Retaining Top Innovators: An Essential Element of Competitiveness for Developing Countries

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The inclusion of indicators for human capital development as a core feature of innovation measurement is an acknowledgement of the importance of highly skilled innovators to successful innovation, especially to high-technology innovation. However, such indicators tend to focus on the conventional supply channels of secondary and tertiary education, overlooking the significant influence of migration.

Openness and permeability are fundamental and essential properties of a functional national system of innovation (NSI). In particular, the mobility of talented people is critical to a system's capacity for learning, adapting, and innovating. Paradoxically, policy support for migration in developing countries presents a difficult balancing act. Although facilitating a developing economy's human capital growth through immigration and international training opportunities, policy support for migration can lead to the net emigration of scarce skills. Further complicating this issue, the most productive innovators are also the most mobile. In this chapter, we argue that the retention of this cohort of innovators is a neglected but important policy objective for developing countries.

The first section of the chapter outlines the disproportionate contribution that exceptional innovators and researchers make to the NSI, and notes that these unusual individuals also tend to cluster geographically. The importance of policies that focus on the retention of high-performance innovators and their clustering within specific locations is underlined.

In the chapter's second section, the principles of innovation-led growth and its centrality to the economic development of middle-income countries are discussed. In particular, we refute the argument that innovation—especially radical innovation—should not be a priority and that developing countries should instead focus on the acquisition and absorption of readily available existing technology. Using South Africa as an example, we argue that the loss of highly productive researchers and innovators is a critical issue, and that achieving innovation-led growth will require a full spectrum of researchers and innovators.

The scarce 'human factor' in innovation

In order to study the impact of policies that affect an economy's innovative capacity, we look first at the people who actually perform the tasks associated with innovation.

Research and innovation outputs per individual vary widely

Patterns of research and innovation productivity at the level of the individual are highly unequal. As a consequence, research and innovation productivity is skewed, with a relatively small number of contributors accounting for a major portion of the outputs. This empirical observation has been studied over a long period and by a number of authors, including Lotka (1926) and Pao (1985), who have concluded that only a small number of researchers account for a major proportion of the overall output. It is these individuals who change the rules of the game, who create new technology paradigms, and who provide the necessary science that leads to technological revolutions.

This inequality exists across a wide range of fields and output indicators; we consider here three examples in more detail. In the first example, we look at the frequency of scientific publications by author. These data follow a skewed distribution, as originally noted and described mathematically by Lotka (see Figure 1). This mathematical formulation, which became known as *Lotka's Law,* states that the number of authors, *W,* making *n* contributions is about $1/n^2$ of those making a single contribution.[1] In other words, 10% of authors produce 50% of the total publications, and the top 5% of authors account for 39% of publications. Subsequent studies have shown that Lotka's Law overestimates the productivity of high-output researchers and that the distribution

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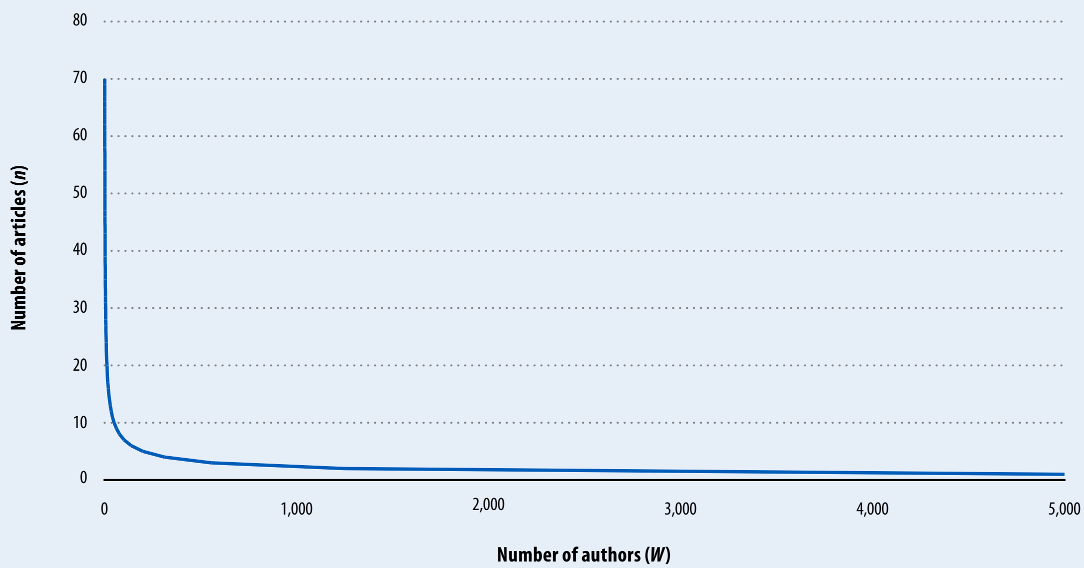
Figure 1: Lotka's Law on publication frequency per author



Source: Curve developed from Lotka's Law (Lotka, 1926).

is more accurately modelled using a standard Pareto distribution with a Gini coefficient of about 0.5.[2] Even under the more conservative estimates, however, it is still apparent that 20% of researchers produce 50% of the total output, and 8% produce 25% of the contributions.[3]

In a second example, also from the research literature, it is noted that the citation rates of scientific articles follow an exponential distribution, as shown in Figure 2. The graph shows that only a small proportion of total articles (less than 0.001%) achieve a citation rate of more than 400 cites per article. On the basis that citation rates reflect the outcome of a specific publication on the research community, it is apparent that only a small number of articles—and, by implication, a small number of authors—significantly influence the global research community.

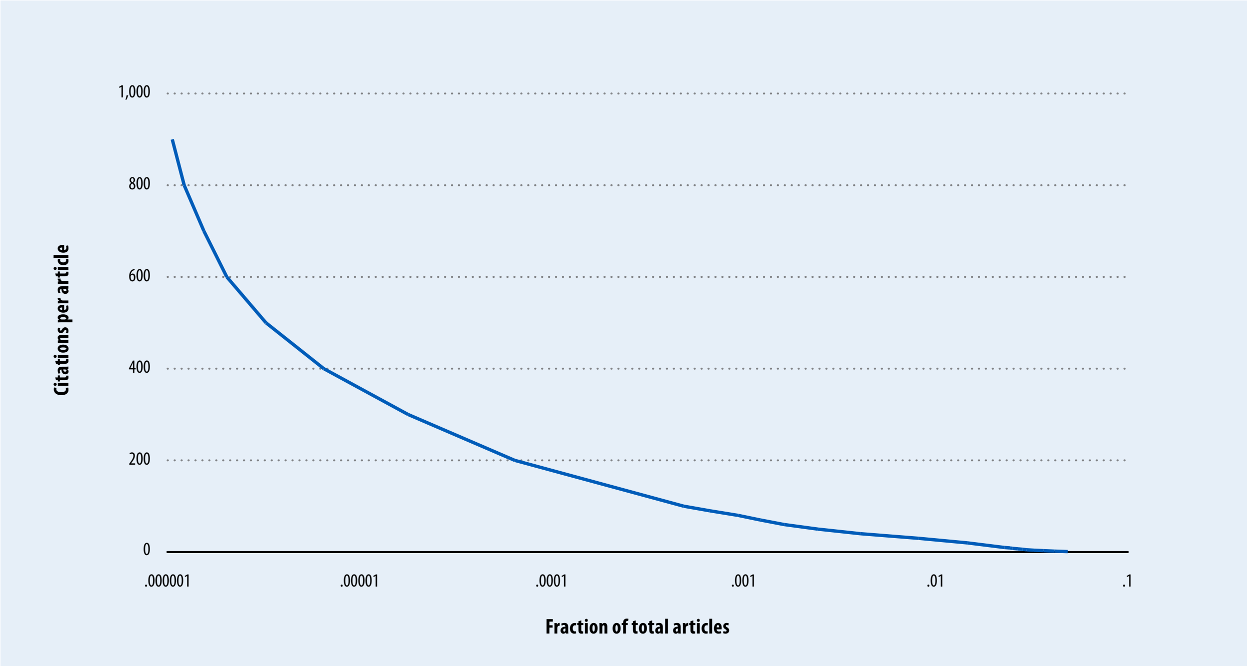
In the final example, we consider the unequal distribution of university licensing income in the United States of America (USA) (see Figure 3). This is an indicator of university-based innovation rather than research performance. It is clear that a handful of US institutions excel in this area, a feat that is considered to be the consequence of the clustering of top inventors working within well-resourced institutions and supported by top administrators, technology transfer staff, and research students. The graph also reinforces the notion that innovation output at an institutional and national level can be influenced by adopting specific policies aimed at attracting and retaining an active group of highly productive inventors. Unfortunately, these data are not available for developing countries, although it is suspected that the results are likely to be even more pronounced in this group, with even fewer universities generating the total licensing income than is the case in developed countries.

The above examples have been chosen to cover output, outcome, and impact indicators. All three examples illustrate clearly the initial proposition: high-impact innovators are a small and elite cohort.

The elite cohort clusters in narrow geographic locations

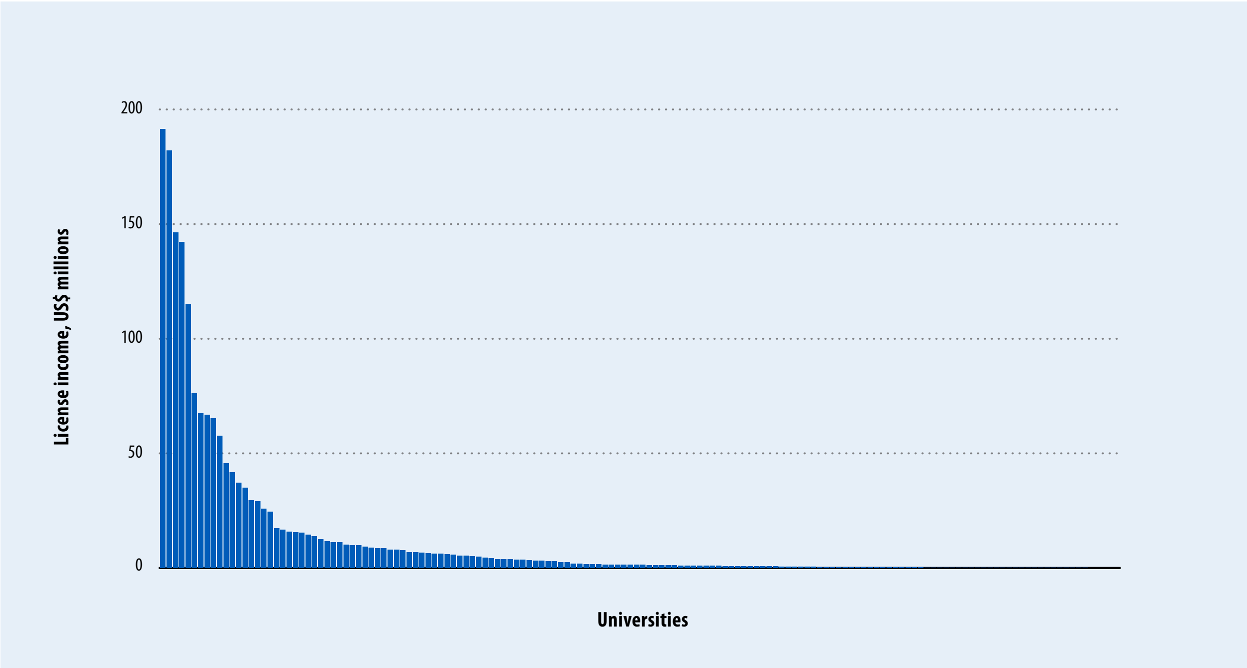
A second characteristic of research and innovation performance is that, in addition to unequal distribution at the level of the individual, performance is also geographically unequal. Talented innovators tend to cluster in the same places, even at the same institutions. This pattern has occurred throughout history and around the world, as can be found in the chronicles of China, Egypt, Greece, India, and Italy, and more recently Vienna. Eric Kandel is well known as the neuropsychiatrist who

Figure 2: Distribution of citations per article



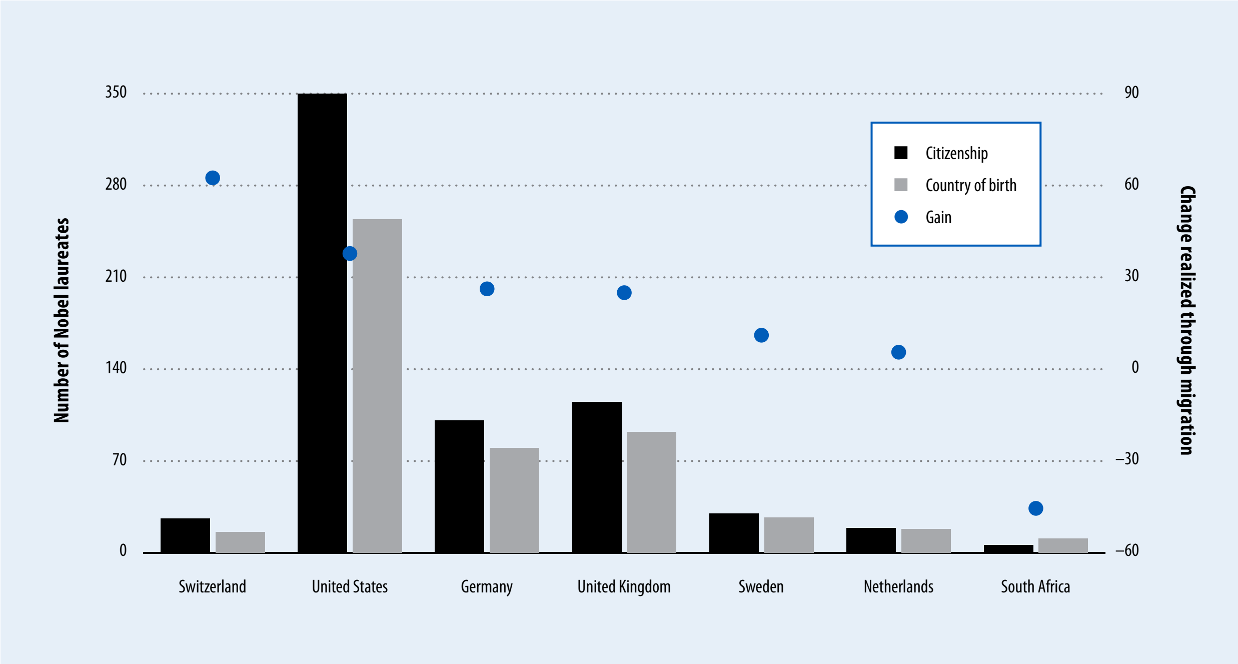
Source: Radicchi et al., 2008.

Figure 3: Distribution of licensing income of US universities (FY 2011)



Source: AUTM, 2013.

Figure 4: The impact of mobility on the citizenship of all Nobel laureates, 1901–2013



Source: http://en.wikipedia.org/wiki/List_of_countries_by_Nobel_laureates_per_capita; Schmidhuber, 2010.

unravelled the physiological basis of memory storage, for which he received the Nobel Prize in 2000. He is also an expert on Viennese history of the end of the 19th century and the beginning of the 20th, a period of remarkable intellectual progress referred to as the 'Age of Insight'.[4] Bringing together a diverse range of people, Vienna supported the blossoming of science and culture, including the work of the physicians Sigmund Freud, Carl von Rokitansky, and Johann Schnitzler; the artists Gustav Klimt, Oskar Kokoschka, and Egon Schiele; the philosopher Ludwig Wittgenstein; and the architects Adolf Loos and Otto Wagner.

Many cities and indeed countries may strive to repeat Vienna's extraordinary output, and Kandel is not the only scholar to have sought an explanation for its distinction. Interestingly, one of the important contributors to this phase of extraordinary insight and progress is considered to be migration, as the city drew intellectuals from all over Central Europe during this period. The combination of a multi-disciplinary and multi-ethnic population with an active cosmopolitan life within the social spaces of the Viennese coffee houses facilitated a powerful cross-fertilization of ideas, the outcomes of which have continued to influence the practice of medicine, psychiatry, music, and other disciplines.

Clusters of high output and performance repeat themselves across time and place as these factors of education, multi-disciplinary discourse, quality of life, human migration, and resources are aligned to the required extent. Although the appearance of these clusters may seem random with respect to time and geography, countries and institutions can and do intervene to influence the likelihood of research and innovation excellence. For instance, many countries have specific policy instruments that appoint internationally ranked researchers to secure, tenured, university-based positions. In South Africa, the Research Chairs Initiative was established in 2006 by the Department of Science and Technology as a strategic intervention aimed at reversing the attrition of research and innovation capacity in the country's higher education institutions and increasing the number of world-class researchers in the country. The initiative has sought to provide well-structured employment packages that include making research grants, facilities, and postgraduate students available to top researchers. By March 2012, 152 chairs had been awarded, of which 89 had been operationalized.[5]

This initiative, together with the Department of Education's performance management framework for South African universities, can be said to have been instrumental in successfully addressing the stagnation in scientific publications by

Table 1: Well-known South African entrepreneurs, in chronological order of innovation (1960s onwards)

Entrepreneur	Industry sector	Company	Date of innovation	Birth	Residence
George Pratley	Adhesives	Pratley (Pty) Ltd	1960s	South Africa	South Africa (deceased)
Ferdinand Chauvier	Leisure and hospitality	Kreepy Krawly	1974	Belgian Congo	USA
Herbert Sheffel	Rail transport	South African Railways	1970s	South Africa	Unknown
Sol Kerzner	Hotel and tourism	Sun International	1980s	South Africa	USA
Patrick Soon-Shiong	Biotechnology and health	Abraxis BioScience	1991	South Africa	USA
Mark Shuttleworth	Information technology	Thawte	1995	South Africa	United Kingdom
Elon Musk	Space and automobiles	PayPal, Zip2, SpaceX, and Tesla	1999	South Africa	USA
Pieter de Villiers	Information technology	Clickatell	2000	South Africa	USA
Roelof Botha	Information technology	PayPal and Sequoia Capital	2001	South Africa	USA
Percy Amoils	Medical (ophthalmic)	Cryoprobe	2002	South Africa	South Africa
Gavin Hood	Film (Tsotsi)	Not applicable	2005	South Africa	USA
Paul Maritz	Information technology	VMware (CEO)	2008	Zimbabwe	USA
Sindiso Khumalo	Textiles and design	Sindiso Khumalo	2009	South Africa	United Kingdom
Chris Pinkham	Information technology	Amazon EC2 and Nimbula	2010	South Africa	USA
Willem van Biljon	Information technology	Amazon EC2 and Nimbula	2010	South Africa	USA

Source: Survey on Innovation Behaviour of the Population conducted by the Institute for Statistical Studies and Economics of Knowledge (ISSEK)/National Research University - Higher School of Economics (HSE), 2011.

South African researchers over the period 1986 to 2004; certainly the output was relatively unchanged over the period 1994 to 2004 (from 3,500 to 4,000 publications), but it then rose steeply to over 9,750 publications by 2012.[6] Local institutions have now adopted strategies that focus on attracting the best academics, leading to a more robust employment market.

Even such proactive policies, however, have been insufficient to retain South Africa's top talent. Historical patterns of mobility have shown that leading researchers and entrepreneurs are more likely to pursue their careers in the USA or the United Kingdom (UK) (see Table 1 and Figure 4). For instance, of the five South African Nobel laureates who have received their prize for chemistry or medicine, all now live in other countries, and South Africa is the only major Nobel country (with more laureates than any other developing countries, and indeed more than many developed ones) that has seen a net emigration of prize winners (see Figure 4).

According to the table of top South African entrepreneurs (see Table 1), only one is still resident in the country. Although South Africa has an impressive reputation for Nobel recipients and entrepreneurs—including the 2013 laureate Michael Levitt and the USA-based space entrepreneur Elon Musk—it has not been successful in retaining this talent and providing longer-term career opportunities. The general pattern is that such talented individuals have migrated to other countries, especially the USA and the UK.

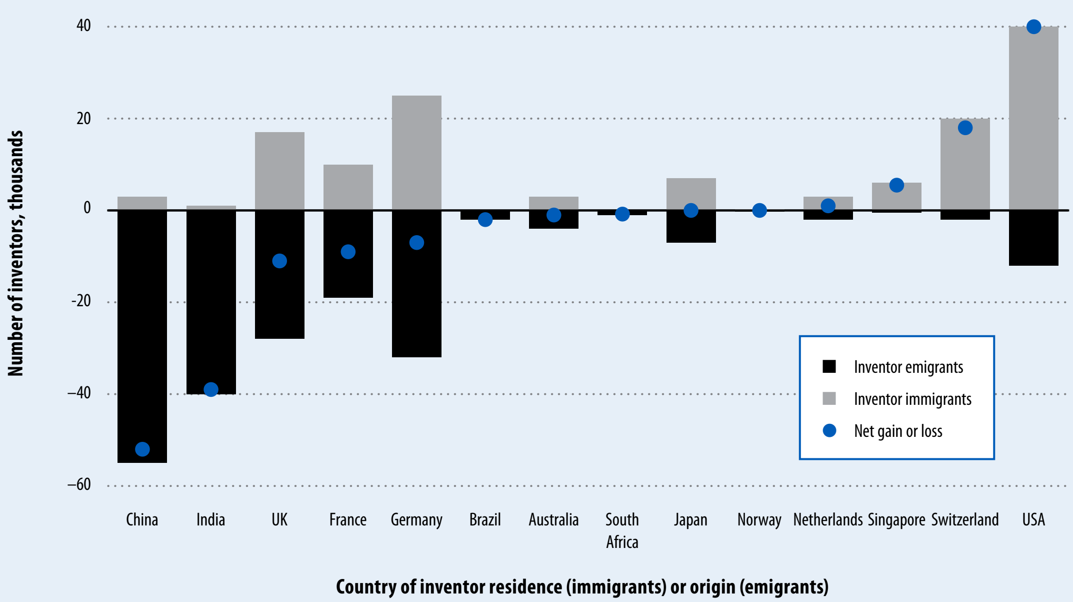
The migration of innovators from developing to developed countries is also evident in statistics on inventions, where it has been shown that inventors in developed countries such as the USA and Switzerland are more likely to be immigrants than natives (see Figure 5), and these inventors are more frequently cited in the patent literature. The ratio of immigrant to total inventors is especially high in Swiss and US universities, where up to 50% of all university inventors are immigrants.[7]

The capacity of some countries to attract and support higher levels of extraordinary talent, allowing it to develop and flourish, is a consequence of many factors that include funding, facilities, international migration, strong local networks and clustering, and the 'Sanger factor' (see Box 1). The probability that the exact circumstances of education, funding, creative thinking, and other framework conditions will occur simultaneously at a specific location and point in time is low despite the efforts of governments to provide such conditions, and countries vulnerable to skills emigration should incentivize this cohort to remain in their countries of birth.

Implications for developing countries: How to train and retain the best human capital

Although it may seem surprising, the relevance to innovation policy of the two characteristics of research and innovation, as described in the previous section and broadly named

Figure 5: Immigrant vs. emigrant inventors, 2001–2010



Source: CDIP, 2013.
Note: In the USA there are 194,000 immigrant inventors, for a net gain of 183,000 inventors.

as the disproportionate productivity of human capital, is often overlooked or ignored in developing countries. Although the need to attract and retain top talent in developed countries has been known and practiced over a long period, it is frequently argued that developing countries should pursue priorities other than the provision of research and innovation infrastructure necessary to retain the elite cohort. In this section, we provide a limited overview of technology policy for developing countries and the two sides of this debate. This is followed by a more detailed discussion of the conditions in South Africa, which illustrates why the loss of human capital is a major problem and hinders efforts to improve innovation output.

There are many views on the optimal economic growth strategy for developing countries, and for every theory there is an exception or even a counterargument. One of the key debates concerns the proper balance between research and development (R&D) and technology transfer/adaption. Innovation is both an inventive (creation of new knowledge) activity and an imitative (reworking of the existing stock of knowledge) one, with the latter being the dominant mode of innovation within firms. These two aspects have also been referred to as the 'learning face' (which acquires and absorbs technology) and the 'innovative face' (which seeks and applies new knowledge). Some studies argue that, in developing countries, the knowledge-using or learning face is quantitatively more important because it draws on the huge stock of existing knowledge that can be exploited for productive activity.[8]

The importance of imitative innovation can be extended to the point that public R&D and radical innovation is no longer a policy focus of developing countries.[9] But this approach does not allow developing countries to take full advantage of their own potential—imitative innovation alone is not sufficient. Instead, such countries should seek to adapt global knowledge to local conditions in order to solve local problems and in pursuit of international markets. They should develop the capability to enable the adoption of newer and better technologies than are currently in use, especially through experiential training for recent graduates, providing a type of experience that is often not available elsewhere. They should develop the necessary human capital to undertake incremental innovation in market-facing enterprises

Box 1: Framework conditions for elite innovators

The following factors are considered essential framework conditions for the emergence of elite innovators:

- **The human factor.** Innovation is undertaken by people who are empowered with the necessary education, training, and skills that facilitate the development of innovative products and services.[1]
- **Public research and development (R&D).** The role of the public sector and the state in supporting innovation is not restricted to providing the necessary policies and incentives for innovation to prosper. The public sector also plays an important role in making the type of innovative breakthroughs from which the private sector is itself able to innovate, thereby driving economic growth and development.[2]
- **Culture.** The openness of societies to new technologies and the pace of innovation itself can be significantly influenced by social culture. Societies that are resistant to innovation, have low levels of trust, impede mobility or migration, and are opposed to collaboration are less likely to be entrepreneurial and produce top innovators.
- **Intellectual property regulation.** A suitable intellectual property regime, which can achieve a balance between the protection of intellectual property rights and support for open innovation, is essential for productive innovation.[3]
- **Advanced information technology ecosystem.** Rapid and reliable communication has become essential for developing and sustaining innovation networks.
- **Support for new firms.** Small and micro-enterprises, particularly new firms, are important for the commercialization of new ideas that can transform these ideas into jobs and wealth. Governments should implement a wide range of measures to support entrepreneurs. These measures include imposing a favourable tax climate, making bankruptcy measures more lenient, and providing incentives for research.[4]
- **The Sanger factor**. This condition refers to the comment made by Fred Sanger on the award of his second Nobel prize, who commented that ' "It's much more difficult to get the first prize than to get the second one . . . because if you've already got a prize, then you can get facilities for work, and you can get collaborators, and everything is much easier."'[5] In other words, success breeds success: talented individuals who receive recognition for an initial achievement are soon rewarded with offers of money, facilities, and prestigious, tenured posts in the expectation of equivalent outputs in the future.

Notes

1. OECD, 2010.
2. Mazzucato, 2013.
3. OECD, 2010.
4. OECD, 2010.
5. Gellene, 2013.

(both state-owned and private). And, finally, they should identify, in-license, and adapt technology while paying special attention to supporting the innovation activities of domestic private companies and state-owned entities.[10]

This perspective has been strengthened by the discussion of innovation-led growth, particularly the strategy that has become known as the 'Beijing Consensus'.[11] China's commitment to a policy of innovation-led growth and the consequent substantial investment in R&D, as a route to economic development and a means of exiting poverty, has been evident since the early 1990s when China began to invest at a level at least three times higher than that of countries with a similar GDP per capita, such as Argentina and South Africa.[12] Since 1995, R&D spending in China has increased at a stunning annual rate of nearly 19% and in 2010 reached a huge US$178 billion PPP[13]—the second largest R&D spending rate worldwide and almost double the rate of a basket of comparator countries. The success of this investment supports the arguments of the Beijing Consensus and the notion that innovation and technology has supported 'super-fast change in some sectors'.[14]

The rapid growth as a consequence of China's approach has prompted South Africa to adopt a similar innovation-led growth strategy.[15] Although it may be premature to assess the outcome of this strategy, it is clear that South Africa is, so far, failing to grow its high-technology industries and remains locked in a resource-based economy. The limited response to several public-sector innovation initiatives, including the Ten Year Innovation Plan and the National R&D Strategy,[16] raises questions about the factors missing in South Africa's innovation strategy. Using the success factors mentioned earlier (see Box 1) as an analytical checklist, it is apparent that South Africa has made progress in the following areas:

- overcoming extremely poor framework conditions of the 1990s;[17]

- providing strong government support for basic science projects, such the Square Kilometre Array project,[18] and public-sector R&D in general; and
- facilitating a high proportion of business enterprise expenditure on R&D relative to the gross expenditure on R&D.

However, South Africa has weaknesses in the following important areas:

- human capital development falls short; this is the most significant weakness of the country's NSI;[19]
- trust among business, labour, and government is lacking; as a result, business is insufficiently involved in the development of the NSI and there is not a strong culture of innovation;[20]
- system-level monitoring is inadequate to inform necessary strategic interventions;[21] and
- the retention of top innovators is inadequate, thereby limiting the impact from this elite cohort (as demonstrated in this chapter). On the assumption that their contribution to the overall innovation output follows a pattern similar to the Pareto distributions mentioned earlier, it is estimated that South Africa's failure to retain the top 5% of researchers and entrepreneurs slices 20% from its potential innovation output.

These weaknesses suggest a number of interventions South Africa could make to address the retention issue. A key starting point is the shortfall in human and social capital. The country needs to actively improve the overall skills level in the economy and build trust between business and government. Policy makers must understand the factors that drive entrepreneurs abroad in more detail, and must address these issues with directed policies that secure better retention. They must improve partnerships among the universities, the public research institutions, and the business sector in order to improve the spillovers from publicly funded R&D. The latter intervention is particularly important given the increasing levels of support for R&D and the relative stagnation in innovation output.

Conclusion

South Africa, alongside other middle-income countries, faces major challenges as it attempts to diversify its economy from a traditional reliance on mineral extraction and primary industry. In charting the way forward, it has adopted the National Development Plan 2030, which has set a clear policy agenda together with many ambitious targets.[22] The Plan is based on the principles of innovation-led growth and clearly identifies the need to improve the quality of education, to support skills development in the population, and to encourage innovation as key enablers for economic development.

Although the country could address the general standard of education and skills development for the population as a whole, this intervention may not succeed in raising the level of innovation, which appears to respond in a nonlinear manner to the standard inputs of public expenditure on R&D and education. The skewed distribution of innovation performance, as outlined in this chapter, may be an important consideration for the new policy agenda. It is not only the number of scientists and engineers per 10 million population that could stimulate higher rates of innovation and increase the contribution of high technology goods and services. The support and retention of elite innovators, high-output academics, and productive entrepreneurs should also be ensured. A failure to address the ongoing emigration of this cohort could slice 20% from its potential innovation output and strip the country of essential skills to meet its transformative needs.

Notes

1 Lotka, 1926.
2 Kyvik, 1989.
3 Kyvik, 1989.
4 Kandel, 2012.
5 National Research Foundation, 2012.
6 Pouris and Pouris, 2012.
7 CDIP, 2013.
8 Arnold and Bell, 2001; Cohen and Levinthal, 1989.
9 Arnold and Bell, 2001.
10 Arnold and Bell, 2001.
11 Ramo, 2004.
12 Walwyn, 2008.
13 OECD, 2012.
14 Ramo, 2004.
15 National Planning Commission, 2011.
16 For the Ten Year Innovation Plan, see Department of Science and Technology, 2007; for the National R&D Strategy, see Department of Science and Technology, 2001.
17 OECD, 2007.
18 Hanekom, 2013; Sapa Reporter, *Times Live,* 2013; Sapa Reporter, *TechCentral,* 2014.
19 Department of Science and Technology, 2012.
20 OECD, 2007.
21 Department of Science and Technology, 2012.
22 National Planning Commission, 2011.

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