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Contents

Drivers of International Research Spending

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ABSTRACT

There has been significant theoretical and empirical research on the causes and effects of research and development (R&D) spending; however, the incentives of individual firms to engage in such an investment, especially firms that differ in characteristics and the institutional settings they operate in, are not well understood. This monograph adds to the literature on the economics of technical change, with a primary focus on research spending as the key input in innovation, in two ways. First, it provides an overview and a critical appraisal of the literature on the drivers of research spending, especially focusing on the extant empirical studies in recent years. Second, it provides estimation results from the determinants of research spending across a large sample of mostly emerging nations using data at the firm level. Based on these findings, implications for technology policies and directions for future research are discussed.

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1

Introduction

The importance of technological change for the growth and well-being of nations cannot be overstated (Chu, 2021; Jones, 1995). Ever since the invention of the wheel and the ability to light the fire, humans have, actively or passively, engaged in and benefitted from new and improved technologies. Another way to gauge the importance of technological change might be to envision the extinction of the human race in the absence of medical breakthroughs to combat famines and pandemics. Arguably, technologies have also been proven effective in preventing or ending military conflicts. Moreover, economic recovery, the launching of sustainable economic growth, addressing social and financial crises, pandemics, global challenges, or other similar problems are to a large extent conditioned by the stimulation of high-technology and innovative solutions (Mazzucato, 2013). A relatively recent development to address such problems is the growth of digital technologies, notably artificial intelligence (AI). A number of these technologies are labor-saving (Acemoglu and Restrepo, 2019, 2020; Acemoglu *et al.*, 2020; Graetz and Michaels, 2018), and thus they enhance productivity and growth. At the same time, ethical concerns of AI for society, including privacy and

surveillance, and the degree it can supplant human judgment are a mounting concern (Pazzanese, 2020).

Many dimensions of the process of technological change have been studied with an emphasis on the input, output and attendant institutions. While these studies are all important in fostering technological development and innovation, our understanding and measurement of them differs. Sequentially, R&D inputs are the fundamental ingredient in this process, and this dimension forms the focus of the current work.

The relationship between technological change and economic growth has been well-documented by the emergence of endogenous economic growth theories (Aghion and Howitt, 1992; Romer, 1990). These studies show that countries investing more in research and development (R&D) tend to grow faster and achieve higher levels of economic and social prosperity than those that invest less. Noteworthy is the fact that a number of papers have focused on innovation and technological change to explain cross-country differences in the levels of development and growth performance (see Dosi, 1990; Freeman, 1989; Goel and Ram, 1994; Verspagen, 1991). Besides the impact on economic growth at the macro level, the effects of R&D and innovation on employment and productivity at the firm level have been studied by researchers (see, for example, Bhattacharya and Rath, 2020; Cirera and Sabetti, 2019).

This monograph adds to the literature on the economics of technical change in two ways.[1] First, it provides an overview and a critical appraisal of the literature on the drivers of research spending, especially focusing on the extant empirical studies in recent years. Second, it provides a unique insight into the empirical determinants of research spending using micro or firm-level data on research spending decisions across a very large sample of mostly emerging nations. Firm-level information on research enables the consideration of many characteristics (e.g., size, vintage, ownership, etc.) of firms that perform research.

R&D as an input may be measured in terms of the number of researchers involved in research, as well as the level and type of research spending. R&D intensity is one of several indicators used to measure

[1] A number of surveys of the overall literature exist. Some of these include: Cohen and Levin (1989), Fagerberg *et al.* (2005), Kamien and Schwartz (1982), Nelson (1959), Reinganum (1989).

progress toward achieving an innovation. Investment in research spending is needed for the advancement of innovation in all fields of study and across all technologies (Gulbrandsen and Aanstad, 2015). Alternatively, research participation can capture research competition, even at a small level of research investment, as well as the ability to innovate and/or imitate. Furthermore, policymakers in many nations, especially emerging economies, would be more interested in fostering research participation to facilitate technology absorption (as compared to the concentration of research spending among a few, likely multi-national, firms). Whereas overall research spending can be ascertained from the outside (by third parties) too, information on research participation by firms is possible only via surveys of individual firms.

Some features of R&D cause resource allocation issues. For instance, due to four key characteristics of R&D, noted by Jones and Williams (2000), an optimal level of R&D investment in an economy is not always achieved (also see Olmos-Peñuela *et al.*, 2016). These characteristics are in fact distortions in the market. They are: (i) the surplus appropriability problem (i.e., the inability to garner all fruits of one's research efforts); (ii), knowledge spillovers (i.e., others can learn from your knowledge by little or no effort); (iii) creative destruction (i.e., the process of new technologies superseding existing ones (also see Mazzucato, 2013; Schumpeter, 1962)); and (iv) duplication externalities (i.e., many firms pursuing the same invention, with the "winner" reaping all or most rewards), also see Dasgupta and David (1994). The implications of these broad distortions have been better understood at the economy-wide level and our use of firm-level data will provide some micro-level insights (Hobday, 2005; Ortega-Argilés *et al.*, 2009).

To place the contributions of this monograph in perspective, it is important to understand that firm-level information on R&D activity and innovative performance is generally difficult to obtain, given the effort involved in conducting and documenting individual surveys. This is especially challenging in the case of secretive and proprietary information that typically characterizes research activity (Mueller, 1966). Whereas aggregate variables allow one to control for the crucial influence of institutions in the innovation process (North, 1990), firm-specific attributes account for equally important factors (Utterback, 1971), such

as vintage or experience (Huergo and Jaumandreu, 2004) and size (Acs and Audretsch, 1987; Cohen and Klepper, 1996; de Jong and Marsili, 2006; Martínez-Ros and Labeaga, 2002; Nooteboom, 1994). For example: What drives research spending at the firm level? Are larger firms more likely to spend on R&D? What about older firms? How can nations fruitfully benefit from R&D? Answers to these and similar questions would feed into answers to broader questions like why some nations are more innovative than others (Shane, 1992).

In addition, it is important to understand that research needs to be supported by various actors (public sector, firms, nongovernmental community) that are willing to make significant investments in many areas. Moreover, appropriate institutional environments (antitrust, regulatory, and intellectual property policies; venture capital; and other factors) and economic and political conditions are important. However, introducing reforms and initiatives with the desire to enhance so-called innovation networks between knowledge producers and users are alone not enough. There is an important role for the government to play as well in the generation of new knowledge.

Since the relationship between science and technology that was put forward by Bush (1945), and the creation of the National Science Foundation in the United States in 1953, the U.S. federal government has supported scientific research for societal benefit far beyond the purposes of national defense. This has institutionalized government support for scientific research with the belief that this would contribute to economic growth by lessening barriers that bring about market failures in the private provision of new knowledge (see Takalo *et al.*, 2013).

Finally, the interplay of private and public research activities, along with the role of institutions, is important. This topic has been studied by Goel and Rich (2005) by borrowing from the structure-conduct-performance paradigm developed in the industrial organization literature. Their framework is a useful way to think about the big picture and sets up potential avenues for government intervention. We argue, in many cases, the so-called innovation eco-systems are populated by actors who do not do research and therefore lack the ability to innovate.

The rest of this monograph is organized as follows: We begin by presenting a schematic diagram that describes our vision about what

constitutes R&D, its various dimensions, and the key players involved in such activity. Next, we offer an extended overview of the literature on the causes and effects of technical change, including the drivers of research spending. We then discuss micro-level data sets on technical changes and R&D activity, with special attention given to the Enterprise Surveys (ES) dataset organized through the World Bank. We employ the ES dataset in modeling cross-country firm-level R&D decision-making. Finally, we provide some recommendations for technology policy and suggest some directions for future research.

References

Acemoglu, D., C. Lelarge, and P. Restrepo (2020). "Competing with robots: Firm-level evidence from France". *AEA Papers and Proceedings, American Economic Association*. 110: 383–388.

Acemoglu, D. and P. Restrepo (2019). "Automation and new tasks: How technology displaces and reinstates labor". *Journal of Economic Perspectives*. 33(2): 3–30.

Acemoglu, D. and P. Restrepo (2020). "Robots and jobs: Evidence from US labor markets". *Journal of Political Economy*. 128(6): 2188–2244.

Acs, Z. J. and D. B. Audretsch (1987). "Innovation, market structure, and firm size". *Review of Economics and Statistics*. 69(4): 567–574.

Aghion, P. and P. Howitt (1992). "A model of growth through creative destruction". *Econometrica*. 60(2): 323–351.

Aoki, R. and J.-L. Hu (1999). "Licensing vs. litigation: The effect of the legal system on incentives to innovate". *Journal of Economics and Management Strategy*. 8(1): 133–160.

Audretsch, D. B. and A. N. Link (2018). "Innovation capital". *Journal of Technology Transfer*. 43(6): 1760–1767.

Audretsch, D. B. and D. Göktepe-Hultén (2015). "University patenting in Europe". In: *The Chicago Handbook of University Technology Transfer and Academic Entrepreneurship*. Ed. by A. N. Link, D. Siegel, and M. Wright. Chicago: University of Chicago Press. 188–207.

Audretsch, D. B. and M. P. Feldman (1996). "R&D spillovers and the geography of innovation and production". *American Economic Review*. 86(3): 630–640.

Belderbos, R., B. Leten, and S. Suzuki (2013). "How global is R&D? Firm-level determinants of home-country bias in R&D". *Journal of International Business Studies*. 44: 765–786.

Bhattacharya, P. and B. N. Rath (2020). "Innovation and firm-level labour productivity: Comparison of Chinese and Indian manufacturing based on enterprise surveys". *Science, Technology and Society*. 25(3): 465–481.

Bigsten, A. and M. Söderbom (2006). "What have we learned from a decade of manufacturing enterprise surveys in Africa?" *The World Bank Research Observer*. 21(2): 241–265.

Bonanno, G. and B. Haworth (1998). "Intensity of competition and the choice between product and process innovation". *International Journal of Industrial Organization*. 16(4): 495–510.

Boone, J. (2000). "Competitive pressure: The effects on investments in product and process innovation". *RAND Journal of Economics*. 31(3): 549–569.

Bozeman, B. and J. Jung (2017). "Bureaucratization in academic research policy: What causes it?" *Annals of Science and Technology Policy*. 1(2): 133–214.

Brown, M. A., L. G. Berry, and R. K. Goel (1991). "Guidelines for successfully transferring government-sponsored innovations". *Research Policy*. 20(2): 121–143.

Bush, V. (1945). *Science: The Endless Frontier: A Report to the President Vannevar Bush*. URL: https://www.nsf.gov/about/history/EndlessFrontier_w.pdf.

Calvert, J. (2006). "What's special about basic research?" *Science, Technology, and Human Values*. 31(2): 199–220.

Cantner, U. and H. Hanusch (1993). "Process and product innovations in an international trade context". *Economics of Innovation and New Technology*. 2(3): 217–236.

Castellacci, F., P. C. Oguguo, and I. M. B. Freitas (2022). "Quality of pro-market national institutions and firms' decision to invest in R&D: Evidence from developing and transition economies". *Eurasian Business Review*. in press. DOI: 10.1007/s40821-022-00202-7.

Chen, Y. and T. Puttitanun (2005). "Intellectual property rights and innovation in developing countries". *Journal of Development Economics*. 78(2): 474–493.

Chu, A. C. (2021). "Patent policy and economic growth: A survey". *The Manchester School*. URL: https://dx.doi.org/10.1111/manc.12392.

Cirera, X. and L. Sabetti (2019). "The effects of innovation on employment in developing countries: Evidence from enterprise surveys". *Industrial and Corporate Change*. 28(1): 161–176.

Cirera, X. and W. Maloney (2017). *The Innovation Paradox: Developing-Country Capabilities and the Unrealized Promise of Technological Catch-Up*. Washington, DC: World Bank. DOI: 10.1596/978-1-4648-1160-9.

Cohen, W. M. and R. C. Levin (1989). "Empirical studies of innovation and market structure". In: *Handbook of Industrial Organization*. Ed. by R. Schmalensee and R. Willig. Vol. 1, Chapter 18. Amsterdam, North-Holland. 1059–1107.

Cohen, W. M. and S. Klepper (1996). "Firm size and the nature of innovation within industries: The case of process and product R&D". *Review of Economics and Statistics*. 78(2): 232–243.

Curlee, T. R. and R. K. Goel (1989). *The Transfer and Diffusion of New Technologies: A Review of the Economics Literature*. Oak Ridge, TN: Oak Ridge National Laboratory. ORNL/TM-11155.

Czarnitzki, D. and A. A. Toole (2007). "Business R&D and the interplay of R&D subsidies and product market uncertainty". *Review of Industrial Organization*. 31: 169–181.

Czarnitzki, D. and A. A. Toole (2013). "The R&D investment-uncertainty relationship: Do strategic rivalry and firm size matter?" *Managerial and Decision Economics*. 34(1): 15–28.

Czarnitzki, D. and K. Hussinger (2018). "Input and output additionality of R&D subsidies". *Applied Economics*. 50(12): 1324–1341.

Dasgupta, P. and J. Stiglitz (1980a). "Industrial structure and the nature of innovative activity". *Economic Journal*. 90(358): 266–293.

Dasgupta, P. and J. Stiglitz (1980b). "Uncertainty, industrial structure, and the speed of R&D". *Bell Journal of Economics*. 11(1): 1–28.

Dasgupta, P. and P. A. David (1994). "Toward a new economics of science". *Research Policy*. 23(5): 487–521.

d'Aspremont, C. and A. Jacquemin (1988). "Cooperative and noncooperative R&D in duopoly with spillovers". *American Economic Review*. 78(5): 1133–1137.

David, P. A. and B. H. Hall (2000). "Heart of darkness: Modeling public-private funding interactions inside the R&D black box". *Research Policy*. 29(9): 1165–1183.

de Jong, J. P. J. and O. Marsili (2006). "The fruit flies of innovations: A taxonomy of innovative small firms". *Research Policy*. 35(2): 213–229.

Dedrick, J. and K. Kraemer (2015). "Who captures value from science-based innovation? The distribution of benefits from GMR in the hard disk drive industry". *Research Policy*. 44(8): 1615–1628.

Dohse, D., R. K. Goel, and M. A. Nelson (2019). "Female owners versus female managers: Who is better at introducing innovations?" *Journal of Technology Transfer*. 44(2): 520–539.

Dosi, G. (1990). "Finance, innovation and industrial change". *Journal of Economic Behavior and Organization*. 13(3): 299–319.

Elzinga, A. (2012). "Features of the current science policy regime: Viewed in historical perspective". *Science and Public Policy*. 39(4): 416–428.

Etzkowitz, H. (2002). *The Second Academic Revolution: MIT and the Rise of Entrepreneurial Science*. London: Gordon & Breach.

Etzkowitz, H. and L. Leydesdorff (2000). "The dynamics of innovation: From National Systems and "Mode 2" to a Triple Helix of university–industry–government relations". *Research Policy*. 29(2): 109–123.

Fagerberg, J., D. C. Mowery, and R. R. Nelson (2005). *The Oxford Handbook of Innovation*. Oxford: Oxford University Press.

Fagerberg, J. and M. Srholec (2008). "National innovation systems, capabilities and economic development". *Research Policy*. 37(9): 1417–1435.

Feldman, M. P. (1999). "The new economics of innovation, spillovers and agglomeration: A review of empirical studies". *Economics of Innovation and New Technology*. 8(1–2): 5–25.

Freeman, C. (1989). "New technology and catching up". *The European Journal of Development Research*. 1(1): 85–99.

Freeman, C. (1995). "The 'national system of innovation' in historical perspective". *Cambridge Journal of Economics*. 19(1): 5–24.

García-Quevedo, J., G. Pellegrino, and M. Vivarelli (2014). "R&D drivers and age: Are young firms different?" *Research Policy*. 43(9): 1544–1556.

Goel, R. K. (1987). *Market Structure, Innovations, and Welfare*. Doctoral dissertation, University of Houston.

Goel, R. K. (1990). "The substitutability of capital, labor, and R&D in U.S. manufacturing". *Bulletin of Economic Research*. 42(3): 211–227.

Goel, R. K. (1992). "On vertical integration into R&D". *Quarterly Review of Economics and Finance*. 32(3): 54–59.

Goel, R. K. (1995). "Spillovers, rivalry and R&D investment". *Southern Economic Journal*. 62(1): 71–76.

Goel, R. K. (1999a). "R&D and output in a regulated vertically integrated oligopoly". *Bulletin of Economic Research*. 51(4): 339–347.

Goel, R. K. (1999b). *Economic Models of Technological Change*. Westport, CT: Greenwood Publishing.

Goel, R. K. (2003). "Rent-seeking in research markets". *Journal of Technology Transfer*. 28(2): 103–109.

Goel, R. K. (2006). "Uncertain innovation with uncertain product durability". *Applied Economics Letters*. 13: 829–834.

Goel, R. K. (2007). "Research spending under regulatory uncertainty". *Journal of Technology Transfer*. 32(6): 593–604.

Goel, R. K. (2020). "IPR infringement in the United States: Impacts on the input and output of R&D". *Journal of Technology Transfer*. 45: 481–493.

Goel, R. K. and D. Göktepe-Hultén (2019). "Risk attitudes, patenting and invention disclosures by academic researchers". *Journal of Technology Transfer*. 44(1): 155–166.

Goel, R. K. and D. P. Rich (2005). "Organization of markets for science and technology". *Journal of Institutional and Theoretical Economics*. 161: 1–17.

Goel, R. K. and J. W. Saunoris (2016). "Institutional path dependence and international research intensity". *Economic Modelling*. 52(PB): 851–858.

Goel, R. K. and J. W. Saunoris (2020a). "Design versus utility innovation: Is corruption sanding or greasing the wheels of innovation?" *Managerial and Decision Economics*. 41(5): 848–860.

Goel, R. K. and J. W. Saunoris (2020b). "Where is the entrepreneurship bang for the patenting buck? Utility versus design patents". *Managerial and Decision Economics*. 41(1): 25–35.

Goel, R. K. and J. W. Saunoris (2021). "The role of socio-historic factors and income inequality in global innovation". *Economics of Innovation and New Technology*. DOI: 10.1080/10438599.2021.1959326.

Goel, R. K., J. E. Payne, and R. Ram (2008). "R&D expenditures and U.S. economic growth: A disaggregated approach". *Journal of Policy Modeling*. 30(2): 237–250.

Goel, R. K., J. W. Saunoris, and X. Zhang (2016). "Intranational and international knowledge flows: Effects on the formal and informal sectors". *Contemporary Economic Policy*. 34(2): 297–311.

Goel, R. K. and M. A. Nelson (2009). "Determinants of software piracy: economics, institutions, and technology". *Journal of Technology Transfer*. 34: 637–658.

Goel, R. K. and M. A. Nelson (2018). "Determinants of process innovation introductions: Evidence from 115 developing countries". *Managerial and Decision Economics*. 39(5): 515–525.

Goel, R. K. and M. A. Nelson (2021). "How do firms use innovations to hedge against economic and political uncertainty? Evidence from a large sample of nations". *Journal of Technology Transfer*. 46(2): 407–430.

Goel, R. K. and R. Ram (1994). "Research and development expenditures and economic growth: A cross-country study". *Economic Development and Cultural Change*. 42(2): 403–411.

Goel, R. K. and R. Ram (2001). "Irreversibility of R&D investment and the adverse effect of uncertainty: Evidence from the OECD countries". *Economics Letters*. 71(2): 287–291.

Goel, R. K. and S. Haruna (2011). "Cost-reducing R&D with spillovers and trade". *Journal of Institutional and Theoretical Economics*. 167: 314–326.

Gores, T. and A. N. Link (2021). "The globalization of the Bayh-Dole Act". *Annals of Science and Technology Policy*. 5(1): 1–90.

Graetz, G. and G. Michaels (2018). "Robots at work". *Review of Economics and Statistics*. 100(5): 753–768.

Griliches, Z. (1957). "Hybrid corn: An exploration in the economics of technological change". *Econometrica*. 25(4): 501–522.

Griliches, Z. (1992). "The search for R&D spillovers". *Scandinavian Journal of Economics*. 94(Supplement): S29–S47.

Gulbrandsen, M. and S. Aanstad (2015). "Is innovation a useful concept for arts and humanities research?" *Arts and Humanities in Higher Education*. 14(1): 9–24.

Hall, B. H., Z. Griliches, and J. A. Hausman (1986). "Patents and R and D: Is there a lag?" *International Economic Review*. 27(2): 265–283.

Haruna, S. and R. K. Goel (2011). "R&D, free entry, and social inefficiency". *Economics of Innovation and New Technology*. 20(1): 89–101.

Haruna, S. and R. K. Goel (2017). "Output subsidies in mixed markets with research spillovers". *Journal of Economics and Finance*. 41: 235–256.

Heidenreich, M. (2009). "Innovation patterns and location of European low-and medium-technology industries". *Research Policy*. 38(3): 483–494.

Hobday, M. (2005). "Firm-level innovation models: Perspectives on research in developed and developing countries". *Technology Analysis and Strategic Management*. 17(2): 121–146.

Hodges, N. J. and A. N. Link (2019). "Innovation by design". *Small Business Economics*. 52: 395–403.

Huergo, E. and J. Jaumandreu (2004). "Firms' age, process innovation and productivity growth". *International Journal of Industrial Organization*. 22(4): 541–559.

Jones, C. I. (1995). "R & D-based models of economic growth". *Journal of Political Economy*. 103(4): 759–784.

Jones, C. I. and J. C. Williams (2000). "Too much of a good thing? The economics of investment in R&D". *Journal of Economic Growth*. 5: 65–85.

Kamien, M. I. and N. L. Schwartz (1982). *Market Structure and Innovation*. Cambridge: Cambridge University Press.

Knack, S. and P. Keefer (1995). "Institutions and economic performance: Cross-country tests using alternative institutional measures". *Economics and Politics*. 7(3): 208–227.

Knight, F. H. (1921). *Risk, Uncertainty and Profit*. Vol. 31. Boston: Houghton Mifflin.

Koeller, C. T. (1995). "Innovation, market structure and firm size: A simultaneous equations model". *Managerial and Decision Economics*. 16(3): 259–269.

Lafay, T. and C. Maximin (2017). "How R&D competition affects investment choices". *Managerial and Decision Economics*. 38(2): 109–124.

Lanjouw, J. O. and J. Lerner (1997). "The enforcement of intellectual property rights: A survey of the empirical literature". *National Bureau of Economic Research*. working paper # 6296.

Lee, T. and L. L. Wilde (1980). "Market structure and innovation: A reformulation". *Quarterly Journal of Economics*. 94(2): 429–436.

Leyden, D. P. and A. N. Link (1992). *Government's Role in Innovation*. Dordrecht, Netherlands: Kluwer Academic Publishers.

Link, A. N. (1982). "An analysis of the composition of R&D spending". *Southern Economic Journal*. 49(2): 342–349.

Link, A. N. and J. E. Long (1981). "The simple economics of basic scientific research: A test of Nelson's diversification hypothesis". *Journal of Industrial Economics*. 30(1): 105–109.

Link, A. N. and J. L. Neufeld (1986). "Innovation versus imitation: Investigating alternative R&D strategies". *Applied Economics*. 18(12): 1359–1363.

Link, A. N. and J. T. Scott (2010). "Government as entrepreneur: Evaluating the commercialization success of SBIR projects". *Research Policy*. 39(5): 589–601.

Link, A. N. and J. T. Scott (2018). "Propensity to patent and firm size for small R&D-intensive firms". *Review of Industrial Organization*. 52: 561–587.

Loury, G. C. (1979). "Market structure and innovation". *Quarterly Journal of Economics*. 93(3): 395–410.

Mansfield, E., M. Schwartz, and S. Wagner (1981). "Imitation costs and patents: An empirical study". *Economic Journal*. 91(364): 907–918.

Mantovani, A. (2006). "Complementarity between product and process innovation in a monopoly setting". *Economics of Innovation and New Technology*. 15(3): 219–234.

Martínez-Ros, E. and J. M. Labeaga (2002). "The relationship between firm size and innovative activity: A double decision approach". *Economics of Innovation and New Technology*. 11(1): 35–50.

Mazzucato, M. (2013). "Financing innovation: Creative destruction vs. destructive creation". *Industrial and Corporate Change*. 22(4): 851–867.

Mowery, D. C. (2012). "Defense-related R&D as a model for "Grand Challenges" technology policies". *Research Policy*. 41(10): 1703–1715.

Mowery, D. and N. Rosenberg (1979). "The influence of market demand upon innovation: A critical review of some recent empirical studies". *Research Policy*. 8(2): 102–153.

Mowery, D. C., R. R. Nelson, B. N. Sampat, and A. A. Ziedonis (2004). *Ivory Tower and Industrial Innovation*. Stanford: Stanford University Press.

Mueller, D. C. (1966). "Patents, research and development, and the measurement of inventive activity". *Journal of Industrial Economics*. 15(1): 26–37.

Myrdal, G. (1957). *Economic Theory and Underdeveloped Regions*. London: Duckworth.

Nelson, R. R. (1959). "The economics of invention: A survey of the literature". *The Journal of Business*. 32(2): 101–127.

Nelson, R. R. (1993). *Innovation Systems: A Comparative Analysis*. Oxford: Oxford University Press.

Nooteboom, B. (1994). "Innovation and diffusion in small firms: Theory and evidence". *Small Business Economics*. 6(5): 327–347.

North, D. (1990). *Institutions, Institutional Change and Economic Performance*. Cambridge: Cambridge University Press.

OECD (2015). *Frascati Manual 2015: Guidelines for Collecting and Reporting Data on Research and Experimental Development, The Measurement of Scientific, Technological and Innovation Activities*. Paris: OECD Publishing. DOI: 10.1787/9789264239012-en.

OECD/Eurostat (2005). "Oslo manual: Guidelines for collecting and interpreting innovation data". In: *The Measurement of Scientific and Technological Activities*. 3rd edition. Paris: OECD Publishing. DOI: 10.1787/9789264013100-en.

Olmos-Peñuela, J., P. Benneworth, and E. Castro-Martínez (2016). "Does it take two to tango? Factors related to the ease of societal uptake of scientific knowledge". *Science and Public Policy*. 43(6): 751–762.

Ortega-Argilés, R., M. Vivarelli, and P. Voigt (2009). "R&D in SMEs: A paradox?" *Small Business Economics*. 33(1): 3–11.

Park, W. G. (2008). "International patent protection: 1960–2005". *Research Policy*. 37(4): 761–766.

Pavitt, K. (1984). "Sectoral patterns of technical change: Towards a taxonomy and a theory". *Research Policy*. 13(6): 343–373.

Pazzanese, C. (2020). "Ethical concerns mount as AI takes bigger decision-making role in more industries". *The Harvard Gazette*. October 26, URL: https://news.harvard.edu/gazette/story/2020/10/ethical-concerns-mount-as-ai-takes-bigger-decision-making-role.

Qian, L. and I. K. Wang (2017). "Competition and innovation: The tango of the market and technology in the competitive landscape". *Managerial and Decision Economics*. 38(8): 1237–1247.

Reinganum, J. F. (1989). "The timing of innovation: Research, development, and diffusion". In: *Handbook of Industrial Organization*. Ed. by R. Schmalensee and R. Willig. Vol. 1, Chapter 14. Amsterdam: Elsevier. 849–908.

Romer, P. M. (1990). "Endogenous technological change". *Journal of Political Economy*. 98(5, Part 2): S71–S102.

Rosenberg, N. and R. R. Nelson (1994). "American universities and technical advance in industry". *Research Policy*. 23(3): 323–348.

Salter, A. J. and B. R. Martin (2001). "The economic benefits of publicly funded basic research: A critical review". *Research Policy*. 30(3): 509–532.

Schot, J. and W. E. Steinmueller (2018). "Three frames for innovation policy: R&D, systems of innovation and transformative change". *Research Policy*. 47(9): 1554–1567.

Schumpeter, J. A. (1962). *Capitalism, Socialism, and Democracy*. Oxfordshire, UK: Routledge.

Scotchmer, S. (1991). "Standing on the shoulders of giants: Cumulative research and the patent law". *Journal of Economic Perspectives*. 5(1): 29–41.

Scotchmer, S. (2004). *Innovation and Incentives*. Cambridge: MIT Press.

Shane, S. A. (1992). "Why do some societies invent more than others?" *Journal of Business Venturing*. 7(1): 29–46.

Soete, L., B. Verspagen, and B. ter Weel (2010). "Systems of innovation". In: *Handbook of the Economics of Innovation*. Ed. by B. H. Hall and N. Rosenberg. Vol. 2, Chapter 27. Amsterdam: North-Holland. 1159–1180.

Taalbi, J. (2017). "What drives innovation? Evidence from economic history". *Research Policy*. 46(8): 1437–1453.

Takalo, T., T. Tanayama, and O. Toivanen (2013). "Market failures and the additionality effects of public support to private R&D: Theory and empirical implications". *International Journal of Industrial Organization*. 31(5): 634–642.

Tandon, P. (1984). "Innovation, market structure, and welfare". *American Economic Review*. 74(3): 394–403.

Thursby, J. G. and M. C. Thursby (2003). "University licensing and the Bayh-Dole Act". *Science*. 301(5636): 1052.

Utterback, J. M. (1971). "The process of technological innovation within the firm". *Academy of Management Journal*. 14(1): 75–88.

Verspagen, B. (1991). "A new empirical approach to catching up or falling behind". *Structural Change and Economic Dynamics*. 2(2): 359–380.

Wadho, W. and A. Chaudhry (2018). "Innovation and firm performance in developing countries: The case of Pakistani textile and apparel manufacturers". *Research Policy*. 47(7): 1283–1294.

Yongabo, P. and D. Göktepe-Hultén (2021). "Emergence of an agriculture innovation system in Rwanda: Stakeholders and policies as points of departure". *Industry and Higher Education*. 35(5): 581–597.