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Introduction

Austan Goolsbee and Benjamin F. Jones

Innovation is often seen as a central force for increasing economic prosperity and improving health. From the early days of the Industrial Revolution, policy makers have recognized the role of scientific and technological advancement. The British prime minister Benjamin Disraeli once observed, "How much has happened in these fifty years. . . . I am thinking of those revolutions of science which . . . have changed the position and prospects of mankind more than all the conquests and all the codes and all the legislators that ever lived" (Lockyer 1903, 735). Disraeli's observation is the more remarkable for having been made in 1870; it predated most of what we think of as the major innovations of the last 150 years—electricity, automobiles and airplanes, antibiotics and vaccines, agricultural advances, computers, the internet, biotechnology, and many others. Compared to 1870, US income per capita today is 18 times higher, and life expectancy at birth is 35 years longer.[1]

Economists have come to understand the central role of innovation through studies of economic growth (e.g., Solow 1956), industrial productivity (e.g., Griliches 1979), sectoral dynamics (e.g., Schumpeter 1942), and

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1. For historical real income per capita, see, for example, Jones (2016). For historical life expectancy, see Hacker (2010).

the broader sweep of economic history (e.g., Mokyr 1990; Rosenberg 1982), among other means. US government policy, meanwhile, has come to promote innovation through a suite of mechanisms from systems of intellectual property embedded in the US Constitution to major postwar institutions such as the National Science Foundation and the Research and Experimentation tax credit. Today, the role of public policy to support innovation—and ultimately economic and public health—has perhaps never been felt so acutely. Writing this chapter in 2020, we are collectively facing the coronavirus pandemic.[2] Innovation—including better tests, therapeutic treatments, and new vaccines—will be essential to overcoming the current devastating consequences the pandemic has imposed for health and prosperity.

This volume collects new insights on innovation policy. The contributions study first-order policy mechanisms and actionable ideas that can better fuel scientific and technological advance. Each analysis is based on the latest empirical evidence, understood within the context of existing policies and institutions.

In this introductory chapter, we present an overview of the new contributions, organized around five subjects. The first subject is the social returns to innovation investment, which is central to the case for public support. The second subject is human capital, which can constrain the nation's innovative capacity. The third subject is scientific grant funding, which occurs mostly outside markets and is closely tied to government financing. The fourth subject is tax policy, which can create incentives for and against innovation investment in the private sector. The final subject is entrepreneurship and ways in which government policy may effectively support new venture creation.

The following sections of this introduction consider each of these subject areas, summarizing key findings and highlighting common themes and potential policy implications. Weighing the evidence in each area suggests numerous policy options that may expand the rate of innovative activity in the economy, with potentially high social returns. In the concluding section, we further summarize key themes.

Why Public Policy for Innovation?

The case for public support of innovation rests on two foundations. The first is that innovation is obviously important for society—that is, for raising standards of living. The second is that markets are likely to underinvest in innovation from a society-wide perspective. While the first point is well established, the second point calls for further examination. The private

2. In tandem with this volume, the authors had planned to present their work at a major conference in Washington, DC. Even though that meeting was canceled because of the pandemic, the research collected here provides the same content, in depth, and serves as an up-to-date and accessible resource for innovation researchers and policy makers.

sector invests substantial resources in research and development—about 2 percent of GDP (National Science Foundation 2020). What is the case for public policy to support this private investment or to create large public entities like the NIH and the National Science Foundation?

The answer depends on the social returns to innovation: the broad gains experienced by society from a given advance. If innovation is important to rising standards of living, then these returns may naturally be high. But the case for public policy emerges, more precisely, when the social value created by innovation tends to exceed the value captured by the specific innovator. In this case, where innovation investment creates "positive spillovers" on others, the incentives to invest privately in innovation will be too low.

The most obvious form of such positive spillovers may be those following investments in science and basic research. Vannevar Bush, the founding director of the National Science Foundation, described science as opening an "endless frontier" of progress and the "fund from which the practical applications of knowledge must be drawn" (Bush 1945, 17). Because basic research does not directly produce new products and new services, a private return through market sales of a scientific insight is essentially absent. Yet, to Bush's point, progress in basic research may be essential to many downstream advances, and both anecdotes and broad empirical evidence on such spillovers abound (Ahmadpoor and Jones 2017; Dijkgraaf 2017; Flexner 1939).

To take one example, consider the familiar market innovation of ridesharing (e.g., Uber and Lyft). These businesses depend on the Global Positioning System (GPS), a network of satellites that allows drivers and riders to locate each other. These satellites, first launched in 1978, depend in turn on many scientific breakthroughs, including Einstein's theory of general relativity, which is used explicitly to adjust the clock signals in GPS satellites, prior to launch. And Einstein's theory of general relativity, developed in 1915, depends critically on the initially obscure work of Bernhard Riemann, who in 1854 developed the necessary mathematical tools. These scientific breakthroughs, coming from basic research in mathematics and physics, ultimately opened doors to transformative marketplace innovations.

More broadly, spillovers may exist among marketplace innovations themselves, and these spillovers may be large. Such spillovers can occur through many channels, including the value downstream users receive from the innovation, the value captured by competitors who imitate the innovation, and the value captured by future innovators who build on the new idea. Apple created the first mass-market smartphone, providing large benefits to consumers; it also facilitated imitative entry by other smartphone makers; and it enabled enormous downstream innovation, creating new applications, technologies, and businesses. Not all spillovers from marketplace innovations are necessarily positive, however. For example, through business stealing, an innovation may provide a high return to the innovating business in part by taking business from competitors, who lose out. Innovators may also crowd onto narrow avenues, duplicating and wasting each other's efforts. Whether or not spillovers are positive on net, and the scale of such spillovers, are empirical questions.

In chapter 1 of this volume, "A Calculation of the Social Returns to Innovation," Benjamin F. Jones and Lawrence H. Summers review the existing literature on the social returns to innovation and consider the social returns at an economy-wide scale. The chapter introduces a new method for calculating such returns that integrates across the many spillover margins and many types of innovation. The method further works to incorporate all innovation costs; it avoids picking winners (like the smartphone) and instead includes the costs of successes and failures, as well as innovation costs that go beyond narrow research and development expenditure. The central finding is that the social returns to innovation, as a whole, appear extremely large. Innovation investment appears to pay for itself many times over, with a conservative estimate suggesting that $1 in investment returns at least $5 in benefits on average. Altogether, integrating across this approach and many previous studies, the empirical evidence is robust and clear. The social returns to innovation appear very large and far in excess of the private returns.

Given the evidence for large positive spillovers, there appear to be substantial market failures in innovation, where markets left to their own devices will underprovide innovation investment. This underinvestment in turn constrains growth in standards of living. The case for public investment and public policy to support innovation follows, and innovation policy emerges as a central sphere for governments to advance socioeconomic prosperity and human health. The next question then concerns the specific means of support, given the rich landscape of potential policy dimensions. The balance of the book investigates central dimensions of policy action.

Human Capital for Innovation

At the root of idea creation is innovative labor. This labor is a pipeline for new ideas and, when in limited supply, a potentially fundamental constraint on the rate of progress. The stock of available human capital in turn depends on specific government policies, including education and immigration policy. Chapters 2 and 3 in this volume consider the opportunity to expand the innovative workforce along these lines.

In chapter 2, "Innovation and Human Capital Policy," John Van Reenen studies the sources of innovative human capital and the potential to expand it. He begins with a fundamental observation about innovative labor supply. Namely, increasing spending on innovation, holding the supply of inventive labor fixed, may result in higher prices for the labor rather than more innovation (Goolsbee 1998). By contrast, expanding the supply of inventive labor can both accelerate innovation and reduce its cost. This suggests the key role that human capital policy can play.

Reviewing many margins to expand the pipeline of talent, Van Reenen examines K–12 education, university education, and broader barriers to entering innovative careers. Here we emphasize two of the chapter's key themes. The first theme is that the pool of potential talent appears much larger than the number of people who enter the innovative workforce. For example, the pool of talent based on third grade mathematics test scores appears large compared to the set of individuals who migrate into technology degrees and patenting (Bell et al. 2019a), and features of the child's environment, including household income, as well as gender and race strongly predict entry into patenting (Aghion et al. 2017; Akcigit, Grigsby, and Nicholas 2017; Bell et al. 2019a). Such findings suggest that the national labor pool has a large number of talented individuals, including from underrepresented groups, who do not find pathways into inventive careers.

The second theme is that specific interventions may help children track into inventive careers. For one, early exposure to inventive careers—including through parent networks and through neighborhood exposure to local technology businesses—sharply predicts whether an individual will eventually patent (Bell et al. 2019a). These exposure factors appear causative and suggest that mentoring and other forms of career exposure not only could expand the inventive labor pool but also may be a relatively powerful means to do so (Bell et al. 2019b). School-level interventions also appear promising. Studies of student tracking into gifted or advanced classrooms, using careful research designs, show short- and long-run advantages in math and science skills, and large increases in college enrollment among underrepresented groups (Card and Giuliano 2016; Cohodes 2020). Ultimately, education and career-exposure policies may draw substantially more talent into the innovative labor force, furthering growth. Because inventive careers are also relatively remunerative, these polices may simultaneously improve income mobility and reduce inequality.

Education-oriented policies can expand inventive labor supply over the longer run. More immediate advantages can come through immigration. In chapter 3, "Immigration Policy Levers for US Innovation and Start-Ups," Sari Pekkala Kerr and William R. Kerr examine the role of immigrants in driving US-based innovation and consider various policy reforms that could accelerate US innovation through the immigration channel. A fundamental observation is that immigrants are especially innovative. In particular, while immigrants account for about 14 percent of the US workforce, they account for approximately one-quarter of all US patents and new ventures and one-third of all Nobel Prizes won in the United States. Overall, immigrants are an enormous source of science, engineering, and innovation talent.

Kerr and Kerr review the US immigrant system in detail and consider numerous margins for expanding innovative labor. Several reforms consider expanding the number of visas, including H-1B visas and green cards, and the introduction of targeted visas, such as new forms of visas for entrepreneurs. Other policy reforms consider reallocations within existing quotas. For example, the green card system could relax its heavily binding country-specific caps, which work against countries like India that provide substantial innovative labor. Relatedly, the lottery system used to allocate H-1B visas can be redesigned to allocate more visas to scarce innovative talent. Although comprehensive immigration reform may be needed for changing the overall rate of immigration, several of Kerr and Kerr's actionable policy ideas may achieve large gains by seemingly small adjustments to current practices.

An important set of ideas further connects immigration policy and the US education system. Indeed, US universities attract large numbers of foreign students into their programs, especially for science and technology degrees, and this pipeline of talent is much larger than the numbers of H-1B and other employment visas available upon graduation. Currently, Optional Practical Training visas allow students to work for a limited time after graduation, but the binding green card and H-1B quotas ultimately cause the United States to lose much of this available talent pool. In addition to potentially broadening extensions to H-1B and green card quotas, targeting green cards to those with science and technology degrees ("stapling" green cards to their diplomas) and implementing related policy ideas may expand inventive labor in the United States in particularly targeted and relatively immediate ways.

Scientific Grant Funding

The US science system depends especially heavily on public support. Institutions like the National Institutes of Health (NIH), the National Science Foundation, the Department of Defense, and the Department of Energy, among many other US government agencies, are lead investors in basic research. This research is performed both in government laboratories and, in greater part, through grant funding to researchers outside government, especially in universities. Overall, the US government is the largest funder of basic research in the United States (National Science Foundation 2020).

In chapter 4, "Scientific Grant Funding," Pierre Azoulay and Danielle Li consider these innovation policy tools. The authors consider the case for grant funding as a policy mechanism, review the history of science-funding institutions, and discuss key principles to guide these types of investment. They also discuss mechanisms to continually improve the efficiency and design of science-funding institutions.

The case for science grant funding emerges in both its social returns and its unpredictable uses. Drawing together recent empirical evidence, Azoulay and Li show that the social returns to basic research appear high on average. Yet the exploratory nature of basic research means both that failure is common and that the range of ultimate applications is hard to predict, with returns occurring largely in unexpected spillovers. The example above, linking the market innovation of Uber back to the physics of Einstein and the mathematics of Riemann, shows just how unexpected these spillovers can be. Given this unpredictability, the authors then consider various types of funding mechanisms, comparing grants, prizes, and patents. The authors discuss why up-front grants may be effective when the applied endpoints are unknown and the returns are largely in the spillovers.

Azoulay and Li further investigate policy choices within scientific grant systems. The fundamental uncertainty of basic research suggests tolerance of failure. It further suggests a portfolio approach to science investment. Rather than pick a small number of relatively safe avenues, and crowding grant dollars into these limited conduits, grant design can look across a wide range of independent research avenues, funding projects that may be individually more risky but produce higher collective rates of success. Azoulay and Li apply these design principles to analyze institutions like the NIH and the Defense Advanced Research Projects Agency (DARPA), and consider application areas like Alzheimer's disease. The authors further analyze specific grant allocation mechanisms (such as peer review design) and the implications for grant management policies once awards are given.

Finally, the authors consider means of achieving continuous improvement in the science grant system. They make the fundamental point that the scientific method itself can be used to analyze science funding. Through randomized controlled trials, as well as natural experiments, there are arrays of opportunities to evaluate and improve grant design, increasing the effectiveness of the system and increasing the social returns science funding provides. The authors consider numerous measurement approaches that can help make regular, rigorous evaluation a practical and highly impactful reality.

Tax Policy

When the social returns to innovation exceed the private return, one policy approach is a "Pigouvian subsidy" to encourage innovative behavior. Such a subsidy can raise the private returns to align with the social returns. One way to implement such policies is through tax rate adjustments that aim specifically at innovation investments and outcomes.

In chapter 5, "Tax Policy for Innovation," Bronwyn H. Hall analyzes how advanced economies use tax codes to encourage innovative activity. She highlights the two most common forms of these direct innovation incentives: R&D tax credits (in 42 countries), which help offset R&D investment costs, and so-called intellectual property (IP) boxes (in 22 countries), which reduce tax rates on income from IP. Policy makers face choices, and challenges, in defining the set of activities that count for these tax incentives. Hall explores the practical differences between policies that subsidize the "input," like the R&D credit, versus the "output," like the IP box, and reviews the various policy designs conceptually, with examples from different countries. The chapter then synthesizes the empirical evidence on the effectiveness of these tax instruments.

A substantial body of work documents that private R&D responds strongly to changes in the R&D tax credit. This finding is consistent across many studies and in many different national environments. Hall further examines the detailed design of the credit in the United States, with business examples, and explains that the true size of the credit is much smaller than the statutory rate appears. The credit also ends up being substantially more generous in the United States for recent start-ups than for established companies.

A smaller, recent body of work examines the effects of IP boxes. This research shows that IP boxes appear to impact the location of patent rights across countries. At the same time, there is little evidence that this policy approach increases R&D investment or innovative output. While more studies are needed on IP boxes, R&D tax credits appear to be a more effective mechanism for increasing private innovative investment.

In chapter 6, "Taxation and Innovation: What Do We Know?," Ufuk Akcigit and Stefanie Stantcheva broaden the tax analysis, presenting a framework for many additional margins on which tax policy can influence innovation. They review recent research on the indirect roles of corporate and personal income taxation (as opposed to the direct, innovation-focused tax policies that the Hall chapter emphasizes). Using data on individual inventors in the United States since 1920 and their associated patents and firms, and similar data internationally since 1975, Akcigit and Stantcheva consider how income taxes affect innovative behavior. Their findings document that state and national income tax rates and corporate tax rates can have significant effects on where inventors and firms choose to locate and how much innovation they achieve. At the same time, the authors find that geographic agglomerations substantially reduce the power of tax policy: innovation becomes less sensitive to tax levels in locations where there is already substantial innovative activity.

Akcigit and Stantcheva further discuss the decline in business dynamism in the United States and the role tax policy can play. The declining entry of new firms, and the increasing dominance of incumbent firms, may suggest an unhealthy innovation environment, especially to the extent that new ventures play outsized roles in radical innovations. This decline in business dynamism may also be a contributing cause to the apparent slowdown in US productivity growth. A key observation for tax policy, then, is whether tax policy inadvertently privileges large, incumbent firms. Akcigit and Stantcheva discuss these important issues from a tax perspective as well as from political economy perspectives, where large firms may influence rule setting to their advantage.

Entrepreneurship Policy

This final section considers public policy intended to foster entrepreneurship. In chapter 7, "Government Incentives for Entrepreneurship," John Lerner begins by observing that a great deal of innovative activity in the economy comes from start-up firms, often backed by venture capital investors, rather than from within large companies. Knowing this, governments all over the world have attempted to encourage entrepreneurship, but with mixed success. Lerner presents a sobering overview of the challenges facing governments, drawing on examples from many countries. One challenge involves location. Policy makers often target innovation investments on fairness criteria—geographic equity, for example, leading to substantial investment in places that have not seen much successful entrepreneurship in the past. This emphasis can put new-venture policy in tension with powerful agglomeration economies that make innovation investments more successful in already thriving locations, and studies suggest that returns to public investment are much higher in places with substantial existing private venture activity. Another challenge involves timing, noting the boom-bust patterns that are prevalent in the venture capital system. Cycles in venture capital funding complicate the timing of government policies, which can end up funding new ventures at exactly the moments when the boom is most precarious. Lerner also highlights human capital challenges, where government officials typically have less expertise in the technology and market environments where they invest, compared to professional early-stage investors.

In light of these challenges, Lerner further considers how governments can raise the effectiveness of their entrepreneurship policies. The chapter emphasizes two design principles and some practical examples. The first design principle is independence. The goal here is to insulate investment decisions from political pressures—following a similar model of policy independence as that seen with central banks. The second design principle is private sector matching. By requiring matching funds from the private sector, government policies can leverage the expertise of venture capitalists. At root, these principles can help ensure that public investment achieves high expected returns. These lessons can prove useful at the local, state, and national government levels.

Conclusion

Innovation plays a central role in advancing economic growth and socioeconomic prosperity. Higher productivity leads to higher per-capita income, including higher wages, and makes nations and their workers more successful on the world stage. Scientific and technological advances can lead to longer and healthier lives. And innovations can be critical to overcoming specific and high-stakes challenges, from the coronavirus pandemic to climate change.

This book collects new evidence and new ideas concerning innovation policy. It considers the case for public investment in innovation and reviews numerous levers by which policy can advance innovative activity. The chapters consider mechanisms for expanding the pool of innovative labor, encouraging scientific breakthroughs, increasing corporate R&D investment, and accelerating new venture creation. From R&D tax credits to research grants to the immigration system, the book collects the latest empirical evidence and a range of actionable ideas. The overall picture is a rich menu of public policies that can accelerate scientific and technological advance and reap the rewards that innovation affords.

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