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The Evolving Role of Public R&D and Public Research Organizations in Innovation

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1.1 The Growth in Policies to Leverage Public R&D

1.1.1 Why Invest in Public R&D?

Science has consistently been shown to be a fundamental driver of technological progress and economic growth and a source of innovation to the business sector (Jaffe 1989; Adams 1990; Cohen et al. 2002). Its importance for economic progress has grown due to an increase in the role of knowledge as a driver of competitiveness in global markets and from emerging technologies that have opened up new opportunities for development. The increasingly science-based nature of modern technological advances has made interaction with science central to innovation.[1] Universities and public research institutes are crucial to both the discovery of new technology and the training of students in new techniques and technological developments, with the attendant economic advantages.

Firms and other innovators depend on the contributions of public research and of future scientists to produce innovations of commercial significance (see Nelson 2004). Basic research in science also serves as a roadmap for firms, facilitating the identification of promising avenues for innovation and avoiding the duplication of effort by companies. Close interaction with public research enables firms to monitor scientific

* Lorena Rivera León, WIPO, and Antanina Garanasvili, consultant to WIPO, provided data and analysis for this chapter. On some of these topics, see, also, WIPO (2011).

[1] See OECD (2017), Paunov et al. (2019), and Section 3.4 on technology–science linkages in OECD (2011). This inference is based on patents citing non-patent literature (forward and backward citations). Patents that rely on scientific knowledge are on the increase in high-growth industries such as biotechnology, pharmaceuticals, and information and communication technologies (ICT).

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advances that could transform their technologies and markets. It also facilitates joint problem solving.

In light of the value of research to many firms rather than to one particular firm or entity, economists have traditionally seen knowledge produced by universities as a public good. Indeed, university knowledge has all the hallmarks of a public good – first, the economic value attached to certain kinds of basic and other research cannot be fully appropriated by the actor undertaking the research, not least because some of it may take several years to emerge. Second, the economic value of such knowledge is often difficult or impossible to judge ex ante. As a result, without subsidy, firms would tend to underinvest in the funding of research, in particular in fields that show little prospect of near-term profitability. To avoid this underinvestment in science and research, governments have funded universities to conduct teaching and basic research (the two traditional missions of the university). Scientists are thus able to pursue blue-sky research without the pressure of immediate business considerations. The reward system is based on the scientist's publication and dissemination record, and not on considerations of any kind of private profitability or income.

In many countries, intermediate institutions, in the form of public sector institutions and laboratories, were also set up and funded by government, in order to conduct translational research that could directly benefit industry. Such public research institutes have been important in the history of many high-income countries (the United States of America (U.S.), the United Kingdom) and continue to be important in others (Germany and the Republic of Korea). Scholars such as Nelson, Freeman, and Lundvall see universities and public research institutes as playing a key role in shaping national innovation systems and in the growth and training of scientists more broadly. This is because the magnitude and direction of public research and development (R&D) influences the broader innovation system through three mechanisms: providing human capital and training, advancing knowledge through public science, and through activities to transfer knowledge to economic actors. Recent experience with the software industry has shown that many middle-income countries whose universities only performed the teaching mission managed to accumulate human capital in excess of their developmental needs. These countries were also the most able to benefit from the sudden opening of global demand for software programmers (Arora and Gambardella 2005).

Economic studies have examined the impact of public R&D on business innovation. While imperfect, aggregate studies have found that academic research, and basic research in particular, has a positive effect on industrial innovation and industry productivity. Importantly, although public R&D does not directly contribute to economic growth, it has an indirect effect via the stimulation of increased private R&D. In other words, "crowding in" of private R&D takes place as public R&D raises the returns on private R&D.

Studies examining social rates of return to public R&D are more recent. Social returns to public R&D are often studied as the effect of public R&D on private sector productivity, and are estimated to have a (median) rate of 20 percent, which is smaller than the impact of private R&D on private sector productivity (estimated to be between 30 and 45 percent). Econometric studies at the firm and country level provide less conclusive results as to the positive impact of public R&D on private productivity than estimates at the industry level. A more intriguing result in the UK context found that the rate of return of public council funding (i.e., grants to industry often in collaboration with university, distributed through research councils) had higher social rates of return than direct public sector R&D, often two to three times the rate of return suggested by private R&D.

To some extent, the public good argument for public sector R&D does suggest that we will find such results. To recall, in the case of most public goods, private rates of return are expected to diverge from social rates of return. Public sector investments in R&D are in basic R&D that takes more than seven years to translate into commercial products and needs more private investment in R&D to be fully absorbed in industry. In contrast, private R&D has a gestation lag of about three years, is in applied areas that are less technologically risky, and is oriented toward readily available (or creatable) markets.

Several empirical issues also contribute to the observed result that public R&D does not show a strong direct impact on business innovation and economic growth. Given the many channels of knowledge transfer from public science, estimating all of the economic effects of public R&D is challenging. Transactions rarely leave a visible trace that can be readily identified and measured. Second, the contribution of public R&D can also take a long time to materialize and this time lag can differ by sectors of activity. Finally, the noneconomic impact of public research in areas such as health, and others, is even harder to identify.

1.1.2 The New Rationale for Public Support of "Third Mission" Policies at Universities

Public R&D suffers from a key limitation when compared to private R&D. When firms undertake R&D they usually have an idea of the type of knowledge they need to produce and a commercialization strategy that is directly attached to their R&D expenditure plans. This rarely happens with public sector R&D, with the people undertaking R&D working in a separate organization from the potential users of the knowledge. Consequently, there is always a scope for discoveries, even those with commercial potential, to fail to be commercialized.[2] In other words, public research may produce a lot of inventions, but no significant innovations. It has also led to accusations that academic research lives in an ivory tower, divorced and disengaged from the real world and its problems.

Since the late 1970s, many countries have changed their legislation and created support mechanisms to encourage interactions between universities and firms, including through knowledge transfer (see Van Looy et al. 2011). Placing the output of publicly funded research in the public domain is no longer seen as sufficient to generate the full benefits of the research for innovation (see OECD 2003; Wright et al. 2007). In high-income countries, policy approaches promoting increased commercialization of the results of public research have included reforming higher education systems to include third mission activities creating clusters, incubators, and science parks; promoting university–industry collaboration; instituting specific laws and institutions to regulate knowledge transfer; and encouraging public research organizations to file for and commercialize their IP. The transformation of research organizations into more entrepreneurial organizations is also taking place by increasing the quality of public research, creating new incentives and performance-linked criteria for researchers, enhancing collaboration of universities and public research institutes with firms, and setting up mechanisms for formal knowledge transfer (see Zuñiga 2011).

Contrary to popular perception, it was not the U.S. but Israel that was the first country to implement IP policies for several of its universities in the 1960s. However, in 1980 the US Bayh-Dole Act was the first dedicated legal framework to institutionalize the transfer of exclusive control over federal government-funded inventions developed by universities and businesses. The shift and clarification of ownership over these inventions lowered transaction costs as permission was no longer needed from federal

[2] It is also worth noting that there is a long history of mission-oriented R&D in the public sector that has produced commercially viable products.

funding agencies, and because this gave greater clarity to ownership rights and therefore greater security to downstream – sometimes exclusive – licensees. For instance, the Act also contains rules for invention disclosure and requires institutions to provide incentives for researchers. It also contains march-in provisions reserving the right of government to intervene under some circumstances.

Several European, Asian, and other high-income countries have adopted similar legislation, in particular from the latter half of the 1990s onwards (see Montobbio 2009; Geuna and Rossi 2011). In Europe, in many cases, the challenge was to address the established situation according to which IP ownership was assigned to the faculty inventor – the professor's privilege – or to firms that funded the research (see Cervantes 2009; Foray and Lissoni 2010). Since the end of the 1990s, most European countries have been moving away from inventor ownership of patent rights toward university or public research institute ownership.[3] European policy efforts have sought to increase both IP awareness within the public research system and the rate of commercialization of academic inventions. In Asia, Japan was the first to implement similar legislation in 1998 and, in 1999, shifted patent rights to public research organizations. The Republic of Korea implemented similar policies in 2000.

Policymakers keen to bolster the effectiveness with which publicly funded research can foster commercial innovation today have a rich menu of options thanks to the experimentation with such policies in many countries (see Just and Huffman 2009; Foray and Lissoni 2010). A number of middle- and low-income countries have also moved in this direction (for more details, see Zuñiga 2011). In spite of the lack of an explicit policy framework, many of these countries have put in place general legislation regulating or facilitating IP ownership and commercialization by research organizations.[4] There are four distinct sets of approaches used by countries. In the first set, there is no explicit regulation but rather general rules defined in the law – mostly in patent acts – or legislation regulating research organizations or government funding. A second model consists of laws in the form of

[3] Professor's privilege was abolished in Germany, Austria, Denmark, Norway, and Finland during the period 2000–7, but was preserved in Sweden and Italy where, in the latter, professor's privilege was introduced in 2001.

[4] See Zuñiga (2011). Thailand and the Russian Federation, for instance, do not have specific legislation defining ownership and commercialization rules for research funded by the federal budget at universities and public research institutes. Yet existing revisions to the patent law or other policies give universities the flexibility to create and own their own IP.

national innovation laws. A third, adopted in Brazil, China, and more recently in economies such as Malaysia, Mexico, the Philippines, and South Africa, builds on the model of high-income countries that confers IP ownership to universities and public research institutes, spurring them to commercialize. Fourth, some countries, for example Nigeria and Ghana, have no national framework but rely on guidelines for IP-based knowledge transfer.

Large middle-income economies, such as Brazil, China, India, the Russian Federation, and South Africa, have already implemented specific legislation or are currently debating its introduction. China was among the first to adopt a policy framework in 2002.[5] In addition, a significant number of countries in Asia – in particular Bangladesh, Indonesia, Malaysia, Pakistan, the Philippines, and Thailand – and in Latin America and the Caribbean – Mexico in particular and, more recently, Colombia, Costa Rica, and Peru – have been considering such legislation.[6] However, only Brazil and Mexico have enacted explicit regulations regarding IP ownership and university knowledge transfer so far. In India, institutional policies have recently been developed at key national academic and research institutes, complementing legislative efforts that aim to implement university IP-based knowledge transfer rules (see Basant and Chandra 2007).

In Africa, most countries other than South Africa have neither a specific law on IP ownership by research organizations nor any knowledge transfer laws. However, several countries have started to implement policy guidelines and to support knowledge transfer infrastructure. Nigeria and Ghana, for instance, do not have specific legislation but are both in the process of establishing knowledge transfer offices (KTOs) in all institutions of higher education.[7] Algeria, Egypt, Morocco, and Tunisia have been working on

[5] In 2002, the government provided universities with full rights of ownership and commercialization for inventions derived from state-funded research. The Measures for Intellectual Property Made under Government Funding legislation provides specific rules for IP ownership and licensing, inventor compensation, and firm creation.

[6] See Zuñiga (2011) and internal contributions to this report made by WIPO's Innovation and Technology Transfer Section.

[7] Nigeria's policy framework contains no specific law on IP creation and management at publicly funded research organizations. Instead, regulations are set within federal research institutes and the National Office for Technology Acquisition and Promotion (NOTAP) published "Guidelines on Development of Intellectual Property Policy for Universities and R&D Institutions." These guiding principles explain how each R&D institution can formulate and implement its IP policy to protect tangible research products in order to make them demand-driven and economically viable. The guidelines also promote the use

drafts for similar legislation. In 2010, South Africa implemented the Intellectual Property Rights from Publicly Financed R&D Act, which defines a number of obligations ranging from disclosure, IP management, and inventor incentives, to the creation of KTOs and policies regarding entrepreneurship.

Studies conducted on the group of high-income countries reveal a few important lessons.[8] First, despite the general trend toward institutional ownership and commercialization of university and public research institute inventions, a diversity of legal and policy approaches persists, in terms of both how such legislation is anchored in broader innovation policy and the specific rules on the scope of university patenting, invention disclosure, incentives for researchers (such as royalty sharing), and whether certain safeguards are instituted to counteract the potentially negative effects of patenting.[9] Second, the means to implement such legislation, as well as the available complementary policies to enhance the impact of public R&D and to promote academic entrepreneurship, vary widely. Finally, legal changes alone have not started or contributed to sustained patenting by public research organizations. In the U.S., university patenting is also driven by growing technological opportunities in the biomedical and other high-tech fields, as well as a culture change favoring increased university–industry linkages (see Mowery et al. 2001).

1.1.3 Conflicts and Tradeoffs between the Old and New Rationales for Public R&D

Although, in theory, this rich menu of "third mission" policies was intended to amplify the impact of public R&D, in practice, many countries adopting these policies were also looking to cut back on public spending and intended that budget cuts to universities should be compensated by proactive approaches to revenue generation (Vincent-Lancrin 2006). There is increasing evidence that countries seek to recover the full economic cost of research activity in order to allow research organizations to amortize the assets and

of IP for the benefit of society, and strengthen research–industry linkages by establishing intellectual property and technology transfer offices (IPTTO).

8 Unfortunately, we have very limited knowledge of the mechanisms at play in middle- and low-income countries and this lacuna is an important reason for our comparative study in this book.

9 These can range from legal approaches (standalone or as part of more comprehensive reforms) and university bylaws, to "codes of practice" or general guidelines on IP ownership and management for fostering greater transparency and consistency. See OECD (2003) and Grimaldi et al. (2011).

overhead, and to invest in infrastructure at a rate adequate to maintain future capability. Paradoxically, support for the third mission may have come at the expense of cutbacks in funding for public R&D itself. Thus, in practice, the policies of increasing commercialization of university research and industry funding of public research were often adopted in the context of a tightening of public investments in R&D. Thus, far from amplifying the economic effect of public investments in R&D, commercialization of university research very quickly became a substitute for public funding of research and so its net effect on the economy-wide diffusion of technology may be difficult to gauge.

Second, universities have always regarded themselves primarily as centers of learning, where new knowledge is created and curated through research, and ultimately disseminated via teaching. They see themselves as upholding the four Mertonian norms of communism (common ownership of scientific outputs without resort to secrecy), universalism (universal scientific validity irrespective of who the source of scientific output is), disinterestedness (acting in common scientific interest rather than for personal gain), and organized scrutiny (critical scrutiny of scientific output before acceptance). Academic researchers are a self-selected group who are largely driven by the same set of norms in the pursuit of their individual research careers.

Commercialization activities contradict at least two of the four Mertonian norms, given that they are motivated by private ownership of intellectual property and private gain. This leads to a fundamental tradeoff between the ideal of pure scientific exploration versus profit-driven commercial exploitation. Furthermore, pure scientific exploration is essential to the first mission of the university, the provision of education. Universities caught between scientific exploration and exploitation will struggle to simultaneously reconcile both these aims. Indeed, management science teaches that most organizations struggle both to explore new knowledge and to exploit existing knowledge at the same time (organizational ambidexterity), as the two sorts of activity require a different type of management and entail different risks.

Public research institutes were set up as specialized intermediaries to fulfill the commercialization function: to take up frontier science from universities and adapt them to the needs of local communities and industry. More recently, they have been in (possibly) terminal decline, even in countries where they have been quite successful. The reasons for this decline are not clear and probably deserve a book of their own to explore more rigorously, but it is likely that shifting the locus of commercialization from these specialized intermediaries to universities driven by Mertonian norms may have been inefficient in countries where the institutional frameworks to transfer knowledge directly from universities were still immature and poorly developed. Third mission activities in many countries, however, came at the expense of public research institutes. Whether universities' third mission activities can and should replace public research institutes remains an underexplored question.

Lastly, while nobody denies that the payoffs of academic research are maximized when the private sector uses and builds on research carried out in the public sector, these are not one-way exchanges from universities to firms. Industrial research complements and also guides more basic research. It is also a means of "equipping" university scientists with new and powerful instruments. For such knowledge transfer to work, firms need to be able to assimilate and exploit public research. This capability often requires firms to actively engage in upstream research and actively participate in science (see Cohen and Levinthal 1989). In middle- and low-income countries, even large firms may lack this capability, while in high-income economies small firms may behave in this way. Policies to promote outward knowledge transfer from universities and public research institutes are likely to fail if local firms lack sufficient absorptive capacity.

1.2 Cross-Country Trends in Public R&D

The volume of public sector investment in scientific research is traditionally measured through expenditures on R&D financed by government. R&D expenditures, their distribution across industrial sectors, and the proportion spent on applied and basic R&D are highly variable across countries and have usually evolved with the growth of an economy and the nature of industrial policies to support growth (see also National Science Foundation 2018; UNESCO 2018). The increase in public or private R&D, however, must be seen in the context of the overall growth of R&D. An increase in public R&D is more effective if business expenditures on R&D are high or rising.

Figure 1.1 shows noticeably different overall trends in the R&D intensity (share of R&D expenditures as a percentage of GDP) for high-, middle- and low-income economies between 2000 and 2016. High-income countries spend about 2.5 percent of GDP on R&D, and this is a much larger share than any other group of countries. The sharpest growth in R&D, however, has been in the upper middle-income countries. In both high- and low-income countries, R&D expenditures as a share of GDP have struggled to

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grow, while lower middle-income countries (which includes countries such as India) have seen a decline in R&D intensity.

Public sector R&D can be delivered through a variety of institutions. Universities play a big role in high-income economies where industrial capabilities are at the scientific frontier and so benefit from close links to the basic science produced in university science departments. More specialized public research institutes may be preferred in middle- and lower-income countries that have limited resources to invest in scientific infrastructure and that often prefer to concentrate such investments in a few areas of greatest need to the economy and society. In general, as national income per capita decreases, R&D by public research institutes plays an increasingly important role in economic development. As firms in these economies possess low levels of technological capability, they need the help of public R&D to adapt frontier technologies to domestic conditions. Public research institutes generally undertake applied research geared toward the building of prototypes that can be manufactured by local industry.

In high-income economies, the public sector is responsible for anywhere between 20 and 45 percent of annual total R&D expenditure and

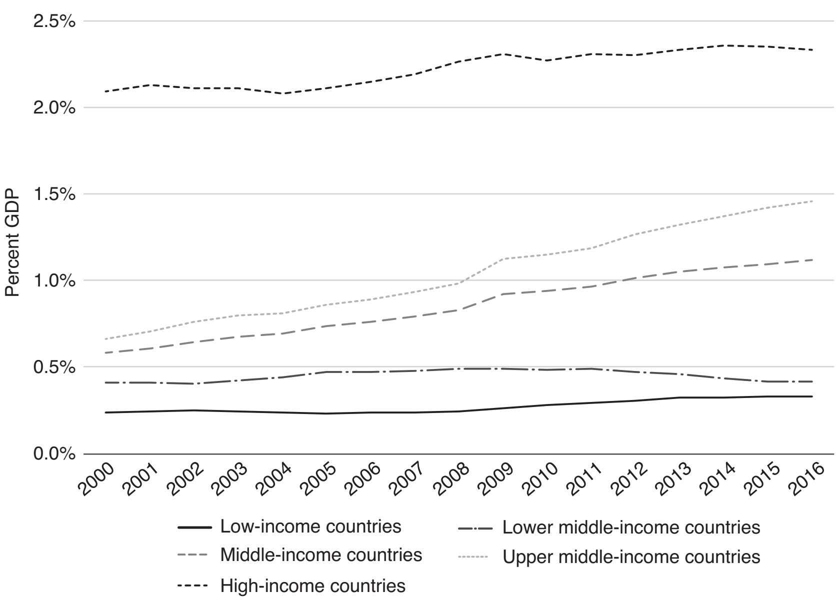

Figure 1.1 Share of R&D (measured by GERD) in GDP by income group of countries, 2000–16
Source: UNESCO Institute for Statistics, March 2019

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almost three-quarters of the expenditure on basic research, with the remaining expenditure on private and applied R&D coming from the private sector. On average, government funding is responsible for about 53 percent of total R&D in the middle-income countries for which data are available. Thus, the distribution of R&D between public and private sectors shows that as the level of a country's per capita income decreases, governmental funding approaches 100 percent.

The data on public and private R&D are patchy but in Figure 1.2 (panels A and B), we plot the data that are available to demonstrate the variability of public R&D even within similar income groups. Although not included in Figure 1.2B, the public sector funded 100 percent of R&D in Burkina Faso in the last year for which data are available (see UNESCO 2018). In Argentina, Bolivia, Brazil, India, Peru, and Romania (also not included in Figure 1.2B) the share of public sector R&D often exceeds 70 percent of total R&D.[10]

Importantly, with some exceptions, governments usually provide the majority of the funds for basic research. Basic research is experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundation of phenomena and observable facts, without any particular application or use in view (for the U.S., see the analysis in Arora et al. 2015). On average, in 2009, the public sector performed more than three-quarters of all basic research in high-income economies.[11] These contributions to basic research are becoming more vital as firms focus mostly on product development and as multinational companies in high-income countries scale back their basic research in a number of R&D-intensive sectors (see OECD 2008). In middle-income countries for which data are available (see Figure 1.3), public research is responsible for the majority of basic R&D: close to 100 percent in China, close to 90 percent in Mexico, about 80 percent in the Russian Federation, and about 75 percent in South Africa. A high share of government in basic research may also be an institutional legacy, often seen in former socialist countries.

[10] Exceptions are Malaysia, China, the Philippines, and Thailand where, for both R&D funding and performance, the business sector has the largest share but, nonetheless, public research organizations play a key role in contributing to industry R&D and ensuing innovation.

[11] See OECD, Research & Development Statistics. Depending on the country in question, it accounts for about 40 percent (Republic of Korea) to close to 100 percent (Slovakia) of all basic research performed.

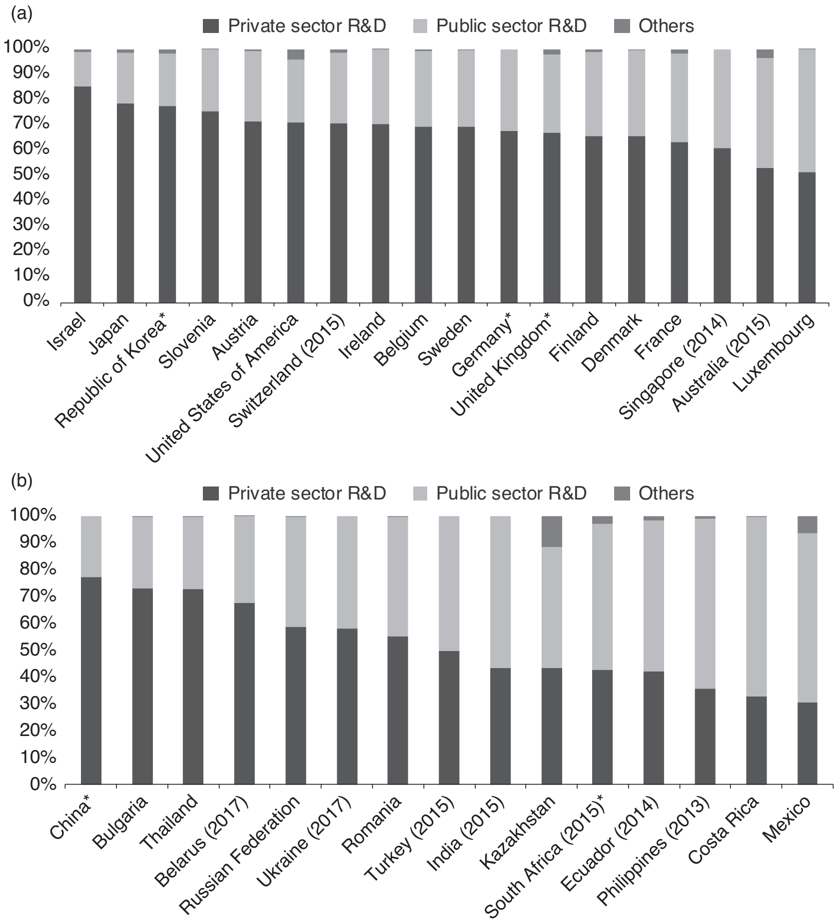

Figure 1.2 Share of public sector in total R&D, high- and middle-income economies
A. Share of public sector in total R&D in high-income countries, in percent, 2016 or latest available year
B. Share of public sector in total R&D in middle-income economies, in percent, 2016 or latest available year

1.3 Challenging Factors in Middle-Income Countries

The consistent increase in R&D intensity in upper-middle and middle-income countries – in the latter case much driven by China only – masks several challenges.

Compared to high-income countries, science and technology (S&T) and innovation conditions in middle- and low-income countries face the following challenges:

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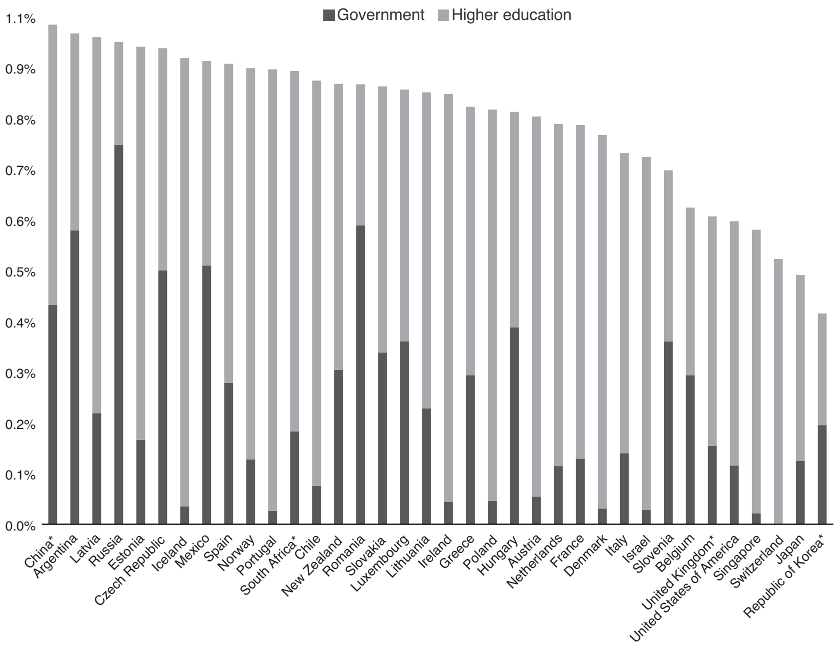

Figure 1.3 Share of basic research conducted by the public sector for 2017, or latest available year, as a percentage of all national expenditures for basic research
Source: Organisation for Economic Co-operation and Development (OECD), Research and Development Statistics Database, March 2019
Note: Figure 1.3 provides data from the most recent available years, between 2015 and 2017 for each country. Some of the distinction between higher education institutions – universities and government as well as public research institutes – is simply definitional and depends on what is defined as a university or a public research institute in a given country.
*Case study countries

- a lower level of S&T;
- low research and innovation capabilities of domestic firms, with the result that government and international donors are often the main funders of S&T and national public research institutes are the main R&D performers;
- less developed human capital for S&T activity, particularly a low number of scientists in firms and the best domestic scientists moving abroad ("brain drain" effect);
- lower quality research and relevance of public research to the business sector;
- limited science–industry linkages, explained by a low absorptive capacity of firms combined with an ensuing lack of "business" demand for S&T;

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- a lack of policies and structures to facilitate academic and other start-ups; and
- constrained access to financing as a barrier to the development of radical or early-stage innovations.

There are several reasons that explain the limited impact of science on economic development in low- and middle-income countries. First of all, in terms of policy strategies, is the need to address basic economic needs such as poverty and health, with science and technology as second-order priorities. Second-, middle- and low-income countries are a very heterogeneous group, with wide differences in the needs and conditions for knowledge transfer. In most low-income countries, many of the necessary elements for science to have an impact on industrial innovation and society are embryonic, while in middle-income countries the foundations exist but are weakly articulated (WIPO 2011; Zuñiga 2011). It is clear, however, that R&D capabilities – both in private and public institutions – in many middle-income economies have improved during the last decade and opportunities to enhance technology commercialization through IP are emerging.

As the remainder of this book shows, structural features have also constrained the development of linkages between universities and firms.[12] Often, commercial activity by universities and researchers has been or is still highly regulated or even forbidden. With few exceptions, most universities fully depend on federal budgets and have weak linkages with regional governments and economies. The lack of absorptive capacity in firms and their natural focus on imitative innovation and acquisition of foreign technology as innovation strategies also contribute to fragmentation in national innovation systems (see Navarro et al. 2010). The technological strategies of firms in lower- and middle-income economies often depend on off-the-shelf imported technology, primarily in the form of machinery and turnkey knowledge transfer from abroad. Often these are also the only options for these firms to access current technology.[13] The barriers to industry–science collaboration reported by firms include a lack of communication channels with universities, differences in organizational culture (in respect of timing and product

[12] See in particular Chapters 10 and 11.

[13] See Zuñiga (2011). In Argentina, for example, according to the innovation survey of 1998–2001, 84 percent of firms that cooperated with other actors in the national innovation systems did so for informational purposes and 58 percent for training purposes; only 21 percent engaged in cooperation for R&D. In Colombia, the percentages of firms (within those that reported links with agents providing technological services) are 31, 50, and 15 percent, respectively.

delivery), uncertainty of a market need/demand for research results, and high costs for developing and commercializing university research.[14]

In this context, one of the main conclusions of this book is that knowledge transfer policies that are not accompanied by policies to strengthen R&D capabilities in firms and industry–science linkages are unlikely to be successful. In addition, as in high-income countries, transforming academia into more entrepreneurial institutions requires cultural change – in particular among researchers, and often an increase in university autonomy, including for more competitive hiring and in terms of resource management. Compared to high-income countries, the following are additional barriers to knowledge exchange from the science base in low- and middle-income countries:

- lack of clear knowledge transfer policies for universities and public research institutes;
- weak operative guidelines on patenting, for example on disclosure and commercialization of IP at the institutional level;
- little awareness about and few incentives for researchers to participate in IP-based knowledge transfer; and
- absence of or inadequate resources for KTOs, with staff lacking the necessary skills and experience related to IP and commercialization.

More generally, an additional friction to the development of IP registration and commercialization in many middle- and low-income countries is the sluggish process of patenting at national patent offices and its relatively high cost (see WIPO 2011; Zuñiga 2011; Chapters 10 and 11 of this book).

However, these characteristics are not shared equally across all low- and middle-income countries. For the most part, work is ongoing to improve the systemic weaknesses in national innovation systems and to give greater autonomy to universities. As evidenced earlier, many of these countries are also in the midst of implementing or setting up knowledge transfer policies and practices. Indeed, in some cases this has already led to significant impacts, both in terms of measured knowledge transfer and the related broader impacts on public research organizations, firms and the linkages between them.

Finally, this book emphasizes that high-income countries struggle with many of the same challenges when it comes to putting in place functioning knowledge transfer practices. A blueprint that could easily be adopted across institutions and countries therefore does not yet exist, even in

[14] For evidence from China on this, see Guan et al. (2005).

high-income economies. Experience and the economic literature show that different stages of development and different innovation systems require different policies and incentives to promote the commercialization of public research (see Guellec et al. 2010). Conditions for knowledge transfer develop over time and depend heavily on research capabilities and science–industry linkages. Having a broad view of the concept of technology commercialization, looking at intermediate steps and broad knowledge transfer activities – not exclusively focused on IP creation and licensing, and academic entrepreneurship – makes for good policy advice.

1.4 Rationale for the Selection of Country Cases

The heterogeneity of high- and middle-income countries with regard to basic features about the organization of public R&D suggests that simply instituting relevant laws and regulations is only a first ingredient to stimulating industry–science linkages. A number of conditions need to be in place at the country and institutional level to reap the resulting benefits. Moreover, diverse stages of development will require different approaches and complementary policies, including safeguards for avoiding the downside risks of university patenting.

Our approach in this book has been to explore in detail the interaction between the institutional frameworks, public policy constraints, and adoption of third mission policies in six countries with a view to distilling lessons from their experience. Although heterogeneous in themselves, this group of countries consists of three high-income economies (the United Kingdom, Germany, and the Republic of Korea) whose experience of third mission policies differs from the oft-cited example of the U.S. Germany is an exemplar of the institution of a collective market economy where public sector R&D and the state more generally played a large role in economic growth and technological prowess. The United Kingdom, by contrast, is more similar to the U.S. in relying on liberal market institutions to promote third mission policies. The Republic of Korea (like Germany) relied on a strong public research institute sector for technological catch-up but has found the institutional change needed to implement broad-based growth (moving away from reliance on large chaebol companies) hard to achieve. We also include the study of three large middle-income countries, namely Brazil, China, and South Africa. Brazil inherited institutions that are similar to those in continental Europe, but it was also influenced by the US system. China transformed

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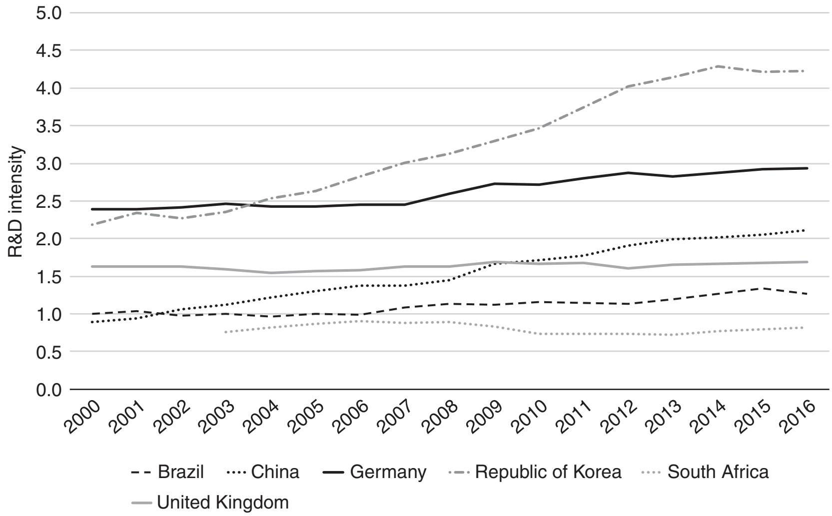

Figure 1.4 R&D intensity (GERD as a percentage of GDP), case study countries
Source: Authors based on data from the UNESCO Institute for Statistics and OECD

itself from a public research institute-led system to one in which universities were reformed to engage with domestic industry. South Africa managed both radical political change and reformed its university system and linkages to industry.

Figures 1.4 and 1.5 build on Figures 1.1–1.3 for the six countries that we study in this book. They enable us to see the precise nature of differences between countries that may often belong to the same income group classification.

Figure 1.4 on R&D intensity shows that the Republic of Korea, China, and Germany saw rising shares of R&D in their economies. The United Kingdom (despite being in the high-income group) had R&D shares that were almost a whole percentage point lower than those in Germany and lower than China (a middle-income country). The R&D intensity was stagnant in the United Kingdom and similar trends are observed for South Africa and Brazil. Figure 1.5 shows the percentage of gross expenditure on R&D that was financed by the government. All countries, except for South Africa, show a declining trend. China and the Republic of Korea show some of the lowest levels, while Brazil and South Africa have markedly higher levels of government-financed R&D. Thus, the six case studies

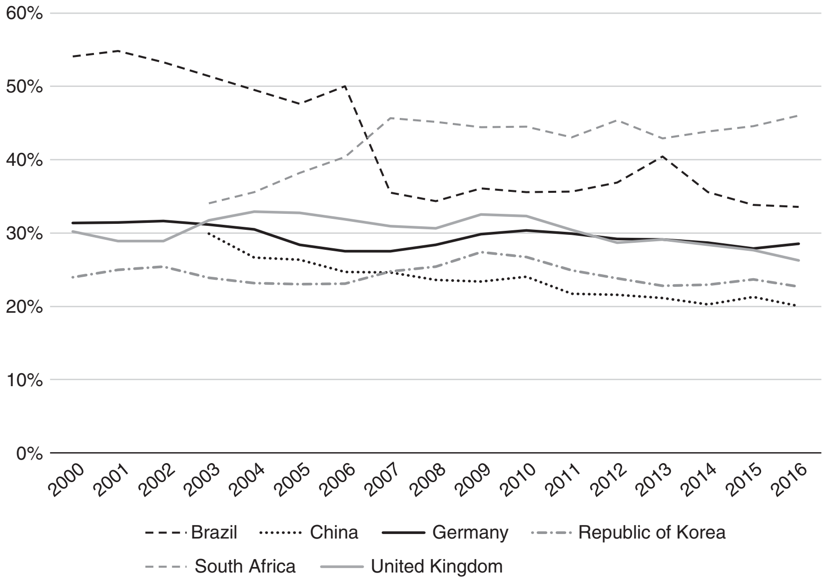

Figure 1.5 Share of GERD financed by the government, case study countries
Source: Authors based on data from the UNESCO Institute for Statistics and OECD

confirm that the backdrop against which stronger knowledge exchange policies have been pursued has been a declining share of government-financed R&D in the context of an overall decline in R&D intensities.

As we noted in Section 1.3, the distribution of R&D between the public and private sectors has varied considerably between countries even within a particular group. In general, countries that had a large role for the state also ended up having large public R&D shares. Figure 1.2 also reports the distribution of public and private sector R&D, including for the group of case study countries, except Brazil, for which no data were available. The smallest shares of public R&D were for the Republic of Korea and China, which have seen a strong role of the state and also public research institutes in their growth histories. South Africa has the largest share of public R&D followed by Germany and the United Kingdom.

A last indicator worth looking at is the distribution of basic research between the share of universities and the share of the government sector in the six countries we study (see Figure 1.3). Here we find that in China most basic research (over 55 percent) happens in the government and the university sector (here institutions of higher education), whereas this is much lower at about 30 percent for the Republic of Korea and Germany and even lower, at 20 percent, for South Africa and the United Kingdom. Basic research in universities is smallest for the United Kingdom and highest for China.

1.5 Summary and Plan of the Book

The most appropriate frameworks for spurring the commercialization of publicly funded inventions – whether in public research institutes or publicly funded universities – depends on the institutional context and will vary due to different starting points. Yet, for the most part, a "one glove fits all" approach has dominated policy thinking in this area. At times, policymakers and institutions have been overreliant on the filing of IP as the only instrument to enhance the impact of science on the economy. A more realistic assessment of the state of their research and innovation systems to identify the role that IP can play in such development (given both its opportunities and costs) is missing and sorely needed.

Providing a more nuanced understanding of optimal policies for knowledge transfer is the overriding objective of this book. Such policies need to be grounded both in the historical evolution of university–industry relations and systematic data underpinned by a rigorous conceptual understanding of what is involved in knowledge exchange between university and industry. In keeping with this objective, we use a recursive approach in the book, as follows.

Part I develops an understanding of broad institutional differences in the nature of public science across countries; a conceptual framework for thinking about knowledge exchange, knowledge transfer metrics, and survey and evaluation frameworks; and a standardized method to assess national or institutional strategies. This first chapter sets out the rationale for third mission activities, shows how policies for third mission activities developed in a fiscal situation that saw a decline in funding for public R&D in many countries, and sets out the main institutional differences between high- and middle-income countries. It also compares basic trends in public R&D for the six countries studied. Chapter 2 develops a conceptual framework to guide the evaluation of knowledge transfer policies, practices and outcomes. Chapter 3 then looks at what corresponding patent metrics exist to produce (internationally) comparable data on formal knowledge transfer practices.

Part II (Chapters 4–9) recounts the historical evolution of knowledge exchange policy and outcomes in three high-income countries (the United Kingdom, Germany, and the Republic of Korea) and three middle-income countries (China, Brazil, and South Africa). Country authors use the unique history of their country to produce narratives of policy evolution and the reasons for success or failure of intended outcomes.

Part III uses an inductive approach to distill optimal policies and identify optimum metrics to support a better framework for knowledge exchange. An important differentiating feature of this book is that we recognize that knowledge exchange is a two-way process where the ability of firms to absorb university-generated knowledge is as important as the ability of the university to reach out. Thus, Chapters 10 and 11 outline policies to raise industrial involvement and university involvement in knowledge exchange, respectively. In each chapter, we contrast the experience of high-income and middle- income countries to draw out the policy implications. What knowledge transfer laws and practices have been put in place in high- and middle-income countries? How have new policies to support IP licensing affected other knowledge transfer channels? Which approaches have demonstrated the best outcomes for public institutions and for firms but also at the broader macro-level? Do approaches exist that are particularly relevant to developing countries? Chapter 12 concludes the book by discussing the interplay between the objectives of knowledge exchange policy and the metrics available to evaluate these objectives, and what remains to be done in this regard. Which overall economic and other impacts have been measured and how? What additional data are required to provide a comprehensive set of metrics for use in benchmarking, monitoring, and policy evaluation? What are the possible sources of such data?

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