Beyond 140 Characters:

Introduction to *The Role of Innovation and Entrepreneurship in Economic Growth*

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Introduction

Are technological innovations and new business starts driving economic growth? Prominent innovators and entrepreneurs express differing views. In 2011, Peter Thiel lamented that "we wanted flying cars, instead we got 140 characters" (Thiel 2011). That same year, Marc Andreesen took the opposite view, arguing that "software was eating the world," a trend that made him "optimistic about the future growth of the U.S. and global economies" (Andreesen 2011). The ensuing decade has provided evidence to support both the optimistic and pessimistic view of the role of innovation and entrepreneurship in economic growth.

The academic literature is likewise divided. Several authors have documented recent sluggish productivity growth rates (Gordon 2000; Bloom et al. 2020) and declines in business dynamism (Decker et al. 2014). Some scholars go even further than Thiel and believe that not only has innovation underperformed over the last several decades, but that it will be difficult or impossible to achieve high levels of growth in the future (Gordon 2012, 2016, 2018; Cowan 2011). Another group disagree with these bleak forecasts for the future, identifying high levels of entrepreneurial growth potential (Guzman and Stern 2020) and pointing to the almost unimaginable possibilities from technologies such as artificial intelligence, advanced genetic engineering, financial technology, and clean energy—technologies for which the economic impact has yet to be fully realized (Mokyr 2018). In fact, some are concerned that future innovation will be sufficiently rapid to cause unemployment and lower wages, for instance as a result of AI or robots (e.g., Acemoglu and Restrepo 2020). Scholars with a historical perspective dismiss the technological pessimists and note how often past predictions of long-term stagnation have proven wrong (Mokyr et al. 2015). Reviewing these literatures, it can truly seem that we are living in both the best of times and the worst of times.

In short, we live in an era in which innovation and entrepreneurship seem ubiquitous, particularly in regions like Silicon Valley, Boston, and the North Carolina's Research Triangle Park, yet many metrics of economic growth have been at best modest over recent years. At the time of this writing, we are in the midst of a pandemic that has consistently challenged our ability to create and scale innovative solutions to pressing problems. While economists have long posited a relationship between innovation, entrepreneurship, productivity growth, and economic output (Schumpeter 1942; Abramowitz 1956; Solow 1956, 1957), the conflicting observations above led us to question just how much we actually know about the role of innovation and entrepreneurship in driving economic growth. This lack of consensus is particularly problematic given the extent to which private and public resources are increasingly being targeted towards programs and policies whose objective is to leverage innovation and entrepreneurship as a source of growth.

Thiel's memorable expression gives one clue as to why both the optimistic and pessimistic views can coexist: we expected dramatic innovations in fields like transportation to dramatically change our physical lives, but instead we have seen far more innovation in information technology as our lives move online. Though not well understood, this heterogeneity is critical. By construction, the impact of innovation and entrepreneurship on overall economic performance reflects the cumulative impact of innovation and entrepreneurship across sectors. Given that there is wide variation across sectors, understanding the potential for growth in the aggregate economy depends on understanding the potential for growth in each individual sector.

This insight motivates the work in this volume, where we leverage industry studies to identify specific examples of productivity improvements enabled by innovation and entrepreneurship, whether via new production technologies, increased competition, new organizational forms, or other means. Taken together, we can then understand whether the contribution of innovation and entrepreneurship to economic growth is likely to be concentrated in a few sectors or more widespread. More specifically, we sought to answer the following questions:

- What is the relationship between innovation/entrepreneurship and economic growth in specific industrial sectors?
- How has the relationship between innovation/entrepreneurship and economic growth changed over time?
- How much do policies, programs, and specialized institutions (such as venture capital) meant to encourage innovation/entrepreneurship ultimately spur economic growth?
- Does innovation/entrepreneurship affect economic performance and social progress through channels other than measured productivity and economic growth, and if so, how can these effects be measured?

We commissioned studies from experts on twelve different industries: manufacturing, information technology, agriculture, energy, transportation, retail, services, the creative sector, government, health care, housing, and education. While innovation and entrepreneurship in some of these sectors have been well studied by economists (e.g., energy, health, IT), others have been less examined (education, housing). In this introduction, we draw out some of the lessons learned by comparing across these very different types of industries.

The ideas in each of these industry studies were discussed and refined at a pre-conference held in July 2019 in Cambridge, MA. Fittingly for a collection of studies on the role of innovation and entrepreneurship, formal presentations and discussions were held at the Computer History Museum in Mountain View, CA, in January 2020. In addition to the twelve industry studies, the conference contained a panel of academic and government economists on the role of public policy in promoting innovation and entrepreneurship, as well as three fireside chats and two panels of practitioners consisting of entrepreneurs, venture capitalists, and policymakers.

Many individuals deserve a great deal of thanks for the success of this endeavor. First, we thank NBER President Jim Poterba and the NBER Productivity, Innovation, and Entrepreneurship

Program Directors Josh Lerner and Nick Bloom for helping to shape the direction and themes of the conference. The NBER conference department, and especially Rob Shannon, provided invaluable logistical support, as did the staff at the Computer History Museum and Natalia Kalas of MIT. We also thank Helena Fitzpatrick and the staff at the NBER Publication Department. Finally, the Ewing Marion Kauffman Foundation provided generous funding for this initiative.

Below, we first describe each of the twelve industry studies, highlighting similarities and differences across sectors, as well as the conclusions of the policy panel. Next, we give a broad overview of the practitioner comments. We then draw out common themes. Finally, we close by addressing the extent to which our conclusions from this conference have been altered or reinforced in light of the 2020 pandemic and the resulting economic situation.

Outline of Chapters

In this volume, we organize the industry studies into three groups: "productivity driver" sectors, which include manufacturing, information technology (IT), agriculture, and energy; the "on-demand" sectors, comprising transportation, retail, professional services, and the creative sectors; and the "cost disease" sectors, which consists of government, health care, housing, and education.

As a preview of these industry studies described below, we first summarize key metrics for each sector in Table 1. Ben Jones revisits many of these aggregate metrics in his concluding chapter. For this table, we define a "sector" using 2-digit North American Industry Classification System (NAICS) codes, although as the detailed industry studies make clear, it is often far from obvious where the boundaries of one sector end and another begin, especially when trying to account for innovative activities. In the first two columns of Table 1, we present metrics that give a sense of the importance of each sector: each sector's share of gross domestic product (GDP) from the Bureau of Economic Analysis and each sector's share of employment from the Bureau of Labor Statistics Quarterly Census of Employment and Wages. In all, the sectors studied in this volume cover more than 75% of U.S. GDP and almost 80% of employment.

The next two columns present common measures of innovativeness. The first of these measures is the patenting rate, defined as number of patents issued to firms in each sector per 1,000 employees. The patenting rate is a measure of each sector's innovative output. Data on patenting are from the Patent and Trademark Office; we link patents to sectors using a crosswalk developed in Goldschlag et al. (2019) that maps USPTO-assigned patent classifications to NAICS codes. Over all the studied sectors, firms produce just under one patent for every 1,000 employees. The second measure is research and development (R&D) intensity, defined as the amount of R&D spending per employee; this is a measure of innovative input. Data on R&D spending come from the Census Bureau and National Science Foundation's Business R&D and Innovation Survey (BRDIS). While BRDIS does not collect R&D data for all sectors, over the six sectors for which we have data firms spend about $21 on R&D for every employee.

The final column presents a measure of the level of entrepreneurship in each sector, the establishment entry rate. This is calculated by dividing the number of new establishments in each sector by the average number of establishments in that sector. Data on establishment entry rates are from the Census Bureau's Business Dynamics Statistics. While this data is not available for the agricultural or government sectors, for the other ten sectors the establishment entry rate is 0.10.

Table 1

	Sector	(1) Share of GDP	(2) Share of Employment	(3) Patenting Rate	(4) R&D Intensity	(5) Entry Rate
		Productivity Driver Sectors				
1	Manufacturing	.12	.088	5.648	23.262	.066
2	IT	.047	.021	2.394	33.222	.107
3	Agriculture	.01	.009	1.927	.	.
4	Energy	.034	.011	.455	6.685	.084
		On-Demand Sectors				
5	Transportation	.03	.04	.503	.488	.139
6	Retail	.059	.113	.117	.	.079
7	Services	.072	.063	.884	24.263	.122
8	Creative	.01	.018	.284	.	.125
		Cost Disease Sectors				
9	Government	.13	.052	.101	.	.
10	Health	.072	.145	.065	.	.092
11	Housing	.041	.063	.435	4.778	.127
12	Education	.011	.088	.016	.	.108
	All Sectors	.767	.794	.924	20.928	.100

Notes: Statistics for the 12 sectors studied in this volume. All statistics are calculated at the sectoral level using 2-digit North American Industry Classification System (NAICS) codes. Column 1 presents data on each sector's share of total value added from the Bureau of Economic Analysis "All GDP-by-industry" data (https://apps.bea.gov/iTable/iTable.cfm?isuri=1&reqid=151&step=1). Column 2 presents data on each sector's annual average share of total employment from the Bureau of Labor Statistics Quarterly Census of Employment and Wages (BLS QCEW) (https://www.bls.gov/cew/downloadable-data-files.htm). Column 3 presents data on the rate of patenting, calculated as the number of patents in each sector divided by employment (in thousands) from the BLS QCEW. Patent data are from the USPTO's PatentsView database (https://patentsview.org/download/data-download-tables). Each patent is matched to a NAICS code using the probabilistic crosswalk from Goldschlag et al. (2019). Column 4 presents data on R&D intensity. R&D data is from the Business R&D and Innovation Survey (BRDIS) conducted by the U.S. Census Bureau and the National Center for Science and Engineering Statistics within the National Science Foundation (https://ncses.nsf.gov/pubs/nsf18313/#general-notes&data-tables). R&D intensity is calculated by dividing each sector's total domestic R&D dollars by total employment from firms surveyed by BRDIS in that sector. Column 5 presents data on the establishment entry rate from the Census Bureau Business Dynamics Statistics (https://www.census.gov/programs-surveys/bds/data.html). Each row lists these statistics for one of the studied sectors. The final row presents combined results for all sectors studied in this volume. All data are from 2015, as this is the last year for which we can map patents to the full set of sectors.

Table 1 reveals extreme heterogeneity across sectors for these measures of innovation and entrepreneurship. The sectoral patenting rate varies by more than two orders of magnitude. The R&D intensity exhibits a similar range across sectors. The most dynamic sectors have an establishment entry rate more than twice as high as the least dynamic sectors, although establishment dynamics appear to be weakly negatively correlated with our measures of innovativeness.

While informative, these statistics can provide only the roughest of sketches about the state of innovation and entrepreneurship in each sector. Each chapter below contains a detailed industry study that puts these numbers into context.

Productivity Drivers

We begin by examining four "productivity driver" sectors. These are sectors that have undergone substantial innovation-driven change to increase measured productivity. Additionally, each of these sectors represents a general purpose technology (Bresnahan 2010) and thus facilitate innovations in other sectors, including the on-demand sectors we describe below.

First, Erica Fuchs, Christophe Combemale, Kate Whitefoot, and Britta Glennon present results on the manufacturing sector, which has experienced dramatic innovation, particularly in the form of widespread mechanization. While manufacturing looks different in the U.S. today than it did half a century ago, the economic statistics are underwhelming. Manufacturing accounts for 66% of U.S. R&D, but only 12.5% of value added. The authors argue that this is largely due to the fact that manufacturing R&D investments made in the U.S. are increasingly realized overseas. Most of the largest manufacturing firms operate internationally and the increasing offshoring of supply chains raises numerous questions about the calculation of national innovation and productivity statistics. The authors also emphasize the importance of heterogeneity across the manufacturing sector, as manufacturing statistics include industries as diverse as automobile manufacturing, pharmaceuticals, and animal slaughtering. Not surprisingly, the amount of R&D conducted and value added varies dramatically across sectors. In her discussion, Kathryn Shaw emphasizes the firm dynamics that underly the observed patterns of R&D and productivity in manufacturing, as increasingly low productivity firms are exiting, leaving the high productivity and high R&D firms, which also tend to be multinationals. Shaw also notes that much of the R&D conducted by traditional manufacturing firms such as IBM are in fields only tangentially related to manufacturing, such as artificial intelligence, making it difficult to know what to classify as manufacturing.

Perhaps the most obvious sector when discussing innovation-driven productivity growth is IT. This sector is examined by Chris Forman and Avi Goldfarb. IT holds a special place because improvements in IT are often behind innovation and entrepreneurship in other sectors. For example, in the on-demand sectors examined below, IT has already revolutionized firms to dramatically reduce frictions, in some cases facilitating near instantaneous fulfillment of consumer needs. The successes in the IT sector over the last half century have been well documented, in particular massive improvements in computing power and the networking of computers through the internet, and more recently these successes have revolutionized business models such as Software as a Service and changed connections across industries through the Internet of Things. While IT has rightly been held up as the model of dynamism, Forman and Goldfarb argue that the IT sector is increasingly showing signs of becoming mature and less dynamic. With a deep dive into patent data, they show that the IT sector has become increasingly geographically concentrated in Silicon Valley, patents increasingly come from a smaller number of firms, and those firms increasingly tend to be incumbents. In his discussion, Erik Brynjolfsson reminds us that patents are an imperfect measure of innovation, and this may be particularly true for software. Nevertheless, Brynjolfsson highlights several other metrics that tell a similar story to Forman and Goldfarb. Namely, high-IT industries are more concentrated using various measures, and the often-intangible assets that are complementary to IT are increasingly found in superstar firms.

Julian Alston and Phil Pardey examine the agriculture sector. Agriculture is a sector that has already undergone many of the massive productivity changes currently occurring in the previous sectors, and thus provides a useful case study for thinking about the future of innovation and entrepreneurship. Alston and Pardey survey the many labor-saving technologies in agriculture over the last century, and consequently the dramatic decline in labor working in agriculture, the small decline in land used for agriculture, and the increase in agricultural inputs (e.g., pesticides and herbicides) and capital (farm machinery). In many respects, the transition in U.S. agriculture over the twentieth century resembles the manufacturing sector in recent decades, with large increases in mechanization and productivity, the sector increasingly filled with low human capital workers, and much of the low valued added production shifting overseas. One unique feature of the agricultural sector is that the government has kept detailed statistics on agricultural output and R&D inputs for a much longer time period than it has in most other sectors, making it possible to construct detailed estimates of return to R&D. These estimated returns are massive, with estimated median internal rates of return ranging across studies from 12-41% per year, and benefit-cost ratios ranging from 7 to 12. Notably, these estimated returns are calculated over many years, and it can take decades for R&D to manifest itself in the productivity statistics. Alston and Pardey also review adoption lags for numerous agricultural technologies, and likewise find 30-50 years between when a technology is introduced and when it is widely adopted; hybrid corn as studied by Griliches (1950) and more recently genetically engineered crops are the rare exceptions that were adopted remarkably quickly. The authors also analyze numerous more recent technologies, including precision agriculture, variable rate seeding and fertilizer, the use of satellite imaging, auto-steering on tractors, and more, and find much slower adoption rates. In his discussion, included in this volume, Brian Wright elaborates on many of the facts documented by Alston and Pardey, particularly emphasizing the influences behind U.S. public support of agricultural research and innovation. Wright also speculates that, over time, farmers have realized that they appropriate a relatively small share of the returns to public research in agriculture, and have instead turned their attention to lobbying for market distorting policies that favor their interests; such a hypothesis is consistent with the slowdown in the increase of corn yields following the adoption of biofuel mandates in the early 2000s.

The energy sector, analyzed by David Popp, Jacquelyn Pless, Ivan Hascic, and Nick Johnstone, is another in which innovations are best viewed over long time scales. The energy industry is characterized by large fixed costs, and so most of the major actors are large incumbent firms. The industry is undergoing a structural transformation, however, and so both of those patterns, the gradual pace of change and the dominance of established firms, may be changing. Costs of renewable energy production in particular have been falling rapidly, with the cost of a kilowatt hour of electricity from solar power in 2017 only about 30% what it was in 2010, and several sources of renewable energy are now nearly competitive with fossil fuels on price. While it has taken decades for the costs of these new technologies to become close to competitive with conventional sources, progress has not been steady, with most innovations (as measured by patents) occurring when conventional energy prices are high. Green energy thus provides perhaps the cleanest example of induced innovation. Clean energy technologies do have some drawbacks relative to conventional sources, namely their intermittency, which highlights the importance of energy storage and transportation and grid management technologies. The latter in particular relies on improvements in information technology and, as the authors show using venture capital data, has opened the door for small, young, entrepreneurial firms to become important players in the energy sector. In his discussion, Hunt Allcott compares the recent rise of fracking and clean energy technologies to historical cycles in the energy market, especially the 1970s oil shock, documenting similar patterns of increasing innovation as energy prices rise. Building on this historical perspective, Allcott then asks several important questions: first, how predictable are energy-sector policies such as cap and trade, and second, are researchers currently too focused on policies that reduce static distortions at the expense of policies that could reduce dynamic disincentives to innovate?

The On-Demand Economy

We next examine the on-demand economy. These are sectors in which general purpose technologies from the productivity driver sectors, often ICTs, have changed how sectors deliver their products, dramatically reducing the speed at which consumers can acquire a product or increasing the geographic scope over which transactions can occur.

Perhaps the most obvious "on-demand" sector is transportation. Transportation was also one of Thiel's (2011) primary examples illustrating the innovation slowdowns in recent decades: since the retirement of the Concorde Supersonic Jet, "the travel time across the Atlantic Ocean… for the first time since the Industrial Revolution, is getting longer rather than shorter." Derrick Choe, Alex Oettl, and Rob Seamans describe the innovations that have occurred in the transportation sector. While passenger travel times for transoceanic travel have been nearly constant over the past several decades, the transportation sector as a whole has made major strides incorporating sensors and other IT technologies. Choe, Oettl, and Seamans focus on warehousing, one part of the transportation sector in particular that has been transformed by these technologies. The importance of delivering goods to consumers has not diminished in importance in recent decades. Last mile delivery services account for an increasing share of employment in the transportation sector, and the use of logistics technologies and autonomous vehicles inside warehouses have allowed firms to sharply decrease delivery times. The authors also review several other recent technologies that would have been impossible without underlying IT innovations, most notably ride sharing apps and self-driving cars. Many (although certainly not all) of the remaining hurdles to widespread adoption of self-driving cars are not technological but rather legal and regulatory, hurdles that ride sharing apps were able to sidestep initially but with which they are increasingly forced to reconcile. In his discussion, included in this volume, Gilles Duranton takes a step back to examine the broader transportation sector. Duranton identifies four features that make the transportation sector unique and affect how innovation occurs in the transportation sector: the presence of externalities, especially congestion, accidents, and pollution; the fundamental role of publicly provided goods, namely infrastructure; the durability of assets; and the fact that transportation effects nearly all other sectors of the economy. While Choe, Oettl, and Seamans document substantial innovation and warehousing and passenger transport, the features identified by Duranton tend to slow the rate of innovation in the broader transportation sector.

Innovations in the transportation sector that have changed how goods are delivered to consumers have consequently ushered in massive changes in the retail sector as well. Francine Lafontaine and Jagadeesh Sivadasan investigate retail in depth. The "retail apocalypse" has been well publicized, with massive closures of retail establishments and drops in retail employment since the late 1990s. The authors show, first, that some of these losses in "traditional retail" have been regained, particularly in employment. Much of this is driven by "big box" stores, which accounted for a growing share of retail sales until about 2009, when they plateaued or experienced a modest decline. In contrast, e-commerce continues to account for a growing share of all retail sales, although by 2017 this share was still less than 7%. But the more important trend is the rise of restaurants. The number of restaurant establishments and restaurant employment has increased dramatically since the early 2000s, more than offsetting losses in retail. While Americans have been eating a growing share of meals away from the home for decades, the recent growth in restaurants is enough to radically change the commercial landscape, with the explosion of restaurants occurring in all types of locations and across all restaurant categories. In her discussion, included in this volume, Emek Basker focuses on how retail has been classified in administrative data, how this classification has changed over time, and how it affects how we view the patterns documented by Lafontaine and Sivadasan, especially in light of the rise of online retail. Basker also further dives into the heterogeneity in the retail apocalypse. While Lafontaine and Sivadasan highlight the rise of restaurants, Basker points out that other customer-facing establishments, such as gyms and nail salons, have also experienced dramatic growth over the last decade.

As many traditional retail establishments close and the manufacturing sector shrinks as a share of employment, numerous authors have documented the growth in the service sector (Fuchs 1980; Buera and Kaboski 2012; Eckert et al. 2019; Delgado and Mills 2020). One might expect this to be a sector of the economy beset by Baumol's cost disease; after all, how much more productive is a barber or hairdresser today relative to fifty years ago? But Mercedes Delgado, Daniel Kim, and Karen Mills show that the services sector is indeed innovative. They identify one subset of the services sector that has been growing especially rapidly, which they call "supply chain traded services." These are services sold to businesses or government in the process of producing a separate final product and include such fields as programming, design, or logistics. The key insight is that many of the jobs that make our high-tech and IT-intensive economy what it is, which allow firms to scale rapidly and serve disparate customers, are themselves service jobs. While these jobs are relatively new, the firms that conduct the jobs tend to be incumbents. In fact, many are firms that used to mainly be manufacturing firms (for instance, IBM used to be known for manufacturing mainframes but now is primarily a consulting and data analysis firm) and manufacturing incumbents now have almost a third of their employees and 40% of their payroll in supply chain traded services. In his discussion, included in this volume, Sharat Ganapati focuses on the spatial aspects of servicification. A large non-tradeable local service sector limits the extent to which industries can cluster in one location; as services become more tradable, this may be expected to unleash larger agglomeration economies. At the same time, Ganapati notes that wage growth in the supply chain traded services sector has been growing faster than employment, suggesting that the labor force for this sector may still be fairly immobile.

Next, Joel Waldfogel discusses the arts, media, and the creative sector. Ironically, this is the sector Baumol and Bowen (1966) described when they introduced the concept of the cost disease: a Beethoven string quartet takes the same amount of labor to perform today as it did in the early 19th century. While this may be true, thanks to improvements in recording and streaming technologies, a much larger audience can now listen to any given performance. Decreasing costs of production and distribution of media content are valuable for at least two reasons. First, there is now "infinite shelf space," facilitating a long tail of content that appeals to consumers with niche tastes. Second and more importantly, when the appeal of new content is unknown at the time of production, increasing the amount of new content makes it more likely that hits will be discovered. Consider the success of independently-published books such as "50 Shades of Gray" (James 2011) or music artists like Ed Sheeren (Davis 2019), both of which would have been unlikely to find a large audience without distribution platforms like Amazon or YouTube, respectively. Waldfogel refers to this second benefit as "the random long tail." Building on the analysis of Aguiar and Waldfogel (2018), which examined the benefits of digitization in the recorded music industry, Waldfogel estimates that digitization has increased sales by about 10% in the movie industry, 50% in television, and 10% in books and, moreover, that the benefits of the random long tail are four to thirteen times larger than the benefits of the "conventional" long tail. Waldfogel also examines the creative labor market and finds that total earnings of creative workers are rising while average earnings per worker are falling, consistent with a larger number of part-time or hobbyist creatives who are now able to sell their content. In his discussion, included in this volume, Gustavo Manso builds on these observations of the creative labor market, noting that lower average earnings for artists is consistent with experimentation: individuals can more easily enter the creative market, learn if they are likely to have success, and if not exit to other types of employment. Thus digitization may paradoxically be associated with both lower average earnings and higher lifetime earnings for artists; Manso (2016) documents similar findings in entrepreneurship more broadly.

The Cost Disease Sectors

Finally, we examine the sectors afflicted by Baumol's "cost disease" (Baumol and Bowen 1966; Baumol 1967), defined as those sectors in which it has been difficult to increase labor productivity. In contrast to the on-demand sectors, the cost disease sectors have so far been largely unable to leverage IT or other general purpose technologies to improve productivity at scale.

Joshua Bruce and John de Figueiredo examine perhaps the ultimate cost disease sector: the government. While the federal government is a massive funder of innovation, innovation within government itself—that is, organizational, regulatory, and policy innovation—is much harder to measure. In terms of the innovation funded by the federal government, more than 40% of R&D dollars go to the Department of Defense, 27% go to Health and Human Services, and 12% goes to the Department of Energy. That leaves only about 10% of federal R&D to go to all other programs, including NASA, the NSF, agricultural research, etc. The distribution of federal scientists and federally-funded patents is similar. What is striking is how little federal research is conducted in areas such as education, housing, and the social sciences, not just as a share of the overall federal research budget, but in absolute terms as well, despite the fact that these areas are major federal policies. In his discussion, included in this volume, Manuel Trajtenberg steps away from the analysis of direct federal funding of intramural research to discuss how the federal government has adopted information and communication technologies to function more effectively; these types of innovations, as noted by Bruce and de Figueiredo, are difficult to capture in official statistics. Nevertheless, Trajtenberg sketches several case studies, including the government's use of digital technologies in the health and transportation sectors, highlighting the crucial role of the government in affecting innovation in several other sectors outlined in this volume.

One sector that has received massive amounts of research spending from both the federal government and private sources is the health sector. But this research tends to overwhelmingly be directed towards new drugs, with a relatively small share of research directed towards health services. Amitabh Chandra, Cirrus Foroughi, and Lauren Molstrom investigate the health sector, with a particular focus on venture capital-led entrepreneurship, and report that 60% of VC investment in health is directed towards firms working on pharmaceuticals, 20% to firms working on medical devices, and only 20% to firms working on all aspects of healthcare delivery and infrastructure. In contrast to the government sector, in which it is difficult to measure innovation, in the health sector numerous measures of innovation inputs and outputs are available; Chandra, Foroughi, and Molstrom make use of data on patenting, academic publications, and public research spending, in addition to the aforementioned VC investment. Overall, the authors conclude that it is likely more difficult to find economically attractive projects in the health sector than in other sectors: VC funding tends to grow more slowly and is directed at earlier stage firms in health than in other sectors. The geographic concentration of health innovations is increasing over time, measured both by patents and publications. The authors present suggestive evidence that many useful innovations that are created away from "health innovation hubs" like Boston and San Francisco are not developed because VCs and other potential funders do not know about them. Given the challenges the private sector faces in identifying and funding attractive projects, does the public sector fill the gap? The National Institutes of Health (NIH) allocate a larger share of funding to basic science than does private industry, a necessary condition for efficient expenditure of public funds. But when it comes to translational research that is directly linked to a disease, the distribution of NIH funding is indistinguishable from private funding. Additionally, the NIH allocates a larger share of funding towards pharmaceuticals, and less towards health care delivery, than does the private sector. Together, these facts raise the possibility that public funding is not working to resolve market failures in the health care sector. In her discussion, Heidi Williams discusses some of the inferential difficulties in determining whether or not health innovation is going in an inefficient direction. She also places the increasing concentration of health innovation in context by comparing it to other sectors, including computing (as also highlighted by Forman and Goldfarb in this volume), biology/chemistry, and semiconductors.

Ed Kung investigates the housing sector. This is likewise a sector that has seen little R&D spending or measurable innovation. While there has been little change in how housing units are constructed, there has been the appearance of numerous real estate technology firms, either tools to use the internet for housing search like Zillow or online home sharing platforms like AirBnB. While these new firms do not increase the productivity of housing construction, they do increase the match quality between home buyers and sellers, and Kung argues that this can represent substantial gains to consumer surplus. Kung also considers potential explanations for the lack of innovation in the construction of new housing units. We highlight in particular his survey of the literature on policy's role in restricting innovations in housing. Land use regulation in particular can stifle the supply of new housing and depress incentives to innovate in the sector; Hseih and Moretti (2019), for instance, conclude that land use restrictions have reduced the GDP growth rate by as much as one third. In her discussion, included in this volume, Jessie Handbury notes that while higher match quality between home buyers and sellers increases welfare, this is reflected in higher sale prices and hence exacerbates issues related to housing affordability. The solution is an expansion in the housing supply, but both Kung and Handbury note innovation in the production of the housing stock is unlikely without policy reforms such as a reform of the aforementioned zoning and land use regulations.

Finally, Barbara Biasi, Dave Deming, and Petra Moser discuss the education sector. They overview the expansive literature documenting the importance of human capital for promoting innovation and entrepreneurship. But in spite of the massive importance of the education sector, as well as the large share of the economy it encompasses, there is very little "formal R&D" in education. In fact, the Congressional Research Service reports that the Department of Education has the smallest R&D budget of any federal agency in fiscal years 2018-2020, about 1/3 of 1% of the R&D budget allocated to the Department of Defense (Congressional Research Service 2019). When researchers have studied the use of new technologies in the education sector, such as the use of computers in classrooms, the results have been uninspiring at best (Chatterji 2018). Instead of technological innovations, most innovation in the education sector over the last 150 years has been institutional or pedagogical in nature. For instance, universal primary and high school and expansion of colleges has sought to close the "leaky pipeline" and provide skills to potential innovators and entrepreneurs. Meanwhile, programs like gifted and talented programs and an expanding menu of college majors seek to improve match quality between students' interests and abilities and the skills that are taught. In her discussion, included in this volume, Eleanor Dillon highlights some difficulties that anyone attempting to improve the education sector's ability to produce innovators will face. In particular, most innovators come from a small number of elite colleges; it is not clear that expanding access to college at non-elite institutions will lead to much of an increase in patenting. Dillon sees more hope in bringing programs that develop entrepreneurial skills to a wider set of colleges, and highlights in particular the role that vocational education could play in developing innovative skills in sectors outside of the high tech sectors in which universities typically patent.

Remarks by Panelists

In addition to the industry-specific studies, we also conducted a panel made up of innovation scholars with experience in the policy space to offer their cross-sectoral perspectives and insights into how policy affects innovation and entrepreneurship. Remarks by these panelists are included as chapters in this volume.

Karen Mills and Annie Dang provide a brief survey of the different kinds of government policies to promote innovation and entrepreneurship. Many government policies are designed to aid small firms, but of course not all small firms promote economic growth equally. Mills and Dang advocate "smart" policy to promote innovation and entrepreneurship that is targeted specifically to the high-growth small firms. These policies frequently look different from policies to help other kinds of small firms, which they classify as "main street" firms like restaurants and coffee shops, "supplier" firms that primarily act as vendors to large firms or the government, and non-employer firms. In particular, high-growth firms will be affected by different policies that affect access to capital (e.g., policies that affect venture capital and R&D tax credits instead of bank loan guarantees), different policies for advice and education (e.g., startup academies instead of small business development centers), and different policies that affect the local ecosystem (e.g., accelerators and incubators instead of Main Street associations).

Lucia Foster focuses on the role of government agencies in producing the innovation and entrepreneurship data used by researchers and policymakers to design the kinds of smart policies Mills and Dang describe. Foster discusses three approaches that the Census Bureau takes towards measurement. First, the Census Bureau has multiple large-scale projects to produce innovation and entrepreneurship statistics from administrative data, which are data collected by government agencies for non-statistical reasons. Second, the Census Bureau conducts numerous surveys designed explicitly to elicit information on innovative and entrepreneurship activities. While survey data is less comprehensive than administrative data, there is greater flexibility to ask different questions as technologies and the structure of the economy change. Finally, the Census Bureau apply indirect inference to document changes in innovation and entrepreneurship; in other words, they identify patterns in productivity or business entry and exit that are predictive of innovative activity.

The final chapter of the volume is a synthetic contribution from Ben Jones, who undertook the task of explicitly linking these industry-level studies to the broader question of the potential sources and barriers to economic growth in the medium term. Jones leverages the industry studies to highlight the striking variation across sectors in their recorded level of innovation and entrepreneurship, and proposes a framework to explain this variation based on the interplay between demand, supply, and institutional factors. One important question is whether the differences across sectors are pre-ordained or whether policymakers can influence outcomes. Demand and supply factors may in large part be determined by basic human preferences or the laws of nature, but to a large extent they also appear to be sensitive to policy. For instance, in sectors for which it is possible to define intellectual property, patent laws and similar can be used to alter the supply of innovators, and funding of basic research can also increase the supply of innovations in different sectors. Policies such as direct buyer mechanisms can be used to increase the demand for innovations. Jones also notes that policy can be used to either increase or impede the scalability of innovations. For instance, privacy rules reduce the ability of innovations in health services to diffuse widely, while ride-sharing services like Uber were able to expand rapidly while they remained outside of existing regulations of the taxi industry. Overall, Jones appears optimistic that policy can be used to promote innovation in sectors in which it is currently lagging, although the relationship between demand, supply, and institutional features is nuanced and determining the best policy is not likely to be easy.

Practitioner Perspectives

This conference was also unique in featuring participation from eleven practitioners from the innovation and entrepreneurship space to give their insights into the role of innovation and entrepreneurship in driving the future of economic growth. The following individuals contributed their perspectives:

- *Katie Finnegan:* Katie Finnegan has long and broad experience at the intersection of technology and retail. In 2012, she founded the e-commerce firm Hukkster, which was later acquired by Jet.com, where she served in a leadership role. In 2016, she became Vice President of Incubation at Walmart.com and co-founded Walmart's incubator, Store No. 8. Most recently, she is the founder and principal of Katie Finnegan Consulting.
- *Alexsis de Raadt St. James:* Alexsis de Raadt St. James is an investor and venture capitalist with substantial experience working with technology firms. She has founded numerous companies and non-profits, including the Althea Foundation, which seeks to support ideas that demonstrate social impact, and Youth Business America, Inc, which provides financial mentoring and loan capital to entrepreneurs who lacked funding from traditional sources. Alexsis is currently the managing partner of Merian Ventures, an early-stage venture firm focused on investing in women-founded firms. Alexsis is the U.S.-U.K. Fulbright Commissioner and sits on several boards.
- *Jose Mejia:* Jose Mejia grew up in rural Venezuela and moved to the U.S. when he was 16. Since then, Jose has been a senior vice present at Juniper Networks, chairman and CEO of Medis Technologies, and president of Lucent Technologies' Worldwide

Operations and Customer Support/Installation organization. Jose currently sits on the board of numerous software as a service firms, including RapidSOS. Jose has received the Ellis Island Medal of Honor, awarded by the U.S. Congress to distinguished immigrants, and been named the Engineer of the Year by the Hispanic Engineer National Achievement Awards Corporation.

- *James Cham:* James Cham is a principal at Bloomberg Beta, which invests in firms that attempt to shape the future of work. Prior to Bloomberg Beta, James has served as a principal at Trinity Ventures and a vice president at Bessemer Venture Partners. He serves on the boards of numerous firms and has spent time working as a consultant and software developer.
- *Barb Stuckey:* Barb Stuckey is a longtime innovator in the food and restaurant industry. Barb has been involved in the food industry in some form or another since spending time in her best friend's parents' Chinese restaurant in suburban Baltimore while growing up. Since then, she has worked for Kraft Foodservice, Brinker International (which operates Chilis, among other restaurants), and Whole Foods. Barb is currently the President and Chief Innovation Officer at Mattson, one of the largest developers of new foods and beverages. Barb is widely recognized as an expert in foods trends and product development, is the authors of a book on food science for the general public (Stuckey 2012), and was featured in the New Yorker article "The Bakeoff" (Gladwell 2005).
- *Arati Prabhakar:* Dr. Arati Prabhakar is the former head of the U.S. Defense Advanced Research Projects Agency (DARPA) from 2012 to 2017 and is currently the founder and CEO of Actuate, a nonprofit organization funding R&D to solve societal problems. In 1984, she became the first woman to receive a PhD in applied physics from CalTech. She was the head of the National Institute of Standards and Technology (NIST) from 1993 to 1997, and has held numerous positions in government, nonprofit, and private research organizations.
- *Chris Kirchhoff:* Dr. Chris Kirchhoff is currently a senior fellow at the Schmidt Futures Foundation. He began his career on staff of the Space Shuttle Columbia Accident Investigation and went on to serve numerous advisory positions to the Department of Defense in Iraq, writing the U.S. government's history of the conflict (Special Inspector General 2009), which the New York Times called "the Iraq Pentagon Papers." He founded and led the Pentagon's Silicon Valley Office, Defense Innovation Unit X, which harnesses emerging commercial technology for national security innovation.
- *Bob Kocher:* Dr. Bob Kocher is currently a partner at Venrock focusing on healthcare IT and services instruments. A trained physician and Howard Hughes Medical Institute fellow, Dr. Kocher was a partner at McKinsey & Company where he led the McKinsey Global Institute's healthcare economic program. After that, he joined the Obama administration as Special Assistant to the President for Healthcare and Economic Policy on the National Economic Council where, among other things, he helped shape the Affordable Care Act, the "Let's Move" childhood obesity initiative, and the Health Data Initiative.
- *Jean Rogers:* Dr. Jean Rogers is the Chief Resilience Officer at the Long Term Stock Exchange. She founded and served as the CEO for the Sustainability Accounting

Standards Board. Prior to that, she worked with Deloitte and at Arup, a global engineering consultancy.

- *Ilan Gur:* Dr. Ilan Gur is the founder of the Lawrence Berkeley National Laboratory's Cyclotron Road and the CEO of Activate.org, both of which manage fellowship programs that support entrepreneurial scientists. Prior to that, Gur founded multiple science-based startups and served as a program director at the Department of Energy's Advanced Research Projects Agency, ARPA-E.
- *Sal Khan:* Salman Khan is the founder and CEO of Khan Academy, a free online education platform. He also founded the Khan School Labs, a brick-and-mortar school designed to experiment with educational approaches, and sits on the board of the Aspen Institute. In 2012, Time Magazine named him one of the 100 most influential people in the world (Gates 2012).

While we do not attribute specific views to specific practitioners (some of whom elected to speak off the record), several common themes emerged.

First, most of the practitioners expressed optimism about the capabilities our current innovation and entrepreneurial system to effectively drive growth in certain domains. For instance, U.S. science and high tech R&D is second to none in the world, and this manifests itself in, for instance, U.S. dominance in biopharmaceuticals and ICTs. But outside of these domains, most concluded that the U.S. faces severe challenges. One challenge is translating high quality science to practice, especially when there is no well-defined career path for individuals with a technical background. This can lead to different parts of the U.S. innovation system working well in isolation but ultimately measuring up to less than the sum of their parts.

Second, many expressed their frustration with the difficulties in making innovation and entrepreneurship democratic. Some sectors, of course, are more democratic than others. But especially in highly technical fields, most innovators and entrepreneurs come from similar backgrounds, and most are white and male. While some were concerned about issues of representation for their own sake, most worried that the homogeneity of backgrounds likely deprives the economy of diverse and radical new ideas—the leaky pipeline problem discussed in the chapter by Biasi et al.

Finally, several of the practitioners expressed concern that the good economic times of the previous several years meant that many younger entrepreneurs never developed the skills to succeed through adversity. During good economic times, funding for projects is more readily available, which also makes it challenging for funders to distinguish great ideas from the merely good. These practitioners expressed concern that, were economic conditions to change, the innovation and entrepreneurship system had not developed the requisite resilience. Unfortunately, within two months of the conference, these concerns were realized, as we discuss in the final section of this introduction.

Broad Lessons

While the individual chapters contribute on their own to our understanding of the prospect for innovation and entrepreneurship across various sectors of the U.S. economy, the ability to compare and contrast the findings that arise from this collection of sectoral studies also allows us to draw some broader, if still tentative, lessons.

Heterogeneity and the "Vannevar Bush Sectors"

The most striking takeaway from this volume is that there are several sectors in which innovation and entrepreneurship are proceeding at a rapid pace, in line with the proclamations of the technological optimists (although even in those sectors the authors in this volume point out several potential headwinds), while in other sectors the amount of innovation and entrepreneurship is very low. We can see this clearly in Table 1: the manufacturing sector produces 5.6 patents for every thousand employees, while the education sector produces 1.6 patents for every *hundred thousand* employees. The detailed industry studies are necessary to move beyond these headline numbers to examine within-industry heterogeneity. For example, while health care performs poorly on the patenting metrics presented in Table 1, our data for the health care sector are for health care *services*; as Chandra et al. show, biotech, pharmaceuticals, and medical devices see the vast majority of health care venture funding.

The detailed industry studies are also valuable to help us understand potential reasons why some sectors see so much more innovation and entrepreneurship than others. One possible explanation for the observed heterogeneity is that sectors experiencing little innovation are already quite advanced (Baumol and Bowen 1966; Baumol 1967), or "fully grown" to use Vollrath's (2020) phrase. While this may be part of the explanation and deserves further study, we do not believe this can completely explain the patterns that we observe. Instead, we note that the sectors that have seen successful innovation and entrepreneurship have been science-based (the "productivity drivers": IT, energy, and agriculture) or have been able to incorporate technologies from those fields (manufacturing and the "on-demand" sectors). In the sectors for which progress has been more mixed, such as health care, the parts of the sector that rely on science have typically seen large advances (i.e., biotech, pharmaceuticals, and medical devices), whereas those that do not have largely stagnated (health care delivery, financing, non-pharmaceutical health interventions).

While the sector-specific studies in this volume do not allow us to make causal claims about why some sectors have been more innovative than others—after all, technological opportunities are not evenly distributed across sectors—we find it telling that the innovative sectors are those for which an innovation system is well established. By innovation system, we mean not only well-funded public institutions to conduct R&D, although such an institution is certainly in place for the innovative sectors (i.e., the NSF, NIH, numerous large R&D projects funded by the Department of Defense and Department of Energy), but well-defined research jobs, career ladders, rewards for innovative success such as intellectual property, and an ecosystem in place to develop and support high growth entrepreneurs.

We term these sectors for which an established innovation system is in place the "Vannevar Bush sectors." U.S. innovation policy today hews remarkably closely to the proposals laid out by

Bush in his famous report "Science: The Endless Frontier" (Bush 1945b), as exemplified by the major U.S. research institutions identified above. The modern IT industry likewise reflects Bush's vision for recording, storing, accessing, and sharing the world's knowledge (Bush 1945a).

While we again stress that causation is difficult, the evidence leads us to suspect that constructing innovation systems for the non-Vannevar Bush sectors will lead, after a long delay, to technological and entrepreneurial opportunities in these areas. Jones reaches a similar conclusion in his synthetic chapter when he notes that the institutional environment—and hence the innovation system embedded in it—is often malleable, and that in many cases innovation outcomes appear quite elastic to the institutional environment. Many of the non-Vannevar Bush sectors are focused in the social sciences, and more specifically in determining how to innovate complicated systems with many stakeholders. It is up to future researchers and policymakers to determine what the equivalent of the NIH for education or housing might look like. But at present it appears that, to a first order, we aren't even trying to build such a system for these sectors.

Measurement Challenges

One challenge with determining the role that innovation and entrepreneurship in economic growth relates to measurement. Indeed, there are challenges both with quantifying innovation-related activities as well as with quantifying productivity and growth. As Foster describes in her chapter, U.S. statistical agencies are both hardworking and creative at tackling the measurement challenge, but there remain fundamental challenges associated with creating definitive ways to measure new things. We are certainly not the only people to note the difficulties with measuring these types of activities; see for instance the recent Brookings Institution initiative (Hutchins Center 2019).

When it comes to quantifying innovation, several chapters in this volume make extensive use of patent data. This is especially true in the Forman and Goldfarb chapter on the IT sector and, to a lesser degree, in the Chandra et al. chapter on the health care sector. Notably, these are two sectors in which the ability to protect innovations via patents was questionable until fairly recently and is still on uncertain ground (molecular compounds in the health sector and software in the IT sector). Of course, patents are at best an incomplete and imperfect measure of the universe of innovations. But this is likely to be a much larger problem in some sectors than others. For instance, in both the education and government sector, many improvements take the form of organizational changes which are not generally patentable.

Productivity and growth are likewise harder to measure in some sectors than others. While statistical agencies have more than a century and a half of experience quantifying output improvements in manufacturing and agriculture, there is less agreement on how to measure successful government or good education. For instance, in the education sector, a large debate surrounds the use of teacher value added measures to assess input quality (Bitler et al. 2019; Chetty, Friedman, and Rockoff 2014a, b, 2017; Jackson, Rockoff, and Staiger 2014; Rothstein

2017) and testing data to assess educational outcomes (Ballou and Springer 2015; Carrell and West 2010; Shavelson, et al. 2010); it is clear that there is no consensus on which measures to use comparable to that related to measuring productivity in, say, manufacturing (Syverson 2011). Relating to the previous lesson, it is probably not a coincidence that we see so little innovation-driven growth exactly in the sectors for which identifying and quantifying improvements—and rewarding the people who make those improvements—is most difficult.

While it is often difficult to measure how innovations in some sectors contribute to productivity growth, innovations in many sectors are, by construction, not reflected in standard measures of growth like GDP. This is particularly apparent with internet-related technologies. While the internet undoubtedly makes firms more productive, it also provides valuable free services to consumers, which are not captured in GDP data (Brynjolfsson and Oh 2012; Byrne, Fernald, and Reinsdorf 2016; Goolsbee and Klenow 2006). Other approaches are therefore needed to quantify the value of innovations in IT, as well as in sectors as diverse as education (the value of better educated citizens is not counted in GDP), energy (a cleaner environment is not included in standard GDP calculations), or health care (health care innovations improve quality of life far above and beyond their contributions to output). Waldfogel's chapter in this volume is therefore a valuable contribution, as he moves beyond traditional productivity accounting to discuss how technological changes in the creative sectors have led to an increase in consumer surplus.

Classification Challenges

Closely related to measurement challenges are challenges classifying where in the economy innovation and entrepreneurship are occurring. The in-depth sectoral studies approach taken in this volume allows the authors of each chapter to move beyond crude industry classifications, documenting how each sector is both affected by innovations in upstream sectors and affects performance in downstream sectors. For instance, Biasi et al. make clear that innovations in the education sector affect every other sector by supplying the future innovators and entrepreneurs. And as we note above, IT now pervades nearly every industry. The Kung and Choe et al. chapters document that the emergence of on-demand housing and rides are among the most important recent innovations in housing and transportation, respectively. Whether these innovations are classified as occurring in the IT sector or in the housing or transportation sector is in some sense irrelevant; they will shape the way we consume housing and transportation services regardless of their official classification.

But how innovations are classified matters a great deal for statistical agencies and, consequently, for policy. Table 1 shows how naively relying on NAICS codes, which are the standard industry classification used by the U.S. government, may lead to distorted conclusions about where innovative activity is occurring. For example, the NAICS code for health includes only health care services; as Chandra et al. show, health care services have seen little innovation compared to biotech, pharmaceuticals, or medical devices. As another example, the NAICS codes for manufacturing include activities such as automobile and aviation manufacturing; automobiles and aircraft experience regular innovation, while there has been little measured innovation in transportation infrastructure, making the transportation sector appear middling in Table 1.

This issue is no less challenging at the firm level: should Netflix be classified as a media and entertainment firm, or as an IT firm? E-commerce firms similarly fall between the transportation, retail, and IT sectors. As Fuchs et al. show, official classifications of the manufacturing sector include firms from a wide array of seemingly disparate sub-industries, from animal slaughtering to oil refining, and Lafontaine and Sivadasan show that, for long periods of time, official classifications of the retail sector included restaurants. Nor do firms remain in one sector over their entire lifetimes; Delgado, Kim, and Mills highlight several firms that began as manufacturing firms but are now primarily in the supply chain traded services sector.

To the extent that our data is collected by industry-specific censuses or surveys, that official statistics are organized by industry, or that policy is targeting towards specific sectors, taxonomical issues threaten both our ability to study innovation and entrepreneurship-driven growth as well as to design policies to improve it.

Challenges of Place

We have mentioned above that, while the health care sector is innovative in producing new drugs and medical devices, it has struggled to improve delivery of health care services to those who need it. The problem of delivering products to potential users is likewise a major challenge in the delivery of government services. Even in the IT sector, arguably the largest bottleneck to growth is providing the infrastructure to allow consumers to take advantage of new innovations. Indeed, this issue seems so ubiquitous that it is worth considering the extent to which failures of innovation and entrepreneurship to generate economic growth are really problems about urban economics and economic geography, that is, challenges related to place.

As we noted, even in the best of cases it can be difficult to draw a line between different sectors. But this is especially the case when the delivery of goods and services are involved. The problems in transportation, retail, and housing all relate to the fact that agents on different sides of a transaction are located in different places. As Kung reviews in his chapter on housing, frictions to relocating resources through space (for instance, due to strict zoning laws) can have large economic costs. And we expect these kinds of frictions to be especially damaging to innovation and entrepreneurship in sectors that involve many stakeholders; the more parties there are to coordinate, the more costly relocation frictions will be. In this sense, we see issues in the housing and transportation sectors as affecting innovation throughout all the other sectors, in the same way that the performance of the education and IT sectors affect all other sectors.

Issues of place may also matter for innovation and entrepreneurship if the type and quality of ideas generated depend on where people are located. Two chapters in this volume, the Forman and Goldfarb chapter on IT and the Chandra et al. chapter on the health sector, make the point that patenting in these sectors has become increasingly geographically concentrated in recent decades, and this is likely to be problematic if individuals from outside of the major sectoral innovation hubs are excluded from the innovation process. At a time when the concentration of overall patenting is the highest it has been in a century and a half (Andrews and Whalley 2021), this is likely to be an issue for the other sectors as well. And innovation and entrepreneurship may be even more spatially concentrated than these statistics suggest; Guzman and Stern (2015) show that even within highly innovative regions, entrepreneurship is clustered within a few zip codes.

Important open questions relate to quantifying costs of spatial concentration of innovation and entrepreneurship and to understanding whether non-innovative regions can better reap the rewards of innovation and entrepreneurship-driven growth through policies to promote innovation and entrepreneurship in those regions or by better diffusion of innovations created in other places, for instance through better transportation and communication technologies (Glaeser and Hausman 2020).

The Future Is Already Here

Several times throughout the conference, we were reminded of science fiction writer William Gibson's famous quip: "The future is already here—it's just not very evenly distributed" (Gibson, 1999). While making concrete predictions about the future path of innovation and entrepreneurship is typically a good way to appear foolish in the eyes of future readers, it seems safe to conclude that the innovations that will most profoundly shape the next decade already exist, at least in a nascent form.

For many of the most impactful technologies of the past, there was a long lag between the first introduction of the technology and when its use became widespread. This is most clearly seen in this volume in the Alston and Pardey chapter on agriculture. While hybrid and genetically engineered crops diffused fairly quickly, reaching more than 80% adoption within a decade or two of their introductions, other technologies like the tractor took almost half a century to see similar levels of adoption. One reason for this, as David (1990) famously points out, is that for the most important innovations, widespread adoption is more complicated than simply switching from one technology to another; changes in organization, in the use of complementary technologies, and in the behavior or customers, suppliers, or rivals also must take place. In addition to examples from agriculture, clean energy (discussed by Popp et al.) and autonomous vehicles (discussed by Choe et al.) are other technologies with long gestation periods that have seen slow but steady improvements in performance and appear poised to make meaningful impacts on future economic growth in the coming decades.

While we are thus living in the future, it is also the case that we are living in the past, with the current distribution of economic activity across sectors determined at least in part by historic innovations. We see this most clearly once again in agriculture, which used to account for almost a third of the entire U.S. population in 1916; today only about 1.5% of the population is in agriculture. This dramatic change is largely driven by productivity improvements in the agricultural sector, most notably mechanization and biological innovations. A similar story is playing out today in manufacturing. While the manufacturing sector is clearly highly innovative, many of those innovations decrease manufacturing's share of employment and GDP. Moreover, as the manufacturing sector continues to shrink as a share of GDP, productivity improvements in manufacturing will have a limited ability to increase aggregate productivity growth. Such observations help to forecast where the future of economic growth is likely to occur. As we noted above when discussing heterogeneity across sectors, we do not see this as a reason to celebrate low rates of innovation, nor do we believe the rate and direction of economic growth are entirely determined by past innovations. Instead, we believe there are opportunities to increase the rate of innovation in sectors that account for a growing share of the economy but have historically received little investment in innovation and entrepreneurship, namely sectors like services, housing, education, and the government.

Innovation and Entrepreneurship during the 2020 Covid-19 Pandemic

Shortly after the conference took place, the novel coronavirus SARS-Cov-2 caused a pandemic, leading to shelter-in-place orders throughout the U.S. and the cancellation of most in-person activities. While it is far too early to assess the long-term effects of the pandemic on innovation and entrepreneurship across different sectors, here we offer some initial observations based on events that occurred throughout the remainder of 2020.

Those sectors that had already embraced general purpose technologies to achieve past productivity growth—namely, our "productivity driver" and especially "on-demand" sectors—were able to respond reasonably well to the pandemic, highlighting the fact that innovation can drive not only growth but also resiliency. For instance, online retailers like Amazon saw large gains in share prices as consumers minimized shopping in-person, by necessity rapidly accelerating the trend towards online shopping; Lafontaine and Sivadasan provide a brief overview of the large adverse effect of Covid-19 on the brick-and-mortar retail establishments and restaurants in their chapter. Many supply chain service sector jobs were also able to switch to online work with minimal disruption. The online delivery of media and entertainment content allowed media platforms to weather the storm as well.

Our impression is that the transition to a pandemic economy appears to have been more difficult for the "cost disease" sectors, which have historically struggled to incorporate innovations from other sectors. School closures forced the education sector to embrace online education technologies at a rate and scale that would have been unthinkable prior to the pandemic; it is far too early to know how the adoption of these technologies have affected educational outcomes, much less the extent to which they will continue to be used when the pandemic subsides. Finally, in the health care sector, the pandemic brought into sharp relief the gap between healthcare innovation and healthcare delivery, echoing themes from the Chandra et al. chapter: the SARS-Cov-2 genome was sequenced in record time and trials for vaccines and antiviral therapies were launched rapidly, but sourcing, manufacturing, and distribution of "low tech" health care materials like masks and other personal protective equipment proved difficult in early the stages of the pandemic.

Of course, at this point we do not yet know whether the choices of participants in different sectors to adopt new technologies in the face of the pandemic will prove to be permanent or transitory, nor whether the events of the past year will induce the development of new technologies in sectors that had previously struggled to innovate. Obtaining answers to these questions will shed light on the future role of innovation and entrepreneurship in driving economic growth across sectors.

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