck, when he made the announcement, cited in Seymour et al. (2007), p. 4.

36. This included: long lasting vitamin A capsules to save the lives of young children and mothers, the antibiotic azithromycin (donated by Pfizer) to prevent trachoma; albendazole and Mectizan to halt elephantiasis, and praziquantel to cure shistosomiasis (Seymour et al., 2007, p. 6.).

37. Most of this section is taken from Gates Foundation (2010).

38. Gates Foundation Fact Sheet (2012), www.gatesfoundation.org/about/Pages/foundation-fact-sheet.aspx.

39. Many philanthropist donate money for global causes. There is potential to try to tap some of these funds for global inclusive innovation activities.

40. Gates Foundation Health Strategy, available at: www.gatesfoundation.org/global-health/Pages/global-health-strategies.aspx.

41. www.grandchallenges.org/about/Pages/Overview.aspx.

42. In a 2010 interview he noted that they had cancelled two-thirds of the 45 grand challenge projects. See http://philanthropy.com/blogs/philanthropytoday/bill-gates-acknowledges-mixed-results-for-%E2%80%98grand-challenge%E2%80%99-grants/30125.

43. *GAVI* (the Global Alliance for Vaccines and Immunization) is a public/private partnership focused on saving children's lives and protecting people's health by increasing access to immunisation in poor countries.

44. GAIN is the Global Alliance for Improved Nutrition created in 2002 by the UN.

45. The Global Fund to Fight AIDs, Tuberculosis, and Malaria was created in 2002 in a special session of the UN as a global public/private partnership.

46. www.xprize.org/prize-development/global-entrepreneurship.

47. Other examples of PATH innovations are a disposable syringe for which it bought the license from a major pharmaceutical company that was not interested in producing it at a low price, and gave it to a company that was; and the development of a marker that would indicate whether a vaccine was still valid. It also has an ideas lab with a large portfolio of innovations at the development stage. See www.path.org.

48. For more on the development of this vaccine see www.path.org/menafrivac/about-mvp.php.

49. www.path.org/menafrivac/about-meningitis.php.

50. www.gatesfoundation.org/press-releases/Pages/path-and-who-receive-grant-010530.aspx.

51. www.path.org/menafrivac/about-mvp.php.

52. www.path.org/menafrivac/launch.php.

53. www.path.org/menafrivac/future.php.

54. GAVI Secretariat, 2012, pp. 8-9. As part of the AMC capacity development agreement the companies agreed to provide 7.2 million, 24.2 million and 20 million doses in 2010, 2011 and 2012, respectively. A second call for supply was issued in March 2011. Four companies responded by May. After evaluation, GSK and Pfizer were again selected to provide an additional 18 million doses a year for 10 years starting in 2014. As of mid-2012 the AMC still had not committed half of the original donor fund of USD 1.5 billion. It plans to use that for other supply calls which it hopes will stimulate new suppliers to produce vaccines at a lower final price.

55. www.vivideconomics.com/docs/Vivid%20Econ%20AMCs.pdf.

56. www.darpa.mil/Initiatives.aspx.

57. See Fuchs (2009) for a decade-by-decade analysis of DARPA's changing focus.

58. For a fascinating history of DARPA's evolution under different Administrations, see Van Atta (2003).

59. For more on the different development strategies of China and India see Dahlman (2012).

60. The United States spends USD 415 billion PPP, China spends USD 149 billion PPP, India spends USD 33 billion PPP (Battelle, 2011).

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Chapter 5

Incubating the incubation cycle: Two approaches to promoting techno-entrepreneurship in weak institutional environments

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While the field of innovation studies is extensive and rapidly expanding, analysis of innovation policy is much less developed. This chapter examines public interventions to support institutional infrastructure for techno-entrepreneurship as an example of an endogenously developing policy process. Mainstream recommendations to support techno-entrepreneurship and innovation clusters focus on best-practice institutions. Consequently, the United States (Silicon Valley, Route 128, etc.), the United Kingdom, Finland, Singapore and Israel emerge as example to emulate. The chapter extends the discussion of these "usual suspects" by examining cases of improbable success: the emergence of Silicon Valley siblings (local ecosystems of innovation) in middle-income economies and localities with a deficient institutional environment. It juxtaposes two public policy approaches to supporting private innovation entrepreneurship: a traditional administrative approach and an emerging search networks approach.

Policy making as an endogenous process

While the area of innovation studies is extensive and rapidly expanding, extraction of usable policy implications has been limited. Fagerberg (2002), in an extensive review of evolutionary economics, concludes that from an evolutionary perspective "one cannot draw very firm conclusion[s] on policy matters". Other economists expressed similar views (*e.g.* Rodrik, 2007), namely that economic theory is consistent with a multiplicity of institutional and policy arrangements, which by nature should be context-specific (one size does *not* fit all). This diminishes the clarity of the policy implications of existing theory.

A similar point is made by senior policy makers and practitioners who are developing innovation clusters and techno-entrepreneurship, particularly in middle-income economies of post-socialist countries, Latin America and Asia. These policy makers are well aware of what to do in terms of the "wish list" of actions to overcome constraints. Yet, while the list of constraints to be overcome may be largely understood, there is as yet no systematic knowledge about the evolutionary processes leading to (eventual) endogenous growth, i.e. a process by which, at any moment in time, the remaining constraints in the national system are overcome, with policy (itself already largely endogenous) playing only a minor role in the process.

The view that policy applications can be inferred linearly and in an almost "trivial" fashion as an afterthought of analysis parallels the logic of the linear innovation model in which innovation is largely a straightforward outcome of university research or company research and development (R&D). The argument made here is that analysis is only one input in our understanding of policy issues and in policy design and implementation. Other relevant issues are related to context, to the policy system itself and to the policy process. Taking all of this, including feedback effects, into account in an integrated fashion is not trivial. Moreover, there are limits to the translation of any conceptual framework into a concrete policy setting. Not only is it essential to understand what has been "lost in translation" but also, and no less important, what has been (unexpectedly) added in the sense of other variables or research requirements not considered in the analysis (such as the contextual setting) which have to be taken into account when dealing with policy.

Because a lot of conceptual or empirical analysis of company R&D and innovation has limited direct usefulness for actual innovation policy, explicitly policy-focused research is needed. Ideally, it would benefit from detailed knowledge of the conditions for successful policy implementation. Academic research in this field frequently strives for "global excellence", which does not necessarily ensure its direct policy relevance. In fact, it often leads to "local irrelevance". This points to major differences between the methodology of focused (action-type) innovation policy research and that of academically oriented innovation-policy research. While both require theory, focused policy research usually has to consider a large number of variables and interrelationships as well as time and budget constraints. This suggests that there are limits to the extent to which the accepted methodologies of academic economics research can be used. It would be difficult to develop a full-scale theoretical model and empirical analysis that includes the whole set of relevant variables (including those associated with the policy process and the experimental assessment of alternative policy profiles) prior to the design and implementation of innovation policy in a particular setting.

The endogeneity of innovation policy also comes from political economy and political science analyses of issues related to the innovation policy system and process. Within the political economy strand of literature, Olson (1965, 1984) was a pioneer in showing how distributional coalitions block change and stifle growth and how major crises destroy old coalitions. Perhaps the most promising development of the argument for crisis as a trigger of concerted action is the "systemic vulnerability" thesis (Doner et al., 2005).

Focusing on East Asian high performers, Doner et al. show how the need to reconcile conflicting constraints and priorities (related to the legitimacy of the elite in authoritarian regimes and considerations of military and geopolitical security) acted as a trigger for the political and business elite to seek creative institutional solutions in order to maintain rapid economic growth. The argument is important because it shifts attention from a well-functioning bureaucracy as a precondition for growth to a country-specific set of contextual factors from which a dynamic public sector might emerge. It also points to a political economy reason for endogenous innovation policy.

Compelling as it is, the systemic vulnerability thesis does not deal with some of the other components of the policy process. Such an intellectual tradition does not seem to go hand in hand with a trial and error process of experimentation by policy makers who search for and implement new institutional solutions for projects, programmes and policies. This process makes use of a multitude of methods (not only those of traditional economic theory), such as case studies, in-depth interviews,[1] benchmarking, consulting, interviews of key individuals, identification of critical variables and dynamic trajectories, even the non-conventional and idiosyncratic, and makes decisions on that basis.

To summarise, the endogenous policy process is defined here as trial and error search and experimentation by policy makers of new approaches and institutional solutions which respond, among other things, to stakeholder needs in order to overcome market or government failure.

Because of the need for careful attention to dynamic links and to local context and for the ability and willingness to engage in a process of trial and error, analysis of endogenous policy and institutional development in innovation remains an exception. This suggests that developing a theory of innovation policy is a daunting task. To make some progress in this direction, the following discussion is limited in two ways.

First, in terms of the object of analysis, it is limited to the process of creating the institutional infrastructure for techno-entrepreneurship associated with technology start-ups and spin-offs. Admittedly, this is a narrow segment of innovation policy, which is of little relevance in low-income economies (where broader approaches to innovation, such as innovation in a given context rather than high-growth innovation-based firms, are usually adopted; e.g. World Bank, 2010). Second, in terms of methodology, the argument relies significantly on the judgment, experience and observations of a seasoned practitioner. It is therefore not possible to document every statement with a reference to the literature as is customary in academic publications.

The chapter first sets the stage with a key issue in the emergence of private-sector-based institutional infrastructure: critical mass. It shows that until the number and diversity of innovation start-ups and spin-offs is sufficient, purely private early-stage support is problematic, as suggested by an example from India. The incubation cycle is then described. Next, common features of traditional support programmes are described, before traditional (reactive) and proactive approaches to the institutional infrastructure are juxtaposed. The proactive search approach is illustrated by the promotion of venture funding.

Emergence of techno-entrepreneurship and its institutional infrastructure: Twin problems of critical mass

Clusters of techno-entrepreneurship and institutional infrastructure to support them: Two sides of the same collaborative process

In 1997 Ramón L. García, a Chilean applied geneticist and biotechnology entrepreneur with a PhD from Iowa State University, contacted Fundación Chile. Fundación Chile is a private-public, non-profit organisation which, among other missions, helps provide the technical infrastructure that allows Chilean agri-business to develop domestically viable variants of crops typical of California's Central Valley. García is the chief executive officer of InterLink Biotechnologies, a Princeton, New Jersey, company he co-founded in 1991. Interlink developed a way to identify novel chemical entities derived from micro-organisms for use in new pharmaceuticals and enzyme additives for human food, animal feed, and bio-control agents. It markets its technical expertise to other firms interested in transferring and licensing new biotechnologies.

After jointly reviewing their portfolios of initiatives, Interlink and Fundación Chile founded a new, co-owned company, Biogenetics South America, to undertake the long-term R&D projects needed to transfer to Chile the technologies necessary to the continuing competitiveness of its rapidly growing agribusiness sector. Without Fundación Chile (the source of venture capital) and García's knowledge of Chile, advanced US education, exposure to US managerial practice and experience as an entrepreneur, the new company would have been inconceivable. Biogenetics SA has successfully developed a technology platform which uses biotechnology to improve grapes and stone fruits, two export crops that are very important to the Chilean economy. The company genetically modified grapes to make them resistant to diseases and was instrumental in developing a programme to make pine trees resistant to an important insect pest. It is currently developing the technology to introduce important quality traits in stone fruits.

Chile is not known for high-technology and early-stage venture capital (VC), which is all but non-existent. Yet after Biogenetics SA, García created two other firms with Fundación Chile.

The example also illustrates the power of search networks for identifying binding constraints (absence of early-stage VC, lack of contacts or networks of contacts with potential clients, partners, marketers and, in this case, investors) and finding people or institutions (Fundación Chile in this case) that help mitigate the difficulties associated with constraints. Early-stage VC and the associated institutional infrastructure are components of the most advanced support systems for start-up and spin-offs but only a few countries have developed early-stage VC. When early-stage VC does not exist, idiosyncratic support structures may emerge. Fundación Chile is a non-profit organisation with a public-sector endowment, yet it is managed like a traditional early-stage VC fund. Yet it has to be more entrepreneurial, inventive and original than is usual, because most elements of the innovation ecosystem which early stage VCs take for granted do not exist in Chile. Fundación Chile for example had to develop its own search networks. Both the start-up firms and the structures supporting them (which again, are not necessarily VC) need to be entrepreneurial.

This example suggests that in middle-income economies, search for and incubation of new entrepreneurial niches often occur in a rigid institutional environment with many vested interests. However, while the public sector may be dysfunctional, it may also be characterised by internal diversity, with pockets of excellence in individual ministries or implementation agencies. By supporting the entrepreneurial segments a virtuous dynamic of continued entrepreneurial growth and public/private co-evolution may be ignited. Thus, talent and entrepreneurship in the public sector that lead to new policy initiatives and Schumpeterian private-sector entrepreneurs are two indispensable and complementary facets of self-discovery, two sides of the same collaborative process.

One can think of such a collaborative process as evolving in four dimensions, one for innovation entrepreneurship and the other three for the institutional infrastructure to support it. First, the number and sectoral composition of firms; second, specialised infrastructure: science parks, incubators, innovation centres and the like; third, professional business services firms that offer tailored services in accounting, tax, marketing and product design and development; and fourth, venture capital firms.

The problem of critical mass

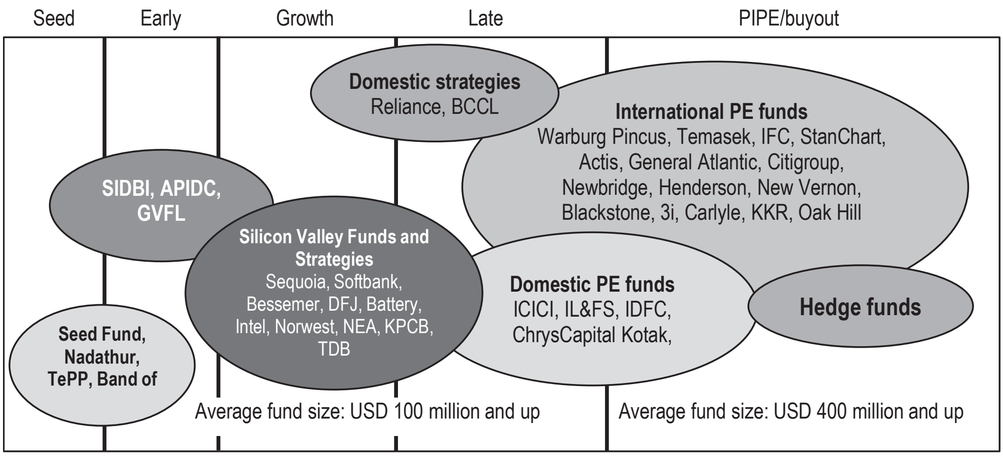
A myriad of schemes have been implemented worldwide to help innovative new, typically small and medium-sized enterprises (SMEs) to overcome investment constraints that are due to real or perceived risks (from unproven technology, management and markets). Such investments imply high transaction costs because of the often small amounts required in relation to the professional costs of due diligence and analysis and monitoring if the investment is made. They also imply longer time horizons than mainstream business before obtaining a sustainable profit or capital appreciation.

As a rule, returns to investments in technology companies are realised after the early financing stage, when the company has grown sufficiently to generate profits. Early-stage deals are here defined as the first and second rounds of institutional funding for companies less than five years old and not part of a larger business group. They are typically small, rarely exceeding USD 200 000. Growth-stage deals are the third and fourth rounds of funding or the first and second rounds of institutional investments for companies more than five years old or floated by large business groups and less than ten years old. Late-stage deals involve companies that are more than ten years old or pre-IPO (initial public offering) deals.

There is a shortage of purely private early-stage financing. This financing has a public good dimension, as it does not generate a commercial return. Until the number and diversity of innovation start-ups and spin-offs reach a certain critical mass, purely private early-stage finance is problematic. Advanced VC industries (in the United States, the United Kingdom, Israel, Chinese Taipei) overcome this by developing families of funds – seed funds, early-stage funds, later-stage and equity funds – in which later-stage transactions cross-subsidise, albeit not explicitly, early stage transactions. Yet in most countries, including many in Europe, the number of start-ups has not reached critical mass, so that public subsidies are widely used to address the public good nature of early-stage financing for new high-technology firms.

Figure 5.1 illustrates the phenomenon of the "missing middle": the lack of small but commercial early-stage investment for a firm that is not yet commercially viable and has a high chance of failure, in this case for India (Dutz, 2007: 171). It shows that there is an abundance of later-stage and buyout funding, and a dearth of seed and early-stage venture capital.

Figure 5.1. India's venture capital and private equity landscape: Skewed toward large and later stage investment deals



Note: Those companies not listed here are known exclusively by their acronyms. APIDC = Andhra Pradesh Industrial Development Corporation; BCCL = Bennett Coleman & Co.; DFJ = Draper Fisher Jurvetson; GVFL = Gujarat Venture Finance Ltd; IFC = International Finance Corporation; IL&FS = Infrastructure Leasing & Financial Services; KKR = Kohlbert Kravis Roberts & Co.; KPCB = Kleiner, Perkins, Caulfield, and Byers; NEA = New Enterprise Associates; PIPE = private investment in public equity; SIDBI = Small Industries Development Bank of India; TDB = Technology Development Board; TePP = Techno-entrepreneurs Promotion Program; UTI = UTI Ventures.

Sources: Venture Intelligence, World Bank.

One reason for the "missing middle" problem is that private support for venture entrepreneurship responds to, rather than creates, commercial opportunities for clusters of innovative start-ups. Synergy and co-evolution of public and private support structures for techno-entrepreneurship are crucial. This co-evolution tends to have three stages. In the first stage, which generates diversity, support structures are predominantly public. In the second stage, pre-emergence, intense private-public institutional experimentation occurs:

commercial and private actors develop a portfolio of institutions to resolve the critical mass problem. In the third stage, critical mass is achieved and a full-fledged private venture capital industry with seed and early-stage segments emerges. The work of Teubal and Avnimelech (various years; also Breznitz, 2007) trace the development of the Israeli VC industry through three phases: creation of background conditions (1949 to the early 1970s), pre-emergence (early 1970s to 1992) and emergence (1993-2000).

Incubation cycle and its stages

Incubation is a process that starts with efforts to stimulate techno-entrepreneurial ideas, goes through various stages of gestation prior to the establishment of a formal business entity, continues through the early years of the new firm's operations until it can leave the incubation cycle and work independently in a commercial environment. To sustain the momentum, the successful entrepreneur acts as a mentor and role model to stimulate the aspirations of the next generation of potential entrepreneurs. These stages interact in successful incubation cycles but for ease of presentation they are separated here into four main stages:

- Stage 1: The groundwork. An effort to stimulate interest in new business creation and a strong flow of ideas for new businesses are essential to creating a fertile climate for entrepreneurship.
- Stage 2: Pre-incubation. The handling of ideas judged to have merit, assembling evidence on how they will address risks, often using a business planning framework, and preparing the different elements needed to launch a new business.
- Stage 3: The incubator. The early stages of a new business which are best carried out in a supportive environment that maximises the chances of survival during the difficult early years and helps it to achieve its growth potential.
- Stage 4: Graduation and payback. The new company has a sustainable cash flow, a growing customer base and the potential to operate in a fully commercial market without continued dependence on often subsidised service provision. At this stage it is retained in the entrepreneurship ecosystem to act as role model and mentor for the next generation of new companies.

Stage 1: Groundwork

The objective of this stage is to increase awareness of entrepreneurship and incubation among those with a technology background so that more people come forward with potential business ideas. General promotion of entrepreneurship is one starting point, with activities ranging from participation in Global Entrepreneurship Week activities to promotion of business plan competitions from mainstream secondary schools to higher education institutions (HEIs).

Specific programmes can encourage targeted audiences to consider new business creation as an alternative to entering a career with a large company, a professional service role with an established firm or public service employment – the more traditional routes for those with higher-level qualifications. For example, Chalmers University Sweden has an entrepreneurship module in its Master's engineering programmes which started as an elective but proved popular and became compulsory in all postgraduate engineering programmes. In the United Kingdom, the BBSRC (Biology and Biological Research Council) included in its doctoral grant programme a module to familiarise participants with the business planning framework to help them consider the possibility of creating a new business from their research work. Also in the United Kingdom, Enterprise in Education supports both practical and theoretical efforts from primary to postgraduate levels to introduce the idea of creating a business.

In public research institutions (PRIs) and HEIs, work is needed to establish the legitimacy of the techno-entrepreneurship model as a part of the core values of traditional academic institutions. Protocols between HEIs and business associations can facilitate this legitimacy but are rarely sufficient. Clear rules of ownership of intellectual property that provide incentives for individual researchers, research teams, and the parent HEI and PRI are also crucial.

HEIs need to adopt career incentives that reinforce the importance of techno-entrepreneurship alongside the traditional emphasis on research publications and teaching contributions for the promotion of academic faculty. A few have included these in their contracts of employment, such as the University of Manchester, and a few promote it as a core value, such as the universities of Europe that formed the Entrepreneurial Universities Group (University of Twente in Holland, University of Warwick in the United Kingdom and University of Aveiro in Portugal).

Celebrating success also helps raise the visibility and social standing of entrepreneurs as role models to stimulate interest and signal the vital role they play in economic dynamism. This is part of developing a culture that views entrepreneurs as central to a successful economic future. At this more general level, television can promote a positive view of entrepreneurship through programmes such as BBCs Dragon's Den which offers a theatrical interpretation of the interaction between business angel investors and entrepreneurs with an innovative business idea.

All of these efforts encourage interest in techno-entrepreneurship and a flow of ideas with potential to enter the next stage of the incubation cycle.

Stage 2: Pre-incubation

This is the crucial filtering phase. Among all the ideas stimulated by the groundwork stage, the business ideas and entrepreneurial teams with the greatest potential are selected to receive help. The activity itself is important as it stimulates others who observe the process to consider possibilities and offer them for consideration. However, in essence the process is one of assembling evidence on the four major areas of risk that will determine whether the innovative idea is likely to succeed. The areas are:

- *Technological*: will the idea work and will it deliver the advantages claimed for it? In some instances this is a proof of concept effort, in some cases it is the transition from a theoretical advance or results that have been gained in a small-scale laboratory experiment to industrial levels of production, and in some cases it deals with the challenge of packaging the novel idea to make it safe to use and attractive to users.
- *Commercial*: will people be sufficiently interested in the new product or service to want to buy it either for a new use, if it is really radically innovative, or to replace an existing product or service? How many potential buyers exist or can be stimulated to buy and how quickly would the new idea be adopted in the marketplace? This concerns the potential of the idea to overcome barriers to entry and resistance to change and the ability to succeed against competition from established practice and show that the innovation has genuine potential.
- *Financial*: can the product or service be delivered at a price that is attractive to potential users and is sufficiently above its cost of production or delivery to enable an attractive profit? How much additional cost is involved in product development, production investment and marketing to ensure that the product or service can achieve its commercial potential. In short, will it generate a good financial return?

- *Personnel*: has the entrepreneur all the necessary skills and personal attributes to succeed either alone, which is highly unlikely, or through a team with complementary skills that are in place or can be brought together at the right time? The willingness to work in a team and to combine individuals with complementary strengths is a key attribute of a successful entrepreneur.

In each of these areas the pre-incubation stage focuses on collecting evidence to support the case for building a strong viable business from the initial innovative idea. The accumulated evidence is often presented in a business plan format, and a growing range of models is available for those managing this phase. Some are proprietary tools, such as the Kaufman Foundation's Sure Start programme which has, in addition to modules for general entrepreneurship, specialist components for technology-based business development. IC^2 of the University of Texas at Austin has similar tools, Quick Start and Market Look, developed through its technology commercialisation programmes. The World Bank InfoDev programme also has a lot of easily accessible material on its website www.infodev.org and its repository of reports and tools at www.idisc.net.

Phase 3: The incubator

At this stage the business is launched and generally is a formal legal entity. Assistance is usually provided via an incubator, where new firms can hire premises on a short-term, easy-in easy-out basis so as to minimize their exposure to costs when their future is uncertain. Typically these offer shared facilities, which reduce barriers to entry by minimising investment requirements, and common services, which enable the new business to present a professional image without having to incur the high costs of operating on its own. Being part of an incubation programme also adds credibility in relation to suppliers, customers and financial intermediaries and helps the firm build up business relationships.

It is important to get a number of key aspects right from the point of view of those managing the programme:

- The target business audience, entry and exit should be a clear part of the overall business strategy. It might emphasise a particular technology (e.g. ICT, biotechnology) or a particular cluster of businesses (e.g. creative and digital media) or a particular geographic spread (*e.g.* a single region or metropolitan area). Entry should entail a formal process and professional criteria relating to commercial potential. Exit should be built into the process from the start and should be adhered to with minimal flexibility to ensure that the initiative remains vibrant and available for the next cohort of businesses.

If the exit requirement is clear from the start, the firm will plan for it, but if any flexibility is implied firms will lobby to stay in the incubator longer.

- The physical configuration of the incubator should be varied and flexible to accommodate changing needs, have common spaces and meeting rooms to encourage interaction among incubating firms for mutual support, and ideally be part of a larger entity to ease graduation from the incubator component into space, potentially in the same building, where graduate firms find a different offer and a commercial contract and a high-quality business image.
- Location and scale will depend on the target audience but should be convenient for developing business linkages with strategic partners and of a scale able to sustain a viable community of new businesses and sufficient revenue potential to cover its operating costs. In the UK market the rule of thumb is that a minimum 4 000m2 is needed to be self-sustaining.
- The service offering includes at a minimum basic business support and can extend to early-stage professional services (bookkeeping, sales assistance, etc.) and gateway services to meet more advanced needs in areas such as finance, legal and marketing. Technology-based firms with high growth potential have been identified as needing more higher-level services early in their life. Because the entrepreneurs typically have a technical background they are usually more receptive to commercially oriented, rather than technical, services and training.
- The commercial strategy should emphasise the development of sustainable viable businesses concerned with sales and commercial success rather than cheap rent and subsidised services. During this stage of the incubation cycle, usually lasting from two to three years, a "hardening" process should ensure that the graduating business will be able to support commercial relationships readily with all its partners: suppliers, clients and service providers.

As incubators have proliferated, performance has varied and attention has turned to ensuring that new incubators follow best practice principles. A good idea badly implemented does not undermine the value of the idea but implementation needs to be improved to maintain the value of the brand. There has also been a move to use the incubator to try and solve problems for which it is not suited. If the flow of potential business ideas is weak, the simple presence of an incubator will not help. More is needed but additional support programmes are not often implemented alongside the incubator.

A variant, the accelerator, has emerged which focuses on a particular subset of new growth firms and has had more general success. The main subset has been Internet and e-commerce businesses for which time to market is short and capital cost is small. With focused intervention and a concentration of prior experience with market entry and connections, new business ideas can be quickly validated and launched with a good chance of success. Other accelerator programmes focus on the second and third tiers of emerging businesses, those that have started and met with some initial market success. Here accelerators do what their name suggests and speed up the firms' growth path.

Stage 4: Graduation and payback

Graduation is an important "rite of passage" and signals that the firm is a fully independent commercial entity with a viable business future. It should be celebrated and used to promote both the firm and the incubation programme. Leaving the incubator should be made as painless as possible for each business, and care should be taken to ensure suitable accommodation for the next stage of the firm's growth and opportunities to continue to sustain business relationships established during the incubation programme.

Keeping graduate entrepreneurs and firms in the broader incubation community also increases the potential for obtaining mentor and role model benefits for the next generation of firms in the incubation cycle. These linkages can be as informal as participating in social events. They can also be more formal, such as acting as mentors or part-time advisors to new entrepreneurs who are likely to relate to someone who has recently gone through the process they are now entering. All of this reinforces the social capital of the incubation cycle and sustains it for the future.

The traditional approach to the incubation cycle

Traditional technology transfer organisations (TTOs) have a linear, science push logic, are usually hosted by a scientific institution that is seeking to gain from intellectual property (IP) it has developed, and focus on the establishment of an intellectual asset through the IP regime. At one level, the more of this type of activity the better as knowledge is organised into clear packages with an identified application, which is a key aspect of the IP system, and there is some clarity about the ownership of the knowledge. However, at another level, there is an almost universal lack of attention to commercial aspects of the IP asset. Put simply, most TTOs cost money rather than create value for their parent institutions and build a legal and administrative culture rather than a value-creating commercial culture.

Better utilisation of the knowledge created requires a non-linear TTO model that gives at least equal attention to the commercial challenges of use and value creation. An agency outside the parent academic and research community with connections to the business community is a good starting point for developing a new culture. Multiple sources of technology from several institutes are also part of the solution. A professional cadre with skills in transfer and a commercial perspective are also crucial to making TTOs more effective instruments which are not based essentially on a science push.

These ideas are being used to design new programmes. In Portugal the University Technology Enterprise Network (UTEN) seeks to build a professional service with nodes in individual universities but with a network culture that includes companies as well as researchers. It draws on international networks because the domestic Portuguese market is too small to sustain new technology-based firms so they need to be helped to be international from the start. Another programme is being established in Mexico which integrates private and public interests. Many institutions are joining to create a critical mass of disclosures with international connectivity (Box 5.1).

In the traditional approach, commercialisation was relatively straightforward: each technology support agency focused on and funded a specific stage of the incubation cycle. This approach has encountered a number of problems. A grant of the Small Business Innovation Research (SBIR) programme to develop a pilot prototype can be as much as USD 1 million. Yet statistically, out of 1 000 ideas, early-stage VC or corporate sponsorship finances only ten. Out of the ten firms financed, only one is later successful, two or three barely cover costs, and the rest fail. If out of 1 000 ideas considered at the pre-incubation stage, only one succeeds, it is not surprising that state technology corporations, multinationals and equity investors invest in existing firms that may become still more successful. So the first problem is that it is not possible to finance all promising ideas, yet picking winners is also impossible. Clear winners do not exist until very late in the process when the incubation process helps them to emerge. New industrial policy has emerged for managing the incubation process: a process with clearly defined cut-off points and performance benchmarks.

Box 5.1. New approaches for upgrading technology transfer and commercialisation in Portugal and Mexico

Portugal upgraded its university-based technology transfer and commercialisation (TTC activities as part of an innovative programme to improve the quality and connectivity of its HEIs. Most Portuguese universities had set up a TTO which was largely funded by a programme of the national IP promotion agency. University rectors accepted the initiative as the activities were fully funded, but because they did not place them at the centre of their development strategies, the positions were filled by relatively junior and inexperienced staff. Changing this situation was a priority of a new programme for academic alliances with prestigious international universities in carefully targeted joint academic programmes. The institutions included Harvard University and the University of Texas, Austin, and involved academics from Portuguese universities who were funded to develop joint PhD programmes and joint research in the targeted areas. An important requirement was to identify and incorporate Portuguese businesses working on the topics of the research programmes.

The TTO component was developed as the University Technology Enterprise Network (UTEN) and involved the construction of a national network of TTOs with a training programme of theoretical and practical knowledge and skills managed by IC^2 of the University of Texas, Austin. TTO staff were placed in US university-related TTOs and trained in working with and for new technology companies. They were helped in Portugal by experienced US-based professionals to identify potential research findings for commercialisation. The network addressed the critical mass problem and the training emphasised the benefits of working together systematically. The involvement of firms in training alongside the TTO staff showed the need to network with the business community and to develop commercial skills in the TTO staff. The international orientation developed connections for potential US market entry. An international orientation is important for new technology-based businesses in small countries as the domestic market may be too small to sustain growth. Rectors now take the agenda more seriously in Portugal and the status of the TTOs has risen markedly over the four years the programme has run.

Mexico is taking a different approach to overcome two major issues. The first solves the critical mass problem with a single TTO that covers several research institutes. The second is to ensure a commercial culture by setting up the new institutions as private entities outside the research institutes and incorporating private-sector partners. The agencies are established under a 2009 law and are known as offices of knowledge transfer. Some are encouraged to have a regional emphasis, typically at the state level, while others address the need for specific approaches for some technologies. To ensure that the quality of the service is of international standard, the first round of centres are being assisted through international partnerships with strong TTOs in the United States and Europe which support practices and procedures through training.

A second problem is more fundamental. Clearly defined accountability rules and transparent management structures exist only at the initial and final stages of the incubation cycle; they are quite ambiguous in the intermediate stages. The logic of the initial stage is that of public-sector grants for research and technology commercialisation. In contrast, the logic of the final stage, when a commercially successful company already exists, is private. Equity venture funds and multinational corporations are the key managing agents at that point. However, there is no agent clearly responsible for managing the commercialisation process in between the initial and the final stages. All the transitional stages happen in the environment of so-called search networks: networks of entities with specific skills, such as early-stage venture capital investors, researchers in universities and R&D institutes with technological expertise, consulting companies with marketing expertise and the legal and investment banking expertise of lawyers and financial intermediaries. This expertise is needed to identify the proposal as a promising idea and decide what needs to be done to move it further along the commercialisation and incubation cycle described in Figure 5.2. A technology incubator, venture capital fund, or national bio- or nano-technology corporation is useful only to the extent that it can rely on and tap into such private-public search networks, which have the capability jointly to transform promising ideas into progressively more articulated deals.

In economies that are global innovation leaders there is much relevant infrastructure: traditional science parks and technology incubators are complemented by this soft infrastructure. In most of the world, however, this is the "missing middle" problem because early-stage search and incubation networks exist in very few countries, such as the United States, the United Kingdom and some small northern European countries. Israel and Chinese Taipei also have institutionalised search networks, as demonstrated by the availability of early-stage venture capital and a number of local technology companies listed on the NASDAQ (National Association of Securities Dealers Automated Quotations) market and on national stock exchanges. A list of countries that lack a viable system to support technology start-ups is telling: it includes Japan, Germany, France and Finland.[2] It is telling because these countries did not fail for lack of trying. Many programmes to support technology start-ups in these countries still focus on funding specific organisations rather than on building capabilities to search and recombine. The result is a perennial "deal flow" problem: there are many promising ideas and private and public funds but a shortage of deals to invest in. A third category involves certain localities in large middle-income economies (Campinas in Brazil, Tomsk and Moscow in Russia, Bangalore and Pune in India) and in Europe (Denmark, Norway, Spain). The experience of these economies and of Israel and Chinese Taipei, which developed technology start-up dynamics in less than one generation, indicates two complementary approaches.

Emerging proactive search approach: Initiation and institutionalisation of search networks

The new proactive approach to commercialisation of science signifies a shift from the organisation of incubators to the incubation process, and emphasises a need for stronger co-ordination of the four tiers of the incubation cycle. No single agent – incubators, venture funds, etc. – can do the job. Incubators provide services to existing firms and have neither the incentives nor the capabilities to go to the science base and look for new ideas with commercial potential. The same applies to VC funds because the costs of searching for new ideas are too high. In Europe, there are incubators that operate as entry points for the new search networks in support of commercialisation, but these networks increasingly play a critical role that cannot be limited to a single organisation. The organisational forms of the emerging search networks are complex and open ended, and call for much experimentation.

Table 5.1 summarises the two approaches: the management of the commercialisation cycle through search networks and the more traditional funding of specific organisations participating in the commercialisation cycle.

Experience reveals two ways to put a proactive private-sector-based approach into practice: search and deal articulation networks. The first globalises informal networks, while the second institutionalises them (i.e. provides governance and structure).

The first way is easier to implement but it is also more fragile as it tends to rely heavily on specific individuals and their ability to work together. Most start-up ventures are financed by retained earnings and the proverbial "3F" (friends, family and fools). This is the most elementary search network for relevant expertise and funding but its reach is limited. The next stage, when angel investor networks are identified and approached, reaches out to more specialised expertise. Since personal interaction and trust are crucial, the reach of the networks remain limited, both geographically and with respect to the range of expertise involved. However, international migration and mobility of talent have globalised local trust-based networks. Diaspora networks that bring technology, venture capital and marketing professionals together with emerging technology start-ups and spin-offs are now a feature of significant developments in advanced innovation clusters (Silicon Valley is the typical example). They combine the trust and shared language of local interactions with global reach and global expertise. More recently, one can observe the emergence of deal articulation consortia that combine technical, marketing, financial and (sometimes) university management expertise to transform promising ideas into projects.

Table 5.1. Two approaches to promoting techno-entrepreneurship

	Co-evolution and search approach	Administrative approach
Focus and objective	Management of the incubation cycle; facilitate development of companies, strengthen linkages across players, improve the micro-environment for venture entrepreneurship	Expansion of funding for existing entities: companies, R&D laboratories, universities, etc.
Role of government agency (*e.g.* Office of Chief Scientist)	System integrator of many players in the technology commercialisation business: early stage funds, venture capital funds, regional administrations, large corporations, etc.	Funding of projects that appear promising
Main instruments	Formation and co-funding of private-public partnerships, encouragement of the creation of consortia to develop ideas and turn them into high-growth companies, and be remunerated on a success fee basis Piloting of new (innovative) commercialisation schemes and programmes (e.g. diaspora mobilization) Attraction of global players with established record of commercial innovation Policy advocacy: improvements in the climate for innovation (e.g. intellectual property rights)	Grants for research and technology commercialisation Equity participation in promising companies
Organisational logic	Public entities serve as second tier organisations and set up incentive framework for private and private-public actors with specialised expertise and connections: technology development consortia, early-stage venture funds and other actors	First-tier programme allocates funds between many competing claims, projects, and organisations
Benchmarks	Israeli Yozma: a second-tier programme to attract global VC players to Israel. Development of viable high-technology commercialisation industry (growth in VC funding, in number of start-ups and IPOs, growth in intensity of joint programmes between academia and industry).	Focus on outputs, not outcomes – number of patents received and companies created
Main risks	Lack of follow-up and patience resulting in weak and parochial (rather than globally connected) first-tier actors: technology development consortia, R&D teams and venture funds	Two main problems: Funding technical and research excellence with little prospect of commercial success Capture by vested interests
Relevant international experiences	Israel, United Kingdom (Science Enterprise Challenge), Spain, Norway, United States (Silicon Valley), Chinese Taipei, Netherlands (Zernike Group)	Public funding of organisations irrespective of their performance

Box 5.2. Example of the search approach:
A private management company co-ordinates all stages of the incubation cycle

Zernike Group began in the late 1980s as the management team of the Zernike Science Park linked to the University of Groningen in the Netherlands where it still has its headquarters. The business grew rapidly to include the management of seed funds, first in Holland and subsequently in Australia and Italy, and to the management of specialist properties, including in Australia, Germany and the United Kingdom. Outside of the Netherlands, national companies have been established with cross shareholdings from Zernike Group currently in about a dozen countries. The culture of the group is entrepreneurial with each national company sharing a trust network across the group even though there are no formal links between the individual national companies. It integrates its technology commercialisation business by offering various types of services:

Facilities management: Operation of specialist property and physical infrastructure geared to the needs of knowledge economy firms including science and technology parks, innovation centres, incubators and technology development centres.

Seed and venture funds: It provides funding for new technology businesses from its own capital and on behalf of others (where it operates as a risk-sharing partner rather than solely as a fee-for-service provider). Funds are targeted at early-stage companies; some have a strict geographic focus (one fund focuses on Umbria in Italy), while others have a technology focus, such as the Dutch government's biotechnology funds which Zernike manages on its behalf.

Business-to-business linkages: It connects firms that are the company's tenants or with which it has investments to broader business opportunities, particularly through its growing international networks to maximise mutual advantage. For example, Zernike arranged access to a state-of-the-art graphics software product at a concessional price for a small information and communication technology (ICT) company in western Australia, in which it had invested as a co-development opportunity, with the UK company that supplied the software. Zernike then introduced the final product to the European market.

Consultancy and advisory services: It provides these to businesses that require specialist professional services and to development agencies that seek to accelerate the development of the global knowledge economy and wish to benefit from advice from practitioners rather than theoreticians.

The second way, more commonly found in Anglo-Saxon economies, institutionalises informal search networks. Institutionalisation occurs in different ways.

A first is through the development of a second-tier organisation with private management companies and the introduction of success-based contracts. Creating a second-tier organisation such as Yozma, a fund of funds which finances early-stage capital, is a widely recognised means of promoting early-stage venture capital industry. Public support is directed to an incubation structure rather than to private venture capital funds. Building on existing connections of Israeli companies to the United States, Yozma invited leading global venture capital companies to establish their spin-off operations in Israel as Yozma funds.

A second is through private management companies involved in all stages of the incubation cycle. As an example, Zernike is a multinational company with headquarters in the Netherlands. It manages technology incubators and venture funds but also advises governments and private-sector players on how to manage the incubation cycle (Box 5.2).

A third is through a focus on the initial stages of the incubation cycle: groundwork and pre-incubation. This approach is prominent in emerging economies characterised by substantial human capital but weak or non-existent institutional infrastructure (Box 5.3).

Box 5.3. Proactive approach to incubation in the Middle East: Oasis500

Oasis500 is the Arab Middle East region's premier entrepreneurship training and mentorship-driven seed and early-stage investment programme. It attracts top technology start-up teams and provides them with opportunities in a region characterised by a lack of seed and early-stage capital. The brainchild of a group of Jordanian business leaders working with His Majesty King Abdullah II, Oasis500 combines the region's human capital and the potential for growth in the region's ICT sector in an effort to trigger entrepreneurial transformation in Jordan and the region.

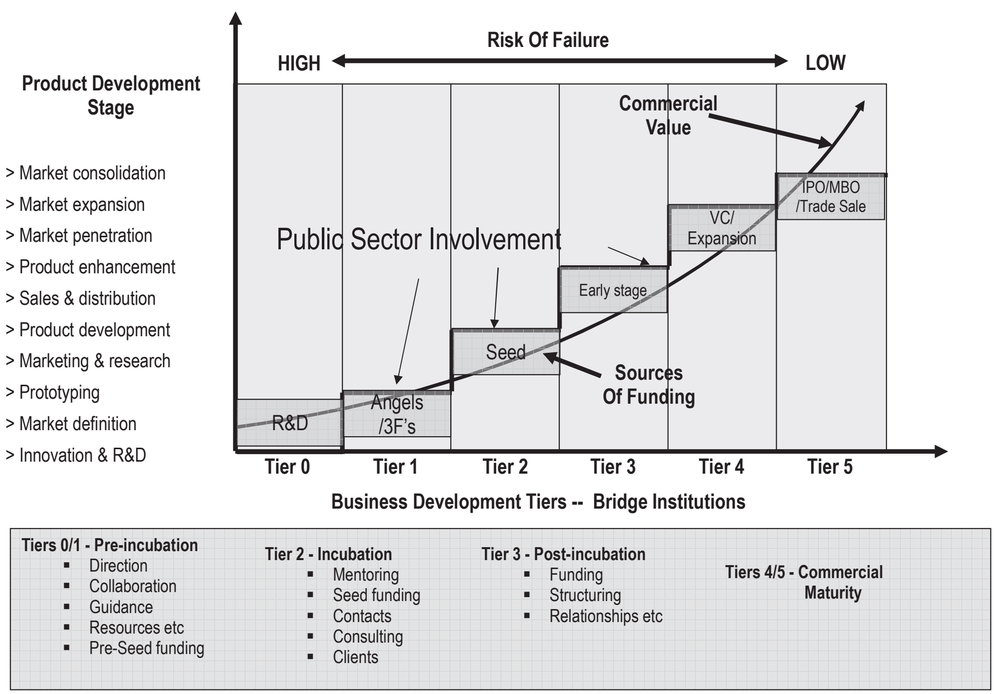
Focusing on accelerating the transformation of ICT, mobile and digital media ventures into viable businesses, Oasis500 runs a four-week boot camp for entrepreneurs. An eight-day intensive training programme is phase one of the boot camp, during which entrepreneurs are exposed to business modelling, pitching, financials, marketing strategies, and illustrations of pitfalls and business experience from sector experts. Following this training, entrepreneurs engage in multiple rounds of pitching in order to refine and evaluate the robustness of their idea and their commitment to it. Because of the invaluable information it yields on potential investments, the boot camp is an integral part of an intensive selection process. Entrepreneurs that successfully pitch their companies for initial investment receive an average cash investment of USD 15 000 as well as USD 18 000 in direct investment services in return for equity in the company. The subsequent 100-day incubation and acceleration period promotes fast growth and tests companies' potential by providing mentorship, weekly coaching, and other entrepreneurial services. The mentor network, currently consisting of 150 business leaders from around the world, is crucial to the companies' success. Oasis500 companies received follow-on investments at valuations of three to eight times their valuation upon joining Oasis500. Exceeding the initial goal of ten investments, Oasis invested in 34 companies in its first year of operations.

Illustration of the search approach: Creation of institutional infrastructure for venture funding

Venture funding in the incubation cycle

Venture funding is an important input in the incubation cycle. It is needed to take the innovative business forward and provide it with adequate finance to move from an embryonic business idea to a strong commercial firm. An articulated chain of finance is required, with a different package of offers at the different stages of the incubation cycle as the needs of the growing business changes. Figure 5.2 distinguishes the different stages through which a typical technology-based business must pass to achieve its potential. At each stage and type of finance a package of advisory assistance needs to be provided along with capital to ensure that the funds are well used and that the foundations laid are capable of sustaining the business through the next stages.

Figure 5.2. The main stages of the commercialisation cycle



Each of the service areas associated with the tiers of growth will see an evolution in the type and level of service as the firms grow. Taking the finance function as an example, there are several stages through which provision may pass. Initially there will be a need for bookkeeping to ensure the new entrepreneur meets the minimal legal requirements of accounting and tax. This can be provided from an external source, and in many incubation programmes a semi-retired professional provides this service for programme companies at low individual cost. As the firm grows, management accounts will have to be put in place to obtain a clear view of cash and profitability. This may lead to an internal appointment. As the firm becomes established and takes on external shareholders, the level of professionalism will need to be enhanced and a fully qualified accountant will likely be appointed to demonstrate good practice and propriety to outside parties and shareholders. If the firm gets to the stage of launch on a stock exchange, a financial director with experience in raising funds and with the reporting standards of the exchange will need to be recruited. While not all firms pass through all these stages, the incubator should hope that some will, and it needs to have arrangements to ensure that developing service needs can be met.

In Figure 5.2 pre-incubation consists first of tier 0, the transition from a traditional academic grant to conduct research to a fund that helps support promising ideas through the next stage of development. This is well before commercial funds can be attracted and the first bottleneck. Proof of concept is the term generally used for this step. The move might be from a single experimental device to one that is capable of being manufactured in volume but it also depends on the technology. The dynamic in biotechnology is different from that which applies to ICTs. Many biotechnology firms are established to take promising molecules through the early stages of product testing. They are in essence applied research units in the form of commercial companies, and they need to arrange funding for several years of operations from the outset as they cannot anticipate revenues until all the regulatory hurdles have been completed. On the other hand, in the ICT sector, unless software products are in the market quickly they lose their window of opportunity as the technology and market move very fast and products are quickly outdated. These firms need much less capital to get started and use early revenues to cover costs and surplus revenues to invest in the next generation of products.

Several research-centred universities have assembled their own funds to help overcome the gap in funding for this type of activity. In the United Kingdom, the University of Cambridge has its Challenge Fund and its Discovery Fund, Imperial College of the University of London has its BLM Imperial Venture Fund, and the University of Manchester has its UMIP Premier Fund. Some research-funding bodies have also taken steps to make funds available for the transition from academic research to commercialisation and a variety of grant programmes have been put in place where there is no other institutional support.

A further part of pre-incubation is in tier 1, when the first external investors are attracted to the business from sources with a different logic of trust from those usually applied by commercial investment funds. The three Fs are important early financial supporters with small but often essential capital and advice. This group is often merged into the usually more arm's-length relationships with business angel investors. These high net worth individuals have capital available for risky early-stage investments. Usually they are active investors who want to offer their knowledge and experience as well as capital. Many have themselves been entrepreneurs and made their capital through an earlier generation of innovative businesses. The angels are often interested in new businesses in areas in which they have some prior business experience and that are located in their communities so they can manage their active contribution alongside their other activities.

If such angels are to be encouraged to play a full part, they need to be part of a local network that brings together people with ideas and people with money. These networks can take various forms and have become more widespread in regions and metropolitan areas with strategies to promote new knowledge-based businesses. In Italy, for example, these local networks have been amalgamated into national networks which extend their geographic reach, share experience and know-how and provide a supportive partner for those who are trying to build a network in their locality.

In some cases there has been a blurring of the boundary between the business angels and the next level of venture funds, the seed funds, through initiatives that create more inclusive forums. The Greater Eastern Investment Forum in Cambridge, United Kingdom, has individual angel members, local and regional early-stage technology fund participation, and formal funds from outside the region can attend its meetings and invest in the companies showcased. A similar integration and deal matching service is designed into the Austin Capital Network in Austin, Texas, which was established to create a marketplace where those with money could meet those with ideas. Another tool that extends reach is the involvement of the diaspora in countries where they have become important in promoting entrepreneurship in the knowledge economy and in providing funding for early-stage businesses development.

When a company reaches tier 2 it has usually entered the formal incubator stage, has established its legal form, and is beginning to trade with commercial clients for its products or services. In many models, it is known as the "valley of death", as many businesses fail during this stage. Seed funds are the first "institutional" investors and their participation in the firm's equity is usually relatively small but still represents significant risk to the investor because the status of the new firm is not clear. A disproportionately large transaction cost is often incurred for each investment, as much the same due diligence effort is needed for a deal of USD 0.5 million as for a deal of USD 5 million. Because of the risk and transaction penalty, seed financing is the area where the participation of commercial agents has to be encouraged, often through some form of partnership with public agencies which support the transaction costs through subsidies or the risk capital by making risk money available from public funds. This is further discussed below.

Mainstream venture capital begins to play its part in the post-incubation (tier 3) stage for businesses that have introduced their product into the market and have achieved a positive, and preferably profitable, trading position. Deal sizes are larger, say USD 1-5 million, and the relationships are more formal. However, the best VC firms are still active in developing the business and instrumental in taking the firm to a higher level of success. This active role is also described more fully below.

When firms reach commercial maturity (tiers 4 and 5), they are well past the intervention of incubation programmes but are included for completeness. Accelerator programmes are concerned with this stage. Larger development capital investments are made to accelerate the company's growth and realise its full potential (tier 4) and its IPO on a formal stock exchange so that the company can raise capital as it expands further (tier 5). In many places activities of the formal stock exchange are weak and show little appetite for relatively young and innovative businesses so that other paths need to be explored. From the point of view of venture funds that are seeking an exit the most frequent path taken, if the flotation option is unattractive, is through sale to an established large business that can refresh its product offering through acquisition of the new smaller firm. This has become a major route for small biotechnology firms which are absorbed into larger pharmaceutical firms once they have reached a certain stage in the product testing regime and their product appears to have real potential. It has also been important in some of the amalgamations in the ICT sector, such as the acquisition of Autonomy, a Cambridge-based start-up that launched in the late 1990s with a small angel investment and was bought for around USD 10 billion by Hewlett-Packard in 2011.

Venture capital is not just the money: The deal flow problem

The challenge is to stimulate a stronger flow of potential deals and to have appropriate venture finance available to take the right ones forward.

One way to institutionalise deal generation is a deal flow facility. The broad-ranging work in the groundwork phase of the incubation cycle helps create an entrepreneur-friendly environment. The deal flow facility fits into this broad effort but is much more specific in its purpose and its contribution. To move a technology from conception to ready for launch as a new business takes a lot of effort and the combination of different types of knowledge. In places where there is no established infrastructure, or where the established infrastructure is not geared to meet the needs of technology-oriented or knowledge-based businesses, a structure has to be built.

The essence of the idea is to co-ordinate all the skills necessary for the knowledge elements that will be needed to launch the new technology-oriented business. Each of the selected consortia has a performance-oriented contract that rewards it for its success in preparing deals that attract venture funding for the new business or new product. These consortia typically need to have a deal source, one or several research-generating agencies to increase the likelihood of generating research findings that can be commercialised, plus experienced professional agents who can provide the legal, financial and commercial knowledge needed to prepare the project. Some consortia focus their operations on a selected technology and others focus on a particular region. They scout for deals and for ideas with good commercial potential. It is easy for such groups to undertake analytical work on projects with little likelihood of generating value, for example by preparing business plans for ideas that are unlikely to find an investor or ever get to market, so it is important when designing the implementation contract that care is taken to weight payments for outcomes rather than for activity.

Institutionalisation of pre-incubation networks

A constraint that often restricts the availability of the right combination of specialist and technical services is the preponderance of vertical professional networks and the tendency for different parts of the local knowledge community to fail to communicate effectively. A priority in creating the right ecosystem is to stimulate horizontal networks so that regular contact professional silos are broken down, and a shared language and mutual understanding emerge. Vertical networks also predominate in academic environments as departmental structures create strong bonds within disciplines but do not encourage horizontal linkages.

Box 5.4. Institutionalising pre-incubation

In the 1980s the rector of the University of Oslo led an initiative to develop a science park next to the university's main campus. His aim was to use it to accelerate the commercialisation of technology from the university's science base. However, the university faculty was not persuaded that commercialisation was a legitimate third mission of the university. As a result, the Rector was replaced at the next election by a candidate who opposed the activity and who effectively stopped formal co-operation with the science park even though it had been established as a foundation with the university as major shareholder.

In this less than promising climate the park's management continued to help those among the faculty who were interested in commercialising their research findings without the support of the university administration. The strategy was to use experienced part-time staff with credibility and informal networks with the university science faculties to identify ideas with commercial potential. They went to different departments of the university and discussed with researchers their activities and thoughts on potential outputs. When they had found ideas with potential and willing academics, these individuals worked with the projects to bring them into the commercial domain – what would now be described as helping them to become investment-ready. The park relied on part-time staff as it lacked money to pay a full-time member of the staff for the task.

Support was offered on a "no gain, no pain" basis, i.e. the potential entrepreneur would not have to pay for the service in advance but would have to share any profits. The park took a minor shareholding in any company that emerged from the process and therefore aligned the incentives of both the academic and the park executive to achieve commercial success. The support included a home for the new company in an incubator environment and use of the park's network to bring together the necessary resources, including capital and additional skills, to launch the new company.

While the companies that emerged inevitably met with mixed success, there were sufficient positive results for the park to continue its role. It eventually had a small number of exits from the portfolio of firms and raised enough capital to build a stake in the development of the second phase of the park. In time this was liquidated and the capital was used to start a small venture fund to invest in a new generation of start-ups.

The original scheme gradually gained notice and a national programme, the FORNY (Commercialisation of R&D Results) programme, was set up. It makes tranches of grant money from government budgets available to cover the costs of taking new ideas to commercial viability. The national FORNY programme is implemented by a group of science and technology (S&T) park managements throughout Norway who obtain the resources necessary to reach their commercialisation objectives.

See: http://erawatch.jrc.ec.europa.eu/erawatch/opencms/information/country_pages/no/supportmeasure/support_mig_0003?tab=template&avan_type=support&country=no.

Box 5.5. Manchester's horizontal networks

Corridor Manchester is one of the largest concentrations of knowledge workers in the United Kingdom. It includes two significant universities and a large teaching hospital as well as specialised arts-related HEIs located along one of the main arteries leading from the centre of the Manchester conurbation. A strategic alliance was formed between the municipality, two universities, the health authority and the Manchester S&T Park to develop the corridor with an emphasis on specialist infrastructure development, quality of life and environmental improvements, and acceleration of the development of knowledge economy firms.

The concentration of knowledge workers in the centre of a conurbation gives rise to plenty of networking activity. However, closer examination revealed that the networks were predominantly vertical in nature, i.e. chemists talking to chemists and financiers talking to financiers. There was an absence of horizontal networks that encouraged members of different professional groups to meet regularly, create linkages and share knowledge. This was recognised as a constraint on the free and effective flow of knowledge and the development of combinations of knowledge which often result in the modern knowledge economy in new ideas and new value added. Improving this situation became a priority for action.

In addition a strong separation was observed between those with a predominantly arts and creative background and those with a hard science background, with few opportunities for the two groups to meet. In part this was because of the different images they had of each other and in part because of the strong verticality of networks. This was particularly important as the area has a strong economy based on creative and digital media, but it required combining the technology of digital platforms with the content of the creative sector to maintain its competitive edge.

A strong message that emerged from the research on network practices in the area was that horizontal networking would be welcomed but that it would have to offer clear value added as there was little interest in networking for its own sake. Therefore a number of topics were found that appealed to different groups, and were both relevant to the community as a whole and required inputs from several sources. The topics included foresight (taking a medium- to long-term look at developments and positioning the combined resource to maximise benefits); environmental management (an emphasis on the local environment of the corridor but clearly within wider concerns about resource management and global warming); and the new industrial revolution (a reference to Manchester's past as a centre of the original industrial revolution and the opportunity to recreate that momentum with a completely different set of inputs for the 21st century).

A loose alliance within the Corridor initiative was identified to take the initiative forward, to build momentum behind these ideas, and to ensure the realisation of concrete outcomes and build a culture of successful implementation.

When designing initiatives to encourage horizontal activity it is crucial to have a clear purpose and potentially valuable outcomes. Busy professionals who might be attracted by the idea will not continue to participate if they do not find it useful. The purpose should be relevant to the economic development of the city or region – an appropriate size for building networks – or appeal to a quality of life issue of importance in the area. The organisers must also bear in mind the need to accumulate knowledge and experience through horizontal activities in order to build a history of valuable outcomes that will draw in new participants and stimulate innovation activity. Boxes 5.4 and 5.5 provide two examples from emerging innovation centres in Oslo, Norway, and Manchester, United Kingdom.

Conclusion

Promotion of technology-based start-ups and innovation clusters has been a concern of government for many decades. In most middle-income economies, a variety of support instruments have been put in place: technology incubators, science parks and SBIR-type programmes. They appear to be of two types: on the one hand, predominantly public-sector and grant-based support to early stages of the incubation cycle (support for R&D and seed funds for commercialisation); and on the other hand, predominantly private-equity and later-stage VC investment in companies that have proved successful.

Management of the incubation cycle, the approach proposed here, focuses on the creation of early-stage private-sector capabilities. It builds on and connects existing programmes, projects and initiatives (technology incubators, technology transfer offices in universities, science parks and other programmes) by institutionalising search networks composed of diverse players that rarely work together (or even talk to each other).

SBIR-type grant-based programmes are popular as they are easy to administer, relatively transparent and result in tangible outcomes, such as technical prototypes. However, there are reasons for scepticism regarding their impact. If there is no early-stage VC, the technical prototypes they tend to fund may not go beyond this stage, even if they have commercial promise.

The emerging proactive search approach is less straightforward as it aims to achieve synergy among players and capabilities that previously did not interact. This approach reveals the deal flow, the co-existence of many promising ideas yet few structured deals, as the binding constraint for the development of innovation clusters and a venture capital industry. This is somewhat counter-intuitive as most studies focus on the shortage of VC finance as the major problem.

The following features of the venture capital industry are important from the perspective of the pro-active search developed in the chapter:

- The venture capital industry as a search network for identifying and combining finance, technical expertise, marketing know-how, business model, standard-setting capacity, etc. (Sabel and Saxenian, 2008). Once integrated, these components become nodes in a new set of search networks for designing and building products. By supporting a diverse portfolio of ventures and combining hands-on monitoring and mentoring with market selection, private-public search deal generation networks organise a process of continuous economic restructuring and also learn about how to improve restructuring itself.
- Sharp distinction between early-stage VC and later-stage VC.
- Focus on generation rather than selection of deals.

The proactive search approach is only emerging. The chapter offered a diverse portfolio of examples to illustrate this approach, along with an analytical and conceptual underpinning of the approach. Such theorising on the basis of empirical evidence will hopefully improve design of relevant public sector programmes and policies.

Notes

1. Analysis of this process is predicated on dialogue with policy makers and other practitioners. At a minimum, the dialogue is triggered by an interview with them. An analysis by Breznitz (2007) of innovation policies and programmes in IT sector in three high performers – Ireland, Chinese Taipei and Israel – is an example of analysis of the innovation system based on extensive and open-ended interviews.

2. Finland is often considered a paragon of innovation owing to single company, Nokia, but techno-entrepreneurship stemming from its domestic science base is quite weak. Sabel and Saxenian (2008) document how Finland's innovation system became a victim of its own success and faces serious challenges for shifting the focus to decentralised innovation clusters.

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Chapter 6

Supporting affordable biotechnology innovations: Learning from global collaboration and local experience

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*This chapter describes policy initiatives of India's Department of Biotechnology for adapting and commercialising biotechnologies to provide affordable quality solutions for local needs in health care, agriculture, industry and the environment. In selected policy areas, India's promotion of global consortia involving local and foreign firms, universities and public research entities supported by domestic public/private partnerships, appears to have been critical in spurring learning, including about structured research protocols that lead to commercial products. The chapter argues that governments and firms need to better learn from evolving local experience through more rigorous performance measurement. This includes the more systematic incorporation of lessons from impact evaluation in project and programme design (with explicit metrics to report and learn from failure), and the institutionalisation in project and programme implementation of "*diagnostic monitoring*" routines for continuous improvement through redesign.*

India's economy has grown remarkably over the last two decades. While growth was initially triggered by economic reforms and a change in policy on foreign direct investment (FDI) that attracted tangible and knowledge-based capital, a key driver of more inclusive growth will be an innovation system that fosters learning so as to adapt local solutions to challenges in health, agriculture, energy and environmental products, among others.[2] Affordable solutions in these areas have the potential to address the needs of all people and especially those in the lowest income groups (the base of the pyramid, or BOP). Such innovation-driven commercialisation efforts should also help give domestic enterprises longer-term competitive advantages as countries open their markets further to global competition.

While many industrialised economies have innovation policies and allocate resources for cutting-edge frontier research and its commercialisation, some emerging economies have attempted to accelerate the technology adaptation and catch-up process by benefiting from already developed and accessible technologies. Generation of frontier technology may certainly be the basis of a long-term growth path for some countries. However, countries with the capabilities to adapt existing technologies to their local needs can stimulate more inclusive growth in the near to medium term, while focusing on the creation of frontier technologies in the longer term.[3]

This chapter looks at six policy areas in which India's Department of Biotechnology (DBT) seeks more rapid adaptation of biotechnology applications to provide affordable quality solutions.[4] India's promotion of *translational research* focuses on *global consortia* for product development involving local firms and foreign firms closer to the technological frontier, universities and public research entities, supported by domestic *public/private partnerships* (PPPs). These appear to have been critical in spurring learning, including about structured research that leads to commercial products. Additional public support goes to *skills development*, *regulation*, and *institutional governance*. The impact of the learning from global consortia is suggested by the fact that 36 of 46 surveyed biotechnology firms (78%) indicated that they collaborate with other firms or academia for co-development, and that 31 of these 36 firms (86%) jointly monitor progress and results via milestones and joint review processes. A notable outcome has been India's first indigenously developed oral vaccine to prevent high infant mortality from rotavirus-caused diarrhoea, which was supported by a global public/private consortium. It is the first time that an Indian company has brought a vaccine successfully through phase III trials, and it was India's first community clinical trial conducted directly through doctors and clinics. With the regulatory approvals expected soon for the product, the vaccine is expected to be sold to governments worldwide, including UN procurement agencies, at a price of USD 1.

This chapter also points to the need for more systematic programmatic learning based on rigorous performance measurement. This includes learning through the systematic incorporation of lessons from impact evaluation in programme design, with metrics that encourage reporting and learning from failure, and the institutionalisation in programme implementation of diagnostic monitoring routines for continuous improvement through redesign. Such rigorous monitoring and evaluation allows for assessing the cost effectiveness of policies and outcomes relative to alternative solutions, provides accountability, and informs and builds support from prospective enterprise applicants and from society at large for demonstrated (rather than presumed) benefits relative to the costs of public support initiatives. It also facilitates joint learning about ways to address emerging challenges effectively through modification of programme design features based on evidence-based analysis and debate. This helps improve the use of public expenditures for innovation and provides a more solid foundation for future funding decisions.

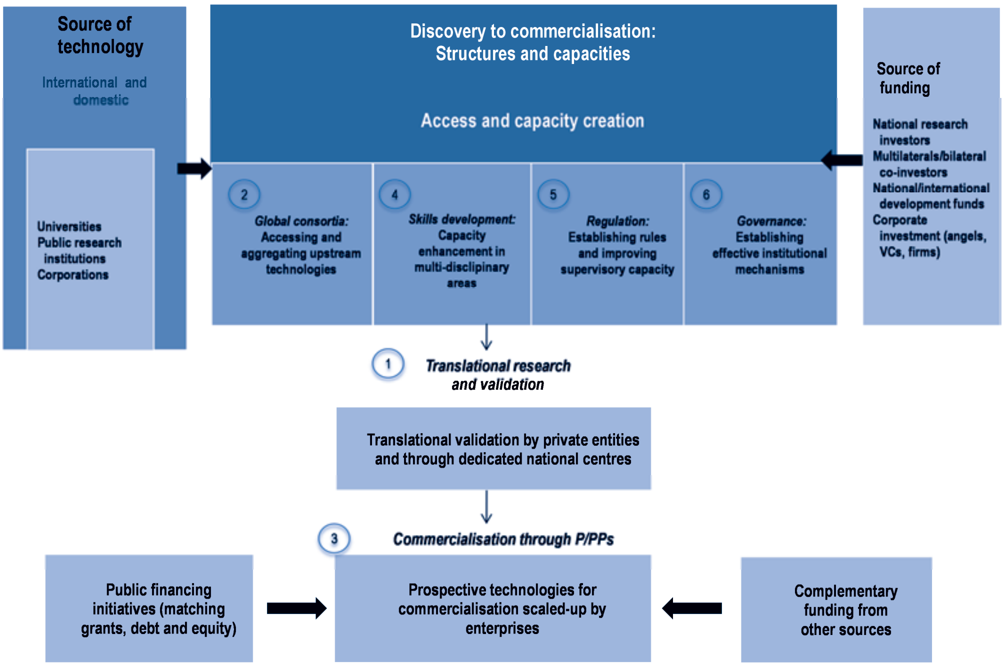
Policies to foster technology adaptation

Biotechnology has many of the characteristics of a general purpose technology (GPT). It drives growth by spreading across important sectors of the economy and stimulating them to innovate through applications for health care and medicine, agriculture and food products, industrial processes including biofuels, and environmental goods and services. Progress in sectors of application feeds back into the GPT, providing incentives for further upgrading and advances in the GPT and thereby creating a self-sustaining positive feedback loop.[5]

Effective biotechnology transfer (from the vantage point of the entity creating a new technology) and absorption (from the vantage point of the entities adopting and adapting the technology to meet local needs) requires a set of steps to contribute to more inclusive economic growth, supported by six complementary policy areas. These policy areas and supportive processes are depicted in Figure 6.1.

In 1986, the Ministry of Science and Technology created the Department of Biotechnology to spur the development of the biotechnology sector in India. Over the past decade, DBT has been developing a more systematic way to accelerate technology adaptation through its attention to these six complementary policy areas.

Figure 6.1. Components of accelerated technology adaptation



Translational research

Most applications of biotechnology to meet specific needs typically have to be adapted and tested in local contexts. While the frontier technology for cost-effective production of a silicon wafer is largely the same everywhere, most biotechnology applications need to be adapted to local biological conditions (climate, soil type, and genetic variations in plants, animals and humans) and tested. Translational validation refers to the adaptation and testing of a technology to meet the needs of the local situation. In this process, component technologies are aggregated and tested under laboratory conditions, followed by validation in the field to ascertain their relevance as an efficacious and cost-effective solution at a commercially relevant scale.[6] Translational validation includes both proven technologies that are currently applied successfully in one context but are being validated for another context and new technologies that are tested and modified under laboratory and field conditions to deliver value in the marketplace (see Box 6.1 for an example).

Box 6.1. An example of translational validation

Researchers at Cornell University have discovered that the trehalose gene (a sugar with high water retention capabilities found in many animals and plants) has the potential to enhance stress tolerance in rice plants under conditions of drought, salinity, and heat. Scientists have modified the gene in rice plants. These plants were tested by Cornell researchers under greenhouse conditions and were found to provide more output of rice grains than plants that were not genetically modified. The key element of translational validation is the testing of these plants in tropical drought-prone regions and validating the performance of the gene and its impact on the plant in terms of providing higher yield under stress conditions. Validation of performance in comparison with plants that are not genetically modified demonstrates the true efficacy of the modified gene in inducing stress tolerance. Further translational effort is involved in validating the efficacy of the gene to induce stress tolerance in other crops such as corn. Validating transgenic technologies for their safety, efficacy and field-level performance is a time-consuming process requiring large investments and specialised skills for testing the technologies and integrating them in different applications.

DBT began supporting translational research around 2005. Its initial focus was confined to a couple of disease segments and a couple of crop stress factors. Over the last five years, DBT consolidated this process and created sustainable frameworks that focus exclusively on translational research. One framework is DBT's Grand Challenge Programme, announced in 2007 as part of its National Biotechnology Development Strategy.[7] Of these programmes, the Vaccine Grand Challenge Programme launched in 2008 is specifically intended to facilitate the accelerated development and validation of cost-effective new or improved versions of vaccines and delivery systems (such as vaccines that do not require refrigeration or needles). Three specialised translational research centres provide dedicated facilities and networking opportunities:

Translational Health Science and Technology Institute (THSTI). Set up in early 2009, THSTI is an autonomous institute established by DBT. It is composed of a series of labs and niche centres. These include a Vaccine and Infectious Disease Research Centre, a Pediatric Biology Centre, a Clinical Development Services Agency, and a Centre for Bio-design and Diagnostics. The centres are currently located in Gurgaon south of Delhi, and will move to a new 200-acre Biotech Science Cluster campus in Faridabad, a short distance away in the state of Haryana. THSTI seeks to create an institutional environment for multidisciplinary research devoted to translating technological advances into medical innovations for affordable health-care solutions. A novel feature is the collaboration among research institutions, hospitals and companies that is being built bottom-up, with common governance, to encourage practicing doctors to work with basic researchers and engineers towards commercialisation. THSTI is modelled on the Harvard-MIT Health Sciences and Technology (HM-HST) programme for multidisciplinary research founded in 1970, which integrates science, medicine and engineering in its academic and research activities to solve human health problems. THSTI benefits from a partnership with HM-HST, which oversees its development, and mentors and trains faculty as required. Learning from India's first community clinical trial for a childhood vaccine for rotavirus infection (Box 6.2) is expected to expedite THSTI's next planned product, a tuberculosis vaccine.

Platform for Translational Research on Transgenic Crops (PTTC). While multinational corporations and larger domestic enterprises may have in-house capacity to move agricultural biotechnologies through the translation process, DBT created a specialised centre for public research institutions and small enterprises. In February 2009, DBT together with the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), a non-profit centre supported by the Consultative Group on International Agricultural Research (CGIAR) based in Hyderabad, set up the PTTC in order to provide an effective interface between lab and land. The centre has high-quality personnel trained in validating gene performance, molecular integrity and the efficacy of transgenic crops developed by the public and private research system. PTTC is already operational and has identified early leads for advancing translational validation. To complement the activities of the PTTC, DBT announced in February 2011 the establishment of a Crop Genetic Enhancement Network to spur the development of improved crop varieties. The network is a globally co-ordinated effort to develop needed genetic enhancement, to analyse variances in crop genomics, and to generate molecular markers in order to enhance produce quality and reduce input costs. International partners contribute to the initiative by pooling existing data and molecular markers and by collaboratively developing markers for further validation.

Translational research platform for processed foods. Another translational research centre established in 2011 is the Bio-Processing Unit (BPU) at the National Agri-Food Biotechnology Institute (NABI) in the "knowledge city" at Mohali in the State of Punjab, the breadbasket of India. NABI is establishing three centres of excellence for research and application at the interface of agricultural, food, and nutritional biotechnology. The BPU will be closely linked to other institutes, the agri-food industry, and entrepreneurs to apply emerging bio-process application technologies to enhance the value of agricultural products.

Global product development consortia

India did not have enough global connectivity to explore contemporary science and its applications. DBT therefore conceived a programme of bilateral public/private partnerships so that Indian researchers and firms could learn about and adopt best practices in technology generation, translation and commercialisation. There was a perceived need to change Indian attitudes towards collaboration. The goal was to work with peers worldwide to improve competencies for developing and delivering biotechnology solutions and managing large research programmes in order to contribute more effectively to mitigating human illness and hunger in the developing world. The emphasis on affordable technologies helped to pool talent, infrastructure, resources, and management abilities to address these challenges. A broader objective was to link domestic to global challenges and to solve them through collective responsibility and resource pooling. The global consortia frameworks, developed prior to the commencement of the collaborative programmes, deal with the methodology for transferring biological materials, intellectual property (IP) co-creation processes and their protection, transfer of technologies, structured research protocols that lead to commercial products, and collaborative monitoring of progress and results via milestones and joint review processes.[8] All partners accepted to pool IP and skills to achieve solutions that could be commonly shared.

The Multi-party Agreement of the Indo-Swiss Collaboration in Biotechnology (ISCB) is an example of such a framework. It binds every partner to a structured approach in research, IP protection, publication protocols, and adherence to certain project management practices (Box 6.2). The exchange of best practices in research, project management, information management, joint publications, along with a collective approach in priority setting and evaluation, are among the key gains from these bilateral product development programmes. The initiatives pool existing intellectual assets from partner countries (background IP) for further advances and application in the research programmes. The intellectual assets co-created by partners through collaborative efforts (foreground IP) are shared. The ISCB consortium arrangement further spelled out the manner in which collaborating partners would donate technology to other developing countries that may gain from accessing the IP created by the consortium.

While international partnerships are sometimes mistrusted because of fears of biased perspectives or unilateral gains by some partners, the DBT model demonstrates that global consortia can make technology and resource sharing possible for global gain. The focus on mid-level research partnerships also facilitates the sustainability of such efforts by including not an isolated issue but a suite of issues.

Box 6.2. Examples of global consortia

ISCB. The Indo-Swiss Collaboration in Biotechnology is the DBT's longest established bilateral research and development (R&D) programme. It was initiated in 1974. It is jointly funded and steered with SDC (Swiss Agency for Development and Cooperation). It promotes research partnerships and adheres to an integrated value chain concept, i.e. continued support through to product development and delivery. Its main goal is to contribute to poverty reduction. After an external evaluation in 1997, a "new ISCB programme" was launched in 1999. It focuses on agricultural biotechnology (disease resistance in wheat, pest control in pulses, monitoring of pesticides, improvement of soil quality, and trans-sectoral topics). It involves more research institutions and a broader group of stakeholders: the private sector, safety and health regulators, and representatives of ethics concerns. Over three phases (a first five-year agreement of USD 15.2 million of which DBT contributed roughly 30%, a second phase to 2007 of USD 7.8 million of which DBT contributed 34%, and a third phase to 2012 of USD 10.1 million of which DBT contributed almost 50%), ISCB has built considerable human capacity, generated licensable technologies for commercial dissemination, and demonstrated a useful governance mechanism. The developed technologies have been externally reviewed and the private sector invited to license them. Sathguru Management Consultants guided the technology showcasing process. Licensees were identified through a transparent process. A consortium of licensees is now bringing the technologies to commercialisation. A Technology Advancement Unit (TAU) was opened in New Delhi in summer 2010 to facilitate and support technology transfer, including guiding project partners during the post-licensing phase. In a novel South-South co-operation, ISCB partners have now extended technology licensing support to Bangladesh for adapting the technologies to local conditions.

Indo-US Vaccine Action Programme (VAP). The Indo-US VAP was initiated in July 1987 for five years, and has been extended six times to July 2016. Its main aim is the development of joint R&D projects for new and better vaccines for major communicable diseases of importance to India. It includes laboratory-based research, epidemiological studies, field trials, vaccine quality control, and delivery of vaccines. More than 50 projects have been initiated and implemented in the areas of rotavirus, HIV, viral hepatitis, malaria, rabies, respiratory diseases, cancer, immune-therapy, polio, typhoid and dengue. More than 500 Indian scientists have been trained in vaccine development in leading US institutions. A major success is India's first indigenously developed rotaviral diarrhoea oral vaccine (Human RotaVirus strain 116E, ROTAVAC). Phase II trials have been completed and phase III community clinical trials for safety and efficacy (conducted directly through doctors and clinics) are taking place on some 6 800 infants in Delhi, Pune and Vellore. Indian licensing for ROTAVAC is expected during 2014 and WHO prequalification in 2015 for supply to UN agencies at a price of USD 1. Bharat Biotech's rotavirus vaccine development project is a PDP between the Hyderabad-based company and DBT, the All India Institute of Medical Sciences (AIIMS) in New Delhi, the Indian Institute of Sciences in Bangalore, the Society for Applied Studies in New Delhi, the Translational Health Science and Technology Institute (THSTI) in Gurgaon, the Bill and Melinda Gates Foundation (which announced in March 2011 that it would give as much as USD 30 million in grants for the phase III trial), the international non-profit Programme for Appropriate Technologies in Health (PATH), the Atlanta Center for Disease Control and Prevention, Stanford University, and the US National Institutes of Health. Bharat Biotech also received support from SBIRI (for phase II trials) and from Biotechnology Industry Partnership Programme (BIPP) (for phase III trials). …/…

Box 6.2. Examples of global consortia *(continued)*

Wellcome Trust, UK. The Wellcome Trust-DBT India Alliance is a five-year GBP 80 million equally funded competitive biomedical research fellowship programme across the full spectrum of biomedical sciences. It is the DBT's largest international partnership to date. Initiated in September 2008, it was modelled along the lines of the Howard Hughes Fellowship, the largest privately funded science education initiative of its kind in the United States. It was designed to support scientists at key stages of their research careers in fields such as neuroscience, cell biology, cancer diagnostics, genetics, and infectious diseases prevalent in the developing world. A follow-on five-year GBP 45 million equally funded R&D for Affordable Healthcare initiative was launched in July 2010 to support translational research projects that deliver safe and effective health-care products for India and other low- and middle-income countries at an affordable cost. It addresses the venture capital funding gap related to the need for a large demonstrable market with the ability to pay. Projects covering any aspect of technology development for health care are considered, including therapeutics, vaccines, diagnostics and medical devices, and regenerative medicine. Proposals drawing on the physical sciences, mathematics, and engineering as well as biomedicine are encouraged. Funding agreements are negotiated on a case-by-case basis; Wellcome Trust Grant Conditions apply, including ring-fencing of funds and fund release in tranches against the attainment of pre-agreed project milestones. One recent award is an ophthalmology project involving collaboration between the L.V. Prasad Eye Institute in Hyderabad and Sheffield University to develop new biocompatible materials for a stem cell-based therapy to restore sight in eyes when the cornea has been damaged by chemicals or burns.

Other bilateral consortia established by DBT include:

Australia. DBT and the Department of Innovation, Industry, Science and Research, Government of Australia in various fields of biotechnology.

Canada. International science and technology partnerships in the area of convergent medical technologies, bio-pharmaceutical and health care research, and clean technologies.

Denmark. DBT and the Danish Agency for Science and Technology in the areas of food, feed and bio energy.

ERA-net. DBT collaborated with the first European Research Area ERA-net project, NEW INDIGO, to foster and co-ordinate scientific co-operation between the ERA and India.

EU. Development of functional foods and ingredients and commercial use of by-products in food processing.

Finland. DBT-Academy of Finland and TEKES in the area of medical diagnostics.

Germany. Research partnership covering various facets of biotechnology research.

IAVI. DBT and the International AIDS Vaccine Initiative to develop next-generation AIDS vaccine candidates.

Japan. DBT and AIST, Japan partnership for life science research.

…/…

Box 6.2. Examples of global consortia *(continued)*

Norway. Multicentric collaborative programme on aqua health.

Sweden. DBT and the Swedish governmental agency for innovation systems support research co-operation between Indian and Swedish scientists in the fields of biology, diagnosis and treatment of tuberculosis.

United Kingdom. Research collaboration between the National Institute of Immunology, New Delhi, and Queens University, Belfast, to advance cancer research and improve patient outcomes by discovering biomarkers for multiple types of cancer.

United States. Contraceptive and Reproductive Health Research (CRHR) programme.

Domestic public/private partnerships

Public/private partnerships (PPPs) established to co-create intellectual assets and commercialise the results need a model different from those generally adopted for infrastructure projects. Whereas public research institutions possess the research skills to create new knowledge, the private sector has a deeper understanding of market needs and of the economic relevance of applications generated from that knowledge. The pooling of resources so that the public sector invests largely in the public good aspects of research and the private sector invests largely in market-related aspects can help innovations reach needy communities more rapidly with sharing of risks and responsibilities.

This section focuses on two complementary DBT competitive PPP funding initiatives for early-stage technology development by Indian majority-owned companies. To support the PPPs through a single window, DBT set up the Biotechnology Industry Research Assistance Council (BIRAC), a not-for-profit Section 25 company. The BIRAC mission is “to facilitate and mentor the generation and translation of innovation by industry, promote academia-industry collaboration and international linkages, encourage techno-entrepreneurship, and enable the creation and sustainability of viable bio-enterprises” (BIRAC 2012a:3). The BIRAC will accomplish this mission by supporting the scale-up of the two existing programmes and through two complementary programmes. One is the new Biotechnology Ignition Grants (BIG) to individual entrepreneurs, start-ups, or an “incubatee” (researchers or degree holders located in an incubator) when there is an unmet need for mentorship and initial funding to develop ideas to the proof-of-concept stage. The other involves Contract Research Scheme (CRS) grants to company partners to perform specific research and validation processes for universities and public research institutes.

Small Business Innovation Research Initiative (SBIRI): Early-stage funding of SMEs. The first PPP initiative created by DBT for domestic early-stage technology development and commercialisation, launched in 2005, was the Small Business Innovation Research Initiative. It was modelled on the US SBIR (Small Business Innovation Research) programme. A stated objective was to attract a greater number of small and medium-sized enterprises (SMEs) to engage in peer-reviewed quality research and accelerate innovation. Box 6.3 describes the eligibility criteria for public support.

Box 6.3. Funding structure of SBIRI

SBIRI is open to Indian-registered and majority-owned SMEs (start-ups and existing firms) with an in-house R&D unit certified by Department of Scientific and Industrial Research (DSIR), groups of such firms, and collaborations of such firm(s) with public R&D institutions. The enterprise must not have more than 500 employees engaged in R&D.[9] SBIRI funds pre-proof of concept and early-stage development.

Phase	Description and funding
I	For establishment of pre-proof of concept of innovation: • 80% grant for project costs up to INR 2.5 million (about UD 50 000). • 50% grant up to a maximum of INR 5 million for larger projects, with interest-free loans for up to 50% of remainder for total project costs exceeding INR 10 million.
II	For product and process development: • Soft loan with 1% simple interest rate for project cost up to INR 10 million. • Soft loan with 2% simple interest rate for project cost up to INR 100 million (about USD 2 million). • Full grant to cover R&D costs of public R&D institutions.

SBIRI established a transparent, structured, time-bound process for reviewing applications. Building on the milestones that life-science firms typically set themselves and the regimes they build for exchanging information with each other, as well as on learning from the global consortia, the selection and monitoring processes are more probing and informative than is usual in private-sector applications for public support. The proposals received undergo a three-step review process: 1) a primary review of the application; 2) a presentation by shortlisted applicants to a review committee; and 3) a site visit by an expert team. About half of the proposals are eliminated at the primary review. The remaining applicants present the merits of their project in terms of innovativeness and socioeconomic relevance to a review committee. For roughly half of these proposals the committee members visit the applicant's research site and interact with the project sponsor and the team.

The review committee members allocate points for the expected capacity of the enterprise to carry out the research, team competency, verification of proposed linkages, and enterprise-level managerial competency and commitment. Each supported project is then monitored by a separate internal monitoring committee, with half-yearly progress reports based on project visits by project investigators; they typically include one or two external experts. Table 6.1 presents the proposals received and approvals granted across biotechnology application areas. Between mid-2005 and mid-2011, 15 batches of applications were processed, 791 project proposals were evaluated, and 86 projects were funded.[10] Over the first 10 batches (with no applicants still waiting for final approval), an average of 15% of applicants secured funding (84 out of 547 applicants). The success ratio has varied between a low of 11% (8 out of 71 applicants in the first October 2005 batch, owing in part to lack of experience in writing grant proposals) and a high of 26% (10 of 39 applicants in the November 2006 batch).

Table 6.1. SBIRI applications and approvals

(as of 30 June 2011)

Calls	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Total
Closing date	Oct 05	June 06	Nov 06	Mar 07	July 07	Nov 07	Feb 08	June 08	Oct 08	Mar 09	June 09	Dec 09	May 10	Oct 10	Feb 11	
Health care	38	49	17	25	22	22	21	29	13	35	26	24	16	26	23	386
Agriculture	15	19	4	12	9	15	8	12	4	10	9	18	11	10	8	164
Industrial Processes	5	19	12	6	6	8	3	6	12	11	9	7	7	3	7	121
Instruments & devices	6	9	5	4	1	7	1	0	0	2	1	3	0	4	3	46
Environment	1	1	1	2	2	5	2	4	1	1	1	0	1	4	2	28
Bioinformatics								1	0	4	5	3	0	2	2	17
Food biotechnol.+								2	1	0	3	2	0	2	1	11
Others	6	1	0	4	0	3	2	2								18
Total	71	98	39	53	39	60	37	56	31	63	54	57	35	51	47	791
Approved projects	8	18	10	7	6	7	7	7	4	10	2	0	0	0	0	6
Ratio (%)	11.3	18.4	25.6	13.2	15.4	11.7	18.9	12.5	15.9	3.7	0%	0%	0%	0%	0%	10.9

Note: Bioinformatics and food biotechnology areas are tracked separately from the eighth batch onwards (previously, they were combined under "Others"). Proposals received from batches 11 onwards are still under consideration, with two additional proposals under batch 11 and four proposals under batch 12 going through the final approval process. This brings the approved total to 92 as of 30 September 2011.

Source: DBT SBIRI database.

To mid-2011, SBIRI had deployed USD 36 million, of which USD 5 million in grants and USD 31 million in soft loans, with a debt-to-grant ratio of roughly 6 to 1. Public SBIRI funding has leveraged an additional USD 33 million in private investment by recipient enterprises, for a total investment of USD 69 million across approved projects. The average public investment of about USD 420 000 per venture is roughly equivalent to the average of the US SBIR programme.[11] This is because the projects supported by SBIRI are not restricted to pre-seed stage funding; they can also receive follow-on project development seed funding.

With the increase in applications in the areas of bio-informatics and food biotechnology over time, these areas have been separately monitored from June 2008. There is a time lag in granting final approval for some proposals because the applicants' research facilities are not certified by the DSIR; certification is mandatory for securing SBIRI funding. SBIRI allows companies that lack DSIR certification to apply, as long as they seek certification while the application is being reviewed. Though SBIRI processes all call and conclude the review process prior to the next call, some proposals remain in the pipeline for approval for two years or more as applicants pursue certification.

SBIRI has funded a heterogeneous mix of ventures, from very early-stage to well-established companies. Of the 86 SBIRI-funded projects, 13 enterprises had annual revenues of USD 25 million or more in 2010. Only five companies had annual group turnover of over USD 100 million.[12] The other recipients are smaller ventures, but all were in existence for three years or more prior to receiving approval. One of the reasons why SBIRI does not fund new start-ups is the need to secure DSIR recognition. Since DSIR does not recognise start-ups, it takes some time for their research facility to be inspected and granted DSIR recognition.

In terms of type of innovation, about a third of funded ventures (27 of 86) are for developing a new product, typically for a preventive or therapeutic solution in health care or a new transgenic crop in agriculture. The others seek to develop new process approaches, devices or validation systems that can accelerate biotechnology development pathways (see Box 6.4 for examples).

Box 6.4. SBIRI case studies

1. Span Diagnostics: towards delivery of affordable disease diagnostics. Ahmedabad-based Span Diagnostics, an SME over three decades old, has sought to position itself as a manufacturer of affordable instruments for Indian and other emerging markets. Span acquired a French company with intellectual assets in diagnostic applications. It then approached SBIRI to secure USD 450 000 to apply its design technologies for the manufacture of new-generation chemistry analysers.

Having gained confidence through this effort, Span also applied for a soft loan under the BIPP scheme for producing monoclonal antibodies and microbial antigens, based on its own technology and on some clones acquired from public partners in the United States and Europe. BIPP provided Span about USD 500 000 to establish the facility and create antibodies for its requirements and for external marketing. As a result, Span currently has a range of technologies and a cGMP-compliant (current good manufacturing practices) facility to provide affordable solutions in disease diagnostics for a wide range of disease segments.

2. NavyaBiologicals: Woman entrepreneur secures two patents towards commercialisation. Bangalore-based NavyaBiologicals, an SME launched in 2006, developed technologies for a novel yeast expression platform for production of complex proteins. Dr. Rajyashri, who leads the company, wanted to test the proof of concept, and SBIRI provided USD 100 000 to validate the platform. Rajyashri perceives this grant to have been the game-changer for her enterprise by helping to lower the risks of the proof-of-concept stage. SBIRI then provided an additional USD 450 000 for phase II funding to scale up the production of the proteins. The two patents secured by the company will help with commercialisation. Navya is already a revenue-positive venture. It now has to undertake clinical validation of its products.

3. Shriram Bioseeds: advancing crop biotechnology innovation through a PPP. About 8.6 million hectares of India's land are afflicted by alkalinity and salinity, as a result of extensive water logging, indiscriminate use of chemical fertilisers and inadequate drainage. Climate change aggravates the situation. Genetically modified rice hybrids tolerant to drought and salinity are expected not only to increase food production but also to improve the income and prosperity of millions of small and marginal farmers. Drought-tolerance technologies generally carry higher risk owing to their inherently uncertain response to environmental conditions.

Shriram Bioseeds, an India-based seed company, has built its research capacity to explore novel genes that can improve crop trait properties. Bioseeds joined with ICGEB (International Center for Genetic Engineering and Biotechnology), an international, UN-linked research organisation with labs in New Delhi, to source genes and engage in collaborative research to generate hybrids with the needed tolerance to drought and salinity. SBIRI provided initial funding of USD 150 000, followed by a subsequent USD 300 000 to help consortium members move the transgenic lines towards translational validation of their efficacy. The partnership will take the technology forward if the field evaluation of the traits of the transgenic lines is successful.

Over the next two to three years, it appears likely that SBIRI will have projects that would need to exit or go "sideways" (i.e. barely manage to exist with low revenues) and do not accomplish the goals they were funded to reach. It is natural for a number of such projects not to succeed. Indeed, the programme would not be achieving its objective (support to higher-risk, underfunded ventures) if all funded projects were successful. Not all SMEs with high invention capacity will succeed on the technology side, and of those with successful research, a number may not be able to reach markets on their own. A mentoring and support mechanism to help enterprises to modify the strategic elements of IP management appears to be missing. These include whether to in-license existing complementary technologies or seek to develop them in-house, whether to patent a new discovery or keep it as a trade secret, whether to out-license the IP to a larger domestic or international company or seek to bring it to market alone or through a consortium, as well as how to actively protect own IP and minimise risk of patent infringement litigation. Other strategic elements involve product development, regulatory validation, and product positioning in response to progress in research and evolving market needs. The SBIRI programme could likely benefit by engaging in enhanced oversight and support in these critical complementary entrepreneurship-related areas.

BIPP: Viability gap funding for larger, higher-risk projects. The Biotechnology Industry Partnership Programme was conceived and put in place by DBT in 2008 as a complement to SBIRI. It addresses national priority needs for novel applications of biotechnology to obtain affordable solutions in health care, agriculture and the environment (green manufacturing and bio-energy). BIPP helps more established enterprises to use higher-risk, discovery-led translational research for application-driven solutions. For these larger projects with a potential span of six to eight years from discovery to market entry, the careful structuring of effective partnerships, mentoring support to industry partners, and the active engagement of public research partners with research skills in a range of disciplines all aim to help mitigate the higher risks. Best practices in research and milestone-based monitoring must be included in all proposals. Box 6.5 describes eligible funding.

Box 6.5. Funding structure of BIPP

BIPP is open to Indian-registered, majority-owned small, medium or large for-profit companies with a DSIR-certified R&D unit, groups of such firms, and collaborations of such firm(s) with public R&D institutions. Support is provided only for discrete novel applications in high-risk areas (break-through research), transformational technology and product development for the public good. Incremental development is not supported. BIPP provides funds for four broad categories:

Category	Description
I	Areas with major social relevance but uncertain market-driven demand
II	High-risk, discovery-based innovation research with the potential of making Indian firms globally competitive
III A	Evaluation and validation of existing products of high national importance based on local innovation (clinical trials)
III B	Evaluation and validation of existing products of high national importance based on local innovation (agriculture field trials)
IV	Major shared-cost facilities that are essential for enabling innovation

The scheme provides grants of 30-50% of the R&D component to biotechnology enterprises as gap funding for testing viability. Technology transfer, commercialisation and licensing arrangements vary with the partnership and cost-sharing model. The government contribution and percentage of royalty are determined by the Apex Committee recommendations based on the Technical Committee's evaluation.

Like SBIRI, BIPP has adopted a three-stage application review mechanism and follow-on monitoring. Supported projects are monitored by an expert monitoring committee established for each project with two or three technical experts, one financial expert and one DBT officer, with periodic mandatory site visits.

Benefits are shared in one of two ways when the venture successfully commercialises its technology. For grants, recipients pay 5% royalty on sales with a cap of twice the original BIPP funding. For fixed interest loans at 2%, there is a specified term for repayment of the debt on successful commercialisation. The fact that 95% of applicants have preferred the 2% interest-bearing loan to paying 5% royalty on grants suggests that financing terms may need recalibration. As most of the BIPP recipients are entities with revenue streams from their existing products, this imbalance may reflect industry confidence in bringing the new products to market. BIPP confers the IP rights on the industry partners. For projects developed jointly by public and private partners, benefit-sharing arrangements for IP exploitation are set in advance. BIPP reviews the "freedom to operate" rights of developers prior to the award so that there will be no major hurdles involving background IP exploitation.

Table 6.2. BIPP applications and approvals (as of 1 August 2011)

Calls	1	2	3	4*	5	6	7	8*	9*	10*	11*	12	13	14*	15	16*	
Closing date	Dec08	June09	Aug09	Aug09	Dec09	Apr10	July10	Sept10	Dec10	Dec10	Dec10	Dec10	Mar11	Mar11	Aug11	Aug11	Total
Health-care	34	3	22	5	20	9	11	10	6	21	0	8	9	0	4	9	171
Agriculture	6	5	4	0	11	6	6	0	1	0	26	0	11	11	5	0	92
Clinical trial	13	1	11	1	13	3	3	3	3	2	0	3	4	0	3	2	65
Ind. products & processes	2	1	6	1	7	1	3	8	6	0	0	0	3	7	0	0	45
Bio-medical devices and instruments	2	1	0	0	2	0	2	0	1	7	0	0	2	0	3	16	36
Infrastructure	0	12	7	3	1	0	2	4	3	0	0	0	0	0	2	0	34
Bio-energy	5	1	6	0	1	0	1	0	2	0	0	0	1	0	2	0	19
Field trial	2	0	1	0	0	2	1	0	0	0	1	0	0	0	0	0	7
Environmental biotechnology	0	0	0	0	0	0	0	0	4	0	0	0	0	0	1	0	5
Total	64	24	57	10	55	21	29	25	26	30	27	11	30	18	20	27	474
Supported projects	10	4	11	2	7	4	6	6	1	5	4	1	0	0	0	0	61
Ratio (%)	15.6	16.7	19.3	20.0	12.7	19.0	20.7	24.0	3.8	16.7	14.8	9.1	0	0	0	0	12.9

Source: DBT BIPP database; asterisks denote special calls (see text for details).

Table 6.2 presents the proposals received and approvals granted. From December 2008 to the end of July 2011, 16 batches were processed, 474 applications were evaluated, and 61 proposals were funded.[13] Of these 16 calls for proposals, 9 were general calls and 7 were special calls: H1N1 vaccine development (call no. 4), bio-similars (officially approved subsequent versions of more complex molecular biopharmaceutical products following patent expiry on the original product, no. 8), affordable health-care products (no. 9), anti-virals (no. 10), priority agriculture areas (no. 11), value added to agricultural produce for food and non-food applications (no. 14), and affordable health-care technologies (no. 16). Over the first 11 batches, an average 16% of applicants secured funding (60 out of 368 applicants). The success rate has varied between a low of 4% (1 out of 26 applicants in the December 2010 special call for affordable health-care technologies) to a high of 24% (6 out of 25 applicants in the September 2010 special call for bio-similars).

To mid-2011, BIPP deployed USD 36 million, of which USD 13 million in grants and USD 23 million in soft loans, with a debt-to-grant ratio of roughly 2 to 1. Public BIPP funding has leveraged an additional USD 66 million in private investment by the recipient enterprises for the approved 61 projects for a total investment of USD 102 million. It is noteworthy that over a shorter span of time (two-and-a-half years vs five-and-a-half for SBIRI), BIPP has leveraged roughly the same amount of public funding (USD 36 million) into twice the additional private-sector contributions (USD 66 million versus USD 33 million in additional private investment under SBIRI).

Box 6.6. BIPP case studies

Tergene Biotech Ltd. With support from BIPP, Tergene Biotech, a privately held start-up, took the challenge of developing an indigenous vaccine to tackle pneumonia. Pneumonia kills an estimated 1.6 million children under the age of five globally, every year, according to the World Health Organization; the report card released by the International Vaccine Access Center documents that pneumonia claims lives of more than 370,000 children every year in India. The entire immunization program for pneumonia in all the developing regions have been based on highly expensive vaccines provided by multinational companies. Tergene is currently carrying out product validation trials for a superior 15-valent pneumococcal polysaccharide conjugate vaccine. It hopes to deliver it to the developing world at a price that is affordable, at USD 7 a dose as against USD 70 that is currently charged per dose by multinational companies in India. The vaccine will also be containing additional serotypes that should make it highly effective in developing country regions. Tergene has been granted the national innovator award for its pioneering effort in development of this vaccine.

Torrent Pharmaceuticals. This Ahmedabad-based pharmaceutical company discovered a small molecule and wanted to explore its application for diabetes-associated heart disease. The company decided to carry out the phase II clinical validation with the help of domestic and international consultants. BIPP supported this application with two phases of funding totalling USD 3.2 million. The company had to complement the BIPP support with its own resources to carry out the international component, as BIPP is restricted from supporting overseas clinical validation. However, the support provided by BIPP will help Torrent complete Phase II trials and advance the technology through phase III validation. The key contributions of BIPP, in the words of Vijay Chauthaiwale, VP, Discovery Research Centre, are "access to good quality reviewers, coupled with monitoring and progressive support commensurate with the progress of the project". Torrent's efforts are representative of domestic enterprises' ability to undertake international product development and the more comprehensive work required for Phase III trials.

The enterprises funded by BIPP are larger than those funded by SBIRI, with almost all recipient companies having revenue streams from other products. For the 61 projects funded, 19 companies have annual revenues of over USD 100 million (on their own or combined with group companies), 16 between USD 25 million and USD 100 million, and the rest less than USD 25 million. The distribution skewed towards larger firms reflects the ability of beneficiaries to undertake large research challenges by leveraging their presence in the market and their ability to enlarge their research effort with support from BIPP. The projects, other than the two relating to infrastructure development, have a development or validation phase of three to four years before they are ready to enter the market (see Box 6.6 for an example).

Skills development

DBT also has worked on building a more diverse talent pool for the public and private research system. The public talent pool was originally oriented exclusively towards early-stage research and lacked the diversity necessary to carry out mid-level and later-stage translational research.

The importance of engaging a diversity of knowledge communities is illustrated by the need to deal with problems such as India's typical post-harvest loss of a quarter of its agriculture produce. India lacked the talent pool to develop, validate and deploy value-adding technologies to preserve the post-harvest value of farm produce and to convert it into shelf-stable processed food. Such an effort requires combining disciplines such as farm engineering technologies, food science, food engineering, environmental engineering, market needs assessment, international trade and business skills. While many relevant technologies are available and accessible, the inability to translate these technologies denies India significant wealth creation. Similarly, generating energy from crops requires combining the knowledge of plant science, bioprocess engineering, environmental science, economics and business. Validation of a transgenic crop technology for a crop protection trait requires plant breeders, entomologists, plant pathologists, food safety specialists trained in assessment of the safety of proteins and bio-safety specialists trained in environmental safety assessments. In the field of medical research, drug development researchers, clinicians, statisticians and epidemiologists have to work together to validate relevance, safety and efficacy, and devise novel delivery strategies to reach vulnerable communities.

Given the need for such diverse skills, DBT adopted a two-pronged strategy to create multidisciplinary capabilities: re-skilling professional scientists for a more diverse research arena, and encouraging young scientists to engage in multidisciplinary research. It also sought to bring back to India well-trained researchers of Indian origin with proven talent in multidisciplinary areas to work in public research institutions.

Every bilateral research programme forged by DBT has considered mutual exchange of research personnel an essential element of the process of building research capacity. In addition to the 2008 DBT-Wellcome Trust biomedical research fellowship programme (Box 6.2), there are number of additional programmes.

The Ramalingaswamy Re-entry Fellowship Programme. Funded by DBT, this programme helps to attract Indian postdoctoral fellows abroad to undertake a sabbatical with Indian research institutions or universities by providing financial support (research funding and compensation) during their stint in India. The fellowship is for a period of five years, extendable for another five years.

The Tata Innovation Fellowship Programme. This scheme, supported by DBT and Tata, recognises scientists with an outstanding track record in biological sciences and rewards interdisciplinary work, with an emphasis on translation and innovation.

The Stanford-India Biodesign (SIB) Fellowship Programme. Funded by DBT and other supporters and initiated in 2001, the SIB programme has formed a partnership with the All India Institute of Medical Sciences (AIIMS) and the Indian Institute of Technology (IIT) Delhi. It is guided by Stanford University to train future medical researchers. SIB's ultimate aim is to mobilise the Indian medical technologies industry to deliver appropriate health-care solutions to the needy in India's medically underserved regions. It is based on the notion that multidisciplinary teams with engineering, medical and business backgrounds can engage in collaborative knowledge sharing and innovate. Fellowships, teaching innovation, idea generation, product profiling, market analysis, commercialisation, prototyping and validation support are all an integral part of this programme. SIB already appears to have yielded successful results in terms of start-up ventures and products.[14] In view of the benefit of this initiative, other IITs have plans for similar programmes.

Bio-entrepreneurship support. The partnership between DBT and the Association of Biotechnology Led Enterprises (ABLE)[15] exposes graduating students to bio-entrepreneurship. A series of three-day residential entrepreneurship development workshops were initiated in August 2011 across the eight north-eastern states of India to encourage graduating B.E./B. Tech and

Master's and doctoral-level students to consider life sciences entrepreneurship as a career option. The workshops aim to strengthen graduates' business skills to enable them to start commercial biotechnology ventures and cover topics such as technology sourcing, IP and patenting strategies, regulatory issues, business models, accounting, and finance.

Technology management skills. DBT has supported the creation of the Society for Technology Management (STEM), an association of technology management professionals formed on the lines of the US Association of University Technology Managers (AUTM). STEM helps enhance technology management skills in the areas of technology assessment, IP protection, technology valuation, and technology transfer licensing and post-license monitoring.

Regulation

As the policy focus moved to mid-level validation of technologies and products, DBT began establishing regulations and compliance frameworks to ensure process and product safety and technological relevance. This created the need to enlarge the pool of professional regulatory administrators by partnering with regulatory agencies in countries with robust regulatory mechanisms. DBT's efforts have focused on establishing a sound system of regulation for research, especially in agricultural biotechnology, bio-medical discovery-led clinical validation, and animal health products. DBT has established a number of frameworks for regulating the safety and efficacy of these technologies. It has formulated some of these regulations on its own and some in collaboration with other national regulatory bodies.[16]

DBT proposed the Biotechnology Regulatory Authority Bill 2009 to establish an independent, autonomous, statutory agency to regulate the research, transport, import, manufacture and use of organisms and products of biotechnology. Another DBT initiative relates to creating a system of mechanisms for technology transfer and providing a legal mandate for technology-generating agencies to license them to enterprises. This legislation, proposed along the lines of the US Bayh-Dole Act, is intended to draw greater attention to the management of publicly generated technologies. The Public Funded R&D (Protection, Utilisation and Regulation of Intellectual Property) Bill of 2007 has undergone considerable debate and discussion.

DBT has encountered challenges for bringing these regulatory frameworks to fruition. The withholding of approval for transgenic eggplant by the Minister for Environment highlights the difficulties of achieving consensus on regulatory processes. In principle, India's ability to regulate biotechnology-derived health-care and agricultural products effectively should create a competitive advantage; given its abundant scientific and clinical labour, it can carry out the various validation procedures at lower cost. Currently, the costs of regulation in OECD countries typically lead the private sector to confine regulatory validation to products with a sufficiently large global market potential. This is a key reason why large multinationals and public research bodies in industrialised countries do not undertake research on neglected diseases, small acreage crops and low-value agriculture products. If India obtains sufficient regulatory capacity, products approved in India have the potential to reach other developing countries with similar product needs in the areas of health and agriculture.

Institutional governance

Finally, DBT saw the need to create institutional mechanisms that would accelerate translational research. These needed to cover project conceptualisation, creation, management and monitoring and provide for the engagement of domestic, international, public and private partners. Such institutional mechanisms were designed to ensure transparency, speed of execution, and effective management so as to increase the likelihood of success of the translational research support programmes.

A project management entity was conceived for each of the initiatives, including the global product development consortia and the domestic PPP schemes. Where needed, a special purpose vehicle (SPV) was created for the management entity. Specialists with project management ability and consultancy organisations with experience in global project management were retained to support the establishment of management structures that would provide able governance mechanisms. IP management, technology management functions, creation and adoption of project management tools, capacity to train scientists in effective grant writing, and several other non-research related interventions required sourcing of external talent.

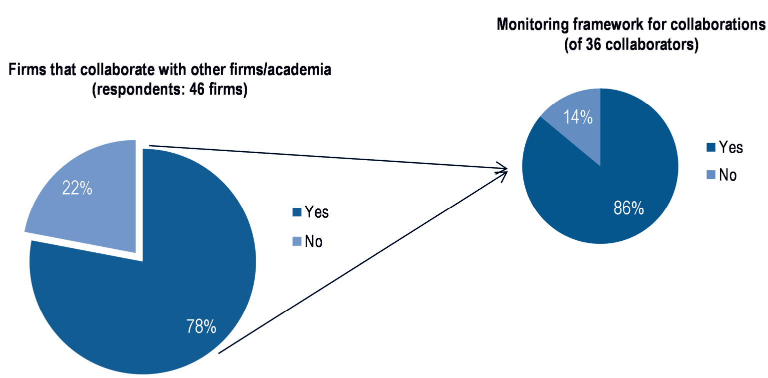
DBT's initial efforts to create SPVs arose from its bilateral product development consortia. Co-investors with DBT in the global consortia initially insisted on vesting project management in management entities in the industrialised partner country because of their project management skills. The bilateral engagements helped to create independent governance mechanisms involving scientists, administrators and technology management specialists from partnering countries. The bilateral engagements required collaborating partners to define the structure for deploying funds, managing research projects, and reviewing results. An examination of some of these governance models shows that they were tailored to meet the needs of specific partnerships. The ISCB partnership described in Box 6.2, for example, is not managed by an independent legal entity, but by a Joint Action Committee with participation from academia, research administrators and industry from both countries. Separate project management units in Switzerland and in India provide day-to-day management support for programme implementation. Adequate external review mechanisms were established, drawing on skills available in both countries. Significant local learning appears to have been generated, with DBT's institutional frameworks initially determined by its bilateral consortia programmes, which were then applied to provide a structured governance mechanism and administrative autonomy for domestic programmes exclusively conceived by DBT such as the domestic PPP schemes.

Learning from performance measurement

Local enterprise learning from global consortia

A recent survey of SBIRI and BIPP recipients sought to understand the extent to which Indian biotechnology firms employ structured research processes, such as co-creation and co-development with other entities and collaborative monitoring of progress and results via milestones and joint review processes.[17] Out of the 70 firms invited to attend the first interactive DBT-BIRAC Innovators Meet held in October 2012, 46 (66%) responded to the Internet survey. At 59% (27 out of 46 firms), the share of respondents in the health-care industry was almost identical to that of the SBIRI and BIPP recipients (57% of SBIRI and 58% of BIPP recipients).[18] Moreover, 55% of respondents reported that they directly meet the needs of those in the lowest income groups, and the ratio is the same for exporting firms.[19]

Figure 6.2. Collaboration supported by structured research protocols, 2012



The survey results suggest that Indian biotechnology firms have been learning not only about international products but also about the benefits of co-creation through partnerships and structured review processes, likely owing in part to India's long-term support of global consortia. Among biotechnology firms, 78% indicated that they collaborate with other firms or academia for co-development.[20] More tellingly, 31 of these 36 firms (86%) report jointly monitoring progress and results via structured research protocols, including in the contracts or informal agreements that govern their partnerships. This includes: 1) common data sharing processes; 2) commercialisation-driven, milestone-based incentives; 3) monitoring via joint review processes; and 4) well-defined escalation mechanisms for dispute resolution.[21]

Programmatic learning from local enterprises

Improving programme implementation requires continuous learning based on more rigorous measurement of the performance of firms benefiting (or not) from support programmes. This learning should come from the inclusion of impact evaluation in programme design, with explicit metrics encouraging reporting and learning from failure, and from the institutionalisation in programme implementation of diagnostic monitoring routines.

Learning from impact evaluation. Ideally, a rigorous methodological framework for monitoring and evaluating innovation support programmes should begin with a concise description of the logic of the programmes, namely how each programme is structured to resolve the problems (market failures or other objectives) and a clear articulation of what programme success would look like. Measurable indicators range from required inputs and activities to achievement of outputs (whether deliverables were produced as intended) and outcomes (whether planned outcomes were achieved). BIRAC programmes, ranging from the promotion of translational research to specific types of skills development and regulatory strengthening, could be evaluated, for instance, for the cost effectiveness of policies addressing objectives stemming from its mandate: 1) development of biotechnology capacity; 2) generation of new (for India) biotechnologies; 3) development and delivery of affordable quality biotechnologies at commercial scale to meet the needs of India's and the world's poor; 4) IP protection of Indian biotechnology; and 5) generation of profitable biotechnology-based enterprises. A full cost-benefit analysis should explore whether there are net gains for beneficiary firms (benefits net of all costs, relative to non-participation in the programme and relative to alternative approaches to achieve similar outcomes)[22]. It should also take into account negative displacement effects (on market participants that would be less well off than before because of the programme).

For a range of BIRAC programmes (BIG, SBIRI and BIPP), the target population includes the funded enterprises, as direct recipients of programme support, and other private and public enterprises, as indirect beneficiaries of learning, capacity building and linkage opportunities. End users also eventually benefit from more affordable goods and services. To assess programme results, it would be desirable to analyse indicators of market-based validation of success, such as:

- the number of enterprises that receive a patent and generate revenues from technology licensing;
- product sales or acquisition by a larger firm;
- indicators of whether projects obtaining soft loans are able to repay them and whether matching grants and soft loans are crowding-in additional resources, including additional private angel or venture capital-private equity or commercial bank financing;
- employment generated;
- changes over time in these variables, relative to the number of enterprises in trouble or failing (recognising that a very high rate of success may imply that the projects funded are not sufficiently risky);
- and complementary measures of social benefits to end users, with households broken down by income groups when meeting the needs of the poor is an explicit programme objective.

It would also be important to analyse indicators of public validation of success, including number of BIG projects that receive SBIRI support, and number of SBIRI projects that receive phase II funding and BIPP support, and that achieve regulatory and clinical or field trial approval. It would be desirable to link these outcome metrics to other factors, such as firm size and revenue at the time of funding, amount of support received per recipient together with other forms of public and private support, whether the project output is mainly intended for local use or also for export, etc. More detailed publicly available data on such programme results would be a positive step forward.[23]

While more detailed information on programme results is an important first step, the crucial issue in assessing programme impact is a comparison of the observed result to an appropriate counterfactual. Programme impact should be defined as the difference between the observed outcome with intervention and the counterfactual, i.e. what would have happened without intervention. Impact evaluation should benchmark the change in the beneficiaries' performance over the programme's support period with the evolution of the performance, over the same period, of a proper control group.[24] If a biotechnology entrepreneur would have commercialised a research-based discovery even without programme support, there would only be direct programme costs and no direct benefit. To make an accurate case for programme impact, it is important to be able to quantify the extent to which the observed outcomes exceed what would have happened without public support.

An increasingly common means of estimating programme impact is to build a randomised control trial (RCT) into programme design before implementing the programme (or the next phase of the programme).[25] Forward-looking programme design with randomisation provides a strong foundation for causal inference. It may be asked whether RCT is appropriate for assessing the impact of specific types of regulatory strengthening or for assessing competitive award-based funding, which typically funds the best projects, or whether the guiding principle of competition would be detrimentally affected if only one of every two (or two of every three) equally good project is funded. Moreover, in a competitive support scheme with random rejection, it may not be clear whether the rejection is based on quality or on random selection, and there may not be a straightforward way for rejected submissions to challenge the results. This concern can be resolved by announcing the submissions that exceed an announced threshold for quality, addressing challenges regarding quality, and then conducting a random draw among the most promising quality-based submissions. A public drawing can be open and transparent so as to alleviate concerns about corruption. More broadly, it is not clear that governments should support the best proposals if the enterprises concerned can secure market-based funding. From a development perspective, scarce public resources are better directed towards proposals with the most impact at the margin. Governments should be concerned with marginal rather than absolute returns, and ideally target enterprises that will only succeed with public support. Finally, credible evidence that scarce public resources are having a strong impact is essential, and randomisation is a powerful way to generate such evidence.[26]

Randomisation across different support schemes could allow systematic testing of a range of specific programmatic features and thus help strengthen programme design and provide a solid empirical foundation for the impact of these programmes. Although the time to end-result for SBIRI and BIPP programmes can be relatively long, some or most of the testing and learning can centre on questions about improving project design to make interventions work better, such as testing different ways to improve programme take-up or testing the quality of different forms of technical assistance. To the extent that the sample size is relatively small, it will be important to focus on a few key features of the programmes. When measuring relatively complex outcomes such as research results, initial commercialisation attempts and business profits, multiple measurements of such outcomes at relatively shorter intervals can, in principle, help to enhance the quality of the measurement (by average out the noise from the underlying signal) when estimating treatment effects and improve the predictive power for future outcomes (McKenzie, 2012). The following programme features are illustrative of the types of areas for which very little is currently known as regards effectiveness; they could be explored and then scaled up or phased out depending on their impact on outcomes. These features are:

- Variations in the level of the matching grant.
- Variations in the time allowed for repayment of soft loans, including periods of extension of the moratorium for repayment of debt obligations.
- Different additional support mechanisms, including: mentoring support for development entrepreneurship to aid in the transition from science-based research to market-driven commercialisation; financial support for firm-level investment in complementary intangible assets (IP protection and associated legal support, market intelligence, software and databases, and investment in worker and management skills upgrading); and funding for technology acquisition (biomaterials, technologies and research tools developed by other local or international firms, or by public institutions, aggregated for sub-licensing).
- Mechanisms to achieve greater synergies between BIG, SBIRI and BIPP.
- Mechanisms to allow early detection of failure, with a variety of strategic options for exit (including methodologies for recognising failures, for salvaging value creation, for transferring intellectual assets created for alternate use, and for timely resetting of objectives).

While it may be politically difficult for a government entity to propose full randomisation in the programme design, given the implication that some deserving proposals will end up as controls rather than as beneficiaries, this approach has the benefit of allowing maximum learning about the impact of programme design features so as to help scarce public funding better achieve programme objectives. Taking this political constraint into account, possibilities to consider include:

- Owing to the larger number of smaller firms applying for a programme such as BIG, there is more potential for clear selection rules that allow a politically acceptable degree of randomisation.

- "Encouragement design" techniques such as sending additional information, brochures and other forms of encouragement to a randomly selected sub-set of firms make the benefits of randomisation known.

In any impact evaluation, it is also important to account appropriately for positive externalities, including learning effects and other spillovers from the broader bundle of support activities, such as public investments in translational research centres, in facilitating global consortia and in strengthening diversified skills development. It would be helpful to know which of these policy areas work better than others and their prioritisation for the allocation of scarce public resources. It would also be important to take account of positive spillovers from other public support programmes that may benefit recipient firms, such as support for biotechnology research by India's CSIR (Council of Scientific and Industrial Research) and ICAR (Indian Council of Agricultural Research).

A final and critical issue related to building capacity for data collection, management and analysis, is better definition of performance measures to distinguish between scientific, business and financial success or failure. Policy makers and policy implementers typically focus on reporting success and are not good at reporting and learning from failure. In evaluating programmes, performance measures and related analysis should allow for distinguishing between failure due to bad luck, to bad programme design or to poor selection of recipients. They should facilitate learning from failure and view this as an important aspect of success. In one concrete example, a BIRAC-supported project was halted by the monitoring committee because the project did not meet its agreed milestone. The head of the collaborating public research entity reportedly did not realise that project support was milestone-based, and agreed to self-fund the project to ensure that it would be viewed as a success rather than labelled as a failure, as this would have been bureaucratically unacceptable.[27] In retrospect, this led to the removal of bottlenecks that had stalled the project and elicited additional effort that turned the project around. But the example also makes clear the need for a means of making the discussion of failure and learning from failure more acceptable. The goal is to facilitate responsible risk taking.

Learning from diagnostic monitoring. A complementary approach is inspired by the recent literature on institutional reform and "learning by monitoring" or "diagnostic monitoring" to improve implementation: how the diagnostic principles of systematic error detection and error correction for continuous improvement, made famous by Toyota-style production systems, can be applied in different public policy contexts for programmatic improvement.[28]

From the diagnostic monitoring perspective, existing biotechnology support initiatives constitute an especially rich body of evolving programmes. Learning and improvement should occur through systematic detection and correction of "mistakes" or identification of areas ripe for improvement. In particular, both SBIRI and BIPP programmes, which include site visits by expert teams, are more probing and informative than is usual for public support programmes. The follow-on site visits by separate expert monitoring teams also are far more probing than is customary. However, at the next level of monitoring – the review of procedures for monitoring and evaluating projects – there is insufficient learning and room for improvement. For example, confidential informal feedback from a few of the project monitoring teams revealed that while the expert monitors adequately assessed the scientific and research capacities of the firms they reviewed, they were not able to provide similar feedback on questions relating to the firms' entrepreneurial capacities and business process improvement capabilities. For example, did the inventor know whether it would be better to seek help from a patent expert and try to patent the discovery and seek to commercialise it in-house? To license out the idea? To seek to be acquired by a larger firm? Or, for example, did the inventor realise that he or she was better at inventing than managing a business, and that the commercialisation imperative required finding a partner who would be the more appropriate CEO of the incipient company? The monitoring experts felt that such matters were not part of their remit, although they realised that resolving such issues would help make the programmes more successful. More fundamentally, the support schemes would benefit from a systematic institutional routine for re-examining the remit of the monitors (and other key actors) and incorporating what they learn about the limits of their current ways of operating into a revised routine in order to overcome them and improve performance. In short, it seems that DBT's initiatives are well on the way to becoming Toyota-style learning organisations, but could benefit from more rigorous and thorough application of the "continuous redesign for improvement" learning principles they already embrace.

The recommendation here is for implementers of innovation support schemes to consider applying more systematically the diagnostic monitoring principles of error detection and error correction for continuous improvement, going from helping programme recipients to detect and resolve their deficiencies early, to helping existing support schemes to detect and resolve deficiencies in their schemes, to comparing existing support schemes with the most agile comparable global support schemes to allow learning from alternative approaches. Such monitoring could be initiated by a diagnostic review of the worst-performing scheme recipients to learn which performance metrics may be most appropriate and which can explain sub-par performance; or by organising a meeting of the group of experts who have monitored programme beneficiaries with the beneficiary enterprises for a joint exploration of the range of issues that an expanded set of initiatives could help address. The goal of such a meeting would be to assess the current guidelines for monitoring experts and re-write them in light of the learning that emerges from the meeting, possibly modifying or enlarging the composition of the monitoring teams and the types of support that the schemes provide. It would be useful to devise regular error detection and error correction routines at the level both of programme interaction with firms and of programme improvement.

In terms of an appropriate form of randomised experimental evaluation in programme design, three types of firms might be compared as innovation support schemes are expanded: control firms that do not receive any programme benefits, treatment firms that receive specific support scheme benefits, and treatment firms that receive the benefits of the enhanced diagnostic monitoring, with some randomisation of firms, for instance through a lottery selection (which could mean that some firms selected under the programmes would become control firms and only benefit from the programmes slightly later than others). This type of evaluation could help achieve funders' expectations of a more rigorous basis for evaluating impact and the direction of further scale-up.

Notes

1. This chapter is based on Vijayaraghavan and Dutz (2012).

2. In a recent interview, Prime Minister Manmohan Singh emphasised the need to address India's inclusive development needs through research on communicable diseases, agriculture and environmentally friendly technologies, such as those that conserve energy and save water (Singh, 2012).

3. This chapter builds on one of the main conclusions of Dutz (2007), namely that India (and all developing countries) stands to gain more from catching up to the global knowledge frontier through adaptation of existing technologies to meet local needs and affordability concerns than from trying to push out the global frontier through creation of new-to-the-world technologies. Based on a 2006 survey of roughly 2 300 manufacturing enterprises in 16 Indian states, the use of existing technology in new settings is significantly more likely to lead to increases in productivity than riskier efforts to create new-to-the-world knowledge.

4. Wilson and Rao (2012) focus on biotechnology applications in healthcare products for infectious diseases, in particular drugs, vaccines, and diagnostics, to explore whether India can play a leading role in the development of new and affordable technologies to address neglected diseases and related health problems of developing countries. They make recommendations to expand global health R&D in India.

5. See Trajtenberg (2009) for a discussion of GPTs as a driver of innovation in developing countries, and earlier discussions in Bresnahan and Trajtenberg (1995) and Helpman and Trajtenberg (1998).

6. Translational research is an alternative to the traditional dichotomy between basic (or fundamental) and applied (and typically more short-term and incremental) research in specific scientific fields. It is a more interactive mode of research in which multidisciplinary and multi-skilled teams (with a great deal of interaction between academic research and industry practice) shorten the overall time frame of the traditional basic-applied research and development continuum to translate existing research results into practical solutions, seeking to move "from bench to bedside" or from lab experiments through clinical trials to point-of-use applications, with significant inputs from users throughout the development process. See

Goldblatt and Lee (2010) and Woolf (2008); see also Popp (2011) and Dutz and Sharma (2012) on the need for policy support for adaptive R&D for green technologies (to adapt existing green technologies to fit local soil, water, air, wind, sun and temperature conditions).

7. DBT adopted this approach modeled on the Grand Challenges for Global Health initiative to solve key health problems in the developing world announced by Bill Gates in 2003, and supported by the Bill and Melinda Gates Foundation, the US National Institutes of Health, the UK Wellcome Trust and the Canadian Institutes of Health Research.

8. Governance mechanisms to support long-term iterative and collaborative innovation are common in a range of rapidly innovating industries such as biotechnology, information and communication technologies, electronics and advanced manufacturing. They appear particularly desirable when the parties cannot specify *ex ante* what innovations would become necessary or feasible or could be produced at a cost-effective price. They typically include agreed milestones to measure and monitor performance, mechanisms for deterring on-going opportunism, and processes for dispute resolution (Gilson *et al.,* 2008). The Indian bilateral consortia frameworks have been inspired by such practices. In turn, they can be seen as precursors of the multi-country non-profit product development partnerships (PDPs), a class of P/PPs first created in the 1990s, which bring together global public, private, academic, and philanthropic participants to focus on the discovery and development of product-specific technologies targeting global health solutions for developing countries. Examples include the International AIDS Vaccine Initiative (IAVI) established in the United States in 1996 and the Medicines for Malaria Venture (MMV) established in Switzerland in 1999. See the FSG Social Impact Advisors' (2007) review of performance measurement approaches based on ten global PDPs.

9. Since the size limit of 500 employees applies only to the enterprise's DSIR-certified R&D unit, the overall size of supported enterprises can be very large, significantly larger than any definition of SMEs.

10. To put these 791 proposals into perspective (a firm cannot submit more than three), India's pharmaceutical industry (a subset of all biotechnology industries) comprises some 250 established firms that account for approximately 70% of the products in the market. They stand at the top of a fragmented base of some 10 000-15 000 smaller producers; see Bruche (2012). As of September 2012, 121 projects had been approved out of 1 010 proposals. See BIRAC (2012b).

11. Since 1992, funding under the US SBIR phase I has typically been up to USD 100 000 while phase II awards have ranged up to USD 750 000. However, it is not uncommon for awards to exceed these thresholds. US SBIR awards in fiscal year 2005 totaled USD 1.85 billion, with almost

USD 1 billion awarded by the Department of Defense. The average award size was roughly USD 315 000, with phase I awards averaging USD 110 000 and phase II awards averaging USD 760 000; see Table 1 in Link and Scott (2010).

12. To put these sales figures into perspective, in 2009 worldwide sales of the top 10 Indian pharmaceutical companies in the pharma subset of biotechnology industries ranged from USD 498 million (Glenmark Pharma) to USD 1.52 billion (Dr. Reddy's) (Bruche, 2012, Table 1). According to the 2011 BioSpectrum–ABLE biotechnology industry survey, revenues of the Indian biotechnology industry stood at roughly USD 3.5 billion. Biopharma including diagnostics and devices accounting for 62%, bio-agriculture 14%, bio-industry 3.6%, bio-informatics 1.4%, and bio-services 19%. See http://biotechnews.co.in/April2011/toTheReaders.pdf.

13. As of March 2012, 93 proposals were funded out of 551 applications. See BIRAC (2012c).

14. The Jaipur knee, designed by SIB students, was selected as one of *Time* magazine's top 50 inventions for 2009. Two 2008 SIB fellows started a company, ConSure Medical, which was recognised as one of the top 75 start-ups in India by DARE magazine. Another invention by two SIB students at AIIMS, IntraOz, took first place in the India Innovation Pioneers Challenge 2009; it helps doctors administer drugs intravenously into the bone marrow of patients in trauma or having a heart attack.

15. ABLE is a non-profit industry association established in April 2003 which represents biotechnology firms, investment banks, venture capital firms, leading research and academic institutes, law firms, and equipment suppliers.

16. The various regulations, rules and acts introduced include: Recombinant DNA Safety Guidelines and Regulations, 1990; Revised Guidelines for Safety in Biotechnology, 1994; Revised Guidelines for Research in Transgenic Plants & Guidelines for Toxicity and Allergenicity Evaluation of Transgenic Seeds, Plants and Plant Parts, 1998; Guidelines for Generating Pre-Clinical and Clinical Data for r-DNA Based Vaccines, Diagnostics and other Biologicals, 1999; Guidelines and Standard Operating Procedures (SOPs) for Confined Field Trials of Regulated Genetically Engineered (GE) Plants, 2008; and Protocols for Food Safety Assessment of Foods Derived from Genetically Engineered Plants, 2008.

17. The authors gratefully acknowledge Charles Sabel, who co-designed the survey and co-analysed results.

18. 36% of survey respondents are mainly active in human drugs, 15% in diagnostics, and 6% in vaccines. Of the remainder, 17% are in industrial products and processes, 13% in agriculture and livestock, and 13% in oth-

er activities (2 in stem cell development, 2 in edible oils, 1 in bio-plastic environmental products, and 1 in agricultural medicinal plants). 72% of respondents were more than 5 years old.

19. Of 27 firms that export (57% of total respondents), 15 address the BOP segment (56% of exporting firms).

20. The question was: "Does your firm have collaborative relations with other firms and/or academia in the co-development of new products and/or the improvement of existing products?"

21. The question was: "In the contracts or informal understandings governing collaborative relations with other firms and/or academia, does your firm, or its collaborator(s), specify particular forms of monitoring or joint evaluation of progress and results (such as forming a joint project-review committee, fixing milestones, etc?" Representative responses for a follow-up question asking about the particular forms of monitoring or joint evaluation of progress and results include: "Joint working group and joint steering committee. Common process of information and data sharing, well-defined escalation mechanism"; "Weekly telecom, Sharepoint data updates, technical discussions in one-to-one meetings"; "Milestone-based evaluation and addressing critical achievement or short fall"; "Weekly meetings and quarterly reviews. Not treated very differently from internal team."

22. Alternatives should include an evaluation of the lower-cost home-prepared water-salt-sugar solution relative to oral rotavirus to prevent diarrhoea, and policies such as offering large prises relative to matching grants and soft loans.

23. Scarcity of publicly available data on programme results is not limited to India. Twenty-five years after the onset of the US SBIR, the National Academies' recommendations still identified pressing needs for better data collection and analysis, emphasising that SBIR programme managers should give more attention and resources to a systematic evaluation supported by reliable data (National Research Council, 2008).

24. See Cadot et al. (2011), Banerjee and Duflo (2011), and Lopez Acevedo and Tan (2011) for expositions of the desirability of rigorous impact evaluation to justify policy interventions and to improve their design.

25. A complementary approach is quasi-experimental evaluation, which uses historical data and relies on appropriate econometric techniques to compare beneficiary firms with a group of control firms constructed to be as similar as possible to the treatment group. Lerner (1999) assesses the long-run success of firms participating in the US SBIR programme by examining the employment and sales growth of 1 435 enterprises over a ten-year period, with three-fifths of the enterprises chosen to resemble the

awardees closely. He finds that SBIR awardees enjoyed substantially greater employment and sales growth than the matched firms, and were more likely to subsequently receive venture capital (VC) financing. However, the superior performance of awardees was confined to firms in regions with substantial VC activity. The SBIR awardees receiving larger grants did not perform better than those receiving smaller grants. This suggests that awards play an important role in certifying quality but also that distortions of the award process occur (Wallsten, 2000; Audretsch, 2003; Gans and Stern, 2003; Link and Ruhm, 2009; and Link and Scott, 2010).

26. Rodrik (2008) and Easterly (2011), among others, have emphasised that the utility of RCTs is often restricted by the narrow and limited scope of their application. Although RCTs are strong on internal validity (the quality of causal identification), they produce results that can be contested on grounds of external validity (whether the results can be generalised to a broader population of firms, a different location, a different industrial sector). This serves to underscore the appropriate focus of the evaluation challenge, namely what is the best evaluation design that teaches something about how policy performs in a certain context and why a particular intervention works (or not) in a cost-effective way; see http://blogs.worldbank.org/impactevaluations/a-rant-on-the-external-validity-double-double-standard.

27. Based on a conversation with Dr. Renu Swarup, Managing Director, BIRAC, 18 October 2012.

28. See, among others, Sabel (1996, 2005) and Sabel and Zeitlin (2011).

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Chapter 7

Fostering innovation for green growth: Learning from policy experimentation

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This chapter explores the role that innovation can play in achieving a greener economy, with a focus on radical innovations that may help move from "business as usual" to a desirable green growth path. It reviews the role of different types of innovation for green growth, the rationale for innovation policies in a green growth strategy, and experience to date with policies that favour more radical green innovation. It concludes by making the case for mechanisms that facilitate the sharing of what works for green innovation.

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Green growth is firmly on the global policy agenda. The United Nations, the OECD and the World Bank have recently released reports on green growth (UNEP, 2011; OECD, 2011a; World Bank, 2012), all drawing attention to the growing urgency of greener policies. A critical element in a green growth strategy is the pricing of environmental externalities, including taxes or other pricing mechanisms to reduce carbon use, as well as the removal of distortive policies such as subsidies for fossil fuels.

Green growth will require a wide-ranging policy agenda, with innovation as a crucial element. Existing technologies can only be expected to improve outcomes up to a certain point, beyond which natural capital will be depleted, with negative consequences for overall growth. By extending that point, innovation can help to decouple growth from depletion of natural capital or even lead to new types of growth which do not deplete natural capital. Innovation and the related process of creative destruction also lead to new ideas, new entrepreneurs and new business models, and therefore contribute to the establishment of new markets and eventually to the creation of new jobs.

Innovation can play an important role in achieving a greener economy, including in fostering radical innovations that may help move from "business as usual" to a desirable green growth path. To strengthen green innovation, mechanisms that facilitate sharing of what works are important. These centre around learning about: 1) existing green innovation policies (with a focus on rigorous policy evaluation based on learning from experience and embedded in national economic-environmental accounting frameworks); 2) relevant experience from related innovation policy fields (including in industries with global public good characteristics similar to those of green products, such as biotechnology applied to public health); and 3) new as-yet-untried innovation policies (such as how best to foster genuine global consortia to address public good priorities). These are challenging but important areas that urgently require more work and better understanding.

The role of innovation for green growth

Green growth means fostering economic growth and development while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies. Green growth policies aim at combining a greener, more environmentally sustainable economy with as robust economic growth as possible.[1] Most analyses show that this challenge cannot be met by "business as usual". Innovations that can help achieve green growth are of different types (Smith, 2009):

- *Incremental innovation*: This is innovation which modifies and improves existing technologies to use inputs more efficiently, without fundamentally changing the underlying core technologies.
- *Disruptive innovation*: This is innovation which changes how things are done or specific technological functions are fulfilled, without necessarily changing the underlying system or technological regime. Examples include the move from manual to electric typewriters and to word processors, or the change from incandescent to fluorescent lighting.
- *Radical (or systemic) innovation*: This is innovation which involves a full-scale shift in an economy's technological regime and can lead to fundamental changes in its enabling technologies. It is often complex and is also likely to involve non-technological change and a diversity of actors. Examples include the shift to steam power and the related industrial revolution, the development of the internal combustion engine, and the more recent revolution in the ICT (information and communications technologies) sector.

More disruptive and radical frontier innovations—the creation and commercialisation of new-to-the-world technologies (for products, processes, organisation and management, and marketing)—as well as adaptive innovations—the diffusion and adaptation to new local contexts of existing technologies—will be required to achieve the decoupling of growth from environmental pressures at least possible cost.

Surveys of innovation in firms show that incremental innovation is the dominant form of innovation and has enabled substantial progress in environmental performance over the past decades. For most developing countries, promotion of greener growth typically involves diffusing and adapting existing technologies rather than radical innovation. However, the gains are often offset by rising consumption, as in the case of lower-cost personal transportation and electronic equipment. This raises the question of whether incremental innovations will be sufficient to address today's environmental challenges. More radical innovations may also be essential and may require different, and possibly more targeted, policies than those that seek to encourage a sustained rate of incremental innovations.

Radical innovations tend to be pioneered by smaller firms or by new entrants to a market and are often characterised as difficult, lengthy and risky.[2] Their success nearly always depends upon many incremental improvements, refinements and modifications, on the development of complementary new technologies, as well as on organisational change and social learning. Radical innovation is often a process, rather than a discrete event. In the ICT and biotechnology sectors, radical innovations have emerged through the actions of new players that have disrupted incumbents and created new markets. In sectors characterised by large firms, market concentration and oligopolistic behaviour, radical innovations may arise not from the actions of new players but from successive improvements to innovations by existing players or the adoption and application of technologies from other sectors.

An important question for policy makers is to determine which policies will support these more radical innovations, in both industrialised countries and in more technologically sophisticated industries in developing countries that can develop frontier base-of-pyramid green innovations to meet the needs of poor consumers. The next section discusses the rationale for policies to foster innovation in the context of a green growth strategy, before exploring specific policies in more detail.

The rationale for innovation policies in a green growth strategy

If innovation is regarded as an important driver of green growth, the question is whether this can be left to the market or whether policies are needed to support green innovation beyond appropriate environmental policies. The rationale for green policies lies in several market failures (Newell, 2009: UK Committee on Climate Change, 2010; OECD, 2011b; World Bank, 2012). One concerns the traditional negative externality of climate change and other environmental challenges. If firms and households do not pay for the environmental damage resulting from their actions, the environmental impact will be too great. If customers do not pay for the water or resources they use, they may not use it efficiently.

This traditional environmental externality has implications for green innovation because if there is no demand for environmental solutions, demand for green innovation will be below the social optimum. In turn, there will be insufficient incentives for companies to invest in green innovation, because there will be little market demand for the resulting products or processes. Correcting for this negative environmental externality typically implies putting a price on the environmental negatives through taxes, prices, permits or other market instruments (OECD, 2010a).[3]

Apart from the externalities associated with the environment, there are important market failures specific to the market for innovations. The idea that market failure leads to under-investment in research has been the principal rationale for public funding of research and development (R&D) for half a century (Stoneman, 1987; Metcalfe, 1995). Arrow (1962) highlighted three fundamental causes of this failure: 1) indivisibilities, because R&D activity often incurs high fixed costs and economies of scale, while learning-by-doing gives rise to dynamic economies of scale; 2) uncertainty , because investment in R&D is inherently risky and information asymmetries abound in markets for knowledge and technology; and 3) externalities because given the fact that knowledge has the properties of a public good, performers of R&D can only imperfectly appropriate their results as the use of knowledge does not preclude its simultaneous use by others. The lack of appropriability is reflected in positive externalities (as shown in a range of empirical studies), with social returns exceeding private returns. Under these circumstances, there will be under-investment in the production of new knowledge. Traditional responses to market failures due to non-appropriability of the results of R&D include: policies aimed at strengthening intellectual property rights (notably the patent system); R&D subsidies to private producers of knowledge; and policies that can help capture externalities through (horizontal) R&D co-operation (Geroski, 1995).

In addition to these two important market failures, due respectively to environmental and knowledge externalities, some market failures and barriers to innovation may also be unique to, or more prevalent in, the market for green innovation (UK Committee on Climate Change, 2010), such as:

- Dominant designs in energy and transport markets can create entry barriers for new technologies owing, for example, to the high fixed costs of developing new infrastructures.
- Uncertainty about prospects for success and the long timescales for infrastructure replacement and development may be a particularly important barrier in the energy sector, where the high capital costs of investment tend to make investors risk-averse towards new technologies.
- Differentiation of products in some areas is difficult or impossible, making it difficult for new entrants to get a return on their investment from innovation. This is an issue for the energy sector: customers value electricity but may not possess the information for discriminating between electricity generated from a wind or gas turbine.

This list of potential market failures—and there are others—suggests that policies for innovation will only be successful if they target the main barriers to innovation so as to enhance the performance of the system as a whole. At the same time, not all potential failures in innovation systems make government intervention necessary or desirable. There is often no guarantee that government policy will resolve a market or systemic failure in a way that effectively improves the outcome in welfare terms. Even where governments may improve welfare in principle, they may lack the means or information to do so in practice. Their space of action may be limited: in fact, policy or government failures are often the result of the same constraints as those faced by private actors. Awareness of the possibility of government failure and rigorous *ex ante* evaluation of policies can help to limit the risk of costly but ineffective intervention.

Policies for more radical green innovation

Since there is a strong rationale for policies to foster green innovation, the question becomes: What policies will drive green innovation? The previous section noted the importance of pricing environmental externalities. Pricing mechanisms tend to minimise the costs of achieving a given objective as they provide incentives for further efficiency gains and innovation. However, several studies suggest that policies such as carbon pricing, which work at the end of the innovation cycle, are more likely to stimulate incremental innovation and diffuse existing technologies than to foster radical or systemic innovation (Nemet, 2009; Smith, 2009). Policies that enhance the supply of available knowledge and help develop new technologies and applications are therefore also required (Mowery et. al., 2009).

Apart from the pricing of environmental externalities, green innovation will also require sound framework policies. In most areas, the enabling conditions for innovation are the same for green innovation or innovation more generally. The countries that are the strongest innovators also have the strongest performance in green innovation, a sign that green innovation thrives in a sound environment for innovation (OECD, 2011b). Key elements of such an environment include: good conditions for the start-up, growth and, if unsuccessful, the exit and rapid re-entry of entrepreneurial firms, as well as competitive markets, openness to international trade and investment, adequate and effective protection and enforcement of intellectual property rights, efficient tax and financial systems, and a sound macroeconomic policy.

Aside from good policies to foster innovation in general, governments may need some more targeted policies both on the supply and demand side to help to bend the overall innovation effort toward a greener trajectory. In practice, they include:

- Public *investment in science and research*, which might focus on the areas considered most important for green innovation.
- Policies to foster the *commercialisation of green innovations*. These can involve direct or indirect support for specific or more generic technologies, e.g. grants, tax credits or feed-in tariffs, as well as support for entrepreneurship.

- Policies that foster the development of markets for green innovation through *demand-side measures* such as performance regulations, technology standards and public procurement.

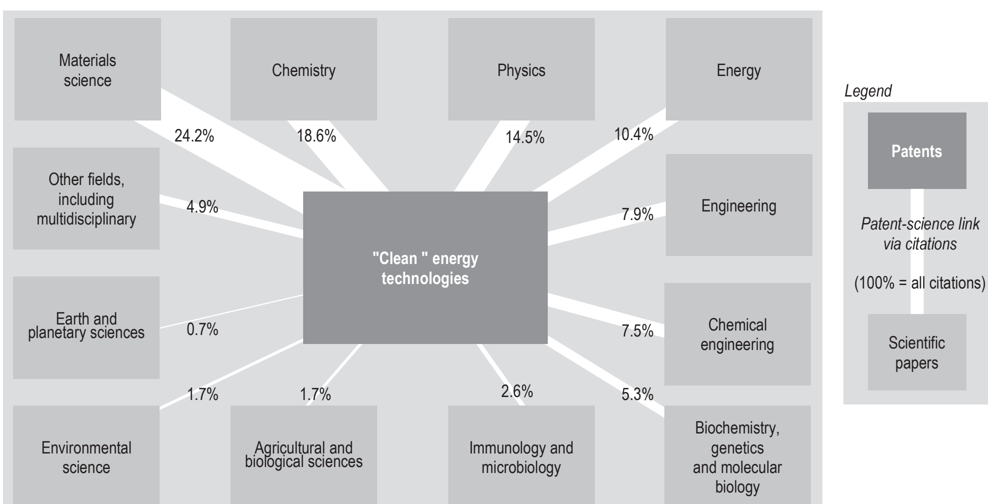
All such policies tend to involve some element of targeting to specific areas of research, technologies or markets.[4]

Targeting science and research policies

Research often provides the seed that ultimately leads to innovation, in particular technological innovation. It can come from many areas and goes beyond the narrow categories of environmental science (Igami and Saka, 2007). For example, a mapping of research in scientific fields that influence innovation in green technologies, as measured by patenting, shows that areas such as chemistry, physics and material sciences are more important for green technologies than areas such as energy and environmental science (Figure 7.1).

Figure 7.1. The innovation-science link in "green technologies", 2000-09

Share of scientific fields cited in total non-patent literature cited in patents for "clean" energy technologies



Source: OECD calculations, based on Scopus Custom Data, Elsevier, December 2010 and EPO, Worldwide Patent Statistical Database, April 2011.

Research has in fact become more multidisciplinary, with scientific progress depending on a wide range of fields. This affects both spending decisions and how trends in specific areas of research spending should be interpreted. For example, government spending on energy R&D and on environmental R&D has not kept pace with the growing urgency of the energy and climate challenge (OECD, 2011b). However, the relatively low levels of energy and environmental R&D do not necessarily imply that these areas require more investment. For example, the development of smart grids, which has important implications for energy use, is mainly due to developments in ICT technologies linked to ICT firms, not to environmental or energy R&D in a narrow sense. This implies that investing in research to provide an underpinning for green innovation will require a broad portfolio of investments, and not simply focused or targeted R&D on energy or environmental R&D. Moreover, such investments will increasingly need to ensure multidisciplinary funding, rather than funding along scientific disciplines. Targeting funding toward specific fields of research may therefore not help strengthen green innovation.

In deciding where to invest, governments should in principle focus on areas in which the social returns to investment are potentially the greatest and in which the private sector is unlikely to invest on its own. These are typically areas in which the risks of market-driven investment are high, the lead times long, and the appropriability of outcomes low. This implies that governments will need to take the lead in investments in basic research that can help overcome fundamental challenges and specific roadblocks to innovation, or that enrich the knowledge base for follow-on investments in green innovation by the private sector. Some of this investment may need to be channelled to research aimed at resolving known challenges. But some will also need to be generic or blue sky, as ideas and new knowledge can emerge from many directions.

An important issue for policy makers is the extent to which they should foster more radical or systemic innovation. Many countries encourage radical innovation by supporting "high-risk research" and "out-of-the-box transformational" technologies, often through new R&D programmes or technology prize funds (Newell and Wilson, 2005; Box 7.1). However, this approach involves some important bottlenecks (Slocum and Rubin, 2008). For example, it is often difficult to understand how a public R&D programme can achieve such "breakthrough" technologies. Moreover, in sectors such as energy, radical innovation may be limited by high rates of concentration and market dominance in existing technologies which provide little incentive for radical and systemic changes.

Others have argued for large investments in relevant public research along the lines of the Manhattan Project or the Apollo Project. However, unlike these projects, green innovations will need to be applied throughout the economy, and mostly in the private sector, and cost containment and wide diffusion will be important for the success of green innovations emerging from public research. It is also argued that pre-determined technological paths may stifle efforts to explore more sustainable technological paths. Mowery et al. (2009) have argued that such a choice is appropriate only when the way forward is relatively clear and when the necessary development work is intrinsically large-scale. In contrast, when the best path to success is uncertain, centralised decision making can suppress innovation and the development of new strategies. There is therefore a likely trade-off between the efficiency of mission-based approaches and the greater innovative potential of a more dispersed, less structured organisation of R&D.

Box 7.1. Prize funds as incentives for breakthrough technologies

Beyond government-directed Manhattan-type strategies for breakthrough technologies, prizes have also re-emerged as incentives for breakthroughs in public and private R&D. In general, prizes are of two types: targeted prizes and blue-sky prizes. Targeted prizes are posted *ex ante* and the sponsor's needs are formalised in terms of the performance standards to be met. The possibility of getting rewards *ex post* is sometimes institutionalised in blue-sky prizes. These are prizes offered for innovations that are not identified in advance. Prize funds were eclipsed by patents as monopoly prizes during the Industrial Revolution, but they have never vanished as an incentive mechanism. Today, they are shifting away from traditional arenas such as the arts to more hard-science areas such as climate and environment, science and engineering, and aviation and space. The amounts in these areas have increased sevenfold in the last decade and most of the money goes to those who solve well-defined problems.

The US Applied Research Projects Agency for Energy (ARPA-E) can be regarded as a translational research entity which announces prize-like grants in the field of renewable energy technologies. The agency's primary task is to identify potential scientific breakthroughs in this field and translate them through proof of concept or prototype on the market. Besides governments or public institutions, private actors have also established prizes to provide incentives for the creation of green technologies. General Electric, for example, recently announced a USD 200 million open innovation challenge to seek breakthrough ideas for a smarter, cleaner, more efficient electric grid.

Although prizes may indeed serve a useful role, their utility should not be exaggerated. There are significant limitations to the use of prizes in the field of alternative-energy technologies. These reflect both the wide range of technological advances that can contribute to progress in this area and the uncertainties involved in both technologies and applications. Interestingly, studies on semiconductors and other electronics-based innovations suggest that public procurement contracts effectively served the same function as a "prize", inducing considerable innovative effort by firms (Reichman et al., 2008; Scotchmer, 2006; McKinsey and Co., 2009).

Few countries can engage in every area of research that could contribute to better environmental outcomes. Governments typically focus their research efforts on their strengths or on areas in which they see a strong need to find solutions that fit the local context. In other fields, they can co-operate with other countries and research centres to gain access to relevant research and work together to find solutions. At the same time, international competition can help drive down the costs of green innovation and benefit from the global process of experimentation.

While there are clear benefits to increasing research for green innovation, other policy issues need to be considered. First, raising investment in R&D too quickly can constrain capacity in the absence of enough qualified researchers to do the work. Second, the impact of any increase in R&D spending will depend on the quality of research proposed and on the ability of the innovation system to turn the results into innovation. More funding is no panacea; improving the performance of the science system and co-operation between science and business may be as important. Third, governments can also strengthen green innovation within the existing research envelope, for instance by prioritising thematic and mission-oriented research aimed at global challenges such as climate change.

Commercialising green innovation

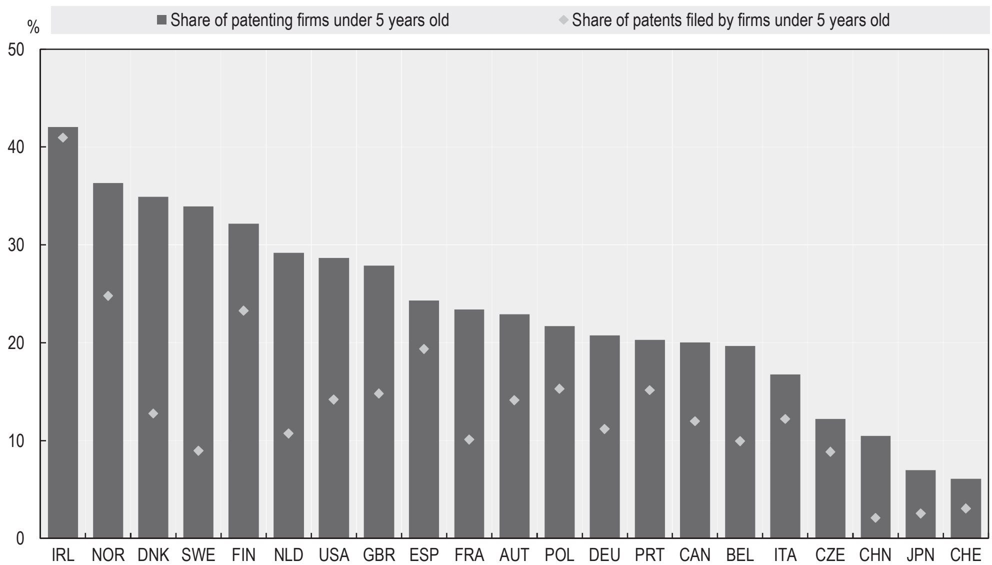
While strong scientific research can be an important foundation for green innovation, it must be translated into commercial applications to have market impact. This requires the fostering of entrepreneurship, government policies to support green innovation in firms and financing of green innovation.

Entrepreneurship and the role of new firms

New firms are the source of much innovation (OECD, 2011c; Figure 7.2). They tend to exploit technological or commercial opportunities that have been neglected by established companies, often because radical innovations challenge their business models. Analysis for the United States and other OECD countries shows that new and high-growth firms contribute substantially to the creation of new jobs (Haltiwanger et al., 2009; Bravo-Biosca et al., 2013). Entrepreneurship and the growth of new firms are particularly important areas for green innovation.

Figure 7.2. Patenting activity by young firms, 2007-09

Share of young patenting firms and share of patents filed by young patenting firms, European Patent Office (EPO) and US Patent and Trademark Office (USPTO)



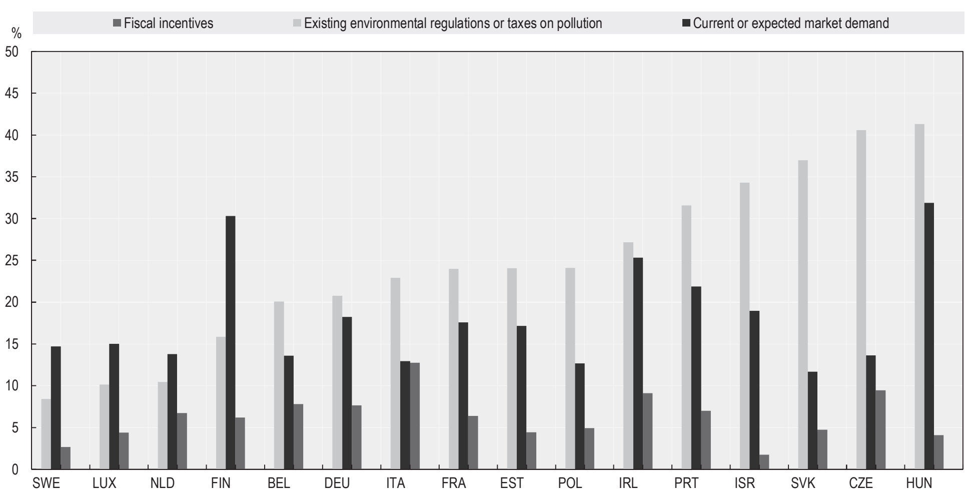
Source: OECD calculations based on the Worldwide Patent Statistical Database, EPO, April 2011; and ORBIS© Database, Bureau van Dijk Electronic Publishing, December 2010; matched using algorithms in the Imalinker system developed for the OECD by IDENER, Seville, 2011.

The experimentation that can lead to the development of new green technologies and markets will necessitate both firm creation and destruction. Many new firms, and their innovations, will ultimately fail, but this is a crucial part of experimentation to address market needs and commercialise innovation. However, most countries do not sufficiently foster the growth of new firms. They can reduce barriers to entry by simplifying and reducing start-up regulations and administrative burdens. Moreover, since new firms know little about their chances to survive, they may be discouraged if market exit is too costly. Some countries could usefully render bankruptcy laws less punitive and offer more favourable conditions for the survival and restructuring of ailing businesses, with due regard to risk management and the need to avoid moral hazard. In some cases, stricter legislation would make investors more confident about giving loans.[5] A lack of exit opportunities for investors, such as a secondary market, can also limit green innovation.

In addition, the growth of new firms is a particular challenge in many countries. Low regulatory barriers can help ensure that gazelles and other high-growth firms do not spend the capital needed to support their growth on overcoming bureaucratic obstacles. Policy should also deal with administrative, social and tax requirements, as these tend to rise with the size of the company and thus increase the cost of growth. New firms and business models may well face particular barriers to growth. For example, the business model may not be compatible with existing regulations, which may not be sufficiently up to date. Governments can help such firms by providing tailored assistance, e.g. through a front-runner desk; this can improve relations between government and entrepreneurs and bring new developments to the policy agenda.

Figure 7.3. Motivations of firms introducing environmental innovations, 2006-08

Firms citing factors as motivations, percentage of innovative firms



Source: OECD, based on Eurostat (CIS-2008) and national data sources, June 2011.

A recent analysis of drivers of venture capital investment in the clean-tech sector for 26 OECD and BRICS countries (Brazil, Russian Federation, India, China and South Africa) (Criscuolo and Menon, 2012) found that longer-term national environmental deployment policies designed to create a market for environmental technologies, such as feed-in tariffs and tradable certificates, are associated with higher investment levels than shorter-term fiscal policies, such as tax incentives and rebates. It also found that supply-push policies have a positive impact on financing as government R&D is an important predictor of the level of investment in clean sectors. Moreover, entrepreneurial companies in the cleantech sector that patent are more likely to receive private financing. The study points to the importance of a combination of supply- and demand-side factors for investment in green innovation, a conclusion also to be drawn from firm-level surveys on the drivers of environmental innovation (Figure 7.3).

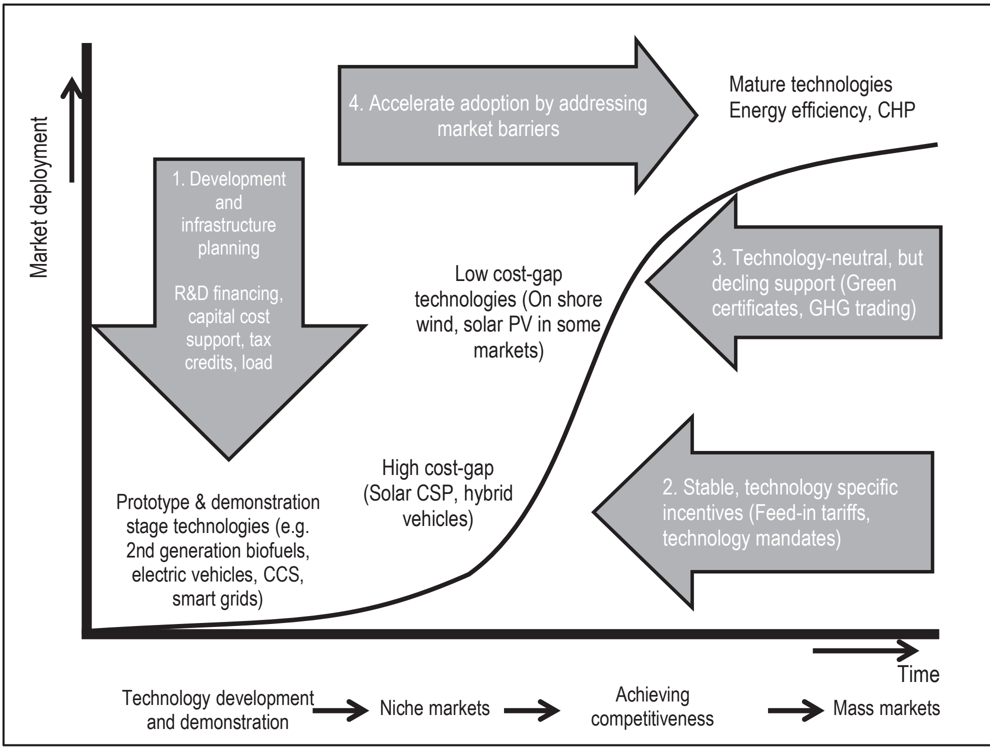
Government support for innovation in firms

Green innovation may also require direct government support for technologies and business innovation. Such support typically involves either direct support for business, e.g. competitive R&D grants or support for collaboration between firms and research institutions, or indirect support, e.g. R&D tax credits or feed-in tariffs. The advantage of direct support for R&D and innovation is that it can focus on activities and actors of greatest interest for meeting public policy goals, i.e. those that may yield the highest social returns. Direct support can also focus on specific barriers to green innovation, such as the possible undersupply of private investment in R&D, the failures of market actors to supply public goods (such as open, credible international technical standards), co-ordination and information problems that hinder networking or other types of collaborative activity, and dominant existing technologies that prevent a level playing field.

The International Energy Agency (IEA) (2010) describes the case for government action at several stages of the innovation cycle for new energy technologies. It points to four stages of technology development, each of which may require a different type of government intervention (Figure 7.4):

1. *Promising but not yet mature technologies*. At this stage, government needs to support research and large-scale demonstration and to begin to assess infrastructure and regulatory needs.
2. *Technologies that are technically proven, but require additional financial support.* Here, combined with regulatory frameworks and standards, governments may wish to provide more technology-specific incentives (e.g. feed-in tariffs) to create a market.
3. *Technologies that are close to competitive.* Governments can provide technology-neutral incentives which will be removed when market competitiveness is achieved.
4. *Technologies that are competitive.* Governments can help to build public acceptance and adoption by identifying and addressing market and informational barriers.

Figure 7.4. A tailored approach to energy technology policy



Source: Adapted from IEA (2008), *Deploying Renewables*.

Focused support for activities that either have high positive externalities or are prone to market or systemic failures can increase the impact of public support. However, such support may be problematic when governments pick specific technologies or innovations over others (whether or not these are "winners" is another question). This makes the design of schemes to provide direct support for R&D and innovation extremely important. Such schemes need to ensure competitive selection processes, select projects that best serve public policy objectives, avoid favouring incumbents or providing opportunities for lobbying, ensure a rigorous evaluation of policy impact, and contain costs. Because such support places greater demands on the information available to governments and on government capabilities to shape programmes, it tends to be more expensive than indirect support in terms of the costs of executing the programme and administering the selection process.

Governments can take steps to include market information and mechanisms in the design of direct support and thus contain costs. In considering the best designs for public support of early-stage venture capital funds, Murray (1999) concludes that the best option is to provide public co-investment with private partners, as this multiplies the financial benefits of success to the disproportionate advantage of venture capital funds and their investors while maintaining incentives for fund managers to make good investment decisions. In this way, well-designed public support can target and amplify market dynamics.

Governments can also introduce design features in their support procedures that increase the efficiency of allocations. Giebe et al. (2005) describe the resource savings and efficiency benefits to be gained from competition among applicants for R&D grants through the use of various auction mechanisms which helps to extract more information from the proposals and avoids some degree of unnecessary funding. The increasingly common practice of giving direct support to pre-competitive ventures and to partnerships, can also reduce problems associated with picking winners at the level of individual firms.

Indirect support, for instance through the tax system, is the alternative to direct support. Traditionally, the argument for tax incentives is based on their non-discriminatory nature and ease of use. The choice of R&D tax incentives will depend on country-level variables such as overall innovation performance, perceived market failures in R&D, industrial structure, size of firms and the nature of corporate tax systems. R&D tax credits are neutral with respect to the type of R&D conducted by a firm and are therefore more in accordance with market rationality than direct support. At the same time, they are less easy to orient toward a specific public policy goal, such as green innovation, and may therefore be less effective in achieving public policy goals or in achieving high social returns. This is their main drawback as a policy tool to foster green innovation: they may support any formal R&D, be it for a potentially path-breaking green innovation or for new toothpaste.[6]

The issue of where governments should direct their support is a complex one. If they choose where support should go, they risk promoting activities that may take place anyway. Moreover, more appropriate technologies or practices may emerge once policy has locked the economy into a less desirable pathway. On the other hand, with too little support environmental objectives may not be achieved. In cases such as low carbon growth or decarbonising energy systems, large-scale system-wide changes must occur relatively quickly, with costs to the environment and potentially to growth. In such cases, a portfolio of public investment which tailors funding approaches to the different stages of technology development may be desirable.

More broadly, policies for innovation and deployment need to encourage experimentation to find means of strengthening environmental performance at the least cost. This should involve a vigorous process of national and global competition among alternative technologies and innovations. Governments should strive to level the playing field between alternative options, but should generally emphasise competition and technology neutrality and avoid supporting specific technologies and solutions.

However, such policies may not always be enough, as green innovation faces additional barriers in some markets, including barriers to entry in the electricity sector. In practice, therefore, many governments provide targeted support for specific technology fields. As noted, such support can be risky because of the lack of information on the maturity of specific technologies and their likely future commercial potential.

The case of renewable energy is instructive. Denmark's experience with FITs (feed-in-tariffs)[7] in stimulating the wind power industry between the mid-1980s and the late 1990s is often cited in this respect. The Danish government guaranteed a relatively high internal rate of return, which provided a strong incentive for investment in wind power. In 1990, the country's capacity of installed onshore wind power amounted to 343MW, 76% of the total capacity of western Europe. This stable and sizable home market provided the Danish wind industry with the necessary testing ground for its technologies. Once a certain level of technical maturity had been achieved in the domestic market, Danish companies moved to the global market (Lewis et al., 2007). However, Denmark's experience with FITs has not been widely replicated.

In some cases, instruments that focus on performance rather than on specific technologies may be more promising. For example, renewable energy certificates, which include requirements for the percentage of electricity to be generated by renewables, give more broad-based incentives for innovation in alternative energy than FITs (Johnstone et al. 2010). However, such measures are unlikely to have a significant impact on less mature technologies since investors will focus on those areas which are "closer to market".

Investment in enabling technologies can also help address problems associated with targeted support. A boost in public funding of renewable energy R&D would be more "productive" if allocated to enabling technologies, such as energy storage or grid management, rather than to specific generating technologies, such as wind, ocean or solar (OECD, 2011d).

While policies to support specific green technologies may be needed to overcome barriers to commercialisation, it is essential to avoid capture by vested interests and to ensure that they meet public policy objectives efficiently. It is also desirable to focus policies on performance rather than on specific technologies or cost recovery. Other important elements include the independence of the agencies that make funding decisions, use of peer review and competitive procedures with clear criteria for project selection. Support for commercialisation should also be temporary and accompanied by clear sunset clauses and transparent phase-out schedules.

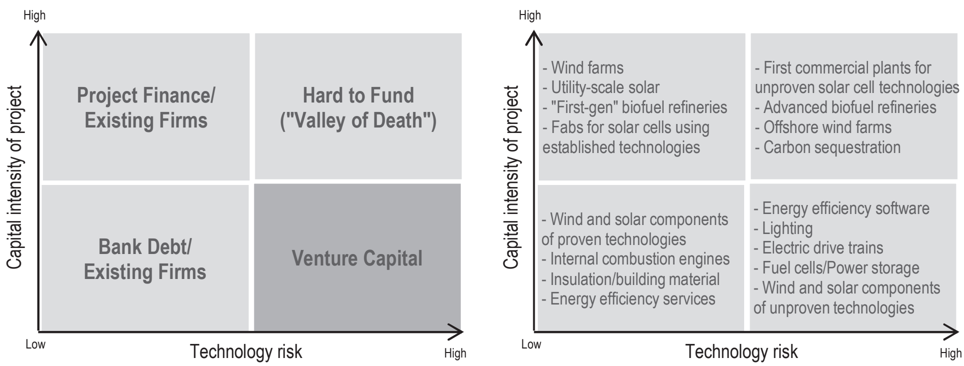
As mentioned, support policies also require a good understanding of the state of development of green technologies. Support for commercialisation should not be provided before technologies reach a sufficiently mature state. Moreover, market structure plays an important role and support mechanisms may need to be tailored to specific markets, depending on the number of competing technological options and the substitutability of different market segments (OECD, 2011d). Some markets may already be converging toward one technology standard (as in the case of combined heat and power), whereas others may still have a wide range of technological options (as in the case of carbon capture and sequestration or electric cars). Moreover, when market segments are poor substitutes, there may be market fragmentation and lock-in effects. This has a significant effect on the efficacy of public support: if public resources benefit only one segment, this raises competition issues, or if they are stretched too thin, this raises efficiency issues.

Financing green innovation

Access to finance is a principal constraint for business-led innovation, particularly in the aftermath of the economic crisis. It is especially problematic for firms engaged in green innovation, owing to the immaturity of the market and, in many countries, the absence of stable policy signals which increase the difficulty of accurately pricing the relative risk of investments in green growth. As a result, such firms find it harder to obtain financing at reasonable cost than firms in more established markets. Moreover, in some cases important learning and demonstration effects will not be realised in the absence of initial support. As a consequence, investment in green innovation, and in particular in renewable energy in most countries, remains underpinned by government incentives.

Financial constraints are especially severe for first-time innovators, since they have no history of success and often only limited access to internal finance. Well-functioning venture capital markets and the securitisation of innovation-related assets (e.g. intellectual property) can be important sources of finance for many innovative start-ups. Venture capitalists are crucial investors for entrepreneurial high-growth start-ups operating in young, dynamic and uncertain industries. At the same time, venture capitalists tend to fund projects with relatively low capital intensity, and those that should quickly be commercially viable (in three to five years) and can be sold within the life of a fund (about ten years). They also seek to diversify their high-risk portfolio by investing in a range of subsectors to increase the chances of obtaining positive "tail" outcomes in their portfolio. Figure 7.5 groups the projects of interest to venture capital funds in the bottom right panel.

Figure 7.5. Financing of risky projects and clean-tech investments



Source: Ghosh, S. and R. Nanda (2010), "Venture Capital Investment in the Clean Energy Sector", *Harvard Business School Working Paper 11-020.*

In the classification of Figure 7.5, a financing gap is likely to arise for capital-intensive projects with a high *technology risk* profile. The gap is greater if both the project's commercial viability and the venture fund's exit opportunities are very uncertain. This is particularly the case for projects characterised by technology risk at the lab development stage, but it also holds for projects at the demonstration and early commercialisation stages. The main reason is that the longer the horizon, the higher the *financing risk* for seed and early-stage venture funds, which may be unable to ensure a successful exit or to raise follow-on funding before the end of the life of the venture fund (Nanda and Rhodes-Kropf, 2010). It is therefore very hard to fund such projects with either debt financing or venture capital, and they may fall into the "valley of death".

Policy can ease access to finance for new and innovative small firms, both through debt (the prevalent source of external funding for all enterprises, including innovative firms) and equity finance. One possibility is risk-sharing schemes with the private sector. Seed capital and start-up financing, often involving business angel funds and networks, play a key role in enabling entrepreneurial individuals to turn new ideas into new products and applications. They can in addition also help start-ups to develop, by providing advice and on-the-ground management expertise.

Governments can encourage such networks and associated markets. Public funds should be channelled through existing market-based systems and private funds and take a clear market approach. Policy should focus on using financial engineering approaches to develop the market for early-stage equity finance, rather than providing finance directly. This requires incentives to develop the necessary skills and experience in venture firms.

However, venture capital, together with public and private spending on R&D, accounts for only a small part of the total recent investment in low-carbon technologies. Funding approaches need to be tailored to the different stages of technology development. Government funding is most relevant for early-stage technology development, while private finance tends to assume a larger share of later-stage technology deployment and commercialisation.

Demand-side policies: public procurement and innovation

Although attention to demand-side policies has increased in recent years, their role in the full portfolio of government innovation policies remains relatively marginal. This section looks at public procurement as an instrument that can potentially foster green innovation. Many governments are currently developing policies in this area. There are at least three rationales for using public procurement as a policy tool for fostering innovation:[8]

1. Because of their purchasing power, governments can shape innovation directly or indirectly. Firms benefit because procurement can help them recuperate the sunk costs of large and sometimes risky investments over a pre-determined period of time. Edler and Georghiou (2007) compared R&D subsidies and non-R&D public procurement and concluded that, over time, public procurement triggered greater and more diverse innovation than R&D subsidies. Public demand can help to achieve a critical mass, in particular by bundling together the demand emanating from various government agencies and bodies. Concentration of public demand through such co-ordination creates clear incentives for suppliers and reduces their commercial risk (Fraunhofer, 2005). Furthermore, by creating a signalling effect as lead user, governments can also influence the diffusion of innovation. Moreover, the reputation of businesses that win procurement contracts may be enhanced (Binks, 2006).

2. Innovative public procurement may also enable governments to innovate to improve process efficiency and enhance the quality and availability of public service delivery, for example in the areas of health, e-government and education (OECD, 2011b).

3. More generally, governments may use public procurement to create a market for certain types of innovations in order to meet a policy challenge that is time-bound. The search for commercial-scale low carbon emission technologies is a case in point.

Public procurement for innovation also faces several challenges. One concerns the public sector's lack of capacity for developing and implementing innovation-oriented procurement. With the increased importance of innovation as an objective, procurement officials are increasingly requested to integrate innovation (and other) considerations in their purchasing decisions. When award criteria include considerations other than economic value, such as innovation, the decision of procurement officials will be somewhat subjective. For instance, if the innovative character of the goods is an aspect of the award decision, procurement officials will need to be well equipped to assess objectively the extent to which each tender is innovative. While many governments have made efforts to create guidance for procurement officials, most countries do not yet have a formal policy explicitly aimed at using public procurement to foster innovation. The problems are more acute at the sub-national level, as municipalities and regions often lack procurement-specific knowledge and personnel. Procurement officials today are expected to comply with increasingly complex rules, to pursue value for money and to take account of economic, social and environmental considerations.

Moreover, the increased use of public procurement to support innovation objectives has also raised the risk of inefficient policies and distortion of the competition process (e.g. non-transparent evaluation criteria or hidden trade barriers). Evidence from an OECD survey on public procurement suggests that most countries do not explicitly consider opportunity costs and potential risks when using procurement to support socioeconomic objectives (OECD, 2012). The expense of achieving these goals should be considered, and the trade-offs, if they exist, need to be made clear. For example, it is necessary to find out if procurement is a more cost-effective way to achieve innovation objectives than other policies. There is also a risk of disrupting the efficiency of procurement if it is used as a lever to support socioeconomic criteria without sound initial cost-benefit analysis.

Innovation-oriented procurement may also be captured by vested interests, to the detriment of new innovative firms. In some countries procurement procedures may give preferential treatment to state-owned enterprises. At the same time, special measures for small and medium-sized enterprises (SMEs) or disadvantaged communities should be contained within the framework of national competition policies as well as international standards and obligations.

Finally, there is limited evidence on the impact of procurement for innovation. Few countries currently analyse public procurement to support systemic improvement, even if most regularly collect basic data on the number of bids, contract awards and the use of open or non-competitive procedures. The use of e-procurement systems strengthens data collection, although the reliability of the data may not always be consistent across government agencies.

Despite these challenges, public procurement offers some important opportunities. The public sector is a very large consumer (approximately 16% of GDP in the EU15 is spent on public procurement) and is therefore a key source of demand. Since the 1990s many countries have promoted green or sustainable public procurement as part of environmental policy. However, it has not been mainstreamed as expected owing to the higher costs or longer payback periods of many green products and services, lack of relevant knowledge and technical expertise among procurement officers, and concerns over potential distortion of fair competition (OECD, 2010b).

In practice, the scope for intelligent demand policies will depend on the weight of public procurement in specific markets and a range of other factors. Governments may want to concentrate their efforts on areas in which the societal yield from their policies may be greatest. A number of factors need to be considered. First, while government demand accounts for up to 25% of GDP in some countries, there are large differences across markets. It tends to be particularly important in sectors such as transportation (government is a large purchaser of equipment), education, office equipment, R&D and construction.

Another important consideration is how concentrated this buying power is. For example, the UK National Health Service operates a unified, nationwide procurement office. For medical innovations involving significant outlays and risk, a smaller (say regional) procurement market may not afford the rates of return needed to merit the investment (the problem of more limited capacities and know-how in sub-national governments aside). To some degree, the relative merit of central versus local procurement will also depend on whether the desired innovation is incremental or radical, and whether it is likely to be capital-intensive. Radical or more capital-intensive outcomes will likely require larger public demand.

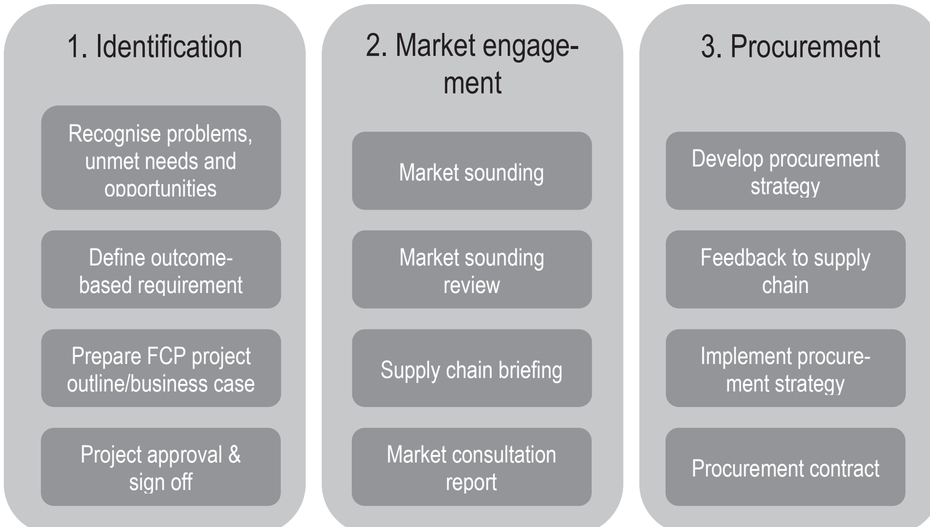
An additional consideration for governments when designing procurement policies is the likely market response to demand for more innovative public procurement. Unless there is an appropriate supply-side capacity, the policy may not stimulate innovation effectively. In practice, this will depend on specific country and sector circumstances and on the technology in question. For some technologies, supply capacities may only be available in the largest and most sophisticated economies. In such cases, procurement efforts may need to go hand-in-hand with international market scanning.

Innovation-oriented procurement is unlikely to take place in a vacuum. Especially if the public sector seeks an incremental change to an existing technology, there is likely to have been a history of procurement in the industry concerned. Administrative records should indicate something about existing supply capacities, as would consultation with industry associations, individual technical experts, and perhaps ministries with innovation responsibilities and know-how. Approaches to innovative public procurement, such as the United Kingdom's Forward Commitment Process, involves providing the market with advance information on future needs, engaging early with potential suppliers, and affording the incentive of a forward commitment, such as "an agreement to purchase a product or service that currently may not exist, at a specified future date, providing it can be delivered to agreed performance levels and costs" (Figure 7.6).

It is also important to consider the international dimensions of demand and public procurement policies. Even if one leaves aside considerations related to World Trade Organisation (WTO) and European Union requirements, it is in the interest of a small economy to maintain an open public procurement market and purchase public goods and services at the lowest (ideally lifetime) cost. There may not be enough supply capabilities in the domestic economy, and public demand may have to be met by foreign suppliers. This could result in spillovers to domestic private demand in related industries (although this is difficult to evaluate).

Some potential synergies can also be developed with other policy measures. Demand-side policies are systemic in nature. This implies that they need to be closely articulated with supply-side incentives, as supply restrictions may jeopardise some demand-led measures. Some countries are currently developing integrated supply- and demand-side policies to address specific challenges. A recent example is the launch of a procurement funding instrument in Finland in June 2009, which is intended to provide incentives for innovation through public procurement. Public procurement units and public utilities (at central and local level) can apply for funding for public procurement of innovations at Tekes, the Finnish funding agency for technology and innovation. The funds can be used both for the planning and R&D stages. External advisors can be involved in the planning stage (in legal, commercial and technological as well as user experience issues) in order to support the procurement process.

Figure 7.6. Process of forward commitment procurement



Source: BIS.

In innovation-oriented public procurement, environmental criteria can be included in the technical specifications or contractual parameters as part of the criteria for best value for money. Yet, innovation goals must be balanced against the need for competition, transparency and accountability in public procurement. Countries should adhere to national competition and public procurement rules as well as related international standards and obligations (e.g. the WTO Government Procurement Agreement). Governments also need to take measures to avoid the dominance of large players, by sourcing competitively from different firms and providing opportunities for SMEs.

Toward increased global learning from policy experimentation

The existing policy mix for green innovation

The preceding discussion demonstrates that no single technology or policy will drive green innovation. Countries will need to use a combination of supply- and demand-side policy instruments to achieve policy goals which may differ from country to country. Policies to foster green innovation will be successful if they improve the performance of the innovation system as a whole, by addressing as a priority weak links in the system. In all countries, the priority assigned to different elements depends on the nature and state of the system: one size does not fit all.

Whether by design or default, countries make different choices in their mix of policy instruments to support innovation. The appropriate policy settings and policy tools will depend on each industry's capacity for innovation, and notably on whether it is involved in innovation at the frontier, in fostering incremental innovation and adopting technologies from abroad, or in building its local capabilities for innovation (Table 7.1; Dutz and Sharma, 2012).

Table 7.1. Policies to foster green innovation and their application in emerging and developing countries

Policy focus	Policy instruments
Promoting frontier innovation (overcoming technological roadblocks, fostering radical innovation, overcoming resistance by incumbents, and scaling up new inventions)	• Investment in public R&D, including thematic and mission-oriented research • Support for early-stage development • International co-operation • Technology prizes • Demand-side policies, such as public procurement, standards and regulations • Front-runner approaches to enable new business models • Regulatory reform and competition policy • Protection and enforcement of intellectual property rights
Promoting adaptive innovation (fostering access and take-up of existing technologies, enhancing efficiency, promoting incremental innovation)	• Taxes and market-based instruments to price externalities and enhance incentives • R&D support, tax incentives • Adoption incentives/subsidies • International co-operation • Co-investment funds • Open trade and investment policies • International mobility of researchers and innovators • Voluntary patent pools and collaborative mechanisms
Building innovation capabilities (developing capabilities to absorb knowledge and foster innovation)	• Taxes and market-based instruments to price externalities and enhance incentives • Education and skills development • Improving the business environment • Linking to global networks and knowledge • Improving infrastructure • Improving governance

Note: A detailed toolbox to foster innovation, including green innovation, is being developed jointly by the OECD and the World Bank. An initial version of the Innovation Policy Platform was released in late 2013.

Source: Based on OECD (2011*e*), *Towards Green Growth,* OECD Publishing; Dutz and Sharma (2012), "Green Growth, Technology and Innovation", *Policy Research Working Paper 5932*, January, The World Bank, Washington, DC.

Even when countries have similar policy goals, their instrument mixes can be expected to differ, as these need to be adapted to the specific environments in which they are intended to work. These environments vary in terms of the structure of the industrial productive base, local institutions and prevailing preferences. For instance, without the institutional ability to implement complex taxation effectively, tax incentives for R&D may be ruled out. Different countries also exhibit different degrees of acceptance of regulation. The efficacy of various demand-side instruments can be highly sensitive to industry-specific characteristics. Policy makers therefore need to strike a balance among possible instruments. For example, direct and indirect support for R&D may be used as complements to make the best use of their respective advantages.

To help policy makers better understand which policies best foster green innovation, more systematic compilation, global sharing and learning about the effectiveness of different policies in different contexts are needed. The Innovation Policy Platform (IPP), being developed jointly by the OECD and the World Bank, is a mechanism to facilitate such learning. Its objective is to collect international and national materials and to turn them into strategic innovation policy intelligence. It seeks to aid policy assessment and design by providing an infrastructure of web-based resources and guidance to facilitate collective learning about innovation policy. For green innovation, it is urgent to learn about: *1*) existing green innovation policies (with a focus on rigorous policy evaluation based on experiential learning and embedded in national economic-environmental accounting frameworks); *2*) relevant experiences from related innovation policy fields (including industries with global public good characteristics similar to those of green products, such as biotechnology applied to public health); and *3*) new as-yet-untried innovation policies (including ways to foster genuine global consortia of public and private actors to address public good priorities).

Learning about the effectiveness of existing green innovation policies

A quality policy evaluation system should inform the choice of the innovation policy mix. Effective evaluation of policies and programmes to stimulate R&D and innovation has become increasingly important for policy makers. The increased emphasis on evaluation is driven by constraints on discretionary public spending, a greater focus on accountability and transparency in policy, and the desire to minimise distortions arising from government actions while maximising the benefits. A small number of the policies discussed above, such as R&D tax credits, have a relatively rich evaluation record, whereas most, including many demand-side policies, remain seriously under-evaluated.

Regarding the effectiveness of existing green innovation policies, almost all evidence on the impact of policies to date is from high-income countries. And even for these, the evidence on the impact of green innovation policy is scant. Not only are the data available on angel investing in high-income countries insufficient, there are no benefit-cost analyses on the effectiveness of angel tax credits or other policies to promote angel investors. Nor is there an evaluation of the effectiveness of what Chinese banks have been doing to support their green energy producers. Unfortunately, very few policies have been analysed to figure out what the impact of the policies are in terms of overall benefits relative to costs or to alternate expenditures of scarce policy resources. There is an urgent need for well-designed impact evaluations of specific policy interventions. Both experimental impact evaluation with randomised controlled trials and quasi-experimental evaluation of existing interventions are needed, particularly to learn about the effectiveness of different policies to promote both radical innovation and broader absorption of existing green technologies.[9]

Arguably, even more important than calculating whether a particular programme's benefits exceed its costs, is understanding how to improve existing programmes' performance through ongoing experimentation during programme implementation, with continuous feedback for evidence-based iterative learning and improvement built into programme design and implementation. Two complementary sets of evaluation tools are experimental impact evaluation and diagnostic monitoring. For the former, which incorporates randomisation in the programme design, the focus can be on testing how to make the intervention work better, for instance by comparing different approaches to improving programme take-up, or by comparing the effectiveness of different forms of innovation support (variations in the level of matching grant or soft loan provided for R&D, or variations in the types of mentoring support provided for entrepreneurship). For diagnostic monitoring, routines for learning and improvement can be incorporated directly into programme implementation, with systematic feedback received on what works and what does not to be addressed in the next round of programme implementation.

In addition, environmental accounts can be used to improve the policy decision-making process. It would be desirable to evaluate the effectiveness of all existing green innovation policies in the context of a national wealth accounting framework that explicitly incorporates the value of natural capital, since how we measure development will drive how we do development. Assessing the effectiveness of green innovation policies in the context of an aggregate measure of greening would also be useful in measuring performance.[10] This could entail a systematic compilation and analysis over time of all green innovation policies and their impact on green growth, as defined and measured using environmental-economic accounting.[11]

Learning about the effectiveness of policies from related innovation fields

There is unrealised scope for policy learning from related technology domains, in particular from industries with global public good characteristics similar to green products, such as biotechnology applied to public health. In biotechnology, the unmet health needs of poor populations across the world have posed a variety of related innovation challenges, such as developing business models with R&D costs at levels that do not require high-priced blockbuster products. Policy initiatives have been or are being implemented to help provide support for neglected technologies to meet the public health needs of base-of-pyramid households, including R&D grants, specific prize funds, advance market commitments (a demand-pull mechanism complementary to prizes that is most appropriate when key characteristics of the desired technology are known and can be specified in a contract), patent buy-outs, compulsory licenses, patent pools, patent commons and open source approaches.[12] More broadly, the experience of R&D funding entities, such as the National Institutes of Health, or the public health work of non-profit private foundations, such as the Bill and Melinda Gates Foundation, can provide relevant lessons for policy making for green innovation.

Learning about the effectiveness of new green technologies and policies

Apart from learning about the effectiveness of existing technologies and policies, policy makers also need to consider the innovation time frame and the respective benefits and risks of future green technologies and policies. Some innovations are already available commercially and may need no or only limited policy action to improve environmental performance. Other technologies are still under development and may be in pre-demonstration or demonstration phases. Yet other technologies will only emerge over the much longer term, and some may have a significant impact.

The timing of innovations may give one technology or innovation an advantage over another (Newell, 2009). For example, a technology with greater short-term advantages than another may become established and “lock out” other technologies. Even if the long-term benefits of the “locked-in” technology result in lower overall social benefits, it excludes other technologies. However, technologies dropped at an early stage may later reassert themselves and become successful. The OECD (2003b) describes this path dependence effect in detail, highlighting the example of the electric car, a technology which may be resurgent after being locked out decades ago. Another aspect of lock-in is the impact on incentives for further innovation. If policy focuses on the deployment of available technologies, it may reduce the market for future innovations, and this will reduce incentives to invest in R&D and efforts to develop such innovations (David et al., 2009). There are no simple answers to this problem.

One approach that can inform long-term investment decisions associated with the introduction of new technologies and innovations involves the use of scenario studies, technology foresight, and road-mapping. These can provide insight into the scope for technological progress and innovation in different areas and may therefore help guide decisions. The IEA's Energy Technology Perspectives is an important example of such an approach. This approach can also point to options that may be available at little or zero cost and could be implemented with relative ease, such as improvements in energy efficiency in existing buildings (McKinsey, 2009; IEA, 2010).

By fostering a diverse portfolio of potential options for action and by carefully considering the timing of the most lumpy and irreversible investments, governments may also help preserve options for new innovations as they emerge. This is one more reason for a strong focus on research, innovation, and entrepreneurship, all of which contribute to the process of experimentation that is central to the emergence of new options to address global environmental challenges.

In addition, a strong focus on demand-side policies, aimed at strengthening markets for green innovations, may help avoid policy being unduly locked into poor supply decisions. Inducing strong market signals for potentially promising technologies may mitigate the risk of lock-in. However, strong demand-side policies are not without their difficulties. Government-led demand-side policies, including regulatory and public procurement policies, may be guided more by political considerations and vested interests than by emerging market demands. However, market-based economic instruments, such as carbon taxes, may be insufficient to change current trajectories and may favour technologies with known and relatively low costs. Striking the right balance in the use of demand-side policies clearly remains a challenge.

Finally, a new, and as-yet-untried, innovation policy that may hold promise in the area of green innovation involves fostering effective global consortia to address priorities for public goods by building on existing bilateral consortia. As an illustration, Canada created in 2011, as a new element of its Networks of Centres of Excellence programme, a bilateral Canada-India Research Centre of Excellence (CIRCE) initiative. CIRCE is providing CAD 13.8 million in funding over five years to a consortium of Canadian and Indian universities, public sector research agencies, private-sector partners, and not-for-profit and non-governmental organisations.[13] The objective is to meet research objectives and create substantial impact in strategic areas such as alternative cleaner energy, water quality and resource management, advanced materials and sustainable urbanisation, and other aspects of environmental sustainability. Once the fixed costs of setting up initiatives like this are incurred, it would require relatively little additional cost to enrich and globalise such bilateral consortia by including to the Canada-India platform other appropriate participants, such as a relevant Brazilian or Chinese researcher, as well as relevant private sector corporate researchers and entrepreneurs. CIRCE has indicated interest in complementing their bilateral consortium with multilateral additions. The policy challenge is how best to fund such add-on initiatives, how best to identify and bring in the most appropriate complementary global talent, and how best to assist in the dissemination and commercialisation of the research findings.

Notes

1. Although some recent policy papers have argued that appropriate sets of environmental policies, along with complementary green innovation policies, could in principle improve environmental sustainability without significant adverse impacts on economic growth, or even with co-benefits leading to accelerated growth, the current evidence on synergies through positive policy spillovers seems weak and contradictory (Toman, 2012).

2. Local growth teams (LGTs)—small, cross-functional entrepreneurial clean-slate start-ups located within a multinational company and able to leverage its resources—offer larger companies an organisational solution for undertaking radical innovations more readily; see the case studies of GE's Wuxi LGT, which created a compact ultrasound device for China, and GE's Bangalore LGT, which created an ultra-low-cost ECG for rural India (Govindarajan and Trimble 2012).

3. As Toman (2012) pointed out, as the demand for green innovation is to a substantial extent created "artificially" through policy. And as environmental policies are inherently subject to uncertainty, this leads to investment and financing risks that do not arise for market-driven innovation.

4. Beyond environmental policies that create demand for green rather than brown innovation, green innovation targeting ranges from equal horizontal targeting of the production of knowledge-based assets across all types of green (on preferential terms relative to brown) industries, to more narrow industrial policy-type targeting, namely targeting of specific green industries (e.g. solar *vs*. wind), technologies (e.g. silicon *vs*. thin-film PV cells), and firms. The typical policy recommendation against narrower targeting is that it is more likely to create focused rent-seeking, more technologically risky, and more likely to be misguided as regards market-driven choices.

5. Evidence from the United States indicates that it is more difficult for low-income households to obtain loans in states with generous bankruptcy laws (Gropp et al. 1997).

6. Some tax credit schemes provide additional tax relief for specific fields of research, such as energy R&D. This raises the question of how to distinguish such research from other areas, including how to avoid companies' relabeling of other expenditures to meet the stated criteria.

7. Generally, feed-in tariffs refer to the regulatory, minimum guaranteed price that is paid to a private, independent producer that generates electricity using renewable energy. Occasionally, FITs mean the full price per kilowatt hour received by the producers, including the premium above or additional to the market price, but excluding tax rebates or other subsidies paid by the government (Sijm 2002).

8. Public procurement may also help to alleviate problems of access to finance that particularly affect small firms. Depending on their design, procurement processes may also help offset problems of bias against small firms in the public tendering market. The fact that a market is entailed by the awarding of a contract and that a public agency has evaluated the firm awarded the tender may also help attract additional finance for innovative activities from private sources.

9. An impact evaluation (IE) of a programme or policy seeks to measure quantitatively the program's impact on specific outcomes of interest, and is distinct from monitoring of programme activities. Since beneficiary outcomes are affected by a host of factors (besides the programme being evaluated), identification of the causal link between programme and outcomes is the key challenge. IE tackles this problem by comparing programme beneficiaries (the "treatment" group) to a group of non-beneficiaries (the "control" group). The latter is intended to measure the *counterfactual*; that is, what would have happened to beneficiary outcomes *in the absence of the program.* A prospective, "experimental" IE design with randomised assignment to the programme is considered ideal. Randomisation of treatment at the outset ensures that the treatment and control groups are "similar", in the sense that *on average*, their outcomes would have been the same in the absence of the program. Therefore, comparing the change in outcomes across the treatment and control groups will give a correct estimate of the average programme impact.

10. The SEEA (System of Environmental-Economic Accounting) Central Framework is a conceptual framework for understanding the interactions between the economy and the environment, and for describing stocks and changes in stocks of environmental assets, including the extent of emissions and discharges to the environment resulting from economic activity. It is the first comprehensive international environmental accounting standard and has been developed over 20 years. It was adopted as an international standard by the UN Statistical Commission at its 43rd session in 2012 (European Commission et al. 2012).

11. For an illustration of how green growth can be defined and measured using environmental-economic accounting along dimensions including environmental efficiency, natural resource base, and environmental quality, see Australia Bureau of Statistics (2012, Chapter 7).

12. For a series of analytical papers examining specific innovation policies to speed the development of new health technologies for the developing world, see http://healthresearchpolicy.org/content/assessments. Dutz and Sharma (2012) discuss the relevance of some of these policies for green innovation.

13. www.nce-rce.gc.ca/Competitions-Competitions/Current-EnVigueur/CIRCE-CERCI/Index_eng.asp.

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Chapter 8

Making evaluations count: Toward more informed policy

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Performance measurement is receiving more and more attention, but the implementation of good measurement systems and the utilisation of results remain a challenge. This chapter reviews the practices of various organisations drawing on the literature and the author's own experience working with institutions around the word. It identifies factors that contribute to greater utilisation, including the relevance of evaluations, the credibility of results and the commitment of managers to use evidence to drive decision. This chapter argues that performance measurement needs to be embedded within a broader evaluation system that fosters critical thinking and supports continuous improvement as part of the policy cycle.

Innovation plays an essential role in social and economic development. It paves the way for the creation of high-paying jobs, drives productivity gains, fuels economic growth and improves social welfare. Companies can adopt new technology to create new or significantly improved products, speed order-to-delivery times, and lower costs. The adoption of technology in hospitals can drive down costs and improve patient care. Schools can incorporate technology into new curricula to enrich learning and educational performance. Government can adopt technology to reduce the cost of service delivery and make institutions more responsive to the needs of citizens. Recognising the importance of innovation, governments around the world have launched a slew of initiatives that aim to accelerate the development and application of technology. In many instances, the allocation of resources has been accompanied by calls for meaningful measurement of results and greater accountability. This is particularly true in an era of tight budgets and fiscal austerity. Executive agencies, legislative bodies and watchdog groups want reassurance that funds are being used appropriately – they want evidence that programmes are being implemented as originally intended and that programmes are effective in achieving intended outcomes, particularly in relation to the amount of funding committed.

In this atmosphere, organisations are placing greater emphasis on trying to measure their performance. In fact, in any journal of public administration or business publication there are articles extolling the virtues of performance measurement. Reciting the mantra "what gets measured gets done", more and more organisations are picking particular aspects of performance to measure, and then devoting significant resources to collecting data and reporting results. However, there is evidence that much of this effort may be wasted. To be useful, the right things need to be measured in the right way. As importantly, data need to be turned into information, information into insights, and insights into action. This calls for embedding performance measurement in a broader evaluation system that fosters critical thinking and continuous improvement as part of a policy cycle.

What is evaluation?

An evaluation is a systematic assessment of the implementation or merit of a programme in order to provide useful feedback for decision making. Evaluations involve collecting data, drawing inferences and making judgments based on empirical analysis. Data used in an evaluation can come from a variety of sources, such as programme documents, focus groups, individual interviews, structured surveys, direct observation and expert testimony.

Evaluations can contribute to developing a better understanding of the dynamics and success of programmes. They can be used to answer a variety of questions, including the following: Has the implementing organisation established appropriate policies, procedures and systems? Have programme activities been carried out as planned and reached intended beneficiaries? Have the knowledge, attitudes and behaviour of beneficiaries changed because of the programme? Have beneficiaries (and the broader society) actually benefited as a result of these changes? Are benefits greater than the cost? The first two questions deal with processes and associated outputs, and the other three relate to the effectiveness of programmes in terms of achieving intended outcomes.

In general, evaluations can provide information that can be used to help ensure greater accountability, identify areas for improvement, and determine whether continued funding is merited. The evaluation community often makes the distinction between monitoring and evaluation, with the latter divided into formative and summative evaluation. Monitoring involves tracking progress against plan on a regular basis using a pre-defined set of indicators. Managers monitor performance to identify areas warranting attention and focus on deviations from stated targets. While monitoring is done as part of routine programme management, evaluations are conducted periodically at key stages in the life of programmes. Formative evaluations are conducted periodically during programme implementation in order to identify steps needed to address deficiencies in programme design or execution and/or highlight ways to capitalise on success. Evaluations are formative to the extent that evidence concerning programme performance is collected, interpreted, and used by managers and other stakeholder to decide how to strengthen ongoing programmes. Summative evaluations conducted at the end of a programme provide a chance to document its history and reach a more definitive conclusion on its impact.

The promise unfilled

There is no shortage of advice on how to plan and execute good evaluations. A web search on “monitoring and evaluation” turns up literally millions of links to documents that are full of guidelines, performance measures, data collection templates, descriptions of analytical techniques and standards of practices. Organisations can download (for free) innumerable evaluation handbooks published by government agencies, development institutions and foundations. All of these handbooks counsel the importance of making programme evaluation an integral part of programme management from initial planning through start-up, ongoing implementation and reauthorisation. However, many organisations still face significant challenges for establishing evaluation systems that generate valid and reliable data.

Moreover, despite the amount of resources devoted to evaluation, utilisation of results remains irregular.

For example, the key concern in developing good performance measures is to ensure that they are valid and reliable. Measures need to reflect the constructs that are to be measured, and use yardsticks that yield accurate and consistent measurements. Once measures are defined, systems need to be put in place to collect the requisite data and maintain quality control. While many organisations have been successful in adopting solid performance measurement systems, others still struggle with the basic rudiments. An international organisation that had developed a training programme for business managers can serve as an example. The model centred on licensing the training programme to independent training institutions around the world, which would be responsible for delivering training in their respective markets. Programme managers had developed a wide range of performance measures, including the number of institutions that had licensed the training programme on a cumulative basis. The programme managers dutifully reported to senior management and an advisory board that the number was growing each year and exceeded the targets set for programme expansion. Unfortunately, the measure was flawed. It did not account for institutions that elected not to renew licenses. Once these were netted out, there was virtually no increase in the number of institutions with current licences at the end of the expansion phase compared to three years earlier. The error seems obvious, but programme managers had reported results year-in and year-out without any questions raised by senior managers or the advisory board.

Another organisation had instituted a programme to help local governments streamline procedures related to starting a business. Reports submitted to donors noted significant impacts. For example, in one country, the organisation reported that, on average, the number of steps required to complete registration had been reduced by 55%; the number of required visits had been reduced by 80%; and the time required to complete all procedures had been reduced by 96%. However, upon external review, it turned out that results were based on a comparison between baseline figures and estimates of likely improvements presented as justification for proposed reforms, rather than actual changes in performance observed after reforms had been implemented. Further research suggested that the bulk of government agencies participating in the programme had not implemented the proposed reforms and many of those that had implemented the reforms suggested changes in procedures but did not realise expected improvements. Again, notwithstanding the clear distinction between forecasted and actual performance, senior management in the organisation appeared unaware of exactly how performance gains were being measured.

The experience in the United States with performance measurement is also instructive. The federal government has tried to instil a "results orientation" in all federal agencies. The cornerstone of this effort rests in legislation passed more than 20 years ago. The Government Performance and Results Act of 1993 (GPRA) required all federal agencies to prepare long-term strategic and annual operating plans, measure performance against stated goals and objectives, and report on progress. Seven years after the landmark legislation was passed, the US General Accountability Office (GAO) undertook a study to examine whether the legislative aims had been met. GAO found that the vast majority of managers (84%) in 28 federal agencies had established performance measures for their programmes in keeping with the mandate. However, managers in 21 of the 28 agencies reported that these data were not used to any significant extent in setting priorities, allocating resources, adopting new programme approaches, changing work processes, setting individual job expectations or co-ordinating efforts with other organisations (US GAO, 2000). The study also noted that "limited confidence in the credibility of performance information is one of the major continuing weaknesses with GPRA implementation." Despite continued emphasis by successive administrations, in 2004, the GAO reported that while there had been a dramatic increase in performance measurement, it had not observed greater use of data in allocating resources or making funding decisions (US GAO, 2004). In 2011, the GAO reported that agencies "often lack information on the effectiveness of programmes" because the validity and accuracy of information was questionable or programmes had not been evaluated at all (GAO, 2011). The GAO reports highlight the need to strengthen management competency and build institutional capacity to measure performance appropriately and put resulting data to good use.

More generally, many evaluations simply end up on shelves – unread or ignored. For example, a study conducted by the Swedish International Development Cooperation Agency (SIDA) concluded, "Evaluations are useful for a very limited group of stakeholders. For a majority of stakeholders the evaluation process could have just as well been left undone." (Carlsson et al., 1999) Another study commissioned by the World Food Foundation (WFP) found that evaluations provide "insufficient contribution to knowledge building within WFP and virtually none among partners." (Baker et al., 2007) Evaluations are a source of information that can be used by policy makers to help make decisions, but their use is not guaranteed. As noted by one commentator, "The policy-making process is a political process, with the basic aim of reconciling interests in order to negotiate a consensus, not of implementing logic and truth." (Weiss, 1997)

Putting results to use

That said, many organisations are making use of evaluations to help drive decisions. For example, a renewable energy programme evaluated a number of years ago provided rebates to homeowners and businesses to help defray the cost of installing solar photovoltaic (PV) systems. From the outset of the programme, the organisation maintained detailed data for each system, including its rated capacity, the make and source of key components, the name of the installation company, the cost of installation, and the number of kilowatt-hours (kWh) generated each month. Additional information was obtained through participant surveys. Using these data it was possible to assess factors contributing to demand and variation in the cost of installation and efficiency of production. This led to several changes in programme design, including the decision to place greater emphasis on larger systems and adjust rebates to reflect income levels and housing values.

Evaluations can also lead to a major shift in the fundamental focus of programmes. Take, for example, the case of a project that was initially designed to help farmers increase production of bamboo on degraded land in order to satisfy demand from a factory producing flooring. An evaluation of the project demonstrated that yields could be increased through improved cultivation practices, but suggested that these practices were not financially sustainable given the high cost of fertiliser. More importantly, the evaluation questioned whether the emphasis on increasing yield was well placed, noting that higher farmer income might be derived from developing value-added activities in villages, including pre-processing of culms prior to shipment and production of bamboo products from waste material. The decision was made to reorient the programme accordingly.

Sometimes it makes sense to terminate programmes. For example, a handicraft programme was initiated with the support of numerous donor agencies, which were attracted by the promise of helping people escape poverty. While an evaluation demonstrated that some participants were better off, in aggregate, the total additional income generated by the programme was less than its cost. The programme worked but at a cost that was greater than the financial benefit derived by programme participants. The decision was made to wind down the programme and reallocate resources to other initiatives.

Increasing the prospect of utilisation

The influence of evaluations has received a great deal of attention in the evaluation community over the past 40 years. Many articles have discussed the ways in which evaluations are used and the factors that affect use. Much of the early literature focused on the *conceptual* and *instrumental use* of evaluations (Weiss, 1995, 1977). The first deals with use of evaluation results to generate a better understanding of the programmes that are the subject of evaluation. The second centres on the use of evaluation results by policy makers to make decisions regarding the subject of the evaluation. In the 1990s, scholars broadened the idea of evaluation to include the learning that takes place as a result of stakeholder participation in the evaluation process (Patton, 1997). More recently, this notion of *process use* has been incorporated with conceptual and instrumental use into an integrated theory of *influence* (Kirkhart, 2000).

Much of the research over the past four decades has focused on identifying the factors that determine whether and how evaluations are used. Based primarily on stakeholder surveys and case studies, researchers have reached various conclusions about the importance of different characteristics of evaluations and the environment in which evaluations take place (Johnson et al., 2009). Major factors are discussed below:

- **Users need to be aware of the results of the evaluation**. Evaluations typically entail the production of a report, which presents the results of the study in the form of findings, conclusions and recommendations. The reports are presented to the organisation that commissioned the evaluation and sometimes shared with external stakeholders through publications, presentations, press releases and peer-to-peer networking. It is hard to ensure that managers and other stakeholders give the reports due attention given their many responsibilities. For example, in response to an online survey available to all UK Department for International Development (DFID) staff, 30% of 254 survey respondents admitted that they had never read all or part of a DFID-commissioned research report (Jones and Mendizabal, 2010).

- **Users need to perceive the evaluation as relevant**. Evaluations are unlikely to be influential if they do not address the concerns of stakeholders. Managers or other stakeholders may consider questions addressed in an evaluation irrelevant, focused on “academic” concerns or esoteric issues rather than the practical matters with which they grapple on a daily basis. Moreover, the timing of an evaluation also has a bearing on influence. Evaluations are more likely to affect the behaviour of an organisation when they are undertaken within the context of an important debate or a pending funding decision. If evaluations are to be used to help stakeholders make more informed decisions, results need to be available when decisions are being made.

- **Users need to accept the results as accurate**. To be influential, the results of an evaluation need to be believed by managers and other stakeholders. Credibility is a function of two primary factors: the quality of the evaluation and prior beliefs.
- **Quality of evaluation.** Quality is, in part, a function of methodological rigor. In general, credibility is enhanced if the study design, method of data collection and analytical technique are seen as sound. To be believed, results need to be perceived by managers and other stakeholders as accurate and reflecting the specific context in which the programme was carried out: the evaluation needs to be seen as anchored in realities "on the ground". In this regard, credibility is related to the quality of arguments presented in the evaluation, particularly with respect to the nature of the evidence provided to support claims and its coherence in terms of the extent to which recommendations address the major issue identified in the evaluation and flow directly from conclusions drawn from the findings presented in the report. Recommendations need to be specific, constructive and feasible, with a clear sense of priority and proper sequencing. In general, reports need to be written in clear, straightforward language that is easily understood.

One caveat is in order. Credibility is a function of the *perceptions* of users. While there may be objective standards for the strength of evidence (see below), the way in which managers or other stakeholders view different types of evidence matters. For example, a number of years back, a programme that aimed to increase the productivity and growth of manufacturing firms in the United States was evaluated. Making use of detailed plant-level data, the performance of programme participants was compared to similar firms that had not elected to participate in the programme, controlling for selection bias using a particular regression technique (Heckman correction). The results were positive and statistically significant. While the methodology was sound, some policy makers remained unconvinced. While predisposed to the programme, they dismissed the study out of hand. They simply wanted to know whether participants liked the programme and believed that it had led to job creation. The policy makers preferred testimonials from gratified constituents to analysis of hard data from evaluators with no vested interest in results.

- **Prior beliefs.** In theory, evaluations enable managers and other stakeholders to acquire new information or a new way of thinking. In so doing, managers and other stakeholders gain knowledge, which either confirms or changes their attitudes with respect to the subject of the evaluation. In this regard, evaluations may influence the *direction* of an attitude (e.g. a programme that was previously well regarded falls out of favour as a result of evidence that it is not meeting stated objectives) or its *salience* (e.g. an issue that had been deemed only slightly important comes to be seen as critical). In general, however, people are less likely to accept the results of the evaluation if they run counter to their prior beliefs. (Evaluations that confirm what some stakeholders already hold to be true can still provide value as an objective source of evidence.)

  These two factors are intertwined. If an evaluation challenges people's prior beliefs it must be perceived as of high quality to convince them to change their opinion. In this regard, the results of an evaluation may be accepted by some users but not by others.

- **Users need to act**. Evaluations take place within organisational contexts marked by varying degrees of leadership, consensus and pressure to change. Recommendations are more likely to be adopted when leaders foster a culture of learning and continuous improvement; there is consensus within the organisation for specific actions, or there is pressure from outside the organisation, including external interest groups and funding agencies. Accountability goes beyond being transparent in reporting performance to committing to address issues identified in evaluations. Evaluations are more likely to be put to use when internal incentives are aligned with efforts to improve performance and follow-up mechanisms are established to monitor and ensure agreed actions.

All of this argues for significant engagement between evaluators and stakeholders. Stakeholder involvement in the evaluation process helps ensure commitment to the evaluation, provides learning opportunities and enhances the use of evaluation results (Preskill et al., 2003). In designing evaluations, thoughtful consideration should be given to the nature of the decisions that managers might be contemplating and the information which they would find useful to their deliberations. By actively participating in evaluation activities, managers and other stakeholders may learn how to think critically about programmes, questioning assumptions and testing hypotheses. Their involvement is also central to a sense of ownership of the evaluation. Stakeholders need to feel that evaluations address issues that they consider paramount and present information in a fair and objective manner.

Using programme theory

Programme proponents believe that the intervention will yield intended results through (often unstated) causal mechanisms. Good programme design requires explicit programme theory – the series of cause and effect relationships that link the intervention to the wanted end-state. Programme theory serves to explain and predict what will happen if the programme is implemented as designed. Programme developers should lay out the programme theory during the design phase and assess its underlying logic. They should be able to show that all causal relations are plausible and sufficient to lead to meaningful change. When done properly, programme theory presents a series of hypotheses that can be tested empirically as part of programme evaluations. For example, manufacturing extension programmes are often sold as a means to boost employment. The theory posits that if companies receive technical assistance through a government-sponsored programme, they will implement new production techniques. If companies implement these new production techniques, they will increase productivity. If companies increase productivity, they will increase sales. If companies increase sales, they will add additional employees. Evaluations can be used to determine whether programmes actually produce the results predicted by the theory.

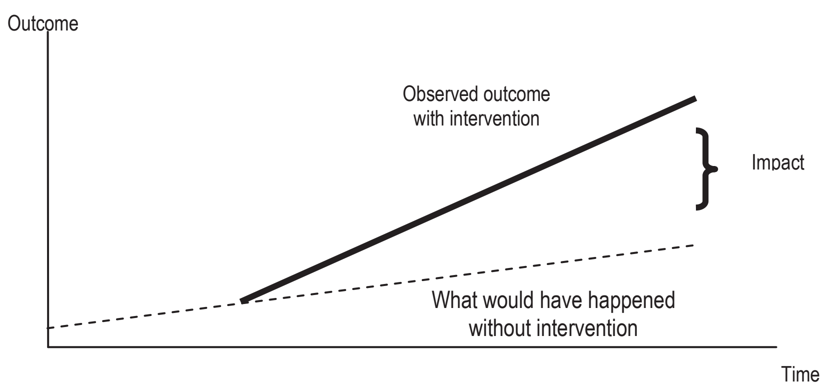
Burden of proof: The attribution conundrum

One of the most perplexing issues facing all organisations is how to assess the effectiveness of programmes. Funding is devoted to programmes in the belief that they will result in desired social and economic outcomes. At the end of the day, it is essential to be able to determine whether programmes have resulted in these outcomes. Programmes found to be effective might merit expansion or replication; ineffectual programmes can be redesigned or terminated. However, the strength of evidence used to justify the merit of programmes varies.

At its heart, assessing programme impacts is about establishing causality. Correlation does not imply causality. Just because certain attributes are observed among programme participants does not mean that these are due to the programme. In demonstrating that a particular programme caused a specific outcome, certain conditions need to be met. First, the cause (programme) needs to happen before the effect (outcome) – this is known as temporal precedence. Second, the cause and the effect need to change together – there needs to be a correlation (covariation) between the programme and observed outcomes. Third, plausible alternative explanations for the observed outcome have to be ruled out – rival hypotheses must be disproved. Finally, the mechanism by which the outcome was produced has to be explained – in other words, a theory linking the programme to the outcome must be articulated.

The fundamental tenet of all impact evaluations is the need to compare the observed situation with the programme to what would have been without the programme (i.e. the counterfactual). The difference in resulting outcomes between these two states constitutes the impact of the programme as illustrated in Figure 8.1. While the counterfactual cannot be observed or known with complete certainty, the concept of comparing observed outcomes to this hypothetical state underlies all valid approaches to assessing impacts (regardless of whether quantitative or qualitative methods are used). Valid comparisons imply that the net effect of interventions is isolated from all other extraneous or confounding factors that influence defined outcomes. For example, efforts to spur greater R&D funding through tax credits, grants, or business counselling services may have been undertaken during a period of significant economic growth. Given a robust economy, programme participants may have committed greater resources to R&D even in the absence of the programme. As a result, the central question is not whether R&D spending grew, but rather whether R&D spending grew more than it would have if companies had not participated in the programme.

Figure 8.1. Programme impact



The major challenge in impact evaluations is to estimate the effect of programmes after netting out extraneous factors that affect outcomes. These factors may include specific events or long-term trends in particular sectors. They may also include developments among programme participants. For example, a programme to boost productivity through the provision of technical assistance should take into account the productivity gains resulting from capital investments made by programme participants who are unrelated to the programme. Similarly, evaluations of the effectiveness of programmes need to account for the voluntary nature of programmes. In most cases, programme participants take part in programmes of their own volition. Some members of the target population may be more inclined to participate because of greater interest, motivation or other conditions that are specific to the participants. This self-selection process can bias results if the factors that lead programme participants to participate are related to the specific outcomes under study. For example, a programme that is designed to increase access to financing is likely to attract progressive companies that recognise potential market opportunities, are willing to assume certain risks in the hope of reaping financial returns, and have sufficient collateral to secure the loan. These same characteristics are likely to be associated with productivity and sales gains. A similar sort of selection bias can occur when organisations select participants based on certain characteristics (administrative selection) which are related to the specific outcomes under investigation. This would be true, for example, of venture capital programmes. In both cases, it would be inappropriate to compare programme participants to non-participants without controlling for the selection process. To do so would run the risk of misestimating programme impacts.

There are four basic quantitative approaches (evaluation designs) that can be used to assess the impact of programmes. The basic difference among the designs revolves around the nature of the control or comparison group. These approaches are:

- **Randomised experiments**. In this approach, subjects (individuals, organisations, cities) are randomly assigned to two groups – a treatment group and a control group. Those in the treatment group participate in the programme, while those in the control group receive an alternative type of assistance or none at all. The critical element of this design is randomisation. Random in this case does not mean haphazard; care needs to be taken to ensure that every firm (or individual) has a known probability of being selected for either group. Random assignment prevents self-selection and helps guarantee that the two groups are similar in aggregate, particularly with respect to extraneous factors that influence outcomes. For example, random assignment helps ensure that both groups are similar in terms of the proportion that are inherently more receptive to making needed changes in business practices, or that fluctuations in market conditions affect both groups equally. As such, the control group serves as the ideal counterfactual. Because of this comparability, claims that observed differences in outcomes between the two groups are the direct result of the programme are harder to refute.

- **Natural experiments**. In this approach, the existence of an exogenous event, which affects some subjects (treatment group) but not others (comparison group), is used to approximate the process of random assignment. The validity of this approach hinges on whether the event really did not reflect any bias in the assignment process.

- **Quasi-experiments**. In a quasi-experiment, the change in the performance of subjects participating in a programme is compared to other similar non-participants. Here again, assignment to the two groups is non-random. To the extent that the two groups are similar, observed differences can be attributed to the programme with a high degree of confidence. Valid comparisons require that the two groups be similar in terms of their composition with respect to key characteristics, exposure to external events and trends, and propensity for programme participation. The issue of the validity of a comparison group is central to this approach. Ideally, the non-participant group should be similar to the participant group with respect to variables affecting outcome measures, but should not have received services through the programme. "Similar" in this context refers to the distribution of values for relevant control variables, i.e. the mean and range.

Several types of designs fall within this general category. These are discussed below in the order of their ability to deal with confounding factors.

- **Regression discontinuity**. In this approach, scores on a specific measure are used to assign targets to the intervention and control groups in an explicit and consistent manner. The difference in post-implementation performance between the two groups is compared, statistically controlling for the variable used in the selection process. For example, scores with respect to the creditworthiness of programme participants may be used to qualify programme participants for participation in a loan assistance programme – a case of administrative selection. Assuming that an explicit cut-off point is used to determine eligibility, the net effect of the programme can be estimated after adjusting for the original selection variable.

- **Statistically equated comparison**. This approach employs statistical techniques to ensure that the intervention and control are as equivalent as possible with respect to outcome-related characteristics. In general, this involves using multivariate regression in which the influence of the programme is estimated after controlling for other variables that may affect outcomes. Selection can be done through the use of two-stage regression or other techniques involving instrumental variables.[1]

- **Matched comparison**. A somewhat less robust approach involves constructing a comparison group that resembles the treatment group as closely as possible based on characteristics considered important in explaining outcomes. For example, programme participants may be matched based on the same set of variables described in the previous technique. Performance differences between the two groups post-intervention are calculated without further statistical adjustment. However, it can be difficult to find matches for participants based on all criteria, e.g. another firm with the same scale, ownership structure or geographical location.

- **Non-experiment (before-after)**. This design relies solely on differences in performance over time among participants. Any observed difference is attributed to the programme. It assumes that no other factors influenced the results. This is highly unlikely in most situations.

The techniques described above are all quantitative approaches to assessing the impact of programmes. They revolve around putting numbers on things. However, as often attributed to Einstein, "Not everything that counts can be counted, and not everything that can be counted counts." (Cameron, 1963). Qualitative research can also be used to assess the effectiveness of programmes. In particular, theory-based case studies can be used to analyse presumed causal paths that link programme activities to intended outcomes. The approach relies on narrative based on document reviews, interviews, and observation. Qualitative research is especially useful for understanding the internal dynamics of a programme and explaining causal mechanisms.

So what approach is best? Randomised experiments are often held up as the "gold standard" of impact assessment and lately there has been a big push toward greater use of them in the development field. For example, the Office of Management and Budget (OMB) in the United States places significant emphasis on randomised clinical trials (RCT) in its Programme Assessment Rating Tool (PART). However, this approach may not always be appropriate. As stated by the American Evaluation Association (AEA) in comments submitted to the OMB, "there is broad-based consensus in the field of evaluations that RCTs are an important methodological tool when applied under the correct circumstances" (2008). It goes on to delineate these circumstances, including an ability to maintain the integrity of treatment and control groups, consistent programme implementation across subjects, high-quality outcome measures, sufficient statistical power, and an ability to address ethical concerns. The AEA also highlights certain inherent limitations of this approach, noting that it has weak external validity (generalisability) owing to the need to maintain strict design protocol, and, by itself, cannot explain why and how programmes affect outcomes. In fact, since it is not based on a detailed analysis of actual operations or conceptual models of programmes, RCTs cannot be used to distinguish between poor programme design and poor implementation. In this regard, programme managers and other stakeholders are not just interested in determining whether a programme is effective or not; they want to know how to improve performance, i.e. what changes in the overall strategy or day-to-day operations are needed to boost performance.

Evaluations are undertaken in a variety of contexts. The general rule should be to use the best possible design from a methodological perspective, taking into account the magnitude of resources committed to the programme and practical considerations related to data availability, time and budget. Most researchers would argue for mixed methods. They would also be sceptic that a single evaluation can provide definitive proof of the merits of a particular programme or type of programme. Even the most rigorous study may not be wholly correct.

Implications

Evaluations are carried out to cast light on a subject – to come to know something about the world – in order to improve it. To be useful, evaluations need to address relevant issues, be carried out with sufficient rigor, and be undertaken in organisations that use evidence and reason to make decisions.

Organisations need to make sure to count what is important and count it correctly. In this regard, indicators need to be selected and defined with care, and requisite data need to be collected and analysed in a suitable manner. Done properly, performance measurement can provide a clear picture of what particular programmes have been able to achieve in terms of measurable results. However, organisations need to go well beyond simply measuring performance. They also need to focus attention on determining the factors that underlie performance, diagnosing the root cause of any identified deficiencies, in order to take appropriate corrective action. They also need to consider a broad range of issues that do not lend themselves easily to measurement. More generally, critical thinking – an ability to state questions clearly, marshal valid and reliable information, weigh evidence, assess the strength of arguments, recognise implicit assumptions and values, and draw reasoned conclusions – needs to be encouraged throughout the organisation. In this respect, formative evaluations are critically important. They provide an opportunity for organisations to examine accepted truths, question the justification for specific claims and call attention to unstated assumptions.

Clearly, organisations need to establish the technical capacity to undertake evaluations successfully. As importantly, to realise the full promise of using evaluations to inform policy, senior managers must actively support the process and cultivate a culture of learning. While evaluations can be required by legislative mandate or outside funders, managers within institutions must be fully committed to using evaluations to help drive their organisations.

Note

1. In the two-stage approach, an initial equation is used to model the selection process. The result of this analysis is then incorporated into a second equation along with other control variables to estimate outcomes. A similar technique known as propensity score matching can also be used to control for selection.

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Chapter 9

Scaling up and sustaining experimental innovation policies with limited resources: Peripheral Schumpeterian development agencies

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This chapter[1] *examines how two historically low-technology economies, Finland and Israel, assumed leadership in new and rapidly evolving innovation-based industries. It argues that "Schumpeterian development agencies", the Finnish Fund for Research and Development and the Israeli Office of the Chief Scientist in the Ministry of Trade and Industry, played a transformative role, by introducing new science and technology policies and facilitating industrial restructuring. However, in contrast to the literature on the developmental state, these agencies were located on the periphery of the public sector and had few hard resources. The chapter describes how their peripheral location facilitated successful experimentation. It also explains how ostensibly marginal agencies were able to scale and monitor new initiatives successfully. More specifically, it shows that reform-oriented policy makers in small states were able to leverage extensive inter-personal networks to facilitate scaling and international openness to ensure monitoring. In identifying the specific mechanisms used by policy makers to introduce, scale and monitor policies, it also shows why these two historically innovative economies have struggled to support experimentation in recent years.*

The statistical data for Israel are supplied by and under the responsibility of the relevant Israeli authorities. The use of such data by the OECD is without prejudice to the status of the Golan Heights, East Jerusalem and Israeli settlements in the West Bank under the terms of international law.

Recent debate over how to promote economic development takes two paths. One school of thought, common in international development organisations, seeks to identify and diffuse "best practice" through universal and invariant programmes designed to promote economic growth. For example, the "Washington consensus" (Williamson, 1990) emphasised the role of macroeconomic stabilisation, private property rights, and domestic and international economic competition for stimulating innovation and growth. This view has been widely applied across a wide range of institutional and economic contexts from Latin American to eastern Europe and East Asia (Sachs, 1993; Wade, 2000; Williamson, 1990). While the Washington consensus has been broadened to incorporate a greater role for government intervention, from financial regulation to social policy and poverty alleviation, this school of thought nonetheless continues to search for, codify and diffuse a specific set of policies across a range of societal and economic contexts (Rodrik, 2007).

An alternative school of thought contends that any efforts to codify best practice are futile, as countries develop in unique and irreproducible ways. The Washington consensus, for example, has proven problematic in at least two respects. First, policy makers rarely implement policies as academics and international sponsors intended, but instead "translate" them into a form that is politically feasible and intuitively appealing to local stakeholders (Kjaer and Pedersen, 2001). Second, even if policy makers directly copied international best practices, these policies might not address context-specific barriers to growth in individual countries (Hausmann et al., 2008). As a result, the literature on successful innovators, such as Denmark, Finland, Ireland, Israel and Chinese Taipei, has identified a range of distinctive, even divergent, policies (Breznitz, 2007a; Lundvall, 2002; O'Riain, 2004; Ornston, 2006). Taken to the extreme, this might suggest that no general lessons are possible: economic development is a result of serendipity, a combination of good governance and the acquisition of qualified managers and public servants.

This tension is most acute at the technological frontier, where firms rely on rapid innovation-based competition, an important source of growth in many late developers (Breznitz, 2007a; Hommen and Edquist, 2008; O'Riain, 2004). This type of competition exemplifies the challenges associated with policy making described above. The rapid introduction of disruptive new standards, technologies and business practices makes it difficult to identify best practice, and traditional industrial policies based on planning have struggled to do so (Breznitz, 2007a; Katz, 1998; O'Riain, 2004). Delegation of these challenges to private-sector actors via market-friendly reform is no less problematic, however, as entrepreneurs are equally uncertain about future products, activities and industries (Breznitz, 2007a; Breznitz and

Zehavi, 2010). For example, entrepreneurs may be unwilling to make risky, long-term investments in product and service development, particularly if they require complementary investments or demand from other actors (Edquist, 1997; Lundvall, 1992). A recent literature suggests that policy makers can respond by relying on "experimentalist" governance, by launching and monitoring a range of developmental initiatives (Breznitz and Zehavi, 2010; Rodrik, 2007; Sabel and Zeitlin, 2010; Schulze-Cleven et al., 2007), but the specific process by which they do so is unclear.

This chapter seeks to illuminate this process by shifting attention from policy programmes to the processes that generate them. It adopts the perspective of a reform-minded policy maker seeking to promote rapid innovation-based growth through a portfolio of developmental projects. To add more empirical substance to this theoretical framework, it examines the experience of reform-minded policy makers in Finland and Israel. Small states are widely perceived to operate at a disadvantage in high-technology markets because they lack the resources and institutions to conduct capital-intensive research and the market size needed to establish industry-defining standards (Dalum, 1992; Katzenstein, 1985; Kristensen and Levinsen, 1983; Lundvall, 2002). However, Finland and Israel have proven remarkably successful in competing in innovation-based industries as diverse as semiconductors, biotechnology, software and telecommunications equipment. While each country leveraged different institutions and instruments to pursue their objectives, they relied on strikingly similar mechanisms to introduce, scale and monitor the portfolios of private-public programmes.

Specifically, this chapter makes two claims. First, it argues that "Schumpeterian development agencies" (SDAs), public organisations with a mandate to facilitate innovation in new industries, played a critical role in precipitating industrial adjustment. In contrast to the literature on the developmental state (Doner et al. 2005; Johnson 1982; O'Riain 2004), these successful SDAs occupied a *peripheral* position in the public sector. Their peripheral position facilitated experimentation by minimising political interference, although it also generated formidable challenges. For example, peripheral agencies possessed few hard resources to scale up successful science, technology and innovation (STI) policies. Furthermore, to the extent that they did successfully scale new projects, this raised their political profile and inhibited their capacity to monitor and adapt these policies.

Consequently, this chapter advances a second claim, explaining how SDAs in small states successfully scaled and monitored portfolios. First, it shows that agencies with limited hard resources were able to leverage close, often informal, ties among elite actors to publicise and implement new programmes. Second, these agencies could rely on international market competition to resist the political and cognitive lock-in that stemmed from both consensual political and social systems and their success (Breznitz and Zehavi, 2010; Schrank and Kurtz, 2005). In other words, this chapter supports the view that, because of their ability to combine internal communication with external vulnerability, small states are particularly well placed to construct and monitor portfolios of private-public projects (Doner et al., 2005; Katzenstein, 1985). In identifying the specific mechanisms by which they do so, the chapter explains why some SDAs may be less innovative than others and why even the most successful SDAs fail to innovate, particularly during good times.

The first section introduces the concept of the Schumpeterian development agency, explaining its importance in introducing experimental STI programmes and the challenges that it faces in scaling and monitoring those policies. The next describes how policy makers in small states have navigated these twin challenges by leveraging their exposure to domestic networks and international competition. This is supported by a review of developments in Finland and Israel. While policy makers relied on agencies and instruments, they also relied on inter-personal networks and international competition to scale and monitor developmental projects. The conclusion discusses how their successes, and failures, yield concrete lessons for policy makers in larger and less developed states. The analysis is based on 215 interviews with policy makers and industry representatives in Israel and Finland during 2000-07.

Schumpeterian development agencies and rapid-innovation-based competition

In each of the countries examined, rapid innovation-based growth can be traced back to Schumpeterian development agencies with an explicit mandate to promote innovation in new industries, such as the Office of the Chief Scientist (OCS) in the Israeli Ministry of Trade and Industry or the Finnish National Fund for Research and Development (Sitra).[2] These agencies evolved to become the institutionalised loci of experimentation, continuously developing and implementing new sets of STI policies that proved to be the kernel of national economic transformation. The programmes were developed as a part of a co-evolutionary process between policy and industry. The ability of these agencies to supply the needed spark to move their rapid innovation-based industries through stages of maturation until they reached success was crucial.

These agencies initially occupied a peripheral position in the political system. Rapid innovation-based industries were marginal, innovation policy was not very salient and the agencies that advanced these objectives possessed limited resources. However, far from constraining experimentation, their peripheral location facilitated innovation for two reasons. First, it generally increased their exposure to new, often radically different, ideas about how to organise political and economic activity. These agencies actively identified and imported new policies from foreign countries and international agencies because they were barred from participating in traditional activities. Second, and just as importantly, their low profile enabled them to introduce, monitor, adapt and abandon new policies with minimal interference from other political and economic actors.

While the Schumpeterian development agency at the periphery of the public sector was thus a seed bed for experimental policy making, reform-oriented agents faced two problems. First, the same lack of resources that insulated Schumpeterian development agencies from political fights limited their capacity to scale projects, even in areas for which scale-up was necessary to affect sectoral or national outcomes meaningfully. For example, the limited ability to offer material incentives made it more difficult to engage the private-sector actors whose participation was central to innovation and growth. The lack of finance also rendered reform-oriented policy makers vulnerable to the risk that other policy makers might fail to support, or even actively undermine, new initiatives.

Second, to the extent that the reform-oriented policy maker could scale new initiatives, success could impair their capacity to monitor, adapt and terminate established programmes or introduce new ones. Successful projects generate powerful constituencies that resist efforts to criticise, modify or eliminate programmes. Meanwhile, as the agency increased in political salience and acquired more resources it was likely to become a target of political infighting. Policy makers were thus involved in a continual process of institutional "dis-entrenchment" in their efforts to modify or terminate ineffective policies. This was in many ways inversely related to their success and centrality in the public sector. Successful policy implementation and economic growth could thus generate cognitive and political barriers to successful experimentation and adjustment.

Schumpeterian development agencies in small states

In order to understand how Schumpeterian development agencies in smaller states successfully managed this dilemma, it is important to understand how they differ from their larger counterparts. First, they have smaller and more cohesive inter-elite networks. Repeated interaction among elites is most visible in the so-called small, neo-corporatist economies of western Europe that rely on formal, centralised bargaining by organised industry and labour associations or functionally equivalent units such as the banking bloc (Katzenstein, 1984; 1985). However, this focus on formal institutions obscures the extent to which elites in corporatist and non-corporatist countries can rely on informal institutions such as common educational background, military service, public service, corporate boards and private clubs to create a similar environment (Breznitz, 2005a; Breznitz and Zehavi, 2010; Moen and Lilja, 2005; Ornston, 2006). In both cases, repeated interaction ensures that policy makers, industry representatives and other key decision makers are more likely to know and trust one another, and this enhances communication among public- and private-sector actors.

These dense networks enabled SDAs with a small amount of financing and little political clout to scale a multitude of experimental innovation policies quickly. Reform-oriented agents were able to use their networks to co-ordinate activity with other policy makers as well as private-sector actors, and, more specifically, to convince firms to share information, commit resources, and co-operate with public-sector initiatives and with each other. They were also able to address more effectively shirking, cheating or other forms of non-compliance in order to construct broad projects that spanned the private and public sectors (Breznitz, 2007a; Breznitz and Zehavi, 2010).

At the same time, cohesive, inter-elite networks created several problems. Consensual political and social systems were difficult to penetrate, particularly for peripheral actors such as the SDAs mentioned above. To the extent that they did so, the same cohesive networks and social capital that enabled them to scale projects prevented them from killing projects that proved inefficient. Consensus building could blind policy makers to the disadvantages associated with new programmes, while programme beneficiaries could rely on dense, inter-personal networks to block reform. Luckily, reform-oriented policy makers were able to leverage a second characteristic of small states—their greater dependence on international markets—to monitor and adapt portfolios (Campbell and Hall, 2009; Katzenstein, 1985; Kristensen and Levinsen, 1983).

International openness facilitated monitoring in several ways. First, it enabled reform-oriented agents to identify and modify or terminate failing projects more quickly. For example, with leading international MNCs and financiers as partners and customers, domestic projects were subject to external evaluation of the highest standards (Breznitz and Zehavi, 2010). Second, policy makers could more easily adapt and terminate programmes, as they lacked the fiscal resources to support loss-making enterprises and industries (Katzenstein, 1985). Finally, international organisations such as the World Trade Organisation (WTO) and the European Union (EU) generated pressure to abandon infant industry programmes as industries matured, even if the programmes were not generating significant losses (Schrank and Kurtz, 2005).

The next sections examine the histories of two very different, ideal-type small states with transformative Schumpeterian development agencies—Finland and Israel—as a theoretical exercise in framework building and elaboration. The aim is to attempt to define mechanisms and processes which can lead to coherent policy implications and be tested in future studies using a larger, more varied, sample. While Finland and Israel relied on different economic institutions and policy instruments to promote rapid innovation-based competition, they relied on strikingly similar processes to scale and monitor those policies. In both cases, new STI policies emerged at the periphery of the public sector, in SDAs that relied on interpersonal networks to introduce and scale radical new initiatives. Economic openness played an equally critical role, both in delegitimising traditional industrial policies and encouraging policy makers to adapt new STI policies. At the same time, as these economies grew and their SDAs enjoyed a higher political profile, they struggled to retain the experimental capacity of earlier decades.

Constructing a portfolio of high-technology research projects in Finland

This section explores how Finland, one of the least research-intensive OECD economies, with low-technology, forest-based products accounting for over half of the country's exports, became a global leader in wireless communications and knowledge-intensive production. New innovation policies played an important facilitating role in stimulating private-sector research and industrial diversification. This section describes how these policies were introduced and implemented within the confines of a highly consensual, historically low-technology economy. It focuses on Sitra, an independent Schumpeterian public agency. It first documents Sitra's peripheral position in the Finnish political system and explains how this helped it to introduce experimental innovation policies. Next, it shows how Sitra compensated for limited hard resources by leveraging social networks, which enabled it to scale new programmes with remarkable speed. It then describes how reform-oriented policy makers relied on economic openness to monitor and adapt established policies and introduce new ones before discussing how Sitra's and Finland's success have inhibited innovation in recent decades.

Establishing a Schumpeterian development agency during the 1970s

As recently as 1980, pulp, paper and related forest-based products accounted for over half of the country's exports (Koski and Ylä-Anttila, 2006) and research and development (R&D) as a share of gross domestic product (GDP) stood at 1.16% (Eurostat, 2010). Private-sector and public institutions reinforced Finnish reliance on established, resource-extractive, low-technology industries. For example, the four large banking groups that monopolised Finnish finance redistributed capital to established pulp and paper firms. The Bank of Finland reinforced investment in capital-intensive, resource-extractive industries by relying on policies such as credit rationing and periodic currency devaluations (Lilja and Tainio, 1996). The latter restored competitiveness in forest and mining companies, but increased costs in import-sensitive industries such as electronics. While public agencies used industrial policies to promote diversification during the 1970s, they did so by establishing state-owned enterprises. These initiatives succeeded in mature, capital-intensive manufacturing industries such as steel and chemicals, but faltered in new, high-technology industries (Sabel and Saxenian, 2008). Public support for industrial research, by contrast, remained limited until the 1970s. While policy makers had subsidised research as early as the 1920s, funding was modest and revolved mainly around academic institutions, such as the Academy of Finland. Technology policy or industry-oriented support was not treated as an independent budgetary item within the Ministry of Trade and Industry until 1967 (Murto et al., 2006). Institutional innovation instead occurred at the periphery of the Finnish public sector with the establishment of Sitra, the Finnish National Fund for Research and Development. It was formed in 1968 to celebrate the Finnish parliament's 50th anniversary. Klaus Waris, the governor of the Bank of Finland who lobbied for Sitra and served as its first president, envisioned that Sitra could use the interest from its EUR 145 million endowment to increase productivity and accelerate industrial restructuring. Waris sought to promote private-sector enterprise as an alternative to increasing reliance on socialist or collective instruments such as bank-based finance, planning and bilateral trade with the Soviet Union (Murto et al., 2006). Sitra did so by co-financing research by private firms. Consistent with its mandate to promote productivity and restructuring more generally, it also launched the first of many surveys to assess the international competitiveness of Finnish industry in 1969 and administered courses on economic policy (initially to integrate Communist politicians and trade union representatives) during the 1980s (Rehn, 1996).

Sitra's peripheral position in the Finnish political and economic system gave it more latitude to introduce new innovation policies. Like Nokia in the private sector, Sitra entered research because the Ministry of Trade and Industry and the Bank of Finland had monopolised traditional instruments such as nationalisation, investment grants and credit rationing. Sitra's research budget was small enough not to threaten political incumbents, such as the Ministry of Trade and Industry, or attract the attention of large established forestry firms. Pulp and paper companies were in fact conspicuously underrepresented in the initial round of funding. Grants were disproportionately distributed to electronics and engineering firms, such as KONE, Vaisala, Airan and Perlos. Nokia was one of the earliest beneficiaries and received EUR 1 million from Sitra's initial budget of EUR 18.1 million (Murto et al., 2006). At the same time, Sitra's impact on the Finnish economy as a whole remained modest. While it increased support for R&D by 50% over previous levels (Murto et al., 2006), public investment in research played a limited role during the 1970s, outweighed by credit rationing, industrial subsidies, nationalisation and other instruments. Instead Sitra, and reform-oriented policy makers more generally, used formal and informal social networks to scale the new innovation-based policies.

Using neo-corporatist and social networks to scale technology policies during the 1980s

Institutional innovation in Finland was precipitated by the country's heavy reliance on foreign markets. In particular, the OPEC-induced oil crises of the 1970s forced policy makers and private-sector actors to adapt their industrial policy instruments, as the crisis directly threatened energy-intensive, resource-based industries such as forestry. While Finland avoided the worst of the crisis, it did so by relying on bilateral trade with the Soviet Union. Increasing dependence on the Soviet Union was perceived as a geopolitical threat and sparked interest in diversification away from traditional, resource-extractive industries. Yet, it was increasingly apparent that traditional industrial policies would not accomplish this. The failure of state-owned enterprises in telecommunications and television discredited nationalisation, and a related corruption scandal placed great pressure on politicians to dissociate themselves from traditional policy instruments (Rehn, 1996). International openness therefore created an opportunity to expand hitherto peripheral technology policies.

Finnish policy makers responded with remarkable speed. In 1983, politicians, consulting with leading industry associations, agreed to expand Sitra's research programme dramatically by establishing a new agency, Tekes, the Finnish Funding Agency for Technology and Innovation. This represented a significant commitment to commercial research. The agency's initial budget quadrupled Sitra's expenditure and rose sharply in subsequent years (Murto et al., 1996). By 2000, public-sector research (government and university) had climbed from 0.60% of GDP to 0.95% of GDP, the highest in the EU. The increase in public-sector research expenditure is particularly impressive because it stimulated even greater effort by private-sector enterprises. Total expenditure on R&D increased from 1.17% of GDP in 1980 to 3.35% of GDP by 2000, trailing only Sweden and Israel (Eurostat, 2010). Finland's capacity to scale new technology policies rapidly and successfully over the course of the 1980s was remarkable. Increased research expenditure in turn enabled firms, notably Nokia, to capitalise on favourable opportunities in new high-technology markets such as digital mobile communications (interview with former Nokia research director on 8 November 2005).

Finland was able to do this because reform-oriented policy makers could use non-market networks to diffuse new ideas about R&D. This was most evident in the case of formal neo-corporatist institutions, which organised industry and labour into hierarchical associations. The bipartite Science Policy Council (subsequently expanded into a tripartite Science and Technology Policy Council) emerged as an important instrument for prioritising technology policy, linking ministers from the departments of education and industry to leading societal representatives and the prime minister. The Council prioritised investment in R&D (most notably during the recession of the early 1990s) and co-ordinated activities among various policy makers (Murto et al., 2006).

While consensus building was most visible within neo-corporatist structures, informal institutions were just as important. For example, Sitra’s courses on economic policy became an important instrument for educating policy makers, corporate executives, trade union leaders and journalists about the importance of innovation and related inputs, such as R&D (Moen and Lilja, 2005). Collectively, these measures forged a consensus on R&D that transcended traditional partisan divisions. One politician who presided over a significant increase in R&D expenditure surprisingly declined to take credit for what other interviewees characterised as a “heroic” decision noting, “all parties of the right, conservatives, liberals, the centre party and at least social democrats, maybe even Communists of that time were able to support that policy orientation. There was even competition [for the] most favourable political movement” (interview with a former member of parliament, 10 October 2005).

The same formal and informal social networks that enabled reform-oriented policy makers to persuade and co-ordinate activity among their peers also explain Finland’s capacity to engage private-sector actors. Industry was well represented within the Council and Tekes (interview with the former director general of Tekes, 1 November 2005). Industry representatives could rely on dense organisational structures to diffuse ideas about the importance of research to their members. For example, Kari Kairamo, CEO of Nokia during the 1980s, used his position as chairman of the Confederation of Finnish Industry to mobilise support for new technology policies (Moen and Lilja, 2005). Membership in informal clubs was just as important, with Kairamo using a weekly roundtable to persuade like-minded industrialists as well as fellow elites within the rural Center Party (interview with roundtable participant, 20 October 2006).

As a result, corporate representatives suggest that the courses and high-level dialogue on innovation policy more generally strengthened technology officers relative to top management.[3] In the words of a research director at a foreign subsidiary that used funding at the height of the dotcom downturn to support an ongoing project, "in all companies, these kinds of investments are so big and they are constantly monitored by management and can even be stopped, you can only afford them here and there … I think [credibility] was quite important" (interview with electronics firm research director, 19 October 2005). It also pressured firms to participate actively in new technology programmes and to commit resources to avoid being ostracised by their professional networks. In the words of the research director quoted above, "you know each other relatively well and it is such that people have to perform. Your peers are watching and your reputation is on the line" (interview, 19 October 2005).

Adapting innovation policy portfolios during the 1990s

If social networks enabled Finnish elites to implement new research policies and, by extension, facilitated movement into risky and expensive new industries such as mobile communications, those same networks created political and cognitive barriers to effective monitoring. Economic openness proved critical in enabling reform-oriented policy makers to adapt new innovation policies, to identify unprofitable projects effectively, and to surmount political resistance. Indeed, they consciously exploited Finland's status as a small, open economy when designing research policies. During the 1980s, research grants focused on export-oriented manufacturing firms, whose performance on international markets was relatively easy to measure and provided a more accurate picture of their commercial potential (interview with Tekes programme director, 28 November 2006).

Vulnerability to external economic and political developments enhanced the efficacy of these design features. The economic crisis of the early 1990s accelerated institutional innovation and hastened the demise of traditional industrial policies, as it was not feasible for a small open economy to bail out uncompetitive enterprises.[4] The near-collapse of the Finnish financial system also exposed weaknesses in Finland's industrial structure, most notably its reliance on large firms in both old (UPM-Kymmene) and new (Nokia) industries. The technology policies of the 1980s, which revolved around large, established firms, did little to alleviate the lack of funding. They also violated new EU restrictions on state aid. Consequently, Tekes was pressured to adapt established technology policies, to reorient funding away from large companies, and to require them to collaborate with small and medium-sized enterprises (SMEs) (interview with Tekes programme director, 27 November 2006).

In addition to adapting established policies to resolve funding deficits among SMEs, policy makers also adapted policies in other ways. Finland was one of the first countries to adopt, in a 1990 Science and Technology Policy Council Report, the concept of a national innovation system that co-ordinated activity across multiple ministries and agencies (STPC, 1990). Policy makers also introduced novel instruments explicitly targeted at new, growth-oriented enterprises; this dramatically expanded the supply of early-stage risk capital (Luukkonen, 2006). Like the technology policies described above, risk capital initiatives originated at the periphery of the Finnish political system. The Finnish venture capital market can be traced to the establishment of Tekes and the subsequent marginalisation of Sitra in the area of research financing. With more than four times Sitra's budget (Murto et al., 2006), Tekes effectively forced Sitra out of R&D (interview with former Finnish Venture Capital Association president on 22 November 2006).[5] Sitra's inability to protect its territory, however, encouraged it to assume a new and revolutionary role in the peripheral field of early-stage risk capital.

Sitra's shift to early-stage risk capital began as early as the 1970s. As the Ministry of Trade and Industry increased research financing for large enterprises, Sitra focused on the small firms which the Ministry neglected (Murto et al., 2006). The creation of Tekes accelerated this shift, prompting Sitra managers to convert soft loans into equity stakes and invest in venture capital funds. Sitra also co-invested with foreign venture capital (VC) funds both in Finland and abroad to enhance its monitoring capacity (interview with former Finnish Venture Capital Association president, 22 November 2006). Like the technology policies of the 1980s, Finnish investment in early stage risk capital emerged at the periphery rather than the centre of the public sector.

When the financial crisis of the early 1990s exposed the limitations of traditional industrial policies, Sitra relied on its social networks to scale its modest investments in early-stage risk capital markets. For example, it established an industry association for the venture capital industry to lobby the Ministry of Trade and Industry more effectively (interview with former Finnish Venture Capital Association president, 22 November 2006). Partly as a result of such efforts, Kera, a regional development agency, launched the first dedicated public venture capital fund, Start Fund of Kera, in 1991 and parliament established an even larger fund, Finnish Industry Investment (FII), in 1996. Meanwhile, the professional association established by Sitra worked with the Ministry of Trade and Industry and other stakeholders to lobby private-sector investments such as pension funds and insurance companies to increase their allocation to early-stage risk capital markets (interview with venture capital director, 20 November 2006), to the point where they represented over half of all funds raised by the industry (Luukkonen, 2006).

Collectively, these developments increased investment in early-stage risk capital markets from EUR 19 million in 1991 to EUR 397 million by 1999 to take third place in the European Union when adjusted for GDP (Eurostat, 2010; Luukkonen, 2006). Increased funding for small, growth-oriented enterprises facilitated industrial growth and diversification. For example, Nokia relied on Tekes-brokered networks to identify and engage suppliers, most notably in the field of software (interview with Nokia executive, 24 November 2006). Suppliers such as Elcoteq used risk capital from Finnish Industry Investment and private-sector investors to internationalise alongside Nokia (Ali-Yrkkö, 2003). At the same time, not all new, growth-oriented enterprises were equally successful.

Flexible adjustment reconsidered: contemporary challenges

While Finland demonstrated formidable capacities to adapt established policy instruments and introduce new ones, Finnish innovation policies were not an unqualified success. On the contrary, the dotcom crash at the turn of the century exposed significant weaknesses. While its macroeconomic impact was limited, the economic downturn revealed that public- and private-sector investments were not particularly profitable. Fund-raising plummeted from EUR 492 million in 2001 to EUR 295 million by 2003 (Luukkonen, 2006) and was slow to recover in subsequent years (Eurostat, 2010). More importantly, the crash demonstrated that policy makers had neglected soft skills such as management and marketing that were critical for commercialisation (Leiponen, 2004; Luukkonen, 2006; Maula and Murray, 2003). The dotcom crash thus precipitated another significant reorientation of Finnish innovation policy.

Like the venture capital initiatives described above, diversification reflected Sitra's efforts to find a new role in an increasingly crowded policy domain. As public actors such as FII and privately managed VC funds assumed a more prominent role in the Finnish VC market at the end of the 1990s, Sitra sold its holdings to private investors and reduced its fund of funds activity. In their place, it launched a range of initiatives to promote interaction among suppliers, producers, consumers and citizens. For example, it launched a mentoring service to link new, growth-oriented enterprises to established firms (Luukkonen, 2006), initiatives in health care and food processing to connect established firms with end users, and internationally oriented programmes that linked Finnish firms to suppliers and consumers in countries such as China and India (interview with Sitra programme director, 27 November 2006).

These new initiatives received high-level attention in the wake of the dotcom crash.[6] As a result, the last decade has seen efforts to introduce a variety of non-technological initiatives. Tekes has devoted increasing attention to demand-side innovation (Nikulainen and Tahvanainen, 2008), the Confederation of Finnish Industry has launched a programme to facilitate the internationalisation of small and medium-sized suppliers (interview with the executive director of Technology Industries of Finland Association, 9 November 2006), and Finland has launched a high-level "rebranding" committee (Rantanen and Raeste, 2010). Finland's status as a small state has thus contributed to its capacity to monitor, adapt and expand its portfolio of private-public projects to promote innovation.

At the time, the crisis illuminated some fundamental challenges. First, Sitra's increasing salience in the Finnish innovation system and public sector made it more difficult to introduce experimental new policies. Partly as a result of the increasing co-ordination of the Finnish innovation system, Sitra's VC investments during the 1990s were closely linked to Tekes' technology policies. In fact, virtually every recipient of Sitra funding received a Tekes grant (Hyytinen and Väänänen, 2003). As a result, it is not surprising that investments in early-stage risk capital proved problematic, as co-ordination effectively reinforced dependence on established R&D policies.

This increasing dependence on specific policy instruments extends to individual industries and firms as well. For example, Nokia used Tekes-brokered networks to identify (and some entrepreneurs suggest to poach) promising individuals and ideas. One venture capitalist, commenting on his inability to retain talent noted, "Nokia has been a big tree in the electronic industry, [which] shadows and kills almost everything … For example, we were investing in one [firm] and we had 17 people up in northern Finland and one year Nokia hired from that company seven people, more than one-third of the company. And think about a small start-up company!" (interview with venture capital manager, 20 November 2005)

Finally, while policy makers have introduced new policies, initiatives remain modest in size and scope. New experiments are considerably smaller than the ambitious technology and venture capital initiatives of the 1980s and 1990s. Furthermore, Finland has devoted comparatively less attention to policy domains, such as continuing education or the aggressive recruitment of foreign direct investment that stimulated innovation in countries such as Denmark (Lundvall, 2002) or Israel (Breznitz, 2007a). While more radical reforms remain possible, this analysis suggests that an increasingly high-profile Sitra is less capable of spearheading such efforts and the modest reforms that it has introduced are unlikely to be scaled until Finland experiences a more severe economic shock.

Israel's ICT evolution

Today Israel is considered an information and communication technology (ICT) powerhouse, with more companies listed on the National Association of Securities Dealers Automated Quotations (NASDAQ) market than any other country except the United States. The Israeli ICT industry is based on an R&D-intensive novel-product-based, export-oriented business model. Elscient, a medical imaging company, was listed on the NASDAQ as early as 1972. This early move, three years after its founding and less than two years after it produced its first medical imaging device, symbolises the very different development path of the Israeli IT (information technology) industry from that of other emerging countries.[7] This impressive record raises a question: how did Israel, a country that as late as 1965 had one of the world's lowest (less than 1%) industrial R&D expenditures as a percentage of GDP develop such an R&D-intensive ICT industry and become a global leader in R&D expenditure at 4% of GDP by the late 1990s, surpassing even Finland? (Katchalski, 1968)

This section follows the co-evolution of Israel's industrial science and technology policies to show the critical role played by a Schumpeterian development agency, the Office of the Chief Scientist in the Ministry of Trade Industry and Employment (OCS). It attempts to analyse how, with very limited resources, it managed to play such a critical role in industrial transformation and to understand its inability to produce much change in the last decade.

The beginning of the industry and the creation of Israel's science and technology (S&T) Schumpeterian development agency

As in Finland, most financial institutions in Israel in the period from the creation of the state to the mid-1990s were unwilling to sponsor new technology-based firms (NTBF). However, there was one critical exception. At the beginning of the 1960s, the Discount Bank investment group (now known as Discount Investment) was joined by Dan Tolkowsky, former commander of the Israeli Air Force. In 1961, he met Uzia Galil, the founder of the Elron group, and throughout the 1960s and 1970s, the Elron group and Discount were the main source of high-technology companies in Israel. Elron, Elbit and Elscient, which all had an initial public offering (IPO) on NASDAQ, were created through this partnership.

Tolkowsky was also crucial at another juncture for the Israeli IT industry. By the end of the 1960s, he realised that Israeli industry needed experienced venture capitalists with larger funds than Discount could muster. In 1971, he decided to fly to the United States to persuade the young VC industry to invest in Israel. He met Fred Adler of New York, a prominent venture capitalist at the time, who was involved in applied materials and data systems. Adler visited Israel and became involved with Elscient. Realising it was futile to raise VC financing in the United States, Adler decided to circumvent the process by bypassing the VC stage and raise money through an IPO. He assumed that after several successful IPOs the Israeli industry would look more inviting to American investors and the VC problem would be solved. Little did he know that he had established a process that would become the *modus operandi* of the Israeli IT industry until the late 1990s.

Another critical point was reached in 1968. As in Finland, experimentation was precipitated by geopolitical vulnerability and dependence on foreign countries. In Israel, a French military embargo led policy makers to channel large investments and R&D to military high-technology. Similar changes followed in civilian industrial R&D policy. The most important was the establishment of the Office of the Chief Scientist in the Ministry of Trade and Industry.

The OCS's first action was to define its objective as maximising industrial R&D by fixing market failures, without targeting specific sectors or technologies. This led the OCS to embark on a long series of horizontal technology policies (HTP).[8] The first programme, which continues to this day under the name "the main R&D fund", provides conditionally repayable loans of 50% of the cost of any approved industrial R&D project originating from the private industry and aimed at developing a new exportable product. The loan is repayable, in the form of "royalties" only if the R&D project ends with a profitable product.[9] Interestingly, the decision to opt for conditionally repayable loans, given the export-oriented product development projects, became useful in providing the OCS with external foreign-market validation of its screening criteria and an incentive to monitor closely the progress of the companies it sponsored. These repayments have become an increasing share of the OCS annual operating budget, reaching 20% during the 2000s.

Many of the earlier employees of the OCS viewed its actions in terms of an R&D-based development ideology. Like Sitra, OCS hoped to encourage industrial transformation by educating and mobilising social and collective action. It did so through intensive and repeated meetings with private-sector decision makers, educating them about the value of R&D and infusing them with enthusiasm for technological innovation. One of the first employees of the OCS described the early years:

> During the early period we tried to create a dynamic of R&D activities, we wanted the industry to routinely conduct R&D and to create a dynamic that will infuse the idea that R&D is something that

> should be done throughout the industry. To create a sort of paradigmatic change in the way businesses thought about what they are doing. Nobody in the industry even thought about R&D at the time, it seemed to them as a horrible risk, so Yaakov [the first chief scientist] just started going around the country trying to convince managers to conduct R&D. We did not really care who, what, why, when; we just wanted to create an R&D dynamic. (Interview with OCS employee, 2 May 2002)

The OCS was soon joined by another agency placed under its jurisdiction, the United States-Israel Binational Industrial Research and Development Foundation (BIRD). BIRD was approved in 1975 and began fostering and financing co-operation between Israeli and US companies. It funded projects for which the R&D was done in Israel and the marketing in the United States. BIRD became crucial not only for sponsoring and helping Israeli NTBFs, but also as an organisation that ensured NTBFs a critical window into their main market, the United States. BIRD became vital in the latter part of this period and throughout the 1980s and 1990s, enticing American multinational corporations (MNCs) to open R&D subsidiaries in Israel.

In so doing, BIRD supplied the Israeli Schumpeterian development agency with extremely high-level foreign monitoring and validation services. The MNCs, by screening and monitoring their investments, acted as "external" high-quality project evaluators. In addition, since the Israeli financial sector was unwilling to finance high-technology companies, the influence of the specific structure of the OCS and BIRD programmes on the organisational development of NTBFs in Israel was crucial. Throughout the 1970s and 1980s a significant percentage of the financial and management resources available to entrepreneurs could be accessed only with a business model based on R&D-intensive product development and American-controlled distribution channels. Consequently, the financial resources of the OCS and BIRD were so limited that the first Chief Scientist commented in an interview that:

> Haim Bar Lev was Minister of Industry and Commerce, and he asked me to be chief scientist after I retired as the head of R&D for the military. It was very easy for me to get into this job since I already knew what existed in Israel, I ha[d] already sponsored every technology company in Israel during my role as the military R&D chief and I can say there were not many of them. When I entered the office they told me the budget was unlimited, but I soon discovered that the scope of research and development was very limited. If in my military role I played with a budget of about USD 500 million, in the industry it was less than USD 10 million and the state treated it very cautiously. This had a few reasons, most importantly was that

> nearly everyone in the Ministry did not understand what is it that they were supposed to be doing. Most of the Ministry personnel thought that industrial R&D is a waste of money. (Interview with Itzhak Yaakov, 9 December 2000)

Nonetheless, this quote also attests to the tight long-term relationships which Yaakov could mobilise to kick start what the OCS team viewed as a paradigmatic shift in industry. Not only was Yaakov for many years the head of the military R&D apparatus, but his first minister, Bar Lev, was a former Israel Defense Force chief of staff, and Efraim Katchalski (Katzir), the head of the Katchalski committee that institutionalised the OCS, who had just been elected the President, was a renowned scientist, one of the pioneers of the Israeli defense industry and one of Yaakov's closest mentors.

While the seeds of the Israeli ICT industry had been planted and some hardware companies had achieved worldwide success in the late 1960s and early 1970s, the software industry was practically non-existent. However, the rapid expansion of defense R&D, and the fast accumulation of ICT skills, by both university graduates and graduates of the military technological units, created local demand for ICT usage, the knowledge base to supply it, and a positive attitude toward this nascent industry.[10] As venture capital was not available for the industry, the business model of many companies was either a joint venture with an established company which acted as the financial backer or the main customer, or to find their first customer before the development phase. Some developed from an ICT consultancy business, but few of these successfully shifted to a product-based business model. In addition, these companies could not secure enough capital to open an American branch, so their first export market tended to be Europe.

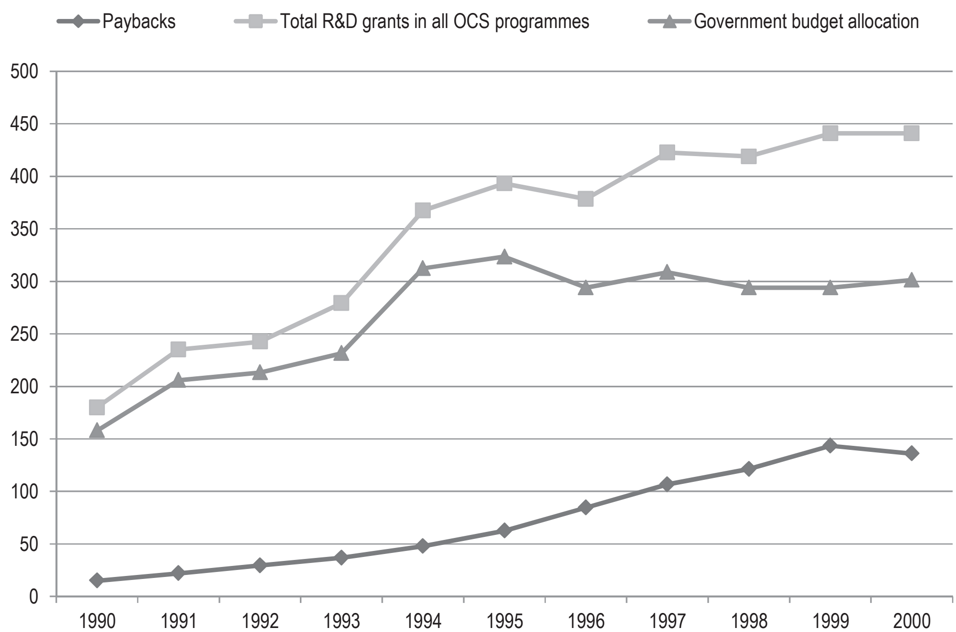
Economic crisis and the rise to prominence of STI policy and the ICT industry

In the 1980s, and more rapidly in the 1990s, another transformation became apparent: the high-technology industry grew while traditional and mixed industries and agriculture lost ground. By 1988, 59% of Israel's industrial exports were high-technology products, and by 1998 they represented over 71%. This trend was maintained: as early as 2000, according to Israel's Central Bureau of Statistics, the IT industry accounted for over 70% of GDP growth (2001).

The economic crisis of the 1970s and the growing military alliance with the United States after the 1973 war meant that the economic ability of Israel to develop full-scale weapons platforms as well as the need for them diminished. Starting in the mid-1980s, there were major downsizing initiatives in the defense industry. For the private IT industry, these decisions proved to be a boon: the defense industries let go a few thousand highly trained and experienced engineers. Many received redundancy packages that enabled them to dedicate their time and money to entrepreneurial activities.

Figure 9.1. OCS total grants and repayments, 1990-99

Year 2000 USD millions



Note: Paybacks are the total amount the OCS injects back into the budget from the royalties gained on past grants; government budget allocation is the total sum of approved annual budget allocation to the OCS from the Ministry of Finance.

Source: OCS (2012), *Summary of Operations 2011*, Office of the Chief Scientist, Ministry of Trade, Industry and Employment, Jerusalem.

But the most crucial decision of these years was the enactment of the R&D law in 1984, which significantly strengthened the OCS. One of the main provisions of the new law was that the OCS would have an unlimited annual budget for its main R&D fund, so that all approved projects to develop high-technology products suggested by private industry would be supported. This was possible because overall demand for R&D funding in Israel was relatively small. However, in the wake of the exceptional growth in the number of grants, a budgetary limit was reintroduced in the 1990s. Many of these projects were successful in international markets, as evidenced by the rising amount recouped by the OCS: from a mere USD 8 million in 1988 to USD 139 million in 1999 (Figure 9.1). These repayments were immediately injected into industry, and the growth cycle continued until the mid-1990s. The influence of the extended activities of the OCS on industrial sector innovative outputs is well documented (Trajtenberg, 2000; Trajtenberg, 2001).

During this period OCS grants proved to be critical in the decision by founders of key companies to establish their companies in Israel. Two prominent examples are Comverse and Mercury Interactive. Comverse began in 1982. Kobi Alexander, an Israeli native, was working as an investment banker for Shearson Loeb Rhodes (now Salomon Smith Barney) in New York, when he met engineer Boaz Misholi, also an Israeli native. Misholi had an idea for developing centralised voice and fax messaging hardware systems to enable big organisations and telecommunication service providers to offer voice and fax mail to their customers. The two returned to Israel, where they knew they could apply for OCS grants, and established Efrat Future Technology. In 1984, they returned to New York and established Comverse, which became the parent company of the Israeli Efrat. Like many Israeli companies, Comverse went public on NASDAQ in 1986 and used its IPO as a final round of VC. While full details of the support granted to Comverse through the various OCS and BIRD programmes are not public, Comverse companies were awarded at least 69 R&D grants for different projects through the main OCS programme between 1990 and 2000.

Aryeh Finegold, an Israeli native who was the founder and manager of Daisy, a 1980s high-flying Silicon Valley firm, founded Mercury Interactive, with a group of former Daisy executives led by Amnon Landan. The group approached Finegold and convinced him to join them in establishing a new company whose main product would be a software-debugging tool. The group decided that, although well connected in Silicon Valley, they would establish Mercury with the help of OCS grants in Israel. Mercury went public in 1993, started to acquire other companies in 1995, and with the growing importance of the Internet, changed its main product line from software debugging to testing and analysing the performance of enterprise and web-based applications. By the time it was purchased by Hewlett Packard, Mercury was Israel's third-largest software company in terms of sales. While full reports are not public, Mercury was awarded at least 14 grants for different projects through OCS's main programme between 1990 and 2000.[11]

In summary, the late 1980s and the first three years of the 1990s saw a surge in both the number of new ICT companies and the number of veteran companies that successfully started to sell their products worldwide. OCS's grants became more numerous and larger, and the Israeli ICT industry was producing companies on the technological cutting edge. Moreover, the early

1990s saw the first Israeli software IPOs on NASDAQ. However, two important ingredients were still missing for the Israeli ICT industry to reach its full potential: 1) large-scale professional venture financing, especially at the seed, and the early sales and distribution stages; and 2) business and management knowledge and information. While the knowledge of how to do business, and especially how to interact with American financial markets, was accessible to some in the Israeli industry, it was limited to the few firms that had been successful, and there was no systematic sharing and dissemination of that knowledge.[12]

Rapid growth: The maturation of the Israeli ICT industry and the adaptation of STI policy

The year 1989 marks the beginning of the rapid international growth of the Israeli ICT industry. The USSR’s democratisation and break-up process led to the last large wave of immigration to Israel, by Jews who had previously been unable to emigrate. This wave was seen as bringing the best and the brightest technologically educated workforce from the USSR, and together with the thousands of engineers made redundant by the defense industry, the question of how to tap this body of knowledge topped the political agenda.

While the convergence of the two events was a historical accident, by then the OCS’s two decades of patiently developing and introducing policies using an HTP framework had influenced the shape of Israel’s S&T policies (Dosi, 1982). In an almost ideal example of science and technology policies based on increasingly more sophisticated waves of HTPs, the OCS initiated and implemented three new programmes with a specific goal: enhancement of the creation, survival, success rates and R&D capabilities of firms.[13] However, each of these programmes was tailored to a different stage in the NTBF life cycle: creation, growth and gaining a long-term sustainable competitive advantage. Interestingly, while the three programmes, the Technological Incubators, Yozma and MAGNET, started operation between 1992 and 1995, they were planned and approved in 1991, the year seen as the high point of the political window of opportunity opened by the massive wave of immigration, which also marked the end of the period in which industrial innovation policies were seen as politically peripheral.

When the OCS initiated the Technological Incubators Programme in 1991, it was presented as a solution to two problems. First, there was the inexperience and inability of many technically oriented or scientific entrepreneurs to become successful commercial entrepreneurs and find very early-stage financing for their ideas. In short, the programme aimed to remedy the lack of management skills and resource problems faced by first-time technological entrepreneurs. The second problem was to assist the technologically skilled Russian immigrants in finding jobs and integrating into a capitalist society. The idea was to open a network of technological incubators to help entrepreneurs in the very early stage of transforming an immature idea into a commercial reality and give them space, financial support, and professional business and management help. As for other OCS programmes, incubation proposals have to come from the market.[14]

Before 1990, ten Israeli firms were listed on NASDAQ. In 1991, three companies engaged in IPOs, and in 1992 there were another nine. Moreover, unlike the low valuation IPOs of the past, some of these resulted in a market capitalisation large enough to allow a respectable exit for an American VC. Under these new conditions, and having learned from the failure of an earlier attempt by the Ministry of Finance to trade a venture capital company called Inbal on the Tel Aviv Stock Exchange, in 1992 the OCS initiated Yozma, a programme to create a vibrant VC industry in Israel. The aim was twofold: to increase the amount of venture capital available to Israeli firms, especially in their expansion phases, and to inject systematic knowledge of the American financial and product markets in the Israeli high-technology industry.

This time, the OCS decided that the necessary skills and knowledge did not exist in Israel, and to succeed there, the VC industry needed strong networks with foreign financial markets rather than the Tel Aviv Stock exchange. As a result, Yozma was created as a government VC fund of USD 100 million, with two functions. The first was to invest USD 8 million in ten private limited partnership venture funds, which would represent 40% or less of the total capital, the rest to be provided by other private limited partners. To get the financing, the funds' managers had to secure investment and partnership from at least one local and one established foreign financial institution.[15]

Yozma was highly successful and became a model for VC-aimed policy worldwide (with mostly limited success). The establishment of the 11 Yozma funds, the growing success of Israeli companies on NASDAQ, the many high-quality Israeli NTBFs looking for capital, and the rapid growth in the demand for IT and the related financial boom resulted in excellent returns for the Yozma funds and a rapid investment of capital into the Israeli VC industry. Today the Israeli VC industry consists of over 70 funds, with many top US and global funds with operations in Israel. It is considered the most advanced and sophisticated in the world (Avnimelech and Teubal, 2003a, 2003b, 2004; Ber, 2002; Breznitz, 2007a; Breznitz and Zehavi, 2010; EI, 2000; Giza, 2000; IVA, 1997-2006).

VC is only one way for a state to induce the growth of IT industries. Moreover, VC policies are given more credit for their influence on economic development than they actually have. However, in Israel, not only has Yozma been an unmitigated success in securing its own goals, but for better or worse, the subsequent growth of the VC industry completely transformed the Israeli software industry by ever more intimately connecting it, and its future, to US financial markets. The success of Israeli companies in the United States in the 1990s, and the growth of the local US-funded VC industry, transformed the industry's institutional environment.

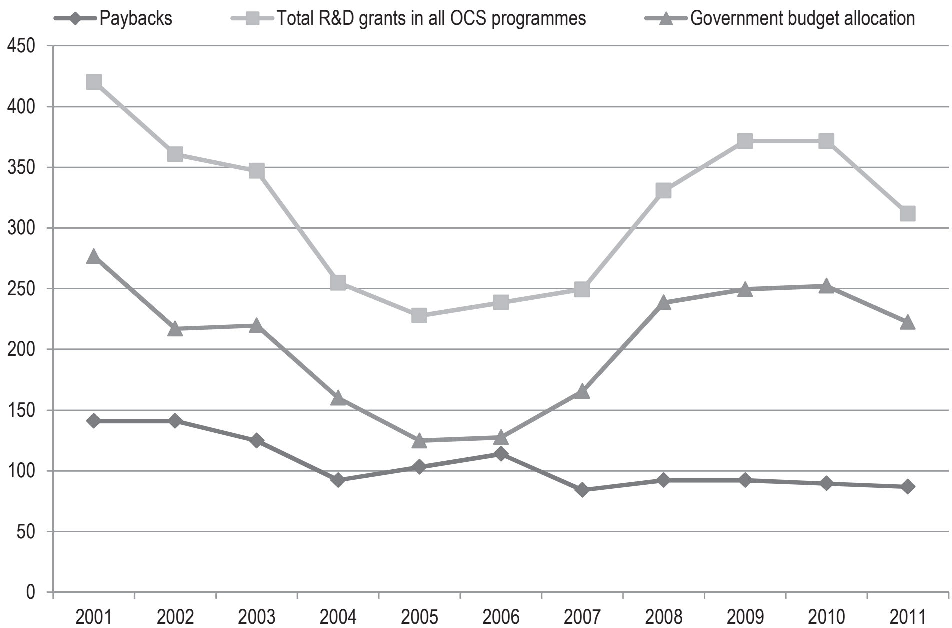
The last initiative designed by the OCS in 1991 was MAGNET, which started operations in 1992. Unlike the other OCS programmes, MAGNET, which stands for Generic Non-Competitive R&D, addresses two problems related to the later stages of the development and maintenance of the long-term competitive advantage of Israeli NTBFs. The first problem is the large number of companies in Israel in the same technological space, all of them too small to compete on the basis of, or to advance, the cutting-edge infrastructural research activities that are crucial to sustaining competitive advantage against large MNCs. The second problem is the underutilisation of academic research done in Israel. Like the OCS programmes, MAGNET grants aid to programmes initiated by private industry. However, MAGNET aims to create a consortium to develop generic technologies. MAGNET consortiums are created for a period of up to three years, and all intellectual property (IP) outputs are shared among the consortium members, who also agree to license the IP to local companies at a cost that does not reflect monopoly status. Over the years, many research consortia in a wide range of technological fields have been formed. For an industry whose companies compete on the basis of their R&D capabilities, MAGNET proved important in enabling companies to develop R&D-related capabilities that they otherwise could not develop or even know about.

The price of success: Political interference and resource stagnation in the 2000s

If the 1990s was the decade in which the OCS received praise and elevated social stature for its important role in transforming Israeli industry from one of the world's least R&D-intensive to one which almost completely relies on novel product R&D, the last decade has seen the OCS suffer the political consequences of this success, and for the first time in its history its budget allocation has steadily declined (Figure 9.2).

Figure 9.2. OCS budget 2000-11

Year 2000 USD millions



Note: Payback are the total amount the OCS inject back to the budget from the royalties gained on past grants, government budget allocation is the total sum of approved annual budget allocation to the OCS from the Ministry of Finance.

Source: OCS (2012), *Summary of Operations 2011*, Office of the Chief Scientist, Ministry of Trade, Industry and Employment, Jerusalem.

At least as important is the continuous erosion of its independence and growing political interference in its decisions. For example, in May 2000, after a (first ever) public selection process led by committees headed by the then president of Ben-Gurion University, Carmel Vernia, the former CEO of Comverse, was appointed as chief scientist. The main reasons given for his selection were his vast experience in running big organisations and the wish both to formalise OCS activities and to build more large companies (in terms of global sales). However, Vernia quickly discovered that one of the main promises he received when agreeing to take the job—that the OCS would become legally independent and would be released from direct control by the Ministry of Trade and Industry—was vehemently opposed by the new minister and his director general, who viewed it as crucial to their political power control over what was by then the most important sector of the economy. After less than two years, and shortly after the minister, Dalia

Itzik, without informing Vernia, decided to transfer ILS 14 million out of the OCS to be used at her discretion to help "distressed" companies, Vernia resigned (Editors, 2000; Peretz, 2002; Rolinik, 2002).

In another example, in July 2010, the Ministry of Finance established a regulation that would prevent the OCS from sponsoring any R&D activities conducted by large companies (defined as those with more than USD 100 million in annual sales) (Grimeland and Coren, 2010). Whether or not that proposition becomes law, this is another indication of the constant interference of other units not only in OCS decisions, but also in the OCS's professional judgment and ability to fulfil its mission.

However, even under these limitations OCS has acted as a Schumpeterian development agency, on three fronts. First, with the great success of the ICT sector and its level of private financing, the OCS has moved away from strictly neutral HTPs and initiated several sectoral policies in clean-tech, nanotechnology and biotechnology. In so doing, the OCS continues to view its role as fixing market failures and intervening when the risks are too high for private industry to bear alone (OCS, 2010).

A second initiative tackles the perceived excessive focus on ICT, and the very low spillovers and linkages between the ICT R&D-producing sector and the rest of the economy, a disconnect that has by now become a classic dual economy situation (Breznitz, 2007a; Breznitz, 2007b; OCS, 2010; Trajtenberg, 2001). In order to foster such linkages and maximise R&D across the business sector, the OCS has allocated funding to a new programme focused on traditional industry since 2005. The programme tries to do so both on the demand side (teaching firms in traditional industries to conduct R&D), and on the supply side by offering incentives and grants for graduate research students and R&D engineers to work or intern in traditional industries' SMEs and undertake research, with the hope that this will lead to new ideas and products in traditional industries. The programme has grown steadily in the last five years and led a significant number of established companies to apply for OCS grants for the first time (OCS, 2010).

Finally, in the aftermath of the dotcom and financial crises, the OCS established various programmes to assist first-time technological entrepreneurs in the pre-seed and seed phases (OCS, 2010). Yet, given steadily declining budgets and constant political interference from politicians and other bureaucratic agencies, the OCS has found it more difficult to scale its new initiatives. Indeed the total budget for all R&D projects approved by the OCS in 2010 is less than 50% of its 1999 budget.

Conclusion

In describing how Finland and Israel entered new, high-technology industries, this chapter shows how reform-oriented policy makers can play a transformative role by introducing experimental STI policies and facilitating rapid innovation-based competition. At the same time, it challenges arguments maintaining that "developmental" agencies occupy a commanding position within the public sector or social networks more generally. On the contrary, this chapter demonstrates that institutional innovation originated at the periphery of the public sector, in agencies that were not trapped by established routines or beholden to entrenched interests.

While analysis has focused on Finland and Israel, policy innovation is by no means limited to these two countries. There are similar developments in Ireland, where the crisis-induced decision to split the Industrial Development Authority permitted the development of new industrial policies targeted at domestic software entrepreneurs (Breznitz, 2007b; O'Riain, 2004). In Denmark, steep cuts to the Ministry of Trade and Industry paradoxically created space for a new generation of policy makers to promote restructuring through sectoral dialogue and reliance on local inter-firm networks (Campbell and Pedersen, 2007; Morris, 2005). In this case, policies were imported from outside the government, from an independently organised roundtable that brought together politicians, policy makers and industry leaders (Pedersen et al*.,* 1992). Outside of Europe, Chinese Taipei's Industrial Technology Research Institute (ITRI) introduced the innovation policies that made it a leading semiconductor manufacturer (Breznitz, 2007a).

In each case, reform-oriented policy makers relied on similar instruments to scale and monitor new STI policies. For example, SDAs used formal and informal inter-personal networks to bring experimental STI policies rapidly to the centre of national discourse. Irish policy makers formed industry organisations, such as the Irish Software Association, to raise awareness about new policies (O'Riain, 2004), while Danish policy makers leveraged local, inter-firm networks to implement new labour market initiatives (Morris, 2005). At the same time, policy makers in small open economies relied on international openness to challenge established industrial policies and monitor new ones. Indeed, innovative policies targeting early-stage risk capital in Ireland and labour market activation in Denmark were responses to deep economic crises during the 1980s which discredited traditional industrial policies and created space for innovative new actors at the periphery of the public sector (Morris, 2005; O'Riain, 2004).

This is not to suggest that peripheral public agencies will successfully scale and monitor new STI policies everywhere. In identifying the specific mechanisms that permit scaling and monitoring, this chapter explains why some countries may be less innovative than others. For example, they may lack effective co-ordinating and consensus-building institutions. They may be fragmented along ethnic, religious or ideological lines, or power may be concentrated in ways that inhibit effective private-public and inter-sectoral dialogue. Alternatively, they may be less vulnerable to external pressure, either because of domestic policy choices that reduce international openness or their location in a region with less geopolitical competition (Doner et al., 2005; Herbst, 2000). Some states may suffer doubly, from a fragmented society and limited international exposure, making it more difficult to scale and monitor new innovation policies.

At the same time, the preceding analysis suggests how policy makers can mitigate these disadvantages. First, policy makers seeking to promote experimentation are better off providing small agencies with a mandate to engage in radical policy experimentation rather than concentrating power in a high-profile, centrally located developmental agency. This finding is as true for large countries as it is for smaller states, as comparatively marginal agencies, such as the Defense Advanced Research Projects Agency (DARPA), spearheaded experimentation in new information and communication technologies in the United States (Whitford and Schrank, 2011).

Second, the paper suggests that the success of Schumpeterian developmental agencies is shaped less by their financial resources than their informal networks. As described above, Sitra and OCS managers both surmounted fiscal constraints by leveraging formal, neo-corporatist fora and personal networks to engage other policy makers and private sector representatives. This is equally true of developmental agencies in larger countries, as organisations like DARPA maintained an experimental capacity by cultivating informal ties to public and private sector researchers (Fuchs, 2010). National governments can actively facilitate this process by promoting closer co-operation among public and private sector actors. This need not involve replicating formal, peak-level structures in Finland (Ornston, 2006), but could instead involve informal institutions. The preceding analysis suggests that roundtables, private sector associations, joint courses on economic policy and shared experiences in military services not only bridge divisions among ideologically or culturally diverse communities, but may prove even more effective than their formal counterparts as co-ordinating, consensus-building and commitment-monitoring institutions.[16]

At the same time, reform-oriented policy makers should remain sensitive to the limitations associated with these strategies. Co-ordination and consensus-building can stifle experimentation by mobilising resources around institutionally-entrenched actors, reinforcing existing prejudices and blinding actors to new ideas. As a result, this chapter also underscores the benefits of economic openness for both large and small states. SDAs increased monitoring capacity by linking STI policies, like Finland's new technology policies and Israel's Yozma programme, to international economic competition. International organisations and external evaluations also played an important role in ameliorating the deficiencies associated with co-ordination and consensus-building. For example, Schrank and Kurtz note that the WTO ensures that firm-specific subsidies will be scaled down even in good times, as competitors litigate against successful recipients (Schrank and Kurtz, 2005). The European Union has formed a similar role in Finland, and Finland has relied on international evaluations to identify problems such as its relative neglect of industrial research during the 1960s (Murto et al., 2006: 32). While small states are uniquely "advantaged" in their reliance on international trade and institutions (Katzenstein, 1985), there is no reason why policy makers in larger states cannot replicate this strategy by deepening economic integration and linking new STI policies to international economic competition.

Notes

1. The authors wish to acknowledge financial support from the German Marshall Fund of the United States and the University of Georgia, the World Bank, and the Kauffman and Sloan Foundations. The authors also benefited from helpful feedback from Avi Hasson, Melanie Kolbe, Yevgeny Kuznetsov, Florian Justwan and Dann Naseemullah. This paper was partly written while Breznitz was a visiting professorial fellow of the Collegio Carlo Alberto and the University of Turin Department of Economics S. Cognetti de Martiis, Moncialieri and Torino, Italia.

2. While countries can also rely on the incremental upgrading of policies and industries to achieve economic growth, the development of new activities by entrepreneurial actors is more relevant for competition in rapid innovation-based industries (Hall and Soskice 2001) It is also more relevant for developing countries to the extent that growth is based on the diversification rather than the deepening of comparative advantage (Rodrik 2007).

3. This point was made in interviews with the former research director of a forestry firm (13 October 2005), the executive officer of an engineering firm (25 October 2005), the research director of a forestry firm (2 November 2005) the chief executive officer of a software firm (3 November 2005), the research director of an engineering firm (4 November 2005) and the former chief executive officer of a forestry firm (31 October 2005).

4. The European Union's requirement that states limit debt to 60% of GDP reinforced external market pressures. With unemployment climbing to nearly 20%, Finland reached this ceiling in less than three years. Policy makers cut expenditure in virtually every domain except research and early-stage risk capital.

5. Sitra also stopped developing surveys on international competitiveness. Although it outsourced this activity to the Research Institute on the Finnish Economy, it continued to conduct research on productivity, innovation and restructuring.

6. For example, the Science and Technology Policy Council and the Prime Minister's office both prioritised demand-side innovation in policy proposals in 2008.

7. For more on the early electro-medical industry in Israel, see Breznitz (2005b); Teubal et al. (1976); and Teubal and Spiller (1977). For the semiconductor industry's history in Israel, see Autler (2000). For a descriptive history of the Israeli high-technology industry, see Levav (1998). For two accounts that briefly discuss the software industry and the causes of its success, see Ariav and Goodman (1994); and de Fontenay and Carmel (2001). For a recent volume on the software industry in emerging economies, see Arora and Gambardella (2005). For a comparative study of Israel and other successful former emerging economies, see Breznitz (2007a).

8. We follow Teubal's definition of HTPs as: "a category of technological policies whose objective is to promote technological development per se, and associated R&D and search management and organisational routines, irrespective of industrial branch or technological area" (Teubal 1997).

9. See the report of the Katchalski committee (Katchalski 1968). For the OCS's earlier definition of its own role as fixing market failures in civilian R&D, see OCS (1975; 1977). For an analysis of the OCS system in its early years, the logic behind it, and the effects of its industrial sector "neutrality" see Teubal (1983, 1997). For an argument that Israel should be seen as a case of diffusion of R&D capabilities from the academic sector to industry, and not creation of R&D capabilities, see (Breznitz 2006).

10. For more on the role of the military in the development of the software industry, see Breznitz (2005a).

11. In another—this time negative—example of the intimate relationship of the Israeli software industry with the American financial markets, both Comverse and Mercury have been embroiled in SEC investigations involving options backdating. Mercury opted to merge with HP in November 2006 after Amnon Landan was fired as the CEO, and Kobi Alexander is currently seeking refuge from the SEC in Namibia, while Comverse remains independent.

12. For example, in 1987 a leading Israeli software company was in severe financial difficulties with a few million dollars in future orders but not enough working capital. At that time, the founders, all technologists without any business education, started to look around frantically for venture capital. Fortunately, a founder's wife worked for Comverse, and Kobi Alexander, Comverse's financial entrepreneur, agreed to meet with them. He was somewhat surprised to learn that they sought investment instead of using the simple financial tool of bridge loans.

13. Interestingly enough, while the wave of immigration from the former USSR created the pretext for the OCS to secure finance and political agreement to start these three programmes, the Russian immigrants have not, thus far, become successful technological entrepreneurs and seem to play the important but more minor role of providing highly skilled labor.

A preliminary analysis of an original dataset of the career paths of founders of Israeli NTBFs that went public on foreign exchanges has yet to find one new immigrant from the former USSR among the 151 founders on which comprehensive data was acquired. This finding is strengthened by an analysis done by researchers at the Central Bureau of Statistics on the distribution of new immigrants in the IT labor market (Abouganem and Feldman 2002).

14. Interview with the director of the incubators programme (8 February 2000), Trajtenberg (2000), and the incubation programme website www.incubators.org.il. For two thorough reviews of the Israeli incubator programme, see Economics (2001); Shefer and Frenkel (2002).

15. Interview with Yigal Erlich, Chief Scientist at the time of Yozma's launching, 21 August 2000.

16. In larger countries, these interpersonal networks may be easier to develop at the regional or local level.

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(92 2012 08 1 P) ISBN 978-92-64-18387-2 – 2014-02

Making Innovation Policy Work

LEARNING FROM EXPERIMENTATION

Contents

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ISBN 978-92-64-18387-2
92 2012 08 1 P

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