PART I

Setting the Context

1

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

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[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).

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