Real Effects of Academic Research Revisited*

Adam B. Jaffe
Brandeis University, Motu Research and NBER

Laura B. Shupp
MIT

Valentina Tartari
Stockholm School of Economics

February 2025

Abstract

This Chapter surveys the findings of social science research on the contribution of universities to innovation and economic growth, both locally/regionally and globally. In the last several decades research has demonstrated universities' causal effects through the mechanisms of knowledge creation, education and training of students, and technology transfer/entrepreneurship. The Chapter summarizes how the literature has studied each of these mechanisms, and how the findings have probed variation across disciplines and economic sectors. The depth and breadth of understanding have been advanced by new microdata and new methods of linking data across inventions, scientists and institutions, and by application of methods from network science. We emphasize that research has proven the importance of these effects on average, but to date has less to say about the determinants of success or failure in different contexts. These findings have implications for public policy to foster innovation both regionally and globally.

---

*We thank the organizers, Megan MacGarvie and Reinhilde Veugelers, for the opportunity to contribute to this book, and we thank the participants of the Economics of Science conference for their helpful comments. We thank Lesley Millar-Nicholson of MIT and Brook Pritchett, John Miner and Steve Susalka of AUTM for useful discussion about university IP licensing and provision of data from the AUTM surveys. Shupp acknowledges support from the National Science Foundation under Grant No. 2141064. Contact: adam.jaffe@motu.org.nz, laura.shupp@fulbrightmail.org, and valentina.tartari@hhs.se

1. Introduction

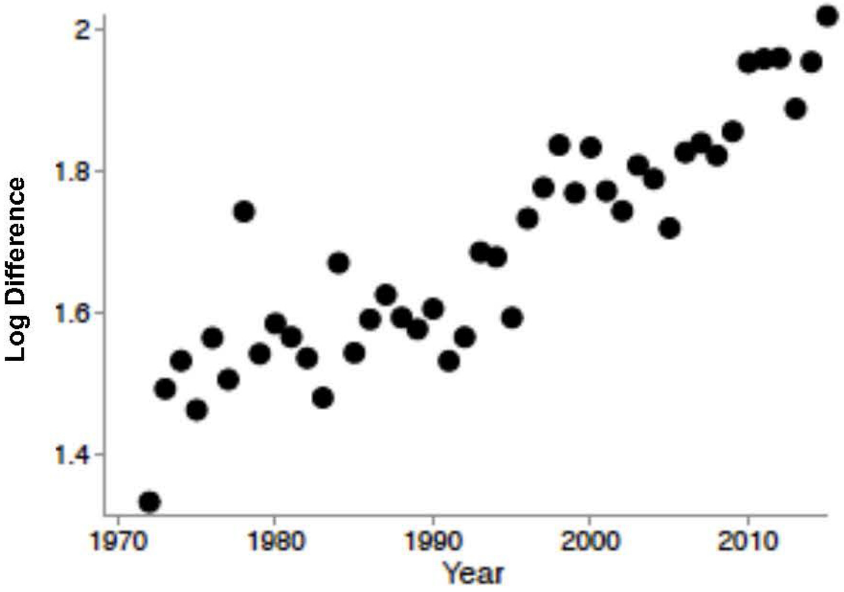
At a deep level over long time frames, it is obvious that universities play fundamental and crucial roles underpinning innovation. They perform a large fraction of all basic research, and they are the preponderant institution in which people receive advanced education and training across the spectrum of human knowledge. Further, universities contribute to commercial innovation and economic growth, both globally and with specific effect in their geographic regions.

Social science research on the economic impact of universities grew in the last quarter of the 20th century. This increased attention was motivated in part by debates over the magnitude of public resources that universities should receive, but also by a concern that greater technological and economic benefit could come from the given level of resources under different policy and institutional practices. Greater attention to achieving the maximal possible return for the public investment in universities can also be seen as a natural evolution from the post-WWII period, in which resources devoted to universities grew dramatically.

Over the same time period, the relationship between university activities and innovation in the surrounding region has itself strengthened. Figure 1 shows that in 1970 U.S. metropolitan areas with a major research university received about 4.5 times as many patents per capita as areas without one; by 2015 this ratio had increased to over 7. As discussed below, this simple correlation does not in itself establish the causal impact of universities, but it is illustrative of the potential importance of the effect.

Figure One

Comparison of University- and Non-University- Regions Over Time



Log difference in patents/capita between Metropolitan Statistical Areas (MSAs) with and without a major research university, by year (Schoellman and Smirnyagin (2025))

Academics as individuals and universities as institutions have undertaken deliberate, sustained efforts to increase these broad social impacts. While this evolution began first and has been particularly pronounced in the case of the United States, the rest of the world has followed suit, sometimes in deliberate imitation of U.S. policies and practices, and sometimes with different approaches.

Jaffe (1989) was an early attempt to take methods that economists had used to study innovation in firms and apply those methods to document the innovation impact of universities. In this

Chapter, we seek to review the large volume of subsequent work, to assess critically where we now stand in terms of understanding this system, to elucidate the implications of this understanding for public policy, and to suggest areas where further research is likely to be fruitful.

1.1 The Historical Origins of Academic Research and Commercialization

The university as we know it today evolved from European universities, some of which date to medieval times. But the roots of what we now call the entrepreneurial university—which proactively seeks to foster commercial activity derived from its teaching and research—are distinctly American.

An American inclination towards the practical and commercial was noted by French diplomat Alexis de Tocqueville during his famous 1831 American visit. Tocqueville observed that Americans pursued science for immediate practical purposes, valuing “every new method which leads by a shorter road to wealth, every machine which spares labor, every instrument which diminishes the cost of production” (Tocqueville 2010). This inclination was manifest in legislation with the Morrill Act of 1862, granting each state 30,000 acres per congressional representative to fund colleges dedicated to agriculture, the mechanical arts (i.e., engineering), and military tactics. These “land-grant” universities became natural links to local economic needs, sustained by their decentralized revenue model that required attracting students and charging tuition (Nelson and Rosenberg 1994). Wisconsin developed dairy science programs for cheese production, Iowa taught food preservation techniques essential for harsh winters, Illinois created railway engineering degrees as Chicago became the nation's rail hub, and Michigan focused on lumber and furniture manufacturing to exploit its vast forests. The Hatch Act of 1887 further aligned academic research with commercial needs by establishing agricultural experiment stations and providing the first targeted federal research funding.

By the 1890s, industrial research laboratories like General Electric (1900), DuPont (1903), and Bell Labs (1925) demanded engineers trained in scientific principles rather than practical applications, transforming land-grant institutions where engineering enrollment surpassed agriculture as universities shifted from shop work to laboratory instruction (Nienkamp 2010). Thus the roots of the modern research and innovation system were planted, with universities claiming basic research and professional training while ceding applied development and commercial exploitation to industry.

Despite this overall division of labor, there were early flickers of university interest in commercialization. In 1912, Frederick Cottrell, a Berkeley chemist, established Research Corporation, a third-party organization designed to handle university patents while insulating universities from the business aspects of patent management. In 1924, Harry Steenbock's patents on vitamin D supplementation through dairy products led to the creation of the Wisconsin Alumni Research Foundation (WARF). This use of affiliated but legally separate foundations to handle patents derived from university research reflected widespread academic ambivalence toward embedding knowledge in exclusionary intellectual property, which was perceived to conflict with existing commitments to open science (Sampat 2006). With the post-WWII growth of federal funding of university research, universities also had to deal with securing funder acquiescence to patent ownership, and agencies and individual funding administrators varied in their tolerance of university patenting.

This arms-length relationship with commercialization began eroding in the 1970s due to three converging forces: increased postwar growth of "use-oriented basic research," declining federal funding that made patent income attractive, and growing government interest in commercialization of the fruits of federally-funded research (Sampat, 2006). The transformation accelerated dramatically with the Bayh-Dole Act of 1980, which replaced the patchwork federal agency approach to university patenting with a standardized framework designed to encourage commercialization. The Act spurred the establishment of Technology Transfer Offices within nearly every major research university, creating formal mechanisms for universities to seek, manage and profit from intellectual property.

The contrasting evolution of European higher education compared with the United States, and even within Europe itself reveals how institutional conditions impact research orientation and commercialization patterns, differences that remain visible centuries later. Unlike American land-grant universities dedicated to using science as a service to society from their inception, European institutions followed trajectories rooted in aristocratic traditions with a theoretical emphasis that created lasting structural divisions. German research universities such as Heidelberg and Berlin pioneered laboratory-based science under the Humboldtian model, which emphasized pure research and academic freedom but remained oriented toward advancing knowledge rather than meeting immediate industrial needs. Applied science was largely confined to polytechnics such as ETH Zurich and Technische Hochschule in Munich, which gained university status only later. In Britain, Oxford and Cambridge held onto classical curricula well into the late 19th century, while technical education developed in separate institutions such as the Royal College of Science and later the red-brick universities.

This European pattern maintained a sharper divide between elite research universities and vocational training until well into the 20th century. Most tellingly, until the late 20th century, European universities prohibited or discouraged patenting, leaving intellectual property to individual professors under "professor's privilege" systems while channeling technology transfer through separate state research institutes like Germany's Fraunhofer Society and France's CNRS rather than through universities themselves. These institutional arrangements, established centuries earlier, help explain why European adoption of university IP ownership lagged the United States by nearly two decades and why similar policy frameworks continue to produce divergent commercialization outcomes across different national contexts.

We will say little in this Chapter about universities outside of the U.S. and Europe. This is in part because these universities have historically been less active in pursuing commercialization. But it also reflects the reality that until recent work (largely focused on China), there has been little social science focus on studying their impact. We will address briefly in the Conclusion the issues raised by our lack of knowledge regarding this part of the world.

In this century, the pervasive influence of digitalization, artificial intelligence, and computational methods across all disciplines of research have caused further evolution of universities' relation to commercialization. This transformation has spawned new forms of university-industry collaboration that center on data access and algorithmic expertise rather than traditional laboratory-to-market channels. The locus of much cutting-edge research that relies on big data and machine learning seems to be migrating from universities to private firms. The ability of patents and other traditional forms of intellectual property to protect the returns to innovation in these domains is unclear, which calls into question the sustainability of the Bayh-Dole model for sharing the economic rewards of commercialized university research. These changes raise questions about the future of university research commercialization that will be considered further below.

2. Analytical Issues

2.1 Creation of knowledge and spillovers

A basic premise of this conference is that innovation is a key driver of improvements in prosperity and well-being over time. Analytically, this role for innovation derives from the *spillovers* generated by knowledge (i.e., benefits derived from knowledge that accrue to people or organizations beyond those that created it). The magnitude of these spillovers is dependent on the *diffusion* of knowledge, because widespread benefits from any given chunk of knowledge are dependent on that knowledge being widely available and usable.

Universities are institutions dedicated to the creation and transmission of knowledge. Indeed, they are arguably the most important category of institutions responsible for the creation and transmission of knowledge leading to innovation that drives economic growth and human welfare.

Consider first the scale of resources devoted to knowledge creation through formal research. U.S. businesses perform about $700 million of ‘research’ annually; universities and related non-profits perform about $100 million in research.[2] But there are several important reasons why the overall contribution of universities to spillovers is likely greater than that of firms.

The incentives facing firms are to do everything they can to prevent the knowledge that they create from ‘spilling’ out, while universities are in the business of disseminating knowledge. In addition to the noted research expenditures, universities spend about $200 million on instruction

---

[2] All of the research expenditure numbers presented here are based on the most recent reported data, for 2022 (NCES, 2024). Totals given above for universities include modest amounts reported for ‘Non-profit organizations’, the largest of which are research centers affiliated with universities. Research is also performed by government, about $70 million total and 10 million basic in 2022.

(National Center for Education Statistics, 2023), and engage in a variety of formal and informal activities such as scholarly publication, technology transfer, and consulting that foster the dissemination of both new and previously discovered knowledge. Indeed, from a broad social and historical perspective we can think of universities as the primary social institution dedicated to the maintenance, curation, and transmission of knowledge, old and new. The flip side of the spillover phenomenon is that innovation is a cumulative process, with new ideas always using and then building on the extant stock of available knowledge. If this stock were not maintained, organized, and transmitted to successive generations of innovators, the process would be greatly hindered.

Further, the preponderance of firm spending on research is for applied research and development, while the preponderance of university spending is for ‘basic’ research; as a result, universities overall perform the majority of basic research (about $70 million, compared to about $50 million at firms). Basic research is defined as “experimental or theoretical work undertaken primarily to acquire new knowledge of the underlying foundations of phenomena and observable facts” (National Center for Science and Engineering Statistics, 2025).

Akcigit et al. (2021) provide quantitative evidence for the particular significance of basic research in generating spillovers. Using a general equilibrium model distinguishing spillovers across research types, they find that approximately 90% of basic research benefits are not internalized by the originating firms. Further, the spillovers from basic research increase the productivity of applied research by 60%. As a result the spillovers simultaneously increase firms' R&D incentives and enhance the resulting applied research effectiveness.

The relationships among basic research, applied research, invention and innovation are subtle. Donald Stokes (1997) famously suggested two distinct fundamental attributes of research:

whether it seeks fundamental understanding of scientific facts and principles, and whether it seeks some practical use. “Pure” basic research in this formulation is characterized *only* by the first attribute, and “pure” applied research is characterized only by the second. Stokes used the work of Niels Bohr as the prototype of pure basic research and that of Thomas Edison as the prototype of the latter. But Stokes’ important insight that there is a third category, which he called “use-inspired basic research”, which is motivated by an application need, but which seeks fundamental scientific understanding as a means to that end. Stokes associated this kind of research with Louis Pasteur, who was motivated by his desire to protect people from disease, but this motivation led him to discover and demonstrate previously unknown fundamental biological processes. Stokes argued that much basic research in the modern world takes this form, so that new understanding of basic science and solution of real-world problems go hand in hand. This can be seen in many aspects of current university research, from fundamental work on how viruses and bacteria interact contributing CRISPR technology, to quantum computing and communications research that is deepening our understanding of quantum physics.

Stokes’ observation about use-motivated basic research is useful for understanding the distinction between the *motivation* underlying research and its potential *consequences*. But regardless of motivation, basic research overall generates large and long-lasting spillovers, and thereby lies at the heart of universities’ contributions to innovation and well-being. While John Maynard Keynes’ quip about practical men being the slaves of defunct economists is mostly seen as a joke, many practical people are indeed dependent on the work of forgotten scientists.

In addition to depending on knowledge diffusion, the beneficial effects of spillovers are also dependent on absorptive capacity, the ability of individuals and institutions to learn about and effectively utilize knowledge that flows around them. The education and training carried out by universities increases the human capital of undergraduates, graduate students, post-doctoral researchers, and faculty. These people carry this human capital with them to multiple institutions in multiple regions, thereby increasing absorptive capacity throughout the system.

2.2 Causality

2.2.1 The causality problem with respect to impacts of university research

As we will discuss below, it is easy to show that cities and regions with more university research expenditure have more innovation and more economic growth. For many people connected to universities, the notion that nearby innovation and its benefits are at least partially due to university research is a no-brainer. But social scientists know that correlation does not necessarily imply causality;[3] even where causation seem obvious we seek ways to measure rigorously the causal effects.

Fundamentally, universities grow and attract resources for reasons that are endogenous to the larger socioeconomic system. This endogeneity of university activities can generate a correlation between the intensity of those activities and the performance of the surrounding region whether or not the activities are actually affecting regional performance. Table 1 provides some examples to explain how failing to account for this endogeneity can lead researchers to overstate universities' causal effects on regional performance.

---

[3] https://imgs.xkcd.com/comics/correlation.png

Table 1: Possible biases in measuring effect of universities on regional economic development, with hypothetical examples

Exogenous factors affect both university location/size and regional innovation/growth.	**City/regional success fosters university success.**
The weather in (what we now call) Silicon Valley is lovely, which might have attracted smart and creative people, thereby facilitating growth of both universities and innovative firms.	Wealthy cities have better infrastructure, which attracts better university faculty, and attracts firms that subsidize university activities.
Universities causal effects that do not operate through the mechanism of research spillovers	**Knowledge spillovers have indirect or second-order effects that are conceptually distinct from the direct spillover effect.**
Harvard has amazing art museums and concerts. These amenities might attract firms and their employees to locate in Cambridge.	Knowledge spillovers may induce firms to move near universities, which in and of itself may have effects on innovation and economic growth that are not a (direct) consequence of the knowledge spillovers themselves.

Note that the effect of these endogenous forces on the university-research-knowledge-spillovers-causal story is not a yes/no question. We would like to measure the *magnitude* of the causal effect. If the effect is real, and these other endogenous forces are also at work, the measured correlation between university activities and regional effects will reflect the *combined* effect of the research spillovers and the other effects, possibly leading us to overestimate the magnitude of the university effect. For example, the growth of a major private sector pharmaceutical cluster in Cambridge and Boston is surely the result, in part, of the research success of Harvard and MIT. But that for-profit activity now surely also feeds back and benefits the universities. As we try to extract the magnitude of the university research spillover effect from data on university and firm activities, we may overestimate its magnitude if we do not consider that feedback effect.

This discussion has focused on the impact of university knowledge spillovers on nearby innovation and growth. At the local level, endogeneity poses severe measurement challenges: the idiosyncratic nature of geographic relationships, combined with mobility across regions, makes it difficult to establish causality. These local-level identification problems largely dissipate when examining global patterns, where changes in university research spending across scientific fields correlate with subsequent innovation in related technological areas. At the global scale, the primary threat to causal inference shifts to a different concern: exogenous changes in technological opportunity or broader intellectual and social trends that might simultaneously drive both university research directions and technological innovation.

The essence of the correlation-is-not-causality problem is that correlation just says that two variables tend to move together. X and Y might be moving together because changes in X *cause* Y to change, but they might also be moving together because some other factor drives both X and Y (or because changes in Y cause changes in X). To solve this problem, we look for changes in X that we know were caused by something that has no direct effect on Y. We call such uncontaminated changes in X "exogenous" changes or movements.

If we can identify such exogenous movements in X, then we can get an unbiased measure of the effect of X on Y by looking at the co-movements of X and Y only in cases of exogenous movements of X. For example, in the original "Real Effects" paper, the effect of university research on corporate patents in the same state was measured using only variations in university research associated with variations in the simple count of universities in the state, and the overall population of the state. The implicit assumption in this approach is that variations in the simple count of universities and in state population do not themselves affect corporate patenting.

That paper could probably not get published today. In the last decade of the 20th century, economics underwent a major causality revolution, such that much stricter standards are now applied to establishing the exogeneity of the drivers used to purge variables whose causal effects we seek to measure of their endogeneity. Roughly speaking, under the old approach, a variable could be considered exogenous if a plausible argument could be made that it didn’t affect Y. But these variables were often nonetheless in a general way endogenous parts of the larger system containing X and Y. For example, while there is no obvious mechanism by which state population affects corporate patenting in that state, population is still endogenous in a general way, depending as it does on fertility and migration, and affecting all kinds of other regional variables such as construction activity. There is therefore no way to really know if the supposedly exogenous movements are truly exogenous.

The easiest way to think about the new approach is with reference to Randomized Control Trials (“RCTs”), such as those used to test new drugs. Suppose we could randomly plop a university in some cities, but not in others. Cities randomly assigned to be ‘treated’ by insertion of a university could be compared a few years later to those that were randomly assigned to the “control” group with no treatment. If the treated cities systematically grew faster than the control cities, that difference could only be attributed to the treatment, i.e. the insertion of a university.

Now, in the real world we cannot arbitrarily vary university activity. But we can do is look for events that had an analogous effect, so called ‘natural experiments’ that create real world situations with the desirable properties of RCTs. For example, Andrews (2023) examines how the establishment of colleges affects local innovation by exploiting an identification strategy based on historical site selection decisions. Using counties that were runner-up locations for new colleges as counterfactuals in a difference-in-differences framework, he finds that establishing a college increases local patenting by 62 percent per year. However, by linking patents to college yearbook data, he discovers that only 12 percent of patents in a college's county came from that institution's alumni or faculty, suggesting that colleges stimulate innovation primarily through indirect mechanisms rather than through direct knowledge transfer from graduates and researchers. Kantor and Whalley (2014) use a different strategy and estimate local knowledge spillovers from research universities by exploiting variation in university spending driven by endowment value fluctuations and stock market shocks, finding that a dollar increase in university spending generates approximately 89 cents of additional labor income in the local noneducation sector.

The causality revolution been extremely valuable to the investigation on the impacts of university research: we now have numerous quite strong confirmations of the importance of the spillover effects. But finding 'clean' exogenous events that drive these processes is dependent on luck and hard work; there are many questions we would like to answer for which there is no obvious natural experiment. Particularly where we have new questions and/or new data, we may see intriguing correlations that suggest a causal effect with no obvious factors that likely would cause a large endogeneity bias. While we need to be careful not to over-interpret such findings, they do tell us something about the world even if they might be hard to get published. Conversely, because good natural experiments are rare, the quest for clean causality sometimes takes researchers to settings that are far afield contextually or historically, with the result that we get clean causa evidence, but it's hard to know if it is applicable to the time and context we most care about. Hence we may learn most from a balanced approach, in which clean causality is viewed as desirable but not the only determinant of whether research is useful.

2.3 Measurement Issues

"Real Effects" in the title of the 1989 paper was a tongue-in-cheek takeoff on what was at the time a burgeoning macro/finance literature documenting real—meaning non-financial—effects of financial actions. In plain English, the obvious effects of university activities are of course quite real. But university boosters and alumni magazines have for a long time claimed broader benefits in terms of economic growth and broader well-being. Our challenge is to quantify the magnitude of universities' effect on these broader effects.

For this purpose it is useful to distinguish 'outputs' and 'outcomes' (Jaffe 1998; Hall and Jaffe 2018). The *outputs* of universities are its direct consequences: new knowledge and students with more knowledge in their heads. The *outcomes* are the ultimate social goals that these outputs facilitate: improved general, widespread understanding of ideas and universal laws of the natural universe and social systems; higher societal income and wealth; improved health; cleaner environment. Some of the benefits of these outcomes accrue to the universities, their faculty and their students. That's a good thing, but for policy purposes we are more interested in the spillovers (i.e. the benefits that flow to parties other than the university, its employees, and customers).

These ultimate outcomes arrive with lags that are often long and always of uncertain duration, ultimately resulting from complex interactions of university outputs with many other factors. Thus tracing the path from university activities to ultimate outcomes is often quite difficult. For this reason, research often focuses on *intermediate outcomes*. An intermediate outcome is something that is not desired for its own sake, but which represents an observable step along a pathway to a desirable outcome. For example, the startup of a new firm based on a university invention, and its success in attracting private financial backing, do not in themselves generate net social benefits. But the fact that the firm gets going and attracts investment means that some people believe they are on the path to producing something valuable, and are willing to put their money behind that belief. Further, we know that on average significant social benefit is associated with the products of startup firms, so it is not unreasonable to treat the kindling of such startups as an intermediate outcome of university research.

Measurement of university inputs is also important. The UMetrics initiative (Lane et al 2015) has created and maintained a dataset built from invoice and payroll data of universities that allows the behavior of individual researchers and their labs to be studied at a granular level. For example, Babina et al. (2023) use UMetrics to link researcher-level funding sources to innovation outcomes, enabling analysis of how shifts between funding types affects publications, patents, and entrepreneurship.

The other major measurement challenges in connections or linkages between and among different aspects of the research and innovation processes. Fundamentally, to measure the impact of science in terms of innovation and technology requires methods to systematically link new products and processes to underlying scientific research. Citations or references to previous publications (which appear in both patents and scientific papers) are widely used for this purpose. Natural Language Processing ("NLP") algorithms are of growing importance as a way to quantify the relationship between textual artifacts of many different kinds (Bergeaud et al, 2026)

This chapter can thus be conceptualized as the effort to understand the relationships among university inputs, outputs, intermediate outcomes and ultimate outcomes. These things are fundamentally hard to measure. We will adopt the approach of the empirical literature, which is to identify proxies or indicators that we believe usefully capture differences and changes in the magnitude of the underlying phenomena.[4]

---

[4] In principle, an indicator is a measurement or statistic that is designed to capture a given phenomenon, e.g. the BLS Unemployment Rate is an indicator of the fraction of the population without work. A proxy is a stand-in that we know is not the phenomenon of interest, but we think is correlated with it, e.g. the number of Google searches for some keyword can be a proxy for the current overall level of interest in a topic. But because knowledge and innovation are on some level inherently unmeasurable directly, this distinction is hard to make. It is hard to say, for example, whether patent counts are an indicator of invention or a proxy for invention, and the answer depends to

The limitations of available proxies can be mitigated by the use of multiple proxies. If distinct proxies, based on different kinds of data, point towards the same conclusions, they are probably valid conclusions. More generally, the limitations of available proxies do not mean that nothing can be learned, but they do mean that caution is called for in interpretation and generalization.

2.4 Geographic Scope of Effects

As noted, universities simultaneously affect the city and region in which they lie, and the world as a whole. In terms of spillovers, there are two conflicting forces at work. Knowledge is a public good; in and of itself this means that knowledge created at a given location can be used anywhere in the world. But the process of knowledge diffusion is not frictionless. At a practical level, people and institutions near a knowledge creator are more likely to learn about the new knowledge, learn about it sooner, and be better able to use it effectively. The dynamic interplay of these forces affects many aspects of the university input/output/intermediate outcome/ultimate outcome process that we wish to study.

First, what constitutes an outcome is different at different scales. Universities attract firms and talented individuals to relocate to university neighborhoods and regions. From the perspective of the university region, such relocation is a (mostly) desirable intermediate outcome, because it leads to increased regional economic growth. But from the global perspective, there's no real outcome: the total amount of economic activity has not changed, it's just been rearranged.

This distinction in turn has policy implications. Drawing in firms and talented people is a regional policy objective that might be pursued by supporting university activities. But for the

---

some extent on how one defines invention. 'Proxy' seems subjectively to better convey our underlying uncertainty about how well we are measuring the phenomenon of interest, so we utilize that term.

world as a whole this is a zero-sum game. Even for individual countries, particularly large ones, this may be a largely zero-sum game, as the relocation may come mostly within a given country.

Finally, research on the outcomes of university research seeks to understand the mechanisms by which these outcomes come about. These mechanisms can be thought of as pathways that intentionally or unintentionally operate to overcome the frictions that otherwise limit the diffusion of knowledge. Hence they are mediated by geography. This means that different mechanisms operate on different geographic scales, and given mechanisms are more or less effective at different scales.

3. Mechanisms of Impact

As outlined in the historical narrative above, universities have been entrusted with multiple societal roles. The current evolution encompasses three fundamental missions. The first, education, comprises of the systematic transmission of knowledge and the creation of human capital through cultivation of intellectual capacity and professional skills. The second mission, research, is dedicated to the generation and dissemination of new knowledge and the advancement of scientific, technological, and cultural frontiers. Finally, the so-called "third mission" has emerged as an increasingly salient dimension of university activity, emphasizing engagement with society beyond the traditional domains of teaching and research. It encompasses a wide range of activities, including technology transfer and commercialization, entrepreneurship, cultural dissemination and outreach, and other forms of engagement with industry, government, and civil society.

These different missions are manifest in the different mechanisms by which universities affect innovation and economic growth. There are, of course, activities in which the different missions overlap. For example, the work of postdoctoral researchers in faculty labs contributes simultaneously to their own training and to the advancement of the faculty's research. Nonetheless, it is useful to organize our discussion of the mechanisms of impact around the three missions. We consider each in turn, highlighting important empirical research that has contributed to our understanding of the operation of each category of mechanisms.

3.1 Creation of human capital

Universities' educational mission constitutes a cornerstone of their contribution to innovation and economic growth, primarily through the creation of human capital. From the perspective of endogenous growth theory (Romer 1990), human capital is not merely an input into production but a dynamic factor that enhances an economy's capacity for technological progress. The presence of some amount of university enrollment in the background of most inventors, innovators, and entrepreneurs is so pervasive that it is very difficult to identify meaningful natural experiments that would capture the effect of such enrollment.

Keith Pavitt's seminal work on the economics of technical change provides a lens for understanding the mechanisms through which education translates into innovation (Pavitt 1984). He argued that the economic usefulness of scientific and technical knowledge lies not only in its direct application to technology but also in the broader skill base it creates, which underpins firms' capacity to innovate across sectors. His taxonomy of innovation patterns highlighted that sectors differ in their reliance on science-based knowledge, yet all benefit from a workforce trained in analytical and research-oriented competencies. This insight reinforces the view that universities play a foundational role in the formation of technological skills that underpin innovative activity. By training students in advanced cognitive and technical skills universities contribute to the development of person-embodied knowledge that firms draw upon in generating and applying innovations. This process extends beyond the acquisition of codified knowledge; it involves the development of problem-solving abilities, adaptability, and absorptive capacity, attributes that enable individuals to integrate and exploit new technologies effectively. Firm-level studies corroborate this view: the presence of highly educated employees, particularly those with postgraduate training, significantly increases the likelihood of successful product and process innovations (Kaiser et al. 2018). Similarly, Zucker, Darby, and Brewer (1998) demonstrated that the presence of "star scientists" in biotechnology significantly accelerated firm-level innovation and the emergence of regional clusters.

Large cross-country evidence shows that regions with stronger university presence and stocks of university graduates experience higher income growth, with positive spillovers to neighboring regions, consistent with localized knowledge diffusion (Valero and Van Reenen 2019). Differential human capital explains a large share of variation in regional income and establishment productivity, underscoring the centrality of skills for development (Gennaioli et al. 2013). Moretti (2004) further documented human capital externalities, showing that a 1% increase in the share of college graduates in a city raises wages for non-graduates by 1.6%, reflecting productivity gains from knowledge diffusion and learning-by-interacting mechanisms. At the same time, it is important to note that the preference for graduates to stay in the same region as their *alma mater* (Stephan 2006; Dahl and Sorenson 2012) is a strong influence in the localized nature of spillovers from universities, as organizations located in proximity of higher education institutions will attract talent more easily than organizations located farther away.

At the global level, migration and mobility of graduates enable the circulation of tacit knowledge across borders, fostering innovation in both sending and receiving countries. It is well established that immigrants in the United States are disproportionately represented among innovators and entrepreneurs (Hart and Acs 2011; Azoulay et al. 2022), and many of these immigrants first come to the U.S. to enroll in a university (Amornsiripanitch et al. 2023). More generally, studies on international flows of university-educated individuals and academics show that mobility contributes to “brain circulation” rather than permanent loss, as mobile graduates often maintain research ties, engage in joint projects, and facilitate technology transfer between countries, also through return migration. For example, Caroline Fry (2023) shows that African scientists who complete formal research training in elite U.S. laboratories and subsequently return to their home institutions raise the productivity of *other* proximate African researchers. These global spillovers are particularly significant in science-based sectors, aligning with Pavitt’s observation that such industries depend heavily on the mobility of highly trained individuals for innovation.

3.2 Creation and dissemination of knowledge

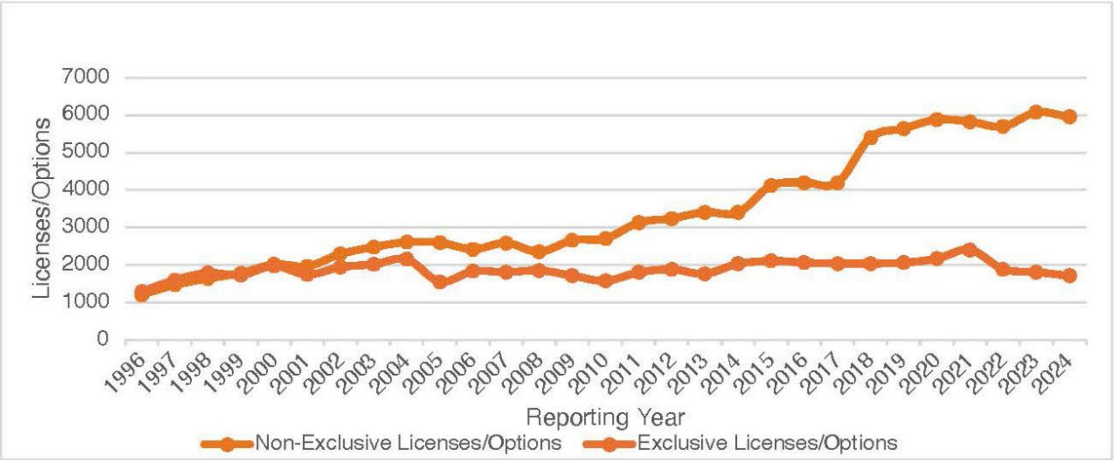
Universities’ research mission is a fundamental driver of innovation and long-term economic growth through the creation of new knowledge. Direct effects occur when universities produce scientific and technological outputs (such as publications and patents) that feed directly into industrial innovation. A famous example is the collaboration in the 1950s between Nobel Prize Laureate Giulio Natta, a professor at the Polytechnic University of Milan, and a researcher at Montecatini, a chemical company, which eventually led to the discovery of isotactic polypropylene. Mansfield estimated that between 11% and 15% of new industrial products in the United States could not have been developed without recent academic research, underscoring the tangible contribution of university-generated knowledge to technological progress (Mansfield 1991; 1995; 1998).

Literature in this area has benefited tremendously from large-scale efforts, both in the U.S. and in Europe, aimed at measuring different aspects of innovation activities and knowledge transfer. Three particularly relevant examples are the Community Innovation Survey (CIS) in Europe, the Carnegie Mellon Survey (CMS) in the U.S., and the Association of University Technology Managers (AUTM) annual licensing surveys, each representing foundational efforts to measure innovation and knowledge flows with different scopes and methodological emphases. The CIS, launched in 1992 guided by the Oslo Manual, provides harmonized cross-country data on innovation activity among European firms. It captures a broad range of innovation activities and systematically measures the importance of external knowledge sources, including universities and public research organizations, as well as collaboration patterns. By contrast, the CMS, conducted by Cohen, Nelson, and Walsh (1994), focused on U.S. manufacturing firms' R&D activities and their reliance on external knowledge sources (Cohen et al. 2002). Unlike CIS, which emphasizes the existence and intensity of linkages, CMS explored the mechanisms of knowledge transfer more in depth.

The AUTM surveys, conducted annually since 1991, systematically track university technology transfer activities, including invention disclosures, patent applications, licenses executed, and revenues from licensing agreements across hundreds of North American universities. These data show changes in licensing activity over time, such as the increasing focus on non-exclusive licensing in the last two decades (Figure 2), as well as data on startup activity across universities (Figure 3). The AUTM data also enable researchers to document substantial variation in technology transfer productivity across institutions and to analyze how organizational factors, regional characteristics, and institutional policies shape commercialization outcomes. For instance, Mowery et al. (2001) used AUTM data to examine the impact of the Bayh-Dole Act on university patenting patterns, while Thursby and Thursby (2002) employed these data to characterize the nature of university inventions and the role of faculty involvement in successful commercialization.

Figure Two

University Licensing over Time



Exclusive and non-exclusive U.S. university licenses and options, 1996-2024. Provided by AUTM, based on data from the AUTM surveys.

Figure 3: University Startups over Time (forthcoming)

Beyond their direct findings, papers using these data sources have been highly influential in policy and academic debates about academic commercialization, challenging the notion that patenting and licensing are the primary avenues for universities to impact industry. By demonstrating that “public expressions of public research” (i.e., publications, conferences, and informal interactions) typically convey academic knowledge more effectively than patents do, Cohen and colleagues provided evidence that investing in open science channels (such as publications and conferences) and university–industry collaboration may yield greater innovation benefits than focusing narrowly on intellectual property. Meanwhile, AUTM-based studies have helped establish that while formal technology transfer generates measurable economic impact, the heterogeneity in commercialization success suggests that institutional context and capabilities matter considerably for translating academic research into market applications.

Empirical studies in other national contexts are not so straightforward in their conclusions. Bercovitz and Feldman's (2006) analysis of Canadian firms reveals sparse interaction patterns, with companies reluctant to engage directly with universities, with the exception of narrowly defined projects that complement existing internal R&D capabilities. In Europe, Laursen and Salter (2004) highlight how manufacturing firms overwhelmingly rely on within-enterprise sources for innovation, with only 2% rating universities as "highly important" for their inventive activities. On the other hand, when firms collaborate with universities, the effects seem to be positive and in line with the evidence from the United States. For example, Scandura (2016) compares firms participating in collaborations with universities with propensity-score-matched similar firms that are not collaborating, measuring the effect of collaboration on R&D expenditure and share of R&D employees. She finds significant and persistent effects, with firms three to five years after the collaboration showing approximately a 20% increase in R&D expenditure per employee and a 3% higher share of R&D employees.

Research spillovers also arise indirectly, because scientific knowledge and methods can help firms in a number of activities, such as avoiding wasteful experimentation when working with complex technologies (Fleming and Sorenson 2004), increasing the productivity of applied research (Nelson 1959; Evenson and Kislev 1976), and identifying and integrating external knowledge more efficiently (Cohen and Levinthal 1990; Gambardella 1995; Cockburn and Henderson 1998).

The economics of innovation literature has highlighted spillovers from universities as key sources in promoting firm innovation and performance (Hall et al. 2003). Empirical studies have found that universities' contribution to industrial innovation is greater the higher the quality of academic research and the closer firms are to universities (Laursen et al. 2011). Anecdotal evidence suggests highly innovative and performing entrepreneurial clusters are located in the vicinity of research universities, such as Silicon Valley around Stanford and the technology cluster around the University of Cambridge (Saxenian 1996).

The most obvious channel through which knowledge emerges from universities and other research organizations involves scientific research published in academic journals. Publications are distributed globally, in principle available for anyone to use regardless of geographical location.[5] But widespread empirical evidence shows that the use of new knowledge is geographically localized (e.g., Jaffe et al. 1993). Adams (2002) finds that knowledge flows from universities tend to be even more localized than spillovers from firms, highlighting the apparent paradox that institutions whose mandate is to produce public knowledge, such as universities, tend to disproportionately benefit local firms. Adams argues that it is precisely because of the open nature of the knowledge that is produced by universities that we observe firms gravitating around academic institutions. New scientific and technical knowledge is often tacit in nature, and so does not transmit without costs. Firms locate close to universities to absorb knowledge which is "reasonably current and not proprietary."

Bergeaud et al. (2025) measure the scientific proximity of different industrial sectors to categories of academic research, and use this to identify firms that are 'close' to significant

---

[5] The price publishers charge to access scientific journals may restrict access for institutions with limited endowments or in developing countries.

academic research in both scientific field and local geography (commuting zones). Firms that are proximate in this double sense spend more on R&D—through both higher R&D wages and greater R&D hours—patent more, and are more likely to open new establishments. At the same time, other contributions, such as Bikard and Marx (2020) challenge the importance of localized knowledge flows, by examining how geographic hubs, defined as "*a geographic concentration of patenting by firms in a specialized technical field*", connect academic science with corporate technology. This paper reconceptualizes how academic outputs become inputs to commercial innovation by demonstrating that hubs facilitate knowledge flow through both supply-side mechanisms (producing higher quality, more applied research) and demand-side factors (attracting disproportionate attention from firms). Most significantly, it reveals that hubs extend the geographic reach of academic knowledge by attracting attention from distant firms.

The important role of universities in fostering local/regional innovation and entrepreneurship makes support of universities an obvious component of policies designed to foster growth in particular regions through innovation. Gruber and Johnson (2019) discuss the problem of growing regional inequality in the U.S. and suggest a systematic effort to combat such inequality by funding regional innovation clusters. Examples of such policies include NSF's Regional Innovation Engines Program, the U.S. Economic Development Administration (EDA) Regional Technology and Innovation Hub program, and programs in other countries such as Canada's Superclusters, the UK's Innovation Accelerators, and the EU's Smart Specialization Strategies (Guzman et al. 2024).

In this context we have also witnessed the establishment of major U.S. Federal programs seeking to harness the potential of regional innovation ecosystems through place-based innovation policy interventions. Relative to traditional research grants, place-based innovation policy interventions are not directed toward a specific research project but rather aim to reshape interactions among researchers and other stakeholders within a given geographic location. Guzman et al. (2024) emphasize that the success of such initiatives depends on the complex interactions among local firms and labor markets, local governments, and universities. The fuel of innovation-driven growth is research spillovers, and these spillovers manifest only if universities have the necessary capabilities and resources and are engaged with regional governments and firms. Place-based innovation policies can catalyze regional economic transformation, but their effectiveness hinges on three critical conditions: meaningful coordination among diverse stakeholders (including universities, industry, government, and community organizations), comprehensive diagnosis of the region's specific innovation ecosystem strengths and gaps, and the formulation of strategically focused interventions that are both financially sustainable and aligned with regional comparative advantages. The dependence of local regional benefits on the local innovation system is highlighted by the challenges Europe has faced in capturing economic benefit from its investments in basic research.

Nagar et al. (2024) undertake a comparison of the research outputs of projects funded by the European Research Commission (ERC) to the outputs of otherwise similar projects. They show that ERC-funded projects receive more patent citations than the control group, but the preponderance of these citations comes from patents of U.S. firms, both established and start-up. This shows that the magnitude of spillovers depends on not only on the 'spilling' organization, but also on the attention and capabilities of the potential recipients.

Discussions of regional innovation policy have traditionally focused on programs that seek to stimulate innovation in historically less innovative regions. But it should be acknowledged that the significant growth in university-led innovation and entrepreneurship in recent decades is itself part of the reason for growing regional inequality. Because proximity matters for spillovers, there is dynamic feedback whereby current innovation success fosters future innovation success. For successful regions, this is a good thing, but at the same time it helps propel the successful regions farther ahead of the less innovative regions, exacerbating regional inequality.

3.3 Commercialization and entrepreneurship

The third mechanism through which universities affect innovation and growth is commercialization and entrepreneurship, the set of processes that transform academic discoveries into marketable products, services, and ventures. In operational terms, this includes invention disclosure, patenting, licensing, sponsored research with firms, and the creation and scaling of start-ups and spin-offs managed through technology licensing and transfer offices (TLOs/TTOs).

Much of the contemporary literature on academic patenting and technology transfer has been shaped by two major policy shifts: the Bayh–Dole Act of 1980 in the United States and the abolition of the professor's privilege in several European countries during the late 1990s and early 2000s. Proponents of the Bayh–Dole Act argued that industrial use of federally-funded research was inhibited under the prior regime, which required funding-agency approval for university licensing and imposed restrictive, agency-specific policies. Bayh-Dole created a standard framework for university licensing of technology derived from federally-funded research, and for the sharing of licensing revenue between the institution and the inventors. Bayh-Dole thus created strong incentives for both institutions and inventors. This legislative change is widely credited with triggering a surge in university patenting and licensing activity, as well as the emergence of academic entrepreneurship as a distinct research field (Mowery and Ziedonis 2002; Grimaldi et al. 2011). Empirical studies following Bayh–Dole have examined the growth of invention disclosures, patents, licenses, and spin-offs, as well as the organizational and incentive structures that underpin these activities (Jensen and Thursby 2001; Thursby and Thursby 2002; Sampat 2006). Though passage of Bayh-Dole was partly a reaction to rather than a cause of the emerging university technology transfer culture, there is no question that the organizational and personal incentives created by Bayh-Dole reinforced and expanded that culture and thereby played a major role in the growing entrepreneurial contribution of universities.

In Europe, the perceived success of Bayh–Dole in the United States motivated a wave of parallel institutional reforms across many countries, including the abolition of the professor's privilege—a regime under which academic inventors retained IP rights. Countries such as Germany, Denmark, and Norway shifted ownership from individual researchers to universities, aiming to replicate the perceived success of the U.S. model. This policy change spurred a wave of research assessing its impact on patenting, licensing, and start-up formation, highlighting the within-European patchwork of university IP ownership that emerged as countries grappled with balancing traditional academic norms against pressures for greater commercialization. The coexistence of professor's privilege and institutional ownership models created misaligned incentive structures across much of the continent. Geuna and Rossi (2011) divide these countries into five groups based on their underlying transitions in university IP ownership which include those maintaining professor's privilege over time (Sweden and Finland), earlier adopters of institutional ownership (the UK since 1977), recent converters to institutional ownership (Germany in 2002 and Norway in 2003), countries that unusually moved from institutional ownership back to professor's privilege (Italy in 2001), and former Eastern European countries that transitioned from government to institutional ownership. Their analysis reveals that these policy changes produced markedly heterogeneous outcomes, with the effectiveness of reforms depending heavily on pre-existing academic cultures, institutional capacity for technology transfer, and the broader innovation ecosystem surrounding universities. Hvide and Jones (2018) provide the most compelling causal evidence from Norway's 2003 abolition of professor's privilege, estimating a 50% decrease in patenting and startup formation rates, an outcome directly inverse to what Bayh-Dole achieved in the United States, where institutional ownership increased university patenting substantially. This stark result aligns with broader patterns identified by Perkmann et al. (2013), in showing that professor's privilege correlates with higher rates of individual academic consulting and informal knowledge transfer, while institutional ownership increases formal licensing but reduces entrepreneurial activity. Together, these findings underscore how identical policy frameworks can produce contradictory results when implemented in different institutional contexts.

A central and general empirical insight from the academic patenting literature is that university inventions are typically embryonic, "*little more than a proof of concept*", and thus require substantial inventor cooperation and downstream development by firms. In their survey of U.S. universities, Jensen & Thursby (2001) report that the most striking finding is precisely the embryonic state of licensed technologies and they argue that academic patents are best seen not as final outputs, but as intermediate inputs into firm R&D and commercialization. This also resonates with the observation that revenues from active commercialization or licensing of patents is usually very limited for universities, and that most TTOs/TLOs do not produce any profit but they are rather in deficit (Jensen et al. 2003). The establishment of TTOs fundamentally restructured the institutional arrangement governing academic commercialization, shifting responsibility and control of academic outputs from the inventor to the university. Jensen and Thursby (2001) document how TTOs emerged as intermediaries to support disclosure, patenting, and licensing activities, while navigating often misaligned motives between university administration and faculty inventors. This formalization of technology transfer channels produced heterogeneous organizational responses and effects that varied significantly by institutional experience and capacity. Mowery, Sampat, and Ziedonis (2002) found that universities with established pre-Bayh-Dole commercialization support and industrial connections adapted more effectively to the new patent regime, while inexperienced "entrants" with less than five patents filed annually prior to 1980 often produced lower-quality patents measured by citation rates. Thursby and Thursby (2002) also provide empirical evidence that successful university commercialization depended on TTOs' ability to manage competing objectives between revenue maximization and broader university missions. Their analysis of total factor productivity revealed that while TTOs increased licensing output, much of this growth reflected increased faculty participation rather than improved organizational efficiency. Beyond these structural tensions, Siegel, Waldman, and Link (2003) draw on interviews with 98 stakeholders to show how organizational practices, incentive alignment, and boundary-spanning activities determine TTOs' effectiveness in facilitating technology transfer. Longitudinal evidence from South Korea reinforces these findings, demonstrating that stronger technology transfer office capabilities and accumulated organizational experience significantly improve licensing and commercialization outcomes (Lee and Jung 2021).

As licensing of university technology grew, TTOs and university faculty increasingly looked beyond licensing to a broader notion of academic entrepreneurship, and startups of companies by university faculty and spinouts or spin-offs of university activities into firms became more prevalent. The literature has evaluated outcomes of these activities along several dimensions such as firm performance, economic impact, and implications for academic research. Empirical studies consistently show that university spin-offs tend to exhibit higher survival rates and innovation intensity compared to other start-ups, largely due to their strong scientific foundations and access to academic networks (Di Gregorio and Shane 2003). The results of this study provide insight into why some universities generate more new companies to exploit their intellectual property than others do. The results show that intellectual eminence, and the policies of making equity investments in TLO start-ups and maintaining a low inventor's share of royalties increase new firm formation. In particular, the authors find an inverse relationship between inventor royalty shares and startup formation, highlighting how royalty distribution policies create opportunity costs for faculty entrepreneurs. This suggests that institutional policies designed to reward inventors through royalty shares might in fact discourage entrepreneurial activity by making licensing more attractive. Despite often promising starts, academic spin-offs' growth trajectories are often modest, with many remaining small and research-oriented rather than scaling into large firms. This may be due to the fact that academic technology spin-offs combine the traditional problems associated with starting a new business with the difficulties associated with the development of new technologies (Clarysse et al. 2011). They therefore suffer from capital and credit rationing due to asymmetry of information, absence of venture capital markets, lack of collaterals and of complementary resources.

At the regional and national level, academic entrepreneurship contributes to knowledge-intensive employment and cluster development, but its aggregate economic impact is debated. Van Looy et al. (2011) argue that while individual universities' contributions may appear small, their cumulative effect across systems is "non-trivial" for competitiveness. Moreover, Grimaldi et al. (2011) stress that entrepreneurial outcomes depend on systemic factors, including venture capital availability, university policies, and researcher incentives. At the same time, an emerging literature has started to focus on the potential impact of universities on local entrepreneurship, business creation and overall economic activity.

Hausman (2022) uses the 1980 Bayh-Dole Act as a natural experiment to measure the causal impact of university technology transfer on surrounding regions. She develops a measure of university-industry technological proximity in regions, based on the frequency with which different industries patent in particular patent classes. This allows her to measure the closeness of the technological match between industry in a region and the university research in that region. She shows that, following Bayh–Dole, better-matched regions experienced higher employment and wage growth and increased corporate patenting of higher quality, as measured by citations. Eesley et al. (2016) investigates how institutional reforms in universities influence entrepreneurial outcomes by analyzing China’s Project 985, a policy aimed at fostering innovation in select universities. The authors find that the reform successfully shaped alumni entrepreneurs’ beliefs about the importance of innovation and increased their engagement in technologically intensive activities, leading to a higher likelihood of founding high-tech ventures. However, these ventures did not achieve superior financial performance compared to those founded by entrepreneurs from non-985 universities or before the reform. Finally, Tartari and Stern (2021), using comprehensive business registration and federal funding data for the U.S., show that the importance for new ventures of co-locating nearby universities has increased over time and that changes in federal research commitments to universities are positively correlated to changes in the probability of high potential start-ups to be funded in close geographical proximity.

3.4 The Institutional and Organizational Context

The mechanisms discussed above, operating through education, research, commercialization and entrepreneurship, do not function in isolation. Their effectiveness is conditioned by the institutional and organizational context in which universities operate, including funding structures, governance arrangements, and faculty norms. In this subsection, we review evidence on how these contextual factors shape the extent to which universities translate their core missions into innovation and economic growth. The first set of contextual factors concerns the sources and structure of university funding, and the extent to which funding regimes embed incentives for commercialization, industry engagement, or local economic development. Welsh et al. (2008) document how U.S. public land-grant universities, given their mandate to serve state and regional development, played a pivotal role developing the agricultural biotechnology sector through industry collaborations. These institutions operate under state oversight and public accountability that emphasizes local economic development. They often mandate interaction with agricultural extension services and accessible education through programs such as ROTC. This local-focused orientation shapes technology transfer policies that favor in-state licensees and regional partnerships, even when this reduces potential licensing revenues (Belenzon & Schankerman, 2009). Belenzon and Schankerman (2013) find that the tendency for in-state inventors to disproportionately cite university patents even after controlling for distance, are significantly stronger for public universities than private ones, suggesting that these structural mandates do affect knowledge diffusion.

Other differences in sources of funding also affect knowledge transfer and commercialization activities. Using detailed data from U.S. universities, Babina et al. (2023) show that negative shocks to federal research funding increase universities' reliance on private funding, accompanied by declines in high-tech entrepreneurship and publications and an increase in patenting. The forgone publications are higher quality and more basic, while the additional patents are lower quality, less general, and more often privately assigned, indicating a shift toward less open and more appropriable forms of innovation.

At the national level, R&D funding structures in different countries reveal distinct approaches to academic research, commercialization incentives, and industry engagement. These varying compositions of funding sources, from mission-oriented agencies to excellence-based grants, create different opportunities and pressures that shape both research priorities and commercialization outcomes. For example, the United States exemplifies mission-oriented funding through agencies like NIH and DoD, which embed practical relevance requirements even within basic research programs. This contrasts with European approaches where the European Research Council explicitly avoids commercial criteria in favor of "frontier research". Interestingly, Nagar et al. (2024) find that ERC-funded research generates citations from about 12 European and 6 U.S. patents per €10 million of research support, suggesting that the focus on frontier research does not preclude commercial applicability.

Bergeaud et al. (2025) compares French funding through direct Laboratories of Excellence (LabEx) grants versus R&D tax credit systems and finds that the targeted competitive program generated 3.4 times more patents per euro than broad tax incentives. National R&D tax credit designs create additional variation in university-industry engagement patterns. Koch and Simler (2020) show that the U.S. credit at 20% primarily benefits large firms with sustained R&D programs, the UK's 230% SME deduction increases university interaction with smaller firms, while France's Crédit d'Impôt Recherche allows university contracts to qualify as expenses at 30% up to €100 million, directly subsidizing academic collaboration.

Beyond funding, universities differ markedly in their organizational and cultural norms governing the relationship between academic research and commercial activity. These internal dynamics explain why universities in the same country and operating in the same scientific disciplines can exhibit vastly different commercialization outcomes. The organizational identity and perceived mission of universities create varying approaches to the rules, practices, and relationship between academic research and commercialization activities. These differences extend beyond formal policies to include beliefs about appropriate university-industry engagement, the legitimacy of entrepreneurial activities, and the balance between academic output and economic impact. These cultural dynamics are inherently difficult to define and measure precisely, as they resist easy quantification and they have evolved considerably over time, particularly as universities have navigated shifting expectations about their role in economic development.

Researchers have employed different approaches to capture these factors. One approach infers organizational culture from observable patterns in institutional behavior over time, for example by examining how the presence of successful academic entrepreneurs within a department generates *demonstration effects*, that is, the process by which visible peer successes reduce uncertainty about commercialization and confer professional legitimacy. Stuart & Ding (2006) show how exposure to peers with commercialization experience affects propensity to engage in entrepreneurship through demonstration effects and professional legitimization. Similarly, Bercovitz and Feldman (2008) demonstrate how peer scientists can motivate or discourage entrepreneurial activities based on traditional scientific values, and how the “commercialization culture” of one’s alma mater influences their subsequent technology transfer activities.

Roche (2023) finds a substantial negative association between a professor's entrepreneurial activity and the publication output of the PhD students they train. Furthermore, she shows that advisors' entrepreneurship decreases students' likelihood of becoming professors themselves and increases their likelihood of working for consulting firms on graduation.

A second approach uses survey methods to directly measure faculty attitudes toward commercialization, entrepreneurship, and industry engagement, how these attitudes correlate with actual commercialization behavior and how they vary systematically by field, career stage, and institutional type. D'Este and Perkmann M (2011) examine how academics in the UK physical and engineering sciences engage with industry, showing that most academics do so primarily to advance their research rather than to commercialize. Literature reveals significant heterogeneity in researcher motivations across institutional contexts and disciplinary focus areas. Hartmann and Henkel (2020) surveyed over 1,400 AI researchers and found that while university and corporate researchers both value the ability to publish research, they differ in their perceptions of resource constraints and publishing restrictions. Higher costs of conducting research, paired with decreasing public allocation of funds for research, makes access to research funding and specialized equipment an important motivation for researchers in STEM (Science, technology and Mathematics) disciplines to collaborate with industrial partners Tartari and Breschi (2011), while the potential for personal financial gain is often a marginal driver in the decision to engage (D'Este and Perkmann, 2011).

Willingness to collaborate with industry and to participate in knowledge transfer also crucially depend on individual characteristics beyond institutional incentives and motivations. Amornsiripanitch et al. (2023) find that immigrant academic entrepreneurs are 16% more likely to achieve an IPO or acquisition. In a different national context, Uhlbach et al. (2022) find that

Danish academics who return after an extended period abroad are more likely to engage in academic entrepreneurship than both native colleagues who never left the country and immigrant academics employed at Danish universities. Finally, a vast body of research finds that gender, seniority and scientific productivity are strongly associated with participation in knowledge transfer activities and commercialization (for reviews see Perkmann et al. 2013, Perkmann et al. 2021). This places broader implications on human capital channels, suggesting that the composition of the faculty body directly influences both the quality and quantity of academic entrepreneurship. Collectively, these aforementioned findings demonstrate that successful university commercialization requires careful attention on the complex and often conflicting motivations of individual researchers, university administrators, and technology transfer professionals.

4. The Sectoral Context

Having established the contribution of universities to innovation through the channels associated with their three core missions, one may now wonder how these insights can be successfully translated into practice. To answer such a question, it is important to understand how transferable scientific findings are across different contexts, and what factors may affect such transferability. One such factor is the sectoral context, defined in terms of academic disciplines, patent technology areas, or economic sectors.

A challenge to comparing university-related innovation activity across sectors is that what constitutes success varies across sectors. In biotechnology, patents protect discrete molecular inventions and commercialization is governed by strict regulatory pathways. In contrast, software-intensive sectors are more dependent on copyright and trade secrets, and development cycles are measured in months rather than years. If the literature concentrates on a narrow set of domains, the unintended consequence may be an overemphasis on particular outcome metrics as the primary indicator of university commercialization. This, in turn, can lead to an underestimation of the impact in other domains, or to metrics that do not generalize well across contexts.

To address these concerns, this subsection reviews the university commercialization literature in two parts: first, in summarizing how the literature describes sectoral characteristics and associated heterogeneity, to the extent it is discussed, and second, in moving beyond these selective descriptions to catalogue which substantive domains exhibit empirical importance and/or statistical significance. By disaggregating what has typically been relegated to dummy variables and pooled analyses, we establish where robust evidence of commercial impact exists.

4.1.1 Characterizing the Sectoral Context

We begin with a review of 42 articles on university commercialization from the base literature reviewed in this chapter. While not exhaustive, this sample provides a reasonable basis for comparison across multiple journals over the period 1985-2025. It is worth noting that different papers ask different questions, spanning the range from the determinants of university research activity to its effects. A detailed list of each article analyzed and its sectoral synthesis can be found in Table 1 in the Online Appendix.[6]

Table 2 summarizes how these 42 studies classify the sectoral context. Over time, the literature has evolved from relying on descriptive analyses involving one or two levels of classification

---

[6] Appendix Tables are available in Jaffe, Shupp, & Tartari. 2026. “Real Effects of Academic Research Revisited.” NBER Working Paper No. 35017.

toward regression analyses that integrate all three, most notably through the explicit incorporation of economic sectors.

Table 2: Sectoral coverage and study design in the university commercialization literature

Panel A: Sectoral classification used				
Classification level		Number of articles		
Discipline only		8		
Patent only		3		
Economic Sector only		5		
Discipline-Patent		3		
Discipline-Economic Sector		8		
Patent-Economic Sector		1		
Discipline-Patent-Economic Sector		8		
Panel B: Number of sectors analyzed per study, by period				
Period	1 sector	2 sectors	3 sectors	total
1989-2000	2	2	2	6
2001-2010	8	6	0	14
2011-2020	2	4	1	7
2021-2025	2	3	4	9
Panel C: Empirical approach				
Method		Number of articles		
Descriptive		10		
Regression		26		

Note: If patents were included as a patent count with no reference to technology areas, they are not included in the count. Disciplines include studies that cover scientists, subject disciplines and university schools and departments.

We now turn to synthesizing how these studies characterize sectoral heterogeneity. To organize this discussion, we draw on insights from Ahmadpoor and Jones (2017), whose analysis of the “paper–patent boundary” provides a guiding lens for understanding variation in how scientific fields connect to technological application. Their work highlights three systematic differences across fields in proximity to commercialization: the nature of the research, the institutional environment in which it is produced, and the temporal distance between scientific discovery and its subsequent application. Broadly, these factors align well with how the university commercialization literature interprets its own heterogenous findings.

Biomedical Sciences

We begin with the biomedical sciences, given much of the literature focuses on explaining why research rooted in disciplines such as chemistry and biology that are applied in economic sectors including biotechnology and pharmaceuticals exhibit particularly strong and observable commercial outcomes. The first and most basic explanation centers on the inherent nature of its knowledge. Multiple studies converge on the idea that biomedical fields possess inherent characteristics conducive to observable commercialization. Life sciences knowledge is highly codified through established scientific protocols and publications, with biology providing the core basis for pharmaceutical innovation. Welsh et al. (2008) describe university biological research as "basic and embryonic," while Thursby and Thursby (2002) note biology is "particularly important for pharmaceuticals" due to the biomedical nature of drug discovery. This dependency on academic research is not merely observational but manifests in concrete outcomes, as demonstrated in Mansfield’s series of firm surveys showing that firms rely the most heavily on products and processes in Drugs. This creates a distinctive complementarity pattern where, unlike other sectors showing crowding-out effects, life sciences is the only domain where public knowledge and internal corporate R&D function as strategic complements (Arora et al. 2023).

Turning to institutional conditions and resource concentration, the biomedical advantage reflects decades of investment and visible measures of inventive activity. Mowery et al. (2002) attribute the consistent high quality of university biomedical patents relative to other technology fields to the long history of biomedical funding and subsequent research (particularly from the NIH) that enabled universities to build strong biomedical capabilities before Bayh-Dole, while non-biomedical fields required "institutional learning" post-1980. This can also be reflected in what

Jensen and Thursby (2001) identify with ‘Medicine and nursing’ having the highest share of university invention disclosure at 44% of the total. More recent literature confirms this ongoing trend, with the highest university patent shares found in genetic engineering (18.1%) and molecular biology (12.1%) (Babina et al. 2020).

Finally, the temporal dynamics of biomedical commercialization create unique path dependencies that reinforce sectoral advantages. While dated, Mansfield (1998) finds that “Drugs and Medical Products” exhibit the longest lag between research and market introduction (approximately 8.5 years), compared with “Electrical,” “Machinery,” and “Information Processing,” which cluster around roughly 5.5 years. These extended timelines imply sustained university-industry engagement. Cohen et al. (2002) further show that public research is most beneficial to firms innovating in pharmaceuticals at both the onset and completion stages of R&D projects. Consistent with these dynamics, Rezaei and Yao (2025) document how large-scale public research funding in biomedicine reinforces cumulative advantages by concentrating resources and venture formation in fields already positioned to translate scientific advances into commercial applications.

Engineering & Electronics

We treat engineering and electronics jointly, as the university commercialization literature frequently blurs distinctions between disciplinary fields and economic sectors in these areas. The synthesis that follows is also more sparse, reflecting a thinner body of evidence that does not align as neatly with the Ahmadpoor and Jones framework.

Nelson and Rosenberg (1994) noted that "the lion's share of university research is in the engineering disciplines and applied sciences…which, by their nature are oriented towards problem-solving" rather than basic discovery. This problem-solving orientation persists today, but perhaps surprisingly, the literature often finds weaker commercialization effects than in biomedicine despite engineering's natural alignment with application.

Upon closer examination, much of this reduced magnitude appears to reflect measurement rather than underlying weakness in university–industry linkages. In engineering- and electronics-intensive fields, commercialization outcomes are less well captured by patent-based measures alone and instead operate through broader channels. It is the literature employing descriptive analyses that highlights the importance of these fields, particularly by documenting firm reliance on university research using survey-based measures and indicators of firm sentiment. Mansfield’s series of firm surveys (1991, 1995, 1998) consistently show that firms in “Instruments” rank second only to “Drugs” in their reliance on academic research. Arora et al. (2023) describe the mechanisms at work behind university dependence, finding that Electronics firms benefit more from hiring PhD graduates than from use of publications or patents. They also find that while Machinery/Equipment firms benefit from PhD graduates, these firms view university patents in related fields as competitive rather than complementary to their own capabilities.

The studies that identify significance in engineering at the patent level include Jaffe (1989) and Babina et al (2020), where Jaffe finds positive effects of geographic proximity between universities and firms, while Babina finds that an increase in federal funding not only decreases patenting in bio/med/pharma, but also in engineering as well as the basic sciences. More recently, Rezaei and Yao (2024) demonstrate how interdisciplinary research can blur traditional sectoral boundaries: neuroscience startups participating in the U.S. federally-funded BRAIN Initiative to advance research in neuroscience became 2.5 times more likely to file AI patents.

While the Initiative showed disciplinary significance across Engineering, Computer Science, and Physics, 88% of "neurotechnology" firms remained classified in the broader healthcare sector, with only 8% in IT. This illustrates how emerging technologies increasingly span multiple disciplines, with AI-related patents serving as bridges between traditionally distinct sectors.

Abramovsky et al. (2007) provide one of the more comprehensive syntheses connecting specific academic disciplines to economic sectors, mapping the co-location of private sector R&D establishments with relevant university research departments. The authors explicitly acknowledge that "the routes through which university research is transferred to businesses...may also differ across industries, and may depend on the nature of the research being undertaken, for example whether it is basic or applied". For example, engineering-intensive sectors such as machinery and communications equipment co-locate with lower-rated, more applied engineering departments, while pharmaceuticals and chemicals co-locate with the highest-quality chemistry and materials science departments conducting basic research.

4.1.2 Measuring Sectoral Significance

We now shift from characterization to measurement, asking where true sectoral significance emerges in the empirical record. From an initial sample of 42 studies, we retain 36 that measure the empirical effects of academic research and incorporate sectoral heterogeneity. Using this filtered sample, we seek to answer (i) whether studies adopt single- or multi-sector designs and which sectors receive the most empirical attention, and (ii) across these sectors, which are reported to generate significant commercialization effects. We classify effects as *significant* using two approaches: statistical significance based on regression or other inferential methods, and sectoral prominence identified through descriptive or correlational analyses that emphasize the magnitude or prevalence of outcomes.

Table 3 addresses the first question. The majority of studies (31 of 36) employ pooled multi-sector designs, though they vary considerably in how they treat heterogeneity, with some examining sectoral differences explicitly and others relegating sectors to control variables. Of the five studies that perform single-sector analyses — too few to establish conclusive evidence of systematic selection — all nonetheless concentrate on biomedical-related domains. This pattern of sectoral coverage, whether through selective single-sector focus or through the sectors receiving the greatest attention within multi-sector designs, suggests a clear predominance of biomedical-related domains in the empirical literature on university commercialization.

Table 3 about here

We now turn to the second question: which sectors generate significant commercialization effects? Among the 36 studies reporting sectoral results, 30 disaggregate sectoral heterogeneity to a specific substantive domain, while the remaining six employ broader categorizations, such as STEM versus non-STEM or technical versus classical, that are too aggregated to derive findings. Of the 30 studies with substantive sectoral classifications, 27 measure biomedical-related effects, and all 27 report statistically significant or descriptively prominent results. The three studies that do not report biomedical significance are dedicated to manufacturing and non-life sciences topics. This pattern indicates not only a biomedical predominance in sectoral focus but also in the significance of reported findings, spanning four decades of research and both methodological approaches.

The foundational evidence for this pattern emerges in the earliest sectoral studies. Beginning with Jaffe (1989), who divides university departments into five technology areas across disciplines and patents, the positive effect of university research on local innovation is most concentrated in Drugs & Medical Technology followed by Chemical Technology with a significant but smaller effect. Acs et al. (1992) extend Jaffe's patent analysis to include unpatented inventions, yet still confirm Drugs & Medical Technology as the second highest invention yield per R&D input. Mansfield's (1991, 1998) economic sector analyses find the Drugs industry uses the highest proportion of academic research (27% products; 29% processes), with no other sector reaching even half this level except Instruments at 16%.

The pattern intensifies in post-Bayh-Dole studies. Jensen and Thursby (2001) show 44% of invention disclosures come from Medicine and Nursing, compared to 25% from Engineering and 19% from Sciences. Mowery and Ziedonis (2002) find biomedical patents consistently highly cited regardless of university type, suggesting established quality advantages in life sciences commercialization. Cohen et al. (2002) report pharmaceutical firms' unique sectoral dependence on public research. This dominance persists through recent work: Belenzon and Schankerman (2013) find Biotechnology, Chemicals, Pharmaceuticals, and Medical Equipment all highly significant, while Electronics, IT, and Telecommunications show no significant effects. Lerner et al. (2025) focus exclusively on biomedical researchers when examining "academic movers," explicitly justifying this choice on the grounds that biomedical research dominates commercialization outcomes.

Outside of biomedical sciences, the evidence is broader but thinner. Online Appendix Table 2 shows that 24 of 31 studies report significant commercialization effects outside of life sciences, predominantly in engineering disciplines and electronics-related sectors. These secondary effects, however, differ in character from biomedical findings. They emerge more consistently through descriptive and survey-based approaches — capturing firm reliance, hiring patterns, and qualitative assessments — than through patent-based measures, where engineering and electronics often fail to reach statistical significance. This pattern reinforces the measurement challenges identified in the preceding section: commercialization in these fields operates through channels that standard patent metrics do not fully capture.

4.1.3 Takeaways

What to take from this? A broader reading of this literature reveals what the findings tell us through their silence as much as their presence. The preeminence of life sciences is partly genuine, reflecting real characteristics of biomedical knowledge and decades of institutional investment, but it is also partly an artifact of how we measure and conceptualize commercialization. The absence of consistently robust findings in engineering, computer science, and other non-biomedical domains, which collectively employ more researchers and generate more economic activity than biomedicine, suggests not that these fields lack commercial impact, but that our measurement frameworks fail to capture it. Together, these factors ensure that most empirical studies, and by extension most policy lessons, derive from biomedicine.

Beyond measurement, the literature is oriented more toward value creation than value capture, particularly outside of biomedicine. Most of the studies reviewed above ask how scientific knowledge reaches technological application, but say less about how that application is appropriated and by whom. Two areas warrant greater attention: sector-specific appropriability mechanisms, and the structure of markets for technologies, which conditions how innovation is organized, produced, and brought to market.

On appropriability, regimes vary dramatically across sectors, a pattern first posited by Arrow (1962) that persists in university commercialization activity. Strong appropriability favors formal mechanisms such as exclusive licensing and patent portfolios, whereas weak appropriability pushes commercialization toward human capital flows, collaborative research, and informal networks. How this plays out in university technology transfer across different sectors remains underexplored, particularly as emerging fields like AI and software challenge not only traditional appropriability boundaries but also what can be appropriated in the first place.

Market structure shapes which technologies get commercialized and how. This dimension receives less systematic attention in part because isolating the effect of market structure on university research efforts proves difficult given that commercialization inherently involves matching uncertain supply from universities to volatile market demand, where entrepreneurs and products frequently fail along complex pathways from lab to market. Together, the interaction of knowledge characteristics, appropriability, and market structure helps explain the persistent sectoral differences in commercialization outcomes documented above.

These measurement and aggregation challenges point towards a necessary evolution in both research design and policy formulation. Future work should develop sector-appropriate indicators that capture value creation in the data-driven economy, and it should account for increasingly globalized, complex, multi-sector supply chains where university contributions may be several steps removed from final products. For policy, the imperative is clear. Copy mechanisms, not sectors. Attempting to replicate biomedical commercialization models in fields with different knowledge characteristics, market structures, and appropriability regimes wastes resources and impede knowledge transfer. Effective commercialization policy requires sector-specific interventions that address the particular market failures and transfer mechanisms dominant in each domain.

5. Artificial intelligence

Chapter 2 discusses overall the contributions of AI to science, but a brief comment is in order here on the unique position of AI within the overall contribution of universities to innovation and growth. While we don't yet know what the long-term consequences of AI will be, it is already clear that tools such as machine learning, neural networks, natural language processing, and large-language models are already making major contributions to innovation across a variety of fields, including software engineering, autonomous devices and vehicles, drug development, precision agriculture, personalized health care, etc.

General Purpose Technologies ("GPTs") are an important source of knowledge spillovers (Bresnahan and Trajtenberg 1995) because their applicability to a wide variety of sectors. Their broad use generates a positive feedback loop in which diverse applications across different sectors and places produce improvements in the GPT itself, which can then be shared back across all those applications. AI tools are a kind of general-purpose *innovation* technology, which are being used to develop new applications in a wide variety of settings. Their many different uses in turn generate improvement in the tools and to some extent are shared, generating potentially enormous innovation benefits and social returns.

While we do not think of AI today as coming from universities, we would not be where we are were in not for a very long gestation period of research that was largely an academic undertaking. In the coming decades we may come to see the long-run social benefits of this academic research as being comparable to those of the biotechnology revolution.

In the medium term, much of the cutting-edge AI work is now centered in firms; numerous academic AI researchers are either dividing their time between academia and industry, or else moving entirely to industry. Interestingly, while the monetary rewards of commercial AI work have no doubt played a role in this shift, there is also evidence that the dependence of AI research on computing resources and very large datasets makes the commercial setting more attractive apart from the personal financial rewards. Yue (2024) examines the research output of researchers with both academic and industrial affiliations and finds that their corporate-affiliated work is significantly more impactful as measured by citations, and shows that this higher quality can be attributed to the greater resources available to the corporate research.

AI may also be changing the nature of the relationships between universities and commercial innovation. While much university-origin innovation in the post-Bayh-Dole era has been governed by IP-licensing agreements, IP appears to be less important for innovation based on large datasets and algorithms. As one example, MIT Professor Daniela Rus is the Co-founder of the company Liquid AI. Liquid AI's stated mission is to "build efficient general-purpose AI at every scale," and they have raised significant private capital. Despite the underlying interconnections between Liquid AI and MIT research, there are no IP licensing agreements between the company and MIT (private communication with MIT TLO). More generally, universities are going to need to learn to navigate this huge and rapidly changing innovation landscape with new kinds of relationships.

6. Conclusion and Future Directions

We've come a long way since Jaffe (1989). The causality question has been put to rest. We've established that geographic proximity to universities benefits firms and regions, although global diffusion of knowledge is also important. In parallel with the deepening of research findings, the phenomenon itself has broadened and deepened: university faculty and students, and of the universities themselves, have greatly increased their direct participation in entrepreneurship and commercialization. New organizational structures and modes of university/firm interaction are developing rapidly, suggesting that the magnitude of universities' impact will continue to grow.

More granular and better linked data: An important source of research progress has been better microdata and new ways of linking data from different sources. The UMetrics microdata on university personnel and laboratories have allowed investigation of questions such as how those labs manage tradeoffs between different sources of external research funding. The AUTM survey data document how the use of different forms of IP vary across institutions and has changed over time. Linkages to university researchers built from databases such as Crunchbase and Pitchbook allow the relationships between startups and university research to be systematically catalogued. Data like this facilitate identifying the kind of natural experiments that resolved the causality issue, because events that are endogenous at the system level are often plausibly exogenous in terms of how they impact specific individuals.

Explicit modeling of network effects: Another important theme in recent work is the explicit use of network methods to understand how universities fit into the innovation system. These methods get at the background contributions by which universities fundamentally support the flow of knowledge, for example by playing key roles in the training and movement of postdocs who carry spillovers and act as connectors throughout the system. This building and facilitation of the spillover "plumbing" may be more important for global innovation in the aggregate than the direct effects seen in specific technology transfer events. Network approaches are just beginning to exploit the potential created by large volumes of microdata and development of methods for large-scale network analysis.

Broadening focus beyond the life sciences: A preponderance of the research has focused on the life sciences. This is due to a combination of the reality that life sciences research is a majority of publicly funded university research, and the fact that invention and innovation are particularly easy to measure in this sector because of reliance on patents and the role of drug and medical device regulation in identifying and defining new products. We have learned a lot from this work, but much uncertainty remains as to how applicable the life sciences model is to innovation in other sectors, both from the perspective of universities seeking to increase/improve technology transfer in other sectors, and of policymakers who want to understand the university-industry system in other sectors. The development of new methods based on large-language models and other natural-language processing algorithms offers the prospect for both better measures of innovation in non-life science disciplines and industry sectors, and also better ways of linking innovation in these sectors to university research.

Institutionalization of technology transfer policy: In terms of policy, most focus in recent decades has been on fostering technology transfer and commercialization. If we look at the policy choices around the world, there has been a convergence on the institution-ownership model. There is no doubt that this model 'works', i.e. that significant transfer of university technology to industry is occurring. But the details do matter. Different technology transfer offices take different approaches; most of them are cost centers rather than profit centers for the universities, and different incentive systems for faculty do matter for the rate of innovation. These details are important both for the institutions and for the overall innovation system.

Basic research and knowledge dissemination remain key: Despite the focus on technology commercialization, it is basic research that is the irreplaceable aspect of what universities do, the often-unsung hero among all the activities universities pursue. This has at times been taken for granted as policy has focused on fostering technology transfer, but as basic funding of universities becomes more precarious, it is important to emphasize both the unique role of universities in performing basic research, and the background role they play in keeping knowledge growing and flowing around the world. Bedrock policies such as allowing endowment income to be tax free and providing significant funding of university fixed costs through overhead cost recovery can be thought of as socially efficient ways to subsidize the underlying innovation network creation and maintenance function of universities.

Growing importance of data and algorithms: Looking to the future, the rapid growth of big data and AI loom large. The Chapter in this volume by Agrawal, et al. probes the possible effects of AI on research. In terms of universities, it is likely that these effects, combined with the different ways that these technologies manifest themselves in commercial products and intellectual property will have significant effects on how universities interact with the commercial innovation system. The impact of universities is likely to remain significant, but the nature of impact and the role of faculty and students and of technology transfer offices are likely to evolve.

Less developed countries also need university-fostered innovation: An important but understudied area is the role of universities in fostering innovation in less developed countries, both historically and potentially in the future. Limited available research shows that borders do matter, and the need for researchers in less developed countries to overcome the barriers represented by national borders is an important practical and policy challenge. Such researchers do benefit from scientific publication of developed world research, particularly if it is published on an open-access basis, but limited access to tacit knowledge and elite scientific networks, inadequate absorptive capacity, and a lack of complementary industrial capability all need to be overcome.

Need for better understanding of heterogeneity of impacts: The thinness of research findings on universities and innovation in less developed countries is an important manifestation of a broader important issue. We've now established that spillovers of various forms from university activities are real and are important on average. But there is very little work that usefully identifies the institutional, cultural, geographical, and other factors that determine why and to what extent these spillovers are large in some contexts and small or nonexistent in others. Research on the heterogeneity of outcomes and the factors necessary for success is sorely needed for public policy formation. Institutions and regions that would like to foster university-supported innovation and growth can know that certain activities have been successful in this regard, but it is very hard for them to know which activities and hence which policies are most likely to be successful in their particular context. At a high level, the overall research trajectory surveyed here can be seen as having succeeded at the level of existence proof, but to make this truly policy relevant, we now must go beyond that to establish an understanding of how the mechanisms operate, with a level of detail that can support successful policy. The expanding use of text processing to extract data from a wide range of documents may facilitate this kind of granular and nuanced analysis.

Universities role in regional inequality: While we recognize the important regional and global benefits of universities, we should also acknowledge their distributional consequences within and across regions. Across regions, proximity effects and resulting agglomeration benefits create a fundamental tradeoff in fostering innovation. Highly innovative regions are the most productive place to send innovation investment, but this exacerbates regional inequality as the innovative rich get richer and other regions fall farther behind. Within successful regions, the concentration of innovation activity also generates congestion costs—rising housing prices, strained infrastructure, and sorting of high-skilled workers towards high-amenity locations—that shape who captures the gains from university driven growth. Modern trade and urban economics has made progress in mapping the geography of innovation at fine spatial scales, but connecting those spatial patterns to both the university, and to the specific local conditions that enable or inhibit university spillovers remains an open frontier. On the policy side, Cass (2025) recently suggested that research funding agencies should impose quotas on the amount of funding going to each metropolitan area. Applicants in Boston would have to compete against those at Harvard and MIT, and the threshold for funding would be lower for applicants from less successful regions. In the long run, talented scholars would have an incentive to move to those less competitive places because their chances of getting funded would improve. Because agglomeration effects are real, such a policy would decrease the overall productivity of public research, but it would also mitigate the extent to which funding exacerbates regional inequality.

> *"It was the best of times, it was the worst of times, it was the age of wisdom, it was the age of foolishness, it was the epoch of belief, it was the epoch of incredulity…"*
> (Charles Dickens, *A Tale of Two Cities,* 1859)

Universities today enjoy tremendous resources, and sit at the heart of key centers of historically unprecedented economic growth and wealth. At the same time, they are under attack as bastions of privilege in an increasingly unequal and troubled world. This contrast is in some ways inevitable, as the innovation system is intrinsically characterized by increasing returns to geographic scale and concentration. The forces by which universities generate wealth and prosperity also generate inequality. But if we address the inequality by strangling the goose, we will lose the golden eggs. Getting those eggs while mitigating inequality depends on efforts to understand the different pathways and mechanisms by which universities' creation and dissemination of knowledge affect the economy and society. Research on these 'real effects' has taught us much, but we still have a long way to go.

References

Abramovsky, Laura, Rupert Harrison, and Helen Simpson. 2007. “University Research and the Location of Business R&D.” *The Economic Journal* 117 (519): C114–41.

Acs, Zoltan J., David B. Audretsch, and Maryann P. Feldman. 1992. "Real Effects of Academic Research: Comment." *The American Economic Review* 82 (1): 363–67.

Adams, James D. 2002. "Comparative Localization of Academic and Industrial Spillovers." *Journal of Economic Geography* 2 (3): 253–78.

Ahmadpoor, Mohammad, and Benjamin F. Jones. 2017. “The Dual Frontier: Patented Inventions and Prior Scientific Advance.” *Science* 357 (6351): 583–87.

Akcigit, Ufuk, Douglas Hanley, and Nicolas Serrano-Velarde. 2021. "Back to Basics: Basic Research Spillovers, Innovation Policy, and Growth." *Review of Economic Studies* 88 (1): 1–43.

Amornsiripanitch, Natee, Paul A. Gompers, George Hu, and Kaushik Vasudevan. 2023. “Getting Schooled: Universities and VC-Backed Immigrant Entrepreneurs.” *Research Policy* 52 (7): 104782.

Andersson, Roland, John M. Quigley, and Mats Wilhelmsson. 2009. “Urbanization, Productivity, and Innovation: Evidence from Investment in Higher Education.” *Journal of Urban Economics* 66 (1): 2–15.

Andrews, Michael J. 2023. “How Do Institutions of Higher Education Affect Local Invention? Evidence from the Establishment of US Colleges.” *American Economic Journal: Economic Policy* 15 (2): 1–41.

Arora, Ashish, Sharon Belenzon, Larisa C. Cioaca, Lia Sheer, and Hansen Zhang. 2023. "The Effect of Public Science on Corporate R&D." NBER Working Paper No. 31899, November 2023.

Arrow, Kenneth J. 1962. "Economic Welfare and the Allocation of Resources for Invention." In *The Rate and Direction of Inventive Activity: Economic and Social Factors*, edited by Richard R. Nelson. Princeton, NJ: Princeton University Press.

Audretsch, David B., and Erik E. Lehmann. 2005. “Does the Knowledge Spillover Theory of Entrepreneurship Hold for Regions?” *Research Policy* 34 (8): 1191–202.

Audretsch, David B., Erik E. Lehmann, and Susanne Warning. 2005. “University Spillovers and New Firm Location.” *Research Policy* 34 (7): 1113–22.

Azoulay, Pierre, Benjamin F. Jones, J. Daniel Kim, and Javier Miranda. 2022. “Immigration and Entrepreneurship in the United States.” *American Economic Review: Insights* 4 (1): 71–88.

Babina, Tania, Alex Xi He, Sabrina T Howell, Elisabeth Ruth Perlman, and Joseph Staudt. 2023. “Cutting the Innovation Engine: How Federal Funding Shocks Affect University Patenting, Entrepreneurship, and Publications.” *The Quarterly Journal of Economics* 138 (2): 895–954.

Beine, Michel, Giovanni Peri, and Morgan Raux. 2024. “The Contribution of Foreign Master’s Students to US Start-Ups.” NBER Working Paper No. 33314, February 2024.

Belenzon, Sharon, and Mark Schankerman. 2009. “University Knowledge Transfer: Private Ownership, Incentives, and Local Development Objectives.” *The Journal of Law and Economics* 52 (1): 111–44.

Belenzon, Sharon, and Mark Schankerman. 2013. “Spreading the Word: Geography, Policy, and Knowledge Spillovers.” *Review of Economics and Statistics* 95 (3): 884–903.

Bercovitz, Janet E.L., and Maryann P. Feldman. 2007. “Fishing Upstream: Firm Innovation Strategy and University Research Alliances.” *Research Policy* 36 (7): 930–48.

Bercovitz, Janet, and Maryann Feldman. 2008. “Academic Entrepreneurs: Organizational Change at the Individual Level.” *Organization Science* 19 (1): 69–89.

Bergeaud, Antonin, Arthur Guillouzouic, Emeric Henry, and Clément Malgouyres. 2025. “From Public Labs to Private Firms: Magnitude And Channels of Local R&D Spillovers.” *The Quarterly Journal of Economics* 140 (4): 3233–82.

Bergeaud, Antonin, Adam B. Jaffe, and Dimitris Papanikolaou. 2025. “Natural Language Processing and Innovation Research.” NBER Working Paper No. 33821, May 2025.

Bikard, Michaël, and Matt Marx. 2020. “Bridging Academia and Industry: How Geographic Hubs Connect University Science and Corporate Technology.” *Management Science* 66 (8): 3425–43.

Bresnahan Timothy F., and Manuel Trajtenberg. 1995. "General Purpose Technologies 'Engines of Growth'?" *Journal of Econometrics* 65 (1): 83–108.

Cass, Oren. 2025. “The Right Way to Cut Science Funding.” *Commonplace*, July 28, 2025. https://www.commonplace.org/p/the-right-way-to-cut-science-funding

Cockburn, Iain M., and Rebecca M. Henderson. 1998. “Absorptive Capacity, Coauthoring Behavior, and the Organization of Research in Drug Discovery.” *The Journal of Industrial Economics* 46 (2): 157–82.

Cohen, Wesley M., Richard R. Nelson, and John P. Walsh. 2002. “Links and Impacts: The Influence of Public Research on Industrial R&D.” *Management Science* 48 (1): 1–23.

Cowan, Robin, and Natalia Zinovyeva. 2013. “University Effects on Regional Innovation.” *Research Policy* 42 (3): 788–800.

Dahl, Michael S., and Olav Sorenson. 2012. “Home Sweet Home: Entrepreneurs’ Location Choices and the Performance of Their Ventures.” *Management Science* 58 (6): 1059–71.

D’Este, Pablo, and Markus Perkmann. 2011. “Why Do Academics Engage with Industry? The Entrepreneurial University and Individual Motivations.” *The Journal of Technology Transfer* 36 (3): 316–39.

Di Gregorio, Dante, and Scott Shane. 2003. “Why Do Some Universities Generate More Start-Ups than Others?” *Research Policy* 32 (2): 209–27.

Dickens, Charles. 1859. *A Tale of Two Cities*. London: Chapman and Hall.

Eesley, Charles, Jian Bai Li, and Delin Yang. 2016. “Does Institutional Change in Universities Influence High-Tech Entrepreneurship? Evidence from China’s Project 985.” *Organization Science* 27 (2): 446–61.

Evenson, Robert E., and Yoav Kislev. 1976. “A Stochastic Model of Applied Research.” *Journal of Political Economy* 84 (2): 265–81.

Fleming, Lee, and Olav Sorenson. 2004. “Science as a Map in Technological Search.” *Strategic Management Journal* 25 (8–9): 909–28.

Fry, Caroline Viola. 2023. “Bridging the Gap: Evidence from the Return Migration of African Scientists.” *Organization Science* 34 (1): 404–32.

Gambardella, Alfonso. 1995. *Science and Innovation: The US Pharmaceutical Industry during the 1980s*. 1st ed. Cambridge University Press.

Gennaioli, Nicola, Rafael La Porta, Florencio Lopez-de-Silanes, and Andrei Shleifer. 2013. “Human Capital and Regional Development.” *The Quarterly Journal of Economics* 128 (1): 105–64.

Geuna, Aldo, and Federica Rossi. 2011. “Changes to University IPR Regulations in Europe and the Impact on Academic Patenting.” *Research Policy* 40 (8): 1068–76.

Grimaldi, Rosa, Martin Kenney, Donald S. Siegel, and Mike Wright. 2011. “30 Years after Bayh–Dole: Reassessing Academic Entrepreneurship.” *Research Policy* 40 (8): 1045–57.

Guzman, Jorge, Fiona Murray, Scott Stern, and Heidi Williams. 2024. "Accelerating Innovation Ecosystems: The Promise and Challenges of Regional Innovation Engines." *Entrepreneurship and Innovation Policy and the Economy* 3 (1): 9–75.

Hall, Bronwyn H., and Adam B. Jaffe. 2018. “Measuring Science, Technology, and Innovation: A Review.” *Annals of Science and Technology Policy* 2 (1): 1–74.

Hart, David M., and Zoltan J. Acs. 2011. “High-Tech Immigrant Entrepreneurship in the United States.” *Economic Development Quarterly* 25 (2): 116–29.

Hartmann, Philipp, and Joachim Henkel. 2020. “The Rise of Corporate Science in AI: Data as a Strategic Resource.” *Academy of Management Discoveries*, April 9, amd.2019.0043.

Hausman, Naomi. 2022. “University Innovation and Local Economic Growth.” *The Review of Economics and Statistics* 104 (4): 718–35.

Hvide, Hans K., and Benjamin F. Jones. 2018. “University Innovation and the Professor’s Privilege.” *American Economic Review* 108 (7): 1860–98.

Jaffe, Adam B., Manuel Trajtenberg, and Rebecca Henderson. 1993. "Geographic Localization of Knowledge Spillovers as Evidenced by Patent Citations." *The Quarterly Journal of Economics* 108 (3): 577–598.

Jaffe, Adam B. 1998. "Measurement Issues." In *Investing in Innovation: Creating a Research and Innovation Policy That Works*. MIT Press.

Jensen, Richard A., Jerry G. Thursby, and Marie C. Thursby. 2003. “Disclosure and Licensing of University Inventions: ‘The Best We Can Do with the S**t We Get to Work With.’” *International Journal of Industrial Organization* 21 (9): 1271–300.

Jensen, Richard, and Marie Thursby. 2001. “Proofs and Prototypes for Sale: The Licensing of University Inventions.” *American Economic Review* 91 (1): 240–59.

Kaiser, Ulrich, Hans C. Kongsted, Keld Laursen, and Ann-Kathrine Ejsing. 2018. “Experience Matters: The Role of Academic Scientist Mobility for Industrial Innovation.” *Strategic Management Journal* 39 (7): 1935–58.

Kantor, Shawn, and Alexander Whalley. 2014. “Knowledge Spillovers from Research Universities: Evidence from Endowment Value Shocks.” *The Review of Economics and Statistics* 96 (1): 171–88.

Koch, Leonie, and Martin Simmler. 2020. “How Important Are Local Knowledge Spillovers of Public R&D and What Drives Them?” *EconPol Working Paper* No. 42, ifo Institute – Leibniz Institute for Economic Research at the University of Munich.

Lane, Julia I., Jason Owen-Smith, Rebecca F. Rosen, and Bruce A. Weinberg. 2015. “New Linked Data on Research Investments: Scientific Workforce, Productivity, and Public Value.” *Research Policy* 44 (9): 1659–71.

Laursen, Keld, Toke Reichstein, and Ammon Salter. 2011. “Exploring the Effect of Geographical Proximity and University Quality on University–Industry Collaboration in the United Kingdom.” *Regional Studies* 45 (4): 507–23.

Laursen, Keld, and Ammon Salter. 2004. “Searching High and Low: What Types of Firms Use Universities as a Source of Innovation?” *Research Policy* 33 (8): 1201–15.

Lee, Kyootai, and Hyun Ju Jung. 2021. “Does TTO Capability Matter in Commercializing University Technology? Evidence from Longitudinal Data in South Korea.” *Research*

Policy 50 (1): 104133.

Lerner, Josh, Henry Manley, Carolyn Stein, and Heidi Williams. 2025. “The Wandering Scholars: Understanding the Heterogeneity of University Commercialization.” Working Paper, April 2025.

Mansfield, Edwin. 1991. “Academic Research and Industrial Innovation.” *Research Policy* 20 (1): 1–12.

Mansfield, Edwin. 1995. “Academic Research Underlying Industrial Innovations: Sources, Characteristics, and Financing.” *The Review of Economics and Statistics* 77 (1): 55.

Mansfield, Edwin. 1998. “Academic Research and Industrial Innovation: An Update of Empirical Findings.” *Research Policy* 26 (7–8): 773–76.

Marx, Matt, and David H. Hsu. 2022. “Revisiting the Entrepreneurial Commercialization of Academic Science: Evidence from ‘Twin’ Discoveries.” *Management Science* 68 (2): 1330–52.

Moretti, Enrico. 2004. “Human Capital Externalities in Cities.” In *Handbook of Regional and Urban Economics*, Vol. 4, edited by J. V. Henderson and J. F. Thisse, 2243–2291. Amsterdam: Elsevier.

Mowery, David C., Bhaven N. Sampat, and Arvids A. Ziedonis. 2002. “Learning to Patent: Institutional Experience, Learning, and the Characteristics of U.S. University Patents After the Bayh-Dole Act, 1981-1992.” *Management Science* 48 (1): 73–89.

Mowery, David C., and Arvids A. Ziedonis. 2002. “Academic Patent Quality and Quantity before and after the Bayh–Dole Act in the United States.” *Research Policy* 31 (3): 399–

National Center for Education Statistics. 2023. "Fast Facts: Expenditures." https://nces.ed.gov/fastfacts/display.asp?id=75.

National Center for Science and Engineering Statistics. 2025. "Survey of Federal Funds for Research and Development 2023–2024." https://ncses.nsf.gov/surveys/federal-funds-research-development/2023-2024.

Nagar, Jay Prakash, Stefano Breschi, and Andrea Fosfuri. 2024. “ERC Science and Invention: Does ERC Break Free from the EU Paradox?” *Research Policy* 53 (8): 105038.

Nelson, Richard R. 1959. “The Simple Economics of Basic Scientific Research.” *Journal of Political Economy* 67 (3): 297–306.Nelson, Richard R. n.d. *Institutions Supporting Technical Advance in Industry*.

Nelson, Richard R. 1994. “The Co-evolution of Technology, Industrial Structure, and Supporting Institutions.” *Industrial and Corporate Change* 3 (1): 47–63.

Nienkamp, Paul. 2010. “Land-Grant Colleges and American Engineers: Redefining Professional and Vocational Engineering Education in the American Midwest, 1862–1917." *American Educational History Journal* 37 (2): 313–330.

Pavitt, Keith. 1984. "Sectoral Patterns of Technical Change: Towards a Taxonomy and a Theory." *Research Policy* 13 (6): 343–73.

Perkmann, Markus, Rossella Salandra, Valentina Tartari, Maureen McKelvey, and Alan Hughes. 2021. "Academic Engagement: A Review of the Literature 2011-2019." *Research Policy* 50 (1): 104114.

Perkmann, Markus, Valentina Tartari, Maureen McKelvey, et al. 2013. "Academic Engagement and Commercialisation: A Review of the Literature on University–Industry Relations." *Research Policy* 42 (2): 423–42.

Rezaei, Roham, and Yufeng Yao. 2025. "Government-Backed Science and Venture Capital." Job Market Paper, UNSW Business School, November 2025.

Roche, Maria P. 2023. "Academic Entrepreneurship: Entrepreneurial Advisors and Their Advisees' Outcomes." *Organization Science* 34 (2): 959–86.

Romer, Paul M. 1990. "Endogenous Technological Change." *Journal of Political Economy* 98 (5, Part 2): S71–S102.

Sampat, Bhaven N. 2006. "Patenting and US Academic Research in the 20th Century: The World before and after Bayh-Dole." *Research Policy* 35 (6): 772–89.

Scandura, Alessandra. 2016. "University–Industry Collaboration and Firms' R&D Effort." *Research Policy* 45 (9): 1907–22.

Saxenian, AnnaLee. 1996. *Regional Advantage: Culture and Competition in Silicon Valley and Route 128*. Harvard University Press.

Schoellman, Todd, and Vladimir Smirnyagin. 2021. "The Growing Importance of Universities for Patenting and Innovation." Working paper, August 2021.

Siegel, Donald S, David Waldman, and Albert Link. 2003. "Assessing the Impact of Organizational Practices on the Relative Productivity of University Technology Transfer Offices: An Exploratory Study." *Research Policy* 32 (1): 27–48.

Stephan, Paula. 2006. "Wrapping It Up in a Person: The Mobility Patterns of New PhDs." *Innovation Policy and the Economy* 7: 71–98.

Stokes, Donald E. 1997. *Pasteur's Quadrant: Basic Science and Technological Innovation*. Brookings Institution Press.

Stuart, Toby E., and Waverly W. Ding. 2006. "When Do Scientists Become Entrepreneurs? The Social Structural Antecedents of Commercial Activity in the Academic Life Sciences." *American Journal of Sociology* 112 (1): 97–144.

Tartari, V., and S. Breschi. 2012. “Set Them Free: Scientists’ Evaluations of the Benefits and Costs of University-Industry Research Collaboration.” *Industrial and Corporate Change* 21 (5): 1117–47.

Tartari, Valentina, and Scott Stern. 2021. “More Than an Ivory Tower: The Impact of Research Institutions on the Quantity and Quality of Entrepreneurship.” NBER Working Paper No. 28846, 2021.

Thursby, Jerry G., and Marie C. Thursby. 2002. “Who Is Selling the Ivory Tower? Sources of Growth in University Licensing.” *Management Science* 48 (1): 90–104.

Uhlbach, Wolf-Hendrik, Valentina Tartari, and Hans Christian Kongsted. 2022. “Beyond Scientific Excellence: International Mobility and the Entrepreneurial Activities of Academic Scientists.” *Research Policy* 51 (1): 104401.

Valero, Anna, and John Van Reenen. 2019. “The Economic Impact of Universities: Evidence from across the Globe.” *Economics of Education Review* 68 (February): 53–67.

Van Looy, Bart, Paolo Landoni, Julie Callaert, Bruno Van Pottelsberghe, Eleftherios Sapsalis, and Koenraad Debackere. 2011. “Entrepreneurial Effectiveness of European Universities: An Empirical Assessment of Antecedents and Trade-Offs.” *Research Policy* 40 (4): 553–64.

Welsh, Rick, Leland Glenna, William Lacy, and Dina Biscotti. 2008. “Close Enough but Not Too Far: Assessing the Effects of University–Industry Research Relationships and the Rise of Academic Capitalism.” *Research Policy* 37 (10): 1854–64.

Woodward, Douglas, Octávio Figueiredo, and Paulo Guimarães. 2006. “Beyond the Silicon Valley: University R&D and High-Technology Location.” *Journal of Urban Economics* 60 (1): 15–32.

Yue, Daniel. 2024. "I, Google: Estimating the Impact of Corporate Involvement on AI Research." SSRN Working Paper No. 5033334, November 2024.