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Introduction

INNOVATION HAS long been perceived as essential to economic growth. Since the pioneering work of Moses Abramovitz and Robert Solow in the 1950s,[1] we have understood that a society cannot expect to grow over a sustained period by simply purchasing more equipment or having individuals work longer hours. Rather, it is by working smarter—getting more goods and services from the same inputs—that we live more comfortably and longer than our great-grandparents. Innumerable studies have documented the strong connection between new discoveries and economic prosperity across nations and over time. This relationship is particularly powerful in advanced nations—that is, countries that cannot rely on copying others as part of a "catch-up" strategy—but innovation is also taking place increasingly in developing countries, as seen in the rise of patenting and venture funding there.[2]

Thus, vibrant innovation is an important goal. Without innovation, economic stagnation is likely, a recipe for social and political polarization as different parts of society fight each other seeking to get as large a slice of the pie as possible.[3] In contrast, if the economic pie is growing, there is more hope, though certainly no guarantee, of social harmony. Indeed, researchers have found that exposure to economic growth early in life means that individuals are less likely to engage in "zero-sum thinking" as they mature. Meanwhile, those who experience a stagnant economy as youths tend to view the world as a fixed-size cake to be divided among the participants and to be oblivious to the fact that this cake might be expanded.[4]

Moreover, the dismayingly long list of critical challenges that the world is likely to face over the next decades suggests another rationale for prioritizing innovation. Our ability to respond to environmental degradation, global warming, pandemics, and terrorism, among other issues, will require innovative breakthroughs.

Making Innovation Happen

It is one thing to say we need more innovation. But how do we achieve it? This question suggests the importance of understanding the processes through which innovators come up with new ideas.

We tend to think of great discoveries as being driven by geniuses working alone. Whether it is Archimedes running naked through the streets of Syracuse after discovering the principle of water displacement or Albert Einstein deriving special relativity during his lunch breaks at the Swiss Patent Office, the image of the lone polymath having a "eureka moment" is seared into the popular imagination. However true this once was—and it probably was not very accurate for much of human history[5]—today the story is particularly misleading. For instance, in 1976, an average of 1.7 inventors were listed on each US patent, while in 2022, patents listed an average of three inventors.[6]

The increased importance of joint invention—whether by large teams of inventors within a single organization or across multiple entities—has its roots in the changing nature of scientific and technological discovery. Today, innovation is characterized by two seemingly paradoxical trends. On the one hand, technological innovation has become more important than ever. But on the other hand, it has become much harder to find new ideas. These two factors have made technology sharing more important than ever.

We can see the evidence for the first point—the increasing importance of and rewards from technology—in many places. One piece of evidence is the rise of venture capital, a key mechanism for promoting innovation.[7] From 1994 to 2024, the US venture capital pool has increased from 0.4% of gross domestic product (GDP) to 4.2%. More generally, American firms are investing more in R&D: the share of corporate R&D has increased from under 1% of US GDP in 1976 to 2.5% in 2024.[8] Technology companies' share of total public market capitalization has also increased from 10% in 1980 to 33% in 2024. To the extent that the market provides a prediction of the future, much of future profitability will come from technology.[9]

We can also see, however, abundant evidence of the second point, the increased challenges associated with making new discoveries. Consider, for instance, the famous "Moore's Law," the observation that the number of transistors in an integrated circuit doubles about every two years. Empirically, this relationship has held up remarkably well since Gordon Moore first noted it in 1965. As a result, semiconductors have become more powerful and ubiquitous in virtually every product in the world: 2024 saw more than a trillion such devices sold for more than $600 billion.[10]

But while there is considerable debate in the technical community as to whether Moore's Law continues (and will continue) to hold (and how progress in semiconductors should be measured more generally),[11] what is certain is that the number of engineers needed to achieve progress in chip design has increased exponentially. Nick Bloom and co-authors show that the research effort in semiconductors has increased by a factor of 18 between 1981 and 2014.[12] The increased cost and difficulty of breaking into frontier markets, of course, does not reflect any decline in the mental acuity of researchers, but simply the fact that much of the low-hanging fruit has already been picked. Similar patterns have been seen historically in pharmaceutical development (at least until the emergence of artificial intelligence) and many other innovative fields. So, the big picture is that R&D becomes more and more expensive and challenging; so, in order to account for the large market caps of the big tech companies or the large returns to venture capital, the rewards must be that much greater as well.

The consequences of the increased importance of technological discovery, and the challenges it presents, are perhaps not surprising. As Ben Jones and other scholars have documented, both scientific and technological accomplishments are increasingly the result of efforts of many teams working together, sometimes within the same organization but also often across firms.[13] This reflects, he shows, the increased complexity of technologies such as semiconductors: no one individual is likely to have the expertise to master them. Similarly, to design and then manufacture COVID-19 vaccines, each of the leading producers engaged dozens of firms scattered across a large number of nations.[14] And over the past few decades, firms have increasingly specialized in specific areas.[15] As a result, coordinating innovation across organizations is a growing and important challenge, which will be the focus of our book.

Facilitating Co-Creation

Many of the systems we have for rewarding innovation are the products of a simpler era, when individuals, working alone or as part of a larger organization, developed most of the ideas required to make a technology work. In an older era, an invention might get a single patent, which would allow the inventor to commercialize the idea as he or she saw fit. But as key inventions have increasingly become the work of multiple teams, the inability of the system to appropriately reward parallel invention has become increasingly problematic.

Much of the impetus to address this problem has come not from governments, but from private firms. As we will document in this volume, there has been a flurry of new organizational structures that allow multiple firms to jointly address complex problems. We will focus in this book on three of these:

- The standard-setting body, where firms agree on a common technical template and commit to making the patents needed to comply with the standard available to license to others on fair terms.
- The patent pool, where key patents (often associated with a standard) are "packaged up" and made available to all who wish to access a license to them.
- The open source organization, where users commit to make their innovations available to others, typically on a cost-free basis (though restricted in other ways).

These new entities, which we term knowledge-sharing organizations, are far from economic curiosities. Many of the industries crucial to the twenty-first century, from mobile devices to genomic software to the Internet itself, have grown in large part as a result of these organizations. Even as early as 2001, sales based in whole or in part on pooled patents reached at least $100 billion and are doubtless far greater today.[16]

But like many innovations, these breakthroughs have created some new problems. First, almost as long as these knowledge-sharing organizations have existed, adept "entrepreneurs" have sought to use them to get an unfair advantage. In particular, the very mechanisms that can facilitate the sharing of technology to accelerate progress can make it easier to collude to maintain high prices, restrict entry by new competitors, and even suppress follow-on ideas.

This seemingly counterintuitive result can be seen in the history of one of the first patent pools, the Singer Sewing Machine patent pool, formed by the three companies holding the key patents for the superior "lockstitch" technology in 1856. As we discuss in Chapter 3, Ryan Lampe and Petra Moser show that in the years after the establishment of this pool, lockstitch patents dropped sharply.[17] In particular, new firms focused their innovative activities on older (and inferior) technologies. It was not until the pool's last patent expired to the pattern reversed.

These issues are of course particularly pressing today. The rise of the "Magnificent Seven"—the highly valued tech giants whose soaring market capitalizations have driven US public markets in recent years—has reinforced fears that technological progress is being used to create market dominance. These fears of monopoly have been articulated by academics from various disciplines, as well as by political leaders on the left and the right.

As a result, governments have long felt—and certainly feel today—the need to supervise efforts by companies to exploit novel technologies, including through patent pools or standard-setting bodies. But determining which institutions and what behavior are beneficial or harmful to society is no easy challenge. New technologies in many industries are complex and hard to understand. The motivation and actions of firms within the "black box" of these organizations can be hard to discern, for both regulators and judges. And firms are adept at spinning stories to justify their actions.

This Book

In this volume, we explore three types of knowledge-sharing organizations in turn. We will have two goals: to understand what makes them tick and how policymakers can best oversee their activities to maximize the good for society. In each case, we will draw on our earlier papers that sought to capture the key features of the organizations in stylized ways.

Each of the three core chapters in this volume, which look at pools, standards bodies, and open source in turn, has a similar structure. We start with a brief history of the knowledge-sharing institution. The chapters then present an economic framework that helps illuminate some of the key features and challenges associated with that institution, as well as the implications for policymakers, corporate executives, and entrepreneurs. Along the way, we present a case or two to illustrate these issues in a more tangible form. We finally end each chapter with a look at a current challenge the institution faces. While these contemporaneous questions may not have easy answers, or fit neatly in the frameworks we present, they suggest opportunities for exploration to researchers interested in the institutions.

Finally, we note three caveats. First, the three types of institutions themselves have innumerable legal and business complexities. Unlike much of the literature, which has focused "in the weeds" on the legal design and implementation of the institutions, our book will take the view from thirty thousand feet. We will focus on the basic economic problems that the organizations pose, abstracting away from some of the nuances in the interest of highlighting fundamental trade-offs. Nor will we consider all knowledge-sharing organizations: protein design banks, paper depositories such as arXiv, and patent depository libraries are a few examples of interesting knowledge-sharing organizations we do not consider, though we anticipate that many of the frameworks discussed here will be applicable in those settings as well.

Second, in Chapters 3, 4, and 5, we will indulge in economic notation. These formulations will allow us to discuss issues more precisely. We will do so, however, in the appendix, so that the main ideas and insights can be grasped in the text without specific knowledge of formal economics.

Finally, we have sought to write a book for multiple audiences, including innovators, policymakers, and academics. Given the long history of patent pools being used for anticompetitive purposes, Chapter 3 focuses on the concerns of policymakers. The much newer area of open source has attracted far less antitrust scrutiny, so our focus in Chapter 5 is more on the questions facing innovators strategically managing their intellectual property. (The standards chapter reflects the concerns of both audiences.) Throughout, and especially in the appendices, we highlight open issues that merit further academic exploration. In the final chapter, we highlight some key lessons for different classes of readers.

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