Chapter 4
Linking University Research and Innovation in the BRICS

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4.1 Introduction

Globally, university research and industrial innovation are concentrated in a few major economies: the USA, Japan, and the European Union. Nevertheless, these activities have become more dispersed internationally over the last few decades. The usual indicators of national research capacity, such as the number of scientists and engineers, internationally indexed scientific publications, and university research expenditure demonstrate the relative growth of emerging economies (UNESCO 2010; OECD 2010). Aggregate investments in R&D have expanded outside of traditional centers, and the BRICS are some of the most relevant cases. Government investments in university research infrastructures and incentives for industrial R&D have enabled these countries to take on a larger share of global research activity.

Major multinational companies still retain most of their R&D laboratories in advanced economies, in their own home countries. However, industrial innovation has become more geographically dispersed, as firms engage in complex collaborative arrangements across countries (Sá 2013). Brazil, China, and India for instance, have seen their industrial R&D expand in recent years. Multinational companies seek new sources of knowledge and expertise globally. In addition to competitive pressures and new patterns of innovation, mergers and acquisitions also influence where multinationals base their R&D efforts (Thursby and Thursby 2006). A number of countries, including the BRICS, seek to capture some of these investments and devise policies and make investments to that effect. Part of that entails bolstering scientific and technological infrastructure, including universities.

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The amount and nature of university research and industrial R&D activities vary widely. Where and how scientific research is performed is linked to the configuration of national higher education and research systems (Clark 1995). Industrial research and development, one important source of innovation, relates to the industrial composition of national economies (Mathieu and van Pottelsberghe de la Potterie 2008). The intersections between research that take place in universities, and the activities leading to innovation in the marketplace, are likewise variegated. Similar patterns of variation are thus to be expected among the BRICS. Even among countries regarded as successful in science and industrial technology, as Germany and Japan for example, the role that universities play in fostering inventions and technological advancement are quite distinct. When purportedly seeking to achieve similar objectives at a fairly broad level of generalization—say strengthening partnerships between firms and universities—governments in the BRICS and elsewhere are dealing with disparate realities. Such realities involve the peculiarities of national academic cultures, business climates, macro- and microeconomic policies, corporate innovation strategies, and relevant institutional arrangements.

Acknowledging these complexities is not popular in contemporary policy talk. Crossnational analyses lean toward more reductionist perspectives that are more amenable to generate practical policy advice (e.g., OECD 2010). The problem of enhancing university–industry linkages is often portrayed as involving a series of on/off switches that need to be adjusted, including for instance the existence or lack thereof of favorable intellectual property regimes, university technology transfer structures, and supportive governance structures. While such issues are clearly not irrelevant, more detailed analyses usually show the resilience of more fundamental orientations and behaviors, related to the broader cultural, economic and institutional factors mentioned above (e.g., Dill and Van Vught 2010).

Acknowledging these complexities does not preclude the identification of common patterns in university and firm behavior, in public policy, and in innovative activity. It is possible to identify trends while understanding the nuances of history and context that influence national trajectories. By delving into the university's engagement with innovation in the BRICS in the relevant chapters in this volume, this analysis brought to the forefront major developments in these emerging economies that help illuminate their unique trajectories. The sections below distill some key findings and conclusions from the country chapters, highlighting distinctive issues that each of the BRICS needs to tackle to link university research and innovation.

4.2 Brazil

Over the past decade, Brazilian Science and Technology (S&T) policy has emphasized innovation. Laws were passed to encourage greater university–industry partnerships, and a number of programs at the federal and state levels have sought to induce commercial and entrepreneurial engagements on campuses. Nevertheless, innovation as measured by traditional indicators such as patents has remained

relatively low. A number of issues continue to prevent Brazilian universities from taking on a more salient role in linking academic research to innovative activity in industry, beyond a few well-known exceptions.

First, the Brazilian higher education system operates within a logic that privileges local orientations and academic outputs, as opposed to a more global outlook and an orientation toward innovative or commercial endeavors. Second, Brazilian industry remains a marginal player in terms of research-based innovation, which limits the demand for academic inputs into the process. Third, while S&T plans and policies have for a number of years emphasized innovation, the underlying policy instruments have reinforced incentives for universities to produce academic outputs, as opposed to engaging in third stream activities.

As a result of these factors, leading Brazilian universities have not been able to establish a role as "national flagships" or "world class" institutions that might serve as anchors for major sustained investments in innovative activity. The most productive research universities in Brazil such as the University of São Paulo and Unicamp do not project their capabilities internationally as leading innovative hubs, although Unicamp has played an important role as a champion of technology transfer activity. In the context described above of increasingly global R&D, national or even local frames of reference remain dominant among Brazilian universities.

Notwithstanding this situation, progress has been made in the country's scientific capacity. Brazil has more than doubled the number of PhDs per 100,000 residents over the last decade. The same is true for internationally indexed scientific papers, but much of Brazil's research is not in the physical sciences and technology-related disciplines. On the other hand, industrial R&D remains relatively limited, although there have been many attempts to enhance such activity. In terms of internationalizing the country's insular higher education system, new institutions have been created over the past decade with regional mandates. Along with scholarship programs that send Brazilian students abroad, such investments have reflected a human resource development orientation, catering both to domestic and international students in the case of the regionally focused universities recruiting South American and Portuguese-speaking African students.

In spite of the scenario described above, Brazilian universities seem to be engaging in technology transfer efforts more intensively. Technology transfer offices, business incubators, and technology parks have been established. University patenting has also been growing in volume, although the "quality" of such patents remains unclear. Sustained, long-range investments in the R&D infrastructure of universities (and industry) are still needed if Brazil is to become a magnet for high value added innovative activities. However, the likelihood of substantial changes occurring in the short term seems quite small. Unlike some BRIC peers, there is no palpable sense in the Brazilian policy debate that the country's universities are "falling behind" or not "up to par" globally, which might motivate greater investments in the academic infrastructure.

4.3 China

China is certainly an outlier internationally in the pace of growth of public and private R&D, as well as patenting activity, as measured by commonly used indicators (UNESCO 2010; OECD 2010). As Mok and Yue describe, the Chinese government has been encouraging university–industry partnerships as a means to induce innovation in industry since the 1980s through various programs. Corporate R&D expenditures have increased substantially over the last decade: by the mid-2000s the industrial sector carried out most R&D in the country (65 %). The Chinese government intends to continue this upward trajectory in research expenditures, with ongoing plans to double the share of national GDP devoted to R&D by 2020, relative to 2004 (to 2.5 % from c. 1.2 %).

A few important trends are identified in universities. A first and more general development concerns the strengthening of university research capacity. The government has invested since the mid-1990s in a number of universities through projects 211 and 985, which purportedly aspire to support "world class" universities. Through these projects the government essentially "picked winners" for additional funding for the most part using political criteria. While often cited for a number of years as evidence of the international race to build competitive research universities (see also Altbach and Balán 2007), Mok and Yue's review suggests that their effectiveness remains to be evaluated.

Second, fostering entrepreneurship has become a goal for the university sector over the last decade through curricular and extracurricular initiatives. Mok and Yue argue that entrepreneurship education programs have expanded since early 2002 when the Ministry of Education launched a pilot program on entrepreneurship education in nine universities. They illustrate the trend with examples of the different models that have been implemented across Chinese universities. They assert that such curricular programs respond to student demand for learning opportunities in this area.

In terms of extracurricular initiatives, science parks have emerged as sites linked to universities to support entrepreneurship, the incubation of technology-based companies, and R&D partnerships. Eighty-six parks have been created in 134 higher education institutions across the country. Evidence on their success in achieving these goals is mixed. Still, the authors claim that in general, the number of university spin off companies has escalated. Government-funded foundations that provide seed and venture capital funding, such as the pioneering Shanghai Technology Entrepreneurship Foundation for Graduates, support the creation of these firms.

The sort of creative and risk-taking behavior underlying entrepreneurial activity can be thwarted in environments shaped by rigid bureaucratic rules and political favoritism. Although characterizing the various government initiatives briefly summarized above as "serious efforts to promote innovation and entrepreneurialism in higher education," Mok and Yue hint at some of the realities of the Chinese context that have a bearing on their actual implementation. They warn that "without serious reviews and critical reflections upon its current university governance structure

with strong political influences from the party in university governance, it would be difficult to see significant changes being introduced to Chinese higher education." This is indeed a distinctively Chinese arrangement of university governance that cannot be ignored, which presents an interesting albeit challenging opportunity for further investigation.

Furthermore, Mok and Yue note that the promotion of entrepreneurship education is strongly directed by the government, following an agenda of employment generation. Universities remain isolated from the private sector and simply comply with ministerial mandates in this area. Such a situation is clearly at odds with the more interactive and collaborative relationships between universities, the business community and relevant government agencies commonly associated with entrepreneurial programs internationally (Kretz and Sá 2013). While Mok and Yue critique this state of affairs, they also recommend that "legislation should be adopted and funding mechanisms created to support relations between private enterprises and HEIs in developing action learning programmes, leading to the new entrepreneurial skills." It might well be the case that in such a centrally controlled system, the government would need to sanction and induce such partnerships. On the other hand, passive and symbolic compliance is a possible unintended outcome that needs to be considered.

More fundamentally, Chinese universities could use a greater degree of autonomy and flexibility if they are to extend their roles in supporting an innovative economy. Recognizing this need, Mok and Yue call for the Chinese government to consider structural reforms in higher education, in the hope that this would lead to more dynamic institutions that can respond more proactively to changing demand.

4.4 India

As the Indian government embraced an innovation agenda in recent years, the role of universities in supporting technological advance has become a matter of policy debate. India has gained significant visibility internationally in the 2000s as a hotbed of global IT outsourcing. Counting on a large contingent of English-speaking university graduates, the country has been at the receiving end of the corporate offshoring trend. Nonetheless, these investments have not been at the high-end of industrial innovation, a situation that policymakers appear to be sensitive to and seeking to address. A consensus seems to have emerged that Indian universities are underperforming in research and advanced education, and hence contributing less than they could to uplift the innovation activities of Indian industry.

Some structural factors contribute to this state of affairs. The institutional differentiation between research institutes and universities has afforded the former a more prominent role in advancing scientific activity. Besides, a small fraction of India's research funding goes to universities. More than 60% of national R&D expenditure is concentrated in three government agencies: The Indian Space Research Organisation (ISRO), Department of Defence Research Organisation (DRDO), and

the Department of Atomic Energy (DAE). Gorur and Rizvi regard these institutional arrangements as "disastrous" for universities and for the standing of Indian science.

Moreover, the scale of the Indian research enterprise is relatively small. In spite of a massive higher education system in absolute numbers, India has not established a national research base commensurate with its size as compared to its BRICS peers. For example, Gorur and Rizvi point to the number of professional researchers engaged in R&D per million people in India, which is about seven to ten times smaller than the corresponding figures in Brazil and China. This is reflected in India's lower scientific productivity.

The Indian industrial sector remains a marginal player in terms of R&D. Most of the national investment comes from the government, and public institutions perform most research. There are bold plans in place to shift the balance in terms of public and private investment, but it is not clear how this will be achieved. Gorur and Rizvi claim that the reluctance of firms to invest in R&D relates to the business climate and government regulations: "it is not easy to borrow capital or obtain government approvals." Without such measures to address these underlying issues, it is hard to imagine how the government could meet its 2013 goals of doubling the share of GDP invested in R&D. The government is counting on a significant increase in private sector spending.

Gorur and Rizvi discuss the contemporary policy context in India as conducive to addressing the overall underperformance of universities, and their lack of participation in efforts to spur innovation. Several government plans and policy documents discuss the need to reform the country's universities and bolster the national research infrastructure. In particular, the 11th and 12th Five-Year Plans (2007 and 2012) provided for increases in government research expenditures and relaxing regulations that inhibited universities from taking proactive steps to enhance their research profile. Furthermore, the authors point to the creation of technological parks and innovation centers as leading to more applied research efforts. The extent to which such units are related to universities remains unclear, but their establishment does follow an international trend around this form of support.

4.5 Russia

The present context of Russian research still reflects the country's post-Soviet decline. Following the demise of the Soviet Union, R&D investments diminished, and it was not until the 2000s that dramatic reductions in funding stopped. Scientific productivity expectedly suffered during these decades (1990–2010), and Russia has seen its participation in global science shrink. Federal investments in R&D have increased in recent years but from a very low base, and represent just about half a percent of national GDP. This growth seems to have taken place in applied research activities.

Like India, Russia displays a combination of two major structural factors that inhibit a more vigorous role of universities in research and innovation. First, it has

long been known that Russian universities are historically and presently junior partners in the national division of research labor. Second, despite some isolated successes in specialized technological sectors (related in Russia's case to the Soviet past), the country does not have an industrial technology base that propels R&D activities and creates a demand for advanced knowledge as input into innovation processes.

The Russian Academy of Sciences has concentrated scientific expertise and production in the country for some time. Despite recent efforts to build up research capacity in universities, the Academy remains the indisputable driver of Russian science. This is reflected in investments made, personnel, and production. To mention but one of the indicators Smolentseva uses, the Academy produces almost five times as many scientific publications (from the Scopus database) as the second next Russian performer, the Moscow State University. This is the only Russian university to produce as many publications as other leading universities in the BRICS. Other universities are much further behind. Furthermore, the Academy is the major producer of basic science research. Universities in fact conduct more applied research than basic investigation. The share of funding for university research has increased over the last decade; however, it seems to be skewed toward the applied end of the R&D spectrum.

Smolentseva argues that there have been some efforts at improving the research capacity of universities, as part of a broader realization that Russia cannot rely on resource-intensive industrial sectors. Such efforts include investments to set up laboratories in universities for distinguished researchers, institutional mergers, and national programs purported to identify and support "world class" universities. According to Smolentseva, none of these seem particularly transformational. These national programs have something in common with the Chinese projects 211 and 985, namely the prevalence of political criteria in the selection of institutions. Mergers intended to make new universities more regionally responsive were not accompanied by changes in funding models and institutional autonomy, which would provide more latitude for those universities in serving local demand.

Government initiatives have also sought to close the gap between universities and industry. New legislation introduced in 2010 allowed universities to create spin-off companies, commercialize inventions, and partner with businesses in such endeavors. Smolentseva argues that although new projects and firms were funded, their economic impact was limited. It seems that several fundamental issues need to be addressed before Russian universities are able to make more substantive contributions to innovation. Smolentseva calls for reforms in areas ranging from university financing, management, and academic freedom, as greater transparency and professional capacity are needed to strengthen university quality. As government policy adopts the rhetoric around promoting an innovation-driven economy, this "cultural component might be an essential obstacle in the search for excellence" in the university sector.

4.6 South Africa

South Africa is the scientific and technological leader in Africa. It counts on a relatively more advanced economy, and some better performing research universities. More than a third of the scientific output in the African continent comes from South Africa. Given these conditions, Pillay claims that South Africa's "potential for innovation is much greater than elsewhere on the continent." Shifting the parameters to the BRICS, however, South Africa lags behind its peers in terms of R&D, university research performance, and the links between academia and industry.

Universities were reformed in the early- to mid-2000s, and the University of Cape Town is presently the strongest research performer. Nonetheless, the scale of South Africa's academic research enterprise is quite small. Brazil's University of São Paulo alone produces more PhDs than the whole of the South African higher education system, and a comparable number of indexed publications. Given the scale of the higher education sector and difficulties in the institutional basis of academic research, there appears to be very a limited interface between universities and industry to account for.

As elsewhere, the promotion of innovation has been part of the government policy agenda. For instance, a Ten-Year Innovation Plan released in 2008 identifies gaps in national innovation and seeks to bolster scientific and technological infrastructures. This is viewed as necessary to increase the knowledge-intensive sectors of the economy. In the context of the geographical dispersion of global R&D described above, South Africa failed to capitalize on mobile investments in innovation as did other BRICS. Unlike other BRICS, South Africa's private sector accounts for the bulk of national R&D investments. Yet, the internal makeup of the country's national research effort has not translated into a stronger connection into global R&D networks.

This suggests that the distribution of R&D investments in South Africa may be a symptom of an underlying weakness in higher education research support and infrastructure, which house 70% of all researchers, rather than an indicator of strength in business research activity. Moreover, recent trends show a continued relative decrease in investments in R&D. To illustrate this pattern, Pillay reports that South Africa's R&D expenditures experienced a declined between 2008 and 2010 in real terms. As a share of national GDP, research expenditures declined from 0.92 to 0.87% in this period, following a period where it had increased from a low of 0.60% in 1997. Most of this decline is attributed to reductions in private sector expenditures, suggesting a difficult climate for university–industry partnerships.

4.7 Concluding Remarks

The BRICS comprise a variegated set of countries in their patterns of research and innovation. Nonetheless, they share similar challenges. Although in all the BRICS there is attention to innovation in the S&T policy debate, there remain significant obstacles in linking university research to technical advances in industry. As synthesized above, the BRICS need to tackle major issues such as the governance and organization of their universities, the culture and orientation of the academic research enterprise, and the policy and regulatory environment that influences university–industry R&D.

South Africa's university sector lacks the capacity to support innovative research programs that interface with technology-intensive industrial sectors, domestically and internationally. Greater knowledge of the interactions that do take place would be welcome in future research. Moreover, the role of South African's universities in supporting "low-tech" innovation would be a useful addition to the literature as well.

China is clearly the locomotive pulling this group forward in terms of a number of proxies for research productivity and innovation. However, the rapid expansion in publication rates and patent filings in recent decades makes China an outlier internationally, rather than simply a good illustration of the relative growth of the BRICS. Chinese expansion in scientific and technological input rests on unique characteristics, such as the size and rate of growth of its economy, and the ability of an authoritarian government to direct investments in key sectors. Underlying the recent expansion in scientific productivity and patenting activity, universities remain tightly controlled and governed through a system of direct political intervention. The ability of universities to evolve as contributors to an innovative economy under these conditions is likely to be limited. Can the "black box" of party-influenced university governance in China be opened, so as to clarify how it impacts decision-making, particularly as it refers to the pursuit of creative and entrepreneurial endeavors? Glossing over such fundamental institutional arrangements when attempting to understand the evolution of university roles in China would be akin to ignoring the role of fundraising in the behavior of American universities.

Brazil and India share some similarities. In both countries innovation has been emphasized in policy over the 2000s, with apparently underwhelming results. India, in spite of its international role as home to important global players in the IT industry, has been mistakenly grouped with China for the good part of the past decade as a rising S&T giant. On closer inspection, it is evident that India lags behind other BRICS in the development of its national research capacity. Like Brazil, India has a small number of research-oriented institutions in a large, but in many ways unresponsive higher education system. In both countries there is a distinctive lack of international orientation and competitive outlook in the leading research institutions, for all their productivity and selectivity at the national level. In India there seems to be a recent awareness of and urgency to address this issue. In Brazil this is not yet the case, but the academic research infrastructure in place is larger than that in India.

Russia finds itself in an unsettling transition: the Soviet Union's geopolitically fueled scientific and technological prowess for part of the twentieth century has virtually evaporated. A shrinking research base and large resource-intensive business conglomerates, neither of which places the country as a major player in global innovation, have succeeded it. Russia distinguishes itself from India by the still significant role of the National Academy of Sciences in basic research, and a larger contingent of trained researchers. Still, its universities remain mostly teaching-oriented, and operate under institutional arrangements that do not provide incentives for innovative research programs and partnerships with industry.

In conclusion, each of these contexts presents substantial challenges for university leaders, researchers, and policymakers who seek to facilitate a larger role for academic research in innovation. It seems evident that it is not possible to address this issue in isolation. The general rules, regulations, incentives, and cultures shaping each university system have an impact on what and how research is conducted, and with what consequences. Solutions will likely not be found in the piecemeal adoption of certain organizational structures such as technology transfer offices and science parks, although their presence may spark new activities and orientations among the actors involved. In some cases much larger decisions about the research mission of universities are necessary, whereas in others, the general policy frameworks under which universities operate and associated institutional outlooks need to be revisited. In the context described above of increasingly decentralized global R&D and innovation activities in industry, more responsive and dynamic research universities would be an asset for the BRICS moving forward.

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