A Review of the Accounting Literature on Innovation

Stephen Glaeser
Kenan Flagler Business School, University of North Carolina at Chapel Hill
stephen_glaeser@kenan-flagler.unc.edu

Mark Lang
Kenan Flagler Business School, University of North Carolina at Chapel Hill
mark_lang@kenan-flagler.unc.edu

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ABSTRACT: We review the accounting literature on innovation, focusing on the economic attributes of innovation that collectively differentiate innovation from other resources: novelty, nonrivalry, and partial excludability. These attributes help innovation drive economic growth but create unique information-based challenges that accounting information and researchers are well suited to address. We discuss the definition and measurement of innovation and highlight common mistakes researchers make when measuring innovation and when using sources of plausibly exogenous variation in innovation. We then review the accounting literatures on the disclosure, management, financial reporting, taxation, and contracting and financing of innovation. For each of these literatures we identify challenges and opportunities for future research.

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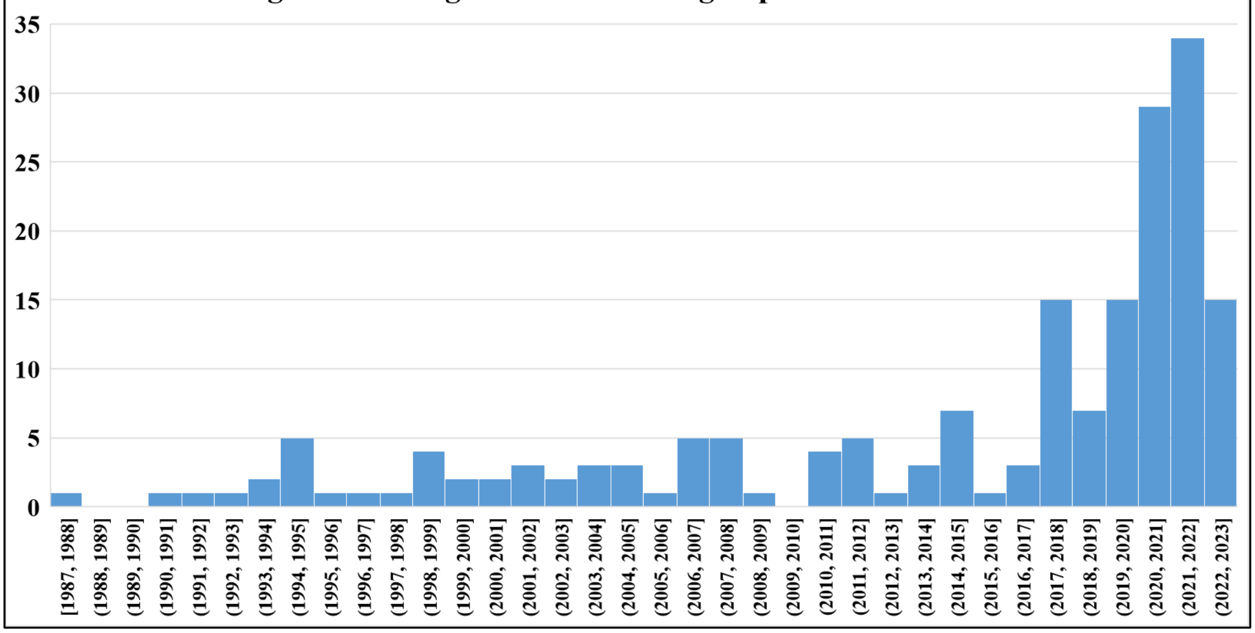
Table of Contents

1. Introduction

We review the accounting literature researching innovation. This literature has boomed in recent years; of the 184 accounting papers on innovation in our review, 100 are dated in the last five years:

Figure 1: Histogram of Accounting Papers on Innovation



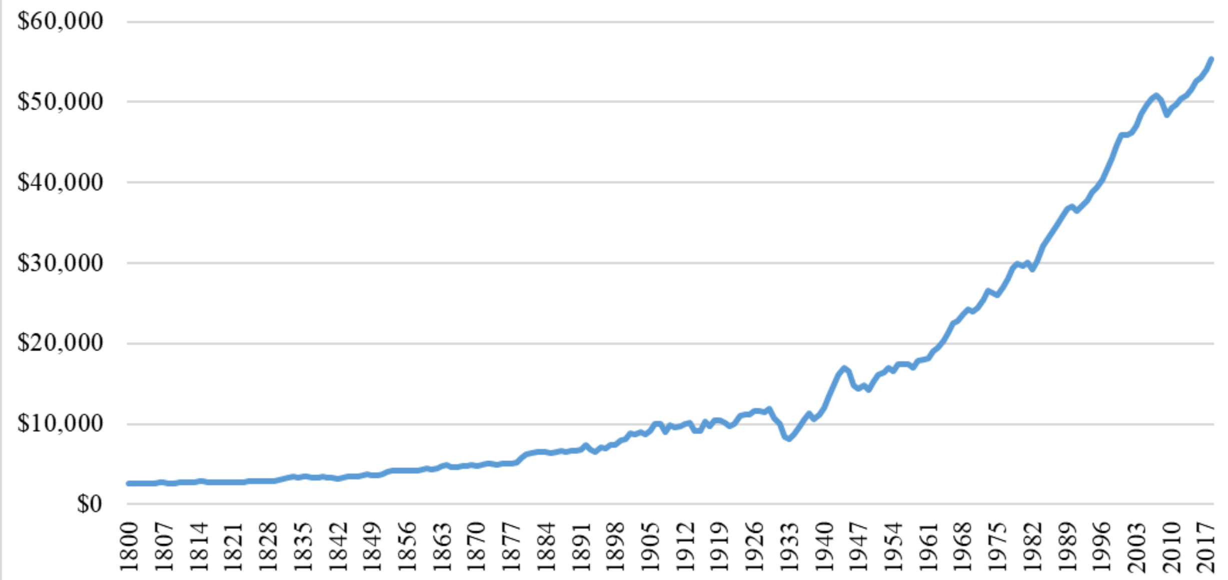
Despite this boom, the accounting literature on innovation has progressed in a disparate fashion with little focus on what differentiates innovations from other assets or how accounting researchers' unique skillsets can contribute to the broader innovation literature. Our review integrates the literature by outlining the unique characteristics of innovation and how they relate to accounting research.

Following Romer (1990), our review focuses on the economic characteristics that differentiate innovations from other assets—novelty, nonrivalry, and partial excludability. Novelty refers to the fact that innovations are new ideas or new ways to implement existing ideas, and hence innovating moves the forefront of knowledge forward. Nonrivalry refers to the ability of multiple parties to use an innovation simultaneously without reducing each other's ability to access the innovation, in contrast to purely private goods for which use by one party precludes use by another (Samuelson, 1954). Partial excludability refers to the inability of innovation owners to fully legally limit others from accessing their innovation, for example because of incomplete property rights under the law, and in contrast to the full excludability of many other types of intellectual property and to physical assets. As we develop in detail, innovation fits naturally into the purview of accounting research because its novelty, nonrivalry, and partial excludability create information-based challenges relevant to many aspects of the accounting literature.

Effectively navigating these information-based challenges is critical because of the importance of innovation to growth. In traditional macroeconomic models, producers combine labor and capital to create growth. Labor and capital are rival goods: as more individuals use, for example, gasoline or require an individual accountant's time, the less gasoline and individualized accounting advice is available to others. Consequently, the amount of available labor and capital limits growth in traditional models. According to these models, to double production one must double the amount of gasoline, the number of accountants, etc. An implication of these models is that absent innovation growth is limited by growth in the available stock of labor and capital. Consequently, as the population grows, *per capita* output remains constant or even declines due to diminishing marginal returns.

However, per capita output has not declined, or even remained fixed, over time. If anything, real GDP per capita has grown exponentially; by one estimate increasing in the US in constant 2011-dollar terms from about $2,545 in 1800 to $55,335 in 2018 (Bolt et al., 2020):

Figure 2: US Real GDP Per Capita, 1800 to 2018



How was the economy able to grow exponentially? In large part, the answer is innovation (Solow, 1957; Romer, 1990; Jones, 2023). Unlike rival labor and capital, nonrival innovations can be used in multiple applications within the firm or across firms without decreasing their usefulness. For example, firms do not need to reinvent their stock of innovations each time they build a new factory. Instead, firms can use their stock of innovations in any number of new factories, without depletion due to nonrivalry. Moreover, new innovations can leverage prior innovations, leading to interactions among innovations that can also drive growth (Jones, 2023). Further, the partial excludability of innovations means that innovators can only partly prevent others from benefiting from their innovations, creating knowledge spillovers that spread the benefits of innovation across the economy, again driving growth.

As an illustration, Henry Ford's idea of producing goods on a moving assembly line allowed him to manufacture automobiles with 1/10th the labor effort. Partial excludability, in Ford's case because of incomplete secrecy, meant that Ford could not fully prevent others from benefiting from his innovation. Nonrivalry meant that when others benefited from Ford's innovation, they did not directly prevent Ford from also using the innovation. Consequently, the moving assembly line directly increased economic growth by allowing Ford and his competitors to create much cheaper vehicles in larger quantities. Moreover, the moving assembly line indirectly increased economic growth as assembly line concepts were applied to other production processes and combined with other innovations. As a more recent example, the nonrivalry of artificial intelligence (AI) has facilitated the spread of AI throughout the modern economy; the five largest firms in the US by market capitalization as of June 1, 2023, Apple, Microsoft, Alphabet, Amazon, and NVIDIA, each leverage aspects of AI and of other innovations.

While innovation's role in aggregate and firm growth helps explain why understanding innovation is important, it does not answer the question of why *accounting* researchers should spend time and effort researching innovation. We argue that innovation is a natural fit for accounting research because novelty, nonrivalry, and partial excludability create information-based challenges that accounting information and researchers are well equipped to solve.

Our review covers a variety of the information-based innovation challenges familiar to accounting researchers. For example, the partial excludability of innovations coupled with their nonrivalry means that they contribute to the social good by creating knowledge spillovers (Romer, 1990). Because these knowledge spillovers begin when the innovation is disclosed, the disclosure of innovation generates positive externalities (Dyer et al., 2020; Kim and Valentine, 2021). However, disclosure imposes proprietary costs on the innovator because it allows others to expropriate some of their innovation's value due to partial excludability, which discourages invention *ex ante*. This tension between the proprietary costs and benefits of innovation disclosure is familiar to accounting researchers (e.g., Verrecchia, 1983).

The proprietary costs and positive externalities of innovation disclosure also complicate the design of legal and tax systems meant to encourage investments in innovation and ensure knowledge spillovers via disclosure. Exacerbating these complications, contracts written for investments in innovation are necessarily incomplete because innovations are difficult to describe *ex ante* due to their novelty (e.g., Aghion and Tirole, 1994). The challenges of incomplete contracting are also familiar to accounting researchers (Christensen et al., 2016). Perhaps even more familiar to accounting researchers is the challenge of designing financial reporting and tax systems to accurately reflect the value of innovations. Standard setters grapple with the recognition and measurement of innovation because innovation is novel and because firms do not necessarily control the benefits of innovations due to partial excludability and nonrivalry. Our review discusses how accounting researchers navigate these and other innovation-specific challenges. A broad takeaway is that many seemingly disparate challenges stem from the unique characteristics of innovation.

The unique characteristics of innovation also make measuring innovation challenging. The partial excludability of innovation discourages public disclosure, the novelty of innovation complicates empirical comparisons, and the nonrivalry of innovation means that many innovations are not clearly owned and operated within a single firm's boundaries. Despite the challenges observing, empirically comparing, and identifying the ownership of innovation, our review identifies a variety of approaches to measuring innovation. For each of these approaches, we highlight strengths, weaknesses, and common pitfalls. We conclude that the best approach to measuring innovation differs across research questions and settings, and we identify research opportunities for developing new empirical techniques, datasets, and sources of plausibly exogenous variation.

Our review also identifies opportunities to extend the literature on innovation, several of which we briefly highlight here. Accounting researchers may be able to integrate disclosure, search, and/or contracting into existing models of innovation and growth (e.g., Romer, 1990; Jones, 2023). In these existing models, innovations implicitly enter the knowledge stock immediately when discovered, are known by all, and can be freely combined and used in conjunction with other innovations. However, in practice innovations enter the knowledge stock when they are disclosed, either intentionally or unintentionally via reverse engineering or misappropriation. After disclosure, other inventors and potential users bear disclosure processing costs to learn about innovations, and best leveraging nonrival innovations typically requires inter-party contracting, often based on accounting information. Updating growth models to incorporate this disclosure, search, and/or contracting can reveal important ways in which these forces moderate the link between innovation and growth, identify empirical constructs of interest such as the relative spillovers to secrecy and patenting, and inform the design of institutions such as the patent system.

Another opportunity is exploring how AI affects information processing and innovation (Blankespoor et al., 2020). Relatively few studies in our review focus on AI, but preliminary evidence suggests that AI is changing the financial reporting, contracting, and auditing landscapes (e.g., Fedyk et al., 2022). AI may even directly affect the creation of new innovations and growth. As noted by Jones (2023, p. 1995), "…growth is constrained by our limitations in processing an exploding number of ideas." AI may significantly lower the costs to process this "exploding number of ideas," helping inventors and managers identify promising opportunities.

Researchers can also explore whether and how innovations reach their best user. For example, many new innovations combine existing innovations in a novel way. However, these existing innovations are often spread across organizations, which creates barriers to optimal colocation. Existing research explores some ways in which firms access other firms' innovations, such as via mergers and acquisitions, but pays less attention to some of the most common methods of doing so, such as royalty agreements and strategic alliances. The advent of commercial databases that cover patent royalty and strategic alliance contracts, such as KtMine, Cortellis, and Thomson Reuters SDC, may yield new opportunities to explore these common methods of accessing other firms' innovations, which often incorporate accounting information.

Another opportunity is exploring how firms implicitly and explicitly contract with individual inventors. Inventors' labor is one of the main inputs into innovation and represents much of R&D expense. Yet we know little about how firms contract with inventors or how managers oversee inventors. Contracting with and managing inventors is different than doing so with other parties because, for example, inventors can misappropriate partially excludable innovations. Closely related are the incentives and contracts of other parties central to the innovation process such as entrepreneurs, venture capitalists, and startups. Studying these parties aligns well with accounting researchers' growing interest in labor and private firms.

Our review also identifies opportunities in well-developed literatures such as financial reporting and tax. The FASB recently implemented a new asset definition in Concepts Statement 5 (i.e., "[a]n asset is a present right of an entity to an economic benefit"). The FASB's new asset definition potentially incorporates innovation, and the FASB has ongoing projects related to the capitalization of intangibles, including innovation. The FASB continues to struggle with the notions of “rights” in its new asset definition, particularly as they relate to features of innovation such as partial excludability and nonrivalry. While existing research largely focuses on the uncertainty of innovation, which largely follows from its novelty, there is much less research that focuses on the financial reporting implications of partial excludability and nonrivalry.

Turning to the tax literature, why do some firms with overseas operations and valuable innovations not leverage the nonrivalry and novelty of innovations to avoid taxes?[1] What is the optimal mix of tax and non-tax policy levers to encourage innovation and the disclosure of innovation? For example, how should a social planner decided between input-rewarding R&D tax credits, output-rewarding innovation boxes, and various legal policies designed to encourage innovation (e.g., strength of patent rights, restrictions on inventor mobility, etc.)?

A final opportunity we highlight here is integrating the innovation and environment, social, and governance (ESG) accounting literatures (Christensen et al., 2021). Stakeholders and citizens increasingly pressure firms and nations to reduce emissions, improve environmental outcomes, etc. One of the few ways for firms and nations to do so without significantly sacrificing profits or living standards is by creating innovations that minimize environmental impacts and use natural resources efficiently (i.e., green innovations). The importance of green innovation raises questions such as how well do ESG reporting standards capture the existence and nature of green innovation and do ESG reporting standards spur green innovation or discourage it due to proprietary costs of disclosure? Does disclosure of innovation help disseminate green innovations beyond the boundaries of a single firm or nation, such that they meaningfully impact aggregate outcomes (e.g.,

[1] We focus on how the unique features of innovation inform the design of tax systems and how they affect firms’ responses to tax incentives. For a more detailed discussion of the interplay between real, reporting, and disclosure effects of taxation on investment more generally, including on innovation, see Lester and Olbert (2023).

emissions)? Do ESG reporting requirements attract historically underrepresented groups to careers in science, such that society can meaningfully increase the rate of innovation production? Can accountants improve the measurement of green innovation?

We provide two notes of caution. First, we review accounting papers and a few closely related papers in other fields. Readers interested in innovation research in related fields can use our review as a starting point but should supplement our coverage with their own review of related literatures in other fields.[2] Second, we caution researchers against merely rehashing prior findings in the innovation setting. For example, simply documenting the importance of risk in a specific innovation setting is unlikely to make a material contribution. To make a significant impact, researchers should develop novel hypotheses rooted in the unique characteristics of innovation, examine existing but unresolved hypotheses that are particularly well suited to the innovation setting, or develop measures that permit unique insights. However, we also note that the unique characteristics of innovation often lead to unique predictions and therefore one cannot extrapolate prior findings in non-innovation settings to research questions rooted in the unique characteristics of innovation.

We organize the rest of the review as follows. Section 2 discusses the definition of innovation, provides examples of what does and does not constitute an innovation, and comments on the various approaches to measuring innovation. Section 3 reviews the accounting literatures on the disclosure, financial reporting, management, taxation, and contracting and financing of innovation. Section 4 provides concluding thoughts.

2. What is innovation?

[2] These readers may find reviews by Hauser et al. (2006), Crossan and Apaydin (2010), He and Tian (2018), and Andrews et al. (2022a) useful.

2.1. Defining innovation

Building on Arrow (1962) and Romer (1990), we define an innovation as a novel idea for an improved production process, product, method, or platform. Innovations differ from other assets because they are novel, nonrival, and partially excludable (Romer, 1990; Aghion and Tirole, 1994). Novelty refers to the condition that the innovation be new to the firm, entity, or society, depending on the specific research context.[3] Nonrivalry refers to the fact that use by one party does not diminish the amount, quality, or availability of the innovation for others. By their nature, ideas, including innovations, are nonrival. Partial excludability refers to the innovation owner's inability to fully limit others' legal access to their innovation.[4] Innovations are partially excludable because the endogenous legal institutions designed to protect and encourage innovation, such as the patent system or trade secret law, offer incomplete protections.[5]

Few accounting studies explicitly define innovation.[6] We suspect that researchers avoid formally defining innovation because any definition will inevitably have material shortcomings.

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[3] For example, a researcher interested in the behavior of individual firms might decide novel to the firm is an appropriate condition for innovation in their setting. Conversely, a researcher interested in how society moves the production possibilities frontier forward might decide novel to society is a necessary condition in their setting. Firms sometimes intentionally or unintentionally imitate other firms' innovations, which reflects the diffusion of knowledge through society. In the case where innovation is defined as new to the firm, this knowledge diffusion would count as innovation, but in the case where innovation is defined as new to society this knowledge diffusion would not. *Ex post*, knowledge diffusion benefits society, as it is unlikely optimal from a societal perspective for a single firm or entity to solely benefit from an innovation (e.g., due to monopoly deadweight losses). However, knowledge diffusion can also *ex ante* discourage invention and innovation disclosure, suggesting the general equilibrium effects of knowledge diffusion are complex and greater knowledge diffusion is not strictly beneficial.

[4] Innovations fall between private goods, which are rival and fully excludable, and public goods, which are nonrival and nonexcludable (Samuelson, 1954). A private good, such as a machine, is rival because one person using it limits the ability of others to use it and is excludable because the owner can legally prevent others from using it. A traditional public good, such as a clean atmosphere, is nonrival because one person using it does not prevent others from using it and is nonexcludable because individuals cannot legally prevent others from using it.

[5] Our definition includes innovations that the innovator could not or did not exclude (e.g., open innovations; Brockman et al., 2018). An alternative approach is to define unexcluded innovations as general knowledge.

[6] An exception is Simpson and Tamayo (2020), who adopt the Oslo Manual (2018, p. 20)'s definition of innovation: "An innovation is a new or improved product or process (or a combination thereof) that differs significantly from the unit's previous products or processes and that has been made available to potential users (product) or brought into use by the unit (process)." As we describe in more detail below, our definition differs slightly because we do not require implementation of the idea and because we do not view a physical product as an innovation (although the idea behind it may be). Our focus on ideas introduces both nonrivalry and partial excludability.

We offer our definition as a starting point and, to the extent that authors find our definition too narrow or too broad, we think laying out those divergences can provide useful structure. As a practical matter, our review did not identify major areas of existing research that would be controversially excluded under our definition, and we believe our definition encompasses most accounting research that the authors intend to speak to innovation.

2.2. What is an innovation? What is not an innovation?

To further clarify our definition, we provide examples of what we do and do not consider innovations. Physical units of a new product and the physical machines used to implement a new production process, such as Ford's physical moving assembly line and the Model Ts built on it, are not innovations because they are rival and fully excludable under the law (i.e., they are private goods). In contrast, the novel ideas for new products or production processes, such as the idea for the removable cylinder head or for the moving assembly line, are innovations.

Innovation is a type of intellectual property and an intangible asset. Some types of intellectual property and intangible assets that we do not consider innovations, such as customer lists, databases, brands, advertisements, and general knowledge, nonetheless have some characteristics of innovation. Our definition excludes many of these intangibles because they are fully excludable under the law (e.g., a competitor cannot legally use Google's brand name). Our definition excludes others of these intangibles because they are not novel (e.g., a customer list is a collection of known data and hence not novel) and/or because they are not ideas (e.g., a customer list or database is not an idea).

Researchers sometime use technology as a synonym for a specific innovation or for the stock of innovations (e.g., Romer, 1990; Jones, 2023). Technology also sometimes refers to the physical embodiment of an innovation. For example, Oxford Languages defines technology as, "machinery and equipment developed from the application of scientific knowledge." Oxford Languages' definition of technology differs from our definition of innovation because it refers to the rival, fully excludable physical assets developed from innovations.

2.3. Measuring innovation

Building on our definition of innovation, we discuss different approaches to measuring innovation. We highlight costs and benefits to each approach and emphasize that the most appropriate approach will be context specific. As with other areas of research, we do not believe that potential measurement issues should preclude researchers investigating important questions, especially if they carefully design tests based on theory and triangulate their analyses.

We note three broad critiques of innovation measurement. First, many measures of innovation only capture the excludable portion of the innovation, such as a patent or trade secret right. The nonexcludable portion, which creates knowledge spillovers, is harder to measure because it is not directly observable and because it naturally spreads across firms, resulting in general equilibrium effects. Second, most studies focus on innovation by public firms. However, a substantial proportion of innovation originates from entities other than public firms (e.g., private firms, government entities, and non-profit organizations). Third, most innovation measures and sources of plausibly exogenous variation derive from the US setting where data is generally high quality and excludability rights are arguably strongest. However, a great deal of innovation takes place outside the US, and international differences in legal protections and other institutions limit generalizability of US-specific results to international settings. We believe there are important opportunities to develop measures of innovation by entities other than public firms, knowledge spillovers, and the general equilibrium effects of innovation, as well as to explore US-specific results in international settings.

Figure 3 provides a stylized timeline of the innovation lifecycle for profit driven firms. The lifecycle begins with the investment stage when firms invest in innovation-inputs including inventors' time and effort. If those investments are successful and the results disclosed to the firm, the firm must decide how to best protect the resulting innovation to prevent misappropriation. The firm must also decide whether and how to disclose the innovation publicly. The protection and disclosure decisions are interrelated as, for example, protecting an innovation with trade secrecy often necessitates a low level of disclosure. Finally, the firm must implement the innovation to profit off it. Implementation can take many forms simultaneously (e.g., licensing an innovation in one geographic market while using it exclusively in another). All three stages of the lifecycle are interrelated and may not proceed in the linear fashion suggested by Figure 3 (e.g., firms may discover novel ideas during the implementation stage). Nonetheless, Figure 3 provides an approximate progression that is useful to structure the subsequent measurement discussion.

Appendix A lists various publicly available data sources that relate to the different measures and sources of plausibly exogenous variation (see also https://iiindex.org/).

2.3.1. Investment: R&D expense and R&D stocks

Perhaps the most common measure of innovation is public firms' financial statement R&D expense, which represents investments that potentially generate innovations. R&D expense has the advantage of being widely observable for public firms but has limitations as a measure of investment in innovation. Potentially because of proprietary costs concerns, R&D expense disclosure is relatively coarse and does not provide the detail necessary to infer the direction or boldness of innovation, how firms protect and disclose their innovation, or other potentially interesting aspects of innovation. Relatedly, R&D expense does not reflect the success of investments in innovation.

An important consideration when using R&D expense to measure investments in innovation is that R&D expense is a flow variable. Depending on the context, a stock variable may be more appropriate, analogous to the fact that in some contexts it is more appropriate to examine the stock of fixed assets rather than capital expenditures. Some authors estimate R&D stocks by accumulating prior R&D expense subject to an assumed yearly depreciation rate. The accuracy of this approach depends in part on choosing an appropriate aggregation period and depreciation rate. Some authors adopt a relatively straightforward but simple 15% or 20% yearly rate, while others estimate industry and/or time specific depreciation rates.[7] Relatively few accounting authors attempt to independently estimate the appropriate depreciation rate.[8]

Accounting researchers could significantly contribute to understanding R&D capitalization and depreciation given their relative expertise in understanding fixed asset measurement and depreciation. For example, researchers could investigate how R&D capital depreciation depends on the type of innovation; firms' economic position as market leaders, monopolists, etc.; expropriation likelihoods; and other potential factors. Similarly, accounting researchers could investigate whether managers opportunistically set R&D depreciation rates when reporting under rules that allow R&D capitalization.

Understanding R&D depreciation rates is not just useful for calculating R&D capital stocks. R&D depreciation rates should reflect the degradation of the private returns to knowledge, which has potential implications for public policy and asset pricing. Moreover, the depreciation rate of R&D capital has potential implications for financial reporting policy in jurisdictions that

[7] See Li and Hall (2020) for a discussion of the literature calculating R&D depreciation rates.
[8] Ewens et al. (2019) and Iqbal et al. (2023) are exceptions. Ewens et al. (2019) use market prices and purchase price allocations in acquisitions and bankruptcy recovery data to estimate intangible capital values and industry-level depreciation rates, while Iqbal et al. (2023) use industry-year regressions of the association between intangible investment and future revenues.

currently allow the capitalization of R&D, as well as in the US as the FASB considers capitalizing internally developed intangibles under the new asset definition.[9]

There are several other issues with R&D expense and stocks as a measure of investment in innovation. First, many firms do not report R&D expense in the financial statements (ostensibly because it is deemed immaterial). However, research suggests that some of those firms engage in limited R&D (e.g., Koh and Reeb, 2015). Second, reported R&D expense is not a "real" quantity because it reflects both the price and the quantity of R&D activity. The main input into R&D activity is scientists' labor supply, which is relatively inelastic. Demand shocks may increase scientists' wages, and hence the price of R&D and reported R&D expense, without increasing the real quantity of R&D activity.

Overall, R&D expense provides an important and consistent measure of innovation investment. However, R&D expense is a coarse measure given its aggregation in required disclosures. Further, R&D expenses reflect nominal investments in innovation rather than real innovation outputs.

2.3.2. Protection: Patents and patent-based measures

While R&D expense measures innovation inputs, patents and patent-based measures are common ways to measure innovation outputs. Because patent examiners review patented innovations for novelty and usefulness, patents are a relatively accurate measure of the existence of the underlying innovation and are the only measure of innovation that directly captures innovations that are novel to society. Because the goal of the patent system is publicly recording the provenance and legal ownership of innovations and providing clear descriptions of how to

[9] See, for example, the FASB's ongoing project on the disclosure and recognition of intangibles: https://www.fasb.org/Page/ProjectPage?metadata=FASB_OBJECTIVESOFRESEARCHPROJECTS_022820221200#intangibles. Accessed March 9, 2023.

recreate them, patent data is incredibly detailed (see Section 3.1.1).[10] In total, patent data has many strengths as a measure of innovation output.

Despite its strengths, patent data has limitations as a measure of innovation output. Surveys suggest that managers do not patent most innovations, do not protect most innovation value with patents, and view patents as the least important method of protecting innovations.[11] The fact that most innovations are not patented would not be an issue for inference if economic forces similarly affected patented and unpatented innovation. Unfortunately, this is unlikely to be the case. Because patenting requires public disclosure, a manager's decision to patent an innovation partially reflects their choice to publicly disclose the existence and nature of the innovation in exchange for the legal protections conferred by the patent. Consequently, economic forces that affect disclosure incentives will cause a substitution between patenting and other methods of protecting innovations, potentially contaminating inferences.

Even though disclosure incentives can affect patenting rates independently of changes in real innovation levels, we do not wish to discourage researchers from using patents to measure innovation. Researchers concerned about biases from examining patents as a measure of innovation can potentially triangulate their analyses by also examining other measures of innovation that do not share the same biases (e.g., R&D expense). Moreover, patenting rates are inherently interesting because patents serve an economically significant role in the economy. Understanding what drives the choice between patents and other methods of protecting innovations

[10] Patent data includes the identity of the lead inventor and their invention team; inventors' home addresses; the current and past owners of the patent (the assignees); the legal claims of the patent; detailed descriptions of the innovation; citations to prior art made by the patent (backward citations); citations received by the patent from subsequent art (forward citations); whether backward and forward citations were added by the examiner or the applicant; the filing, disclosure, and grant date of the patent; the applicant's legal representative, if any; USPTO-assigned technological groups which are analogous to industry classifications (art units, patent classes, and patent subclasses); the identity of the patent examiner; the examination decisions, including rejection reasons, and how the applicant responded to those decisions (office actions); and details of patent infringement litigation.

[11] Arundel and Kabla (1998), Cohen et al. (2000), Arundel (2001), Jankowski (2012), Mezzanotti and Simcoe (2023).

is important to research and public policy, for example because a goal of the patent system is to create public disclosure of innovation.

An important consideration with using patent data is whether and how to control for R&D expenditures. Because R&D expenditures are investments in innovation, controlling for R&D expenditures shifts analyses of patent outcomes towards investment efficiency tests rather than tests of the level of innovation. If researchers are interested in exploring investment efficiency, they need to decide whether to control for the stock or flow of R&D. Given that patent outcomes likely result from R&D expenditures over several years, in most cases it is probably best to control for estimated R&D stocks or for several lags of R&D expenditures. On the other hand, researchers interested in the overall level of innovation or who are directly interested in patents themselves should probably not control for R&D expenditures or stocks.

Beyond using the patent itself, researchers often use citation data from subsequent patents to measure patent impact and trace knowledge flows. While citation data is a convenient way to link a given patent to follow-on innovation, it raises its own issues. Overall citation counts include self-citations so researchers should exclude self-citations or examine them separately if their research question focuses on knowledge spillovers. In addition, applicants may strategically omit relevant citations to avoid ceding legal rights to prior work and may include citations to less relevant patents to disguise this behavior (Schuster and Valentine, 2022). Patent examiners perform a detailed independent search of the related art and add relevant citations omitted by the applicant, intentionally or otherwise. Consequently, researchers can separately examining applicant and examiner added citations to investigate strategic citation behavior. However, the prior art is vast, and examiners may miss relevant prior work. Researchers interested in using citations to measure knowledge flows but concerned about strategic citation behavior can use the textual similarity of patents as an alternative measure of relatedness and follow-on innovation.

Another limitation of patents and citations as measures of innovation is that they do not capture the value of the innovation. Kogan et al. (2017) estimate patent values using stock price responses to patent grant announcements. The Kogan et al. (2017) measure is valuable, but limited because it only captures patent values for publicly traded firms and assumes that information about the innovation is primarily communicated at the grant date.

We conclude by briefly discussing technical issues with patent data. Patent data suffers from truncation bias because patents do not appear in patent databases until they are granted and the delay from filing date to grant date averages about three years (e.g., Hall et al., 2001).[12] A related issue is that the time between R&D investment and developing a patentable innovation and between patent filings and grants is typically several years. Consequently, researchers should think carefully about the expected delay between investment and resulting patent filings and grants when developing tests and interpreting results (e.g., immediate increases in patenting activity likely reflect substitution effects rather than real changes in innovation).[13]

Researchers should also carefully think about how to transform patent and citation data. Researchers commonly take the natural logarithm of patent filings or citations to address concerns about skew or because they expect proportional effects (i.e., they want their model to treat going

[12] Researchers typically address truncation bias in patent data by including year fixed effects in their models and by excluding the final three years of the patent database from their samples (e.g., if the database ends in 2010 they end their samples in 2007). To the extent that researchers do not expect their economic force of interest to correlate with patent examination periods or citing peers' examination periods, these approaches should mitigate truncation bias. Researchers especially concerned about truncation bias can also include industry-year or technology-year fixed effects in their models to control for differences in citation and patenting patterns across industries or technology classes over time. Lerner and Seru (2022) suggest that truncation bias can interact with changes in patenting activity across sectors to bias inferences even in the presence of time-varying fixed effects. They propose using machine learning to adjust citations and patent filings for these cross-sector, time-varying biases.

[13] Researchers must also decide whether to measure patenting activity on the filing date or the grant date. Given patent pendency periods average about three years, the file date is likely more appropriate in most research settings.

from 0 to 1 citation differently than going from 100 to 101 citations). Because patent filings and citations data typically take the value 0 for some observations and the natural logarithm of 0 is undefined, researchers often use the shifted natural logarithmic transformation (e.g., ln[1+citations]). An issue with using the shifted natural logarithmic transformation is that it is unclear how to interpret the resulting estimates. To provide a more interpretable estimate, researchers can instead use the inverse hyperbolic sine transformation (e.g., Burbidge et al., 1988), which is well defined for nonpositive values including zero. Alternatively, researchers can estimate a fixed-effects Poisson model.

2.3.3. Protection: Trade secrets

Based on survey responses, trade secrecy is one of the most, if not the most, prevalent methods of protecting innovation.[14] Trade secrets are generally defined as "information that derive future economic value from not being appropriable by competitors" (Glaeser, 2018b pp. 163-164).[15] Trade secrecy does not protect from reverse engineering or independent discovery, and hence provides less direct legal protection than patenting.[16] However, trade secrecy imposes lower proprietary costs because trade secrets do not require public disclosure. The lack of public disclosure of trade secrets means that their attributes and value are not observable directly. Consequently, and despite their economic importance, there is less research on trade secrets relative to patents.

[14] In the Census Bureau's 2020 Business Enterprise Research and Development Survey, which covers a broad sample of US firms, respondents were more likely to indicate trade secrecy was a "very important" method of intellectual property protection than any other method (e.g., 45% for trade secrecy vs. 25% for utility patents). https://ncses.nsf.gov/pubs/nsf23314/assets/data-tables/tables/nsf23314-tab068.pdf. First accessed May 3, 2023.

[15] Not all trade secrets are innovations. For example, a customer list is not an innovation, but can be a trade secret.

[16] Because trade secrecy offers less direct legal protection, patenting and secrecy are not perfect substitutes. For example, a firm is more likely to protect an innovation that is easily reverse engineered, and hence whose nature will inevitably be disclosed, with patenting than trade secrecy. Therefore, innovation characteristics are likely a first-order determinant of the choice between patenting and secrecy.

Because trade secrets are generally not directly observable, researchers have devised indirect methods to infer them. Some studies infer the presence of trade secrets using textual analysis of financial statements (e.g., Glaeser, 2018b). Others use firms' responses to academic or government surveys (e.g., Breuer et al., 2019). These studies argue that the existence, but not the details, of a commercialized trade secret is often common knowledge, and hence managers are willing to acknowledge the existence of their trade secrets in financial statements or survey responses.[17]

Given the importance of trade secrets, we call for creative research developing better measures of the prevalence, characteristics, and value of trade secrets. Admittedly, measurement is inherently challenging. However, accounting researchers have made considerable progress measuring other difficult to observe phenomena such as tax avoidance and earnings management, and we believe they may be able to do so for trade secrets. Moreover, managers indicate that disclosure incentives, which accountants understand well, heavily influence the choice between secrecy (e.g., Harabi, 1995). Ideally, new measures would permit disaggregation of distinct types of trade secrets to disentangle innovations from other trade secrets (e.g., disaggregating customer lists and computer code). Any new methods will be individually imperfect, but even moderate improvements on current methods could yield new insights and open new avenues of exploration given the fundamental role secrecy plays in the economy.

2.3.4. Disclosure: Narrative disclosures

[17] Relatedly, Glaeser et al. (2020) develop a measure of unpatented R&D using the residuals from a regression of R&D stocks on patenting levels under the argument that unpatented innovation are likely protected by trade secrecy. However, this measure comingles failed innovation, innovations permanently protected with trade secrecy, and in-process innovations that are currently protected with trade secrecy but that will be patented at a future date. Beneish et al. (2022) pair this measure with disclosures of acquired innovation in mergers and acquisitions in deals with no patents to infer the value of acquired trade secrets.

Firms also provide details of their innovations via narrative disclosures in the 10-K, conference calls, and, potentially, other venues. Researchers identify these narrative disclosures via textual analysis; most commonly with the "bag of words approach" (see, e.g., Merkley, 2014). Prior research suggests that firms disclose valuable information via voluntary narrative disclosure and, surprisingly given these disclosures are largely voluntary, some of this information is proprietary. The strength of narrative R&D disclosure as a measure of innovation disclosure is its ubiquity and the ability to compare across all firms that use a given disclosure medium.

The weaknesses of narrative R&D disclosures as measures of innovation disclosure include potential bias introduced by their largely voluntary nature and the difficulty ascertaining what exactly was disclosed. Controls can address some potential sources of bias (e.g., manager fixed effects can address bias due to fixed differences in managers' propensities to voluntarily disclose innovation information). However, difficulty ascertaining the nature of the disclosed innovation can make it difficult to draw specific inferences. Subsequent research can likely use more updated or nuanced textual analysis methods to draw sharper inferences from narrative disclosure.

2.3.5. Disclosure: Scientific publications

Like patents, scientific publications are an important output of the innovation process. Unlike patents, scientific publications do not provide excludability, but like patents scientific publications signal the existence of new knowledge. Scientific publications plausibly create even greater knowledge spillovers than do patents, particularly because scientific publications are more likely to result from fundamental research (the R in R&D; Arora et al., 2021).

Given the externalities of scientific publications, a natural question is why public firms allow their scientists to author them. One explanation is that publishing provides private-firm scientists access to academic and government scientific knowledge via co-authorships and other relationships. Another explanation is that scientists have a taste for science and/or a desire to signal their ability, and as a result accept a compensating wage differential for the ability to publish. A final non-mutually exclusive explanation is that firms protect any privately useful innovations revealed in a scientific publication (e.g., with patents). In total, scientific publications are an intriguing, potentially counter intuitive, but important innovation disclosure choice.

2.3.6. Implementation

Measures of the implementation of innovation are less standardized and tend to rely on either indirect outcomes that are difficult to link to specific innovations or on outcomes that reflect a narrow commercialization decision. Firms can implement innovations internally, externally, or a mix of both.

Firms internally implementing innovations invest in new processes, products, methods, and platforms. Many of these investments appear as general changes in accounting expenses and profits, making it difficult to link the investments to specific innovations. To overcome these issues, some existing literature uses trademarks and product press releases to measure implemented innovations (e.g., Hsu et al., 2022), but these measures do not always reflect innovation (e.g., "Just Do It" is trademarked but is a slogan and not an innovation). Trademark and product press release measures also do not capture innovations that are not directly embedded in products (e.g., process innovations). Consequently, researchers using trademarks and product press releases to measure implemented innovations need to carefully navigate potential measurement error.

To measure externally implemented innovations, researchers can sometimes use innovation royalty agreements or patent sales. Since firms do not license of sell all innovations, royalty agreements and patent sales only capture a specific subset of implemented innovations.

However, royalty agreements and patent sales are an important method of sharing innovations between firms and are therefore important despite the inability to generalize.

Strategic alliances are another important method of implementing innovations. Strategic alliances are inter-company arrangements to undertake a mutually beneficial project while retaining independence.[18] Firms form alliances for many reasons, including sharing capital and risk; gaining access to one another's innovations, business knowledge, and innovation capabilities; and jointly developing technologies and standards (e.g., Bluetooth). Alliances create diversification, coordination, and information-sharing benefits, but also expose partners to adverse selection and moral hazard. However, not all strategic alliances relate to innovation (e.g., Starbucks and Barnes and Noble collocating storefronts is not an innovation).

A large literature outside of accounting studies strategic alliances (e.g., Tjemkes et al., 2023), but few studies within accounting do so. The lack of accounting studies on strategic alliances is surprising given the information and contracting concerns inherit to strategic alliances and the potential importance of accounting information in navigating these concerns. Alliances are particularly important because many new breakthroughs combine existing knowledge, ideas, and innovations (Jones 2023), and alliances can allow firms to achieve those breakthroughs when different parties hold the necessary existing knowledge, ideas, and innovations.

Overall, it is difficult to directly measure the implementation of specific innovations. Researchers have linked innovation investment to subsequent implementation outcomes such as profits or market valuations, but these links do not directly measure innovation implementation. Consequently, measuring implemented innovation in a generalizable manner is difficult.

[18] Alliances can take many forms: joint ventures in which parent companies form a jointly owned subsidiary; equity alliances in which one firm invests in another; and non-equity alliances in which the alliance partners contract without equity stakes. See also Standard Setting Organizations (Section 3.1.2.3), Research and Development Financing Organizations (footnote 45), and patent pools.

Nonetheless, measures such as royalty agreements and strategic alliances are important and interesting even if the inferences drawn from them cannot generalize beyond the specific setting of the measure.

2.3.7. Sources of plausibly exogenous variation

In addition to direct measures, some papers use plausibly exogenous variation in innovation incentives to infer the causal effects of innovation. We discuss five sources of variation that have attracted significant attention in the literature: the Inevitable Disclosure Doctrine (IDD), the Uniform Trade Secrets Act (UTSA), the American Inventors Protection Act (AIPA), R&D tax credits, and innovation boxes. As Figure 3 illustrates, all these sources of plausibly exogenous variation likely affect both the incentives to invest in, and the protection/disclosure of, innovation.

2.3.7.1. Inevitable Disclosure Doctrine and Uniform Trade Secrets Act

Some studies use the IDD or UTSA as sources of plausibly exogenous variation in trade secrecy. The IDD is a legal doctrine recognized by state judiciaries that assumes that it is inevitable that a firms' workers will reveal secrets to subsequent employers. This assumed inevitability of misappropriation allows courts to enforce contractual limits on worker mobility without requiring evidence of actual misappropriation. Consequently, the IDD encourages trade secrecy by reducing the ability of employees to misappropriate trade secrets by taking them to competitors. The UTSA is a law passed by state legislatures that the Uniform Law Commission designed to standardize the definition and enforcement of trade secrets across states. In the process, the UTSA increased the legal protections afforded trade secrecy and reduced uncertainty over trade secret protections. Because the IDD and UTSA increased the protections afforded trade secrets, they are sources of variation in the value of existing trade secrets, the incentives to invest in trade secrets, and the incentives to protect innovations with trade secrecy over other means.

There are several important nuances with the IDD and UTSA. First, because they are adopted at the state level, they affect firms based on the location of their knowledge workers, which is often difficult to ascertain. Most research assumes that the IDD and UTSA affect firms based on their headquarters state, which is a reasonable approximation because top executives work at headquarters and because firms have strong incentives to operate R&D facilities in their headquarters state (Glaeser et al., 2022a).[19]

Another nuance with using the UTSA and IDD as sources of variation in trade secrecy is that they do not capture the magnitude of any change in trade secrecy. The UTSA and IDD only directly identify the directional effect of trade secrecy on outcomes and provide limited insights into the economic magnitude of the effects of trade secrecy. Moreover, the UTSA and IDD do not identify whether changes in outcomes are due to increases in the value of existing trade secrets, new investments in trade secrets, or the decision to protect innovation with secrecy over other means. Despite these limitations, the effect of the UTSA and IDD can generate important insights given our limited understanding of the effects of trade secrecy.

2.3.7.2. American Inventors Protection Act

Another plausibly exogenous source of variation is the 1999 AIPA, which accelerated USPTO dissemination of some patent information and lowered information processing costs for some patents. The AIPA imposes requirements on the approximately half of patent applications filed with the USPTO and with a foreign patent office for the same innovation (twin applications). The AIPA requires disclosure of twin applications within 18 months after the earlier of the US or foreign filing date. Because foreign patent offices typically require disclosure within 18 months of

[19] Some studies use the firms' headquarters location as recorded in Compustat, which is a static header variable that is retroactively applied to all firm-year observations and ignores headquarters location changes. To address this issue, Joshua Lee compiles dynamic headquarter location data from 10-K filings (Jennings et al., 2017, 2020). https://joshualeeacct.wixsite.com/joshualee/data

filing, the AIPA accelerates the USPTO *dissemination* of information in twin applications. If the foreign application is written in a language other than English, the AIPA also accelerates the English translation of the application.[20] This dissemination and translation could significantly lower information processing costs, particularly prior to the advent of global patent databases.

For the approximately half of applications without a parallel foreign filing, the AIPA does not impose any requirements. Instead, the AIPA sets the default disclosure date to 18 months, but in practice many applicants opt to delay disclosure, especially public firm applicants. Further, many applicants with or without a parallel foreign filing choose to voluntarily disclose their applications prior to 18 months to provide notice to competitors, capital markets, or other interested parties. For applicants that voluntarily accelerate or delay their disclosure, the AIPA has no effect. In total, the mandate of the AIPA is more nuanced than requiring prompter disclosure. The AIPA is binding for applicants that would otherwise not have disclosed voluntarily prior to the deadline and that filed internationally, and for these applicants the AIPA disseminates information that was otherwise available internationally.[21]

The existing literature makes a variety of design choices in assessing the effect of the AIPA, and these choices limit comparability. Going forward, the literature would benefit from standardizing design choices to the extent possible. Given the complex and nuanced effects of the AIPA, we suggest the approach outlined in Kim and Valentine (2021) as a useful starting place if interested in firm-level effects (see also Hegde et al., 2022 who examine applications with a parallel foreign filing to draw inferences at the patent application-level). Further, researchers can

[20] For reference, the European Patent Office permits applications in English, German, or French and the Japan Patent Office requires applications in Japanese.

[21] The AIPA could also trigger the release of information in failed applications not filed abroad for which the applicant did not opt out of the 18-month disclosure. However, the materiality of that information is likely small as the applicant did not view it as important enough to opt out of the default disclosure, the applicant did not file for protection abroad, and, most notably, the application did not warrant a patent grant (e.g., because the USPTO rejected it for lack of novelty or insufficient disclosure).

use nuances in the application of the AIPA to provide more textured inferences (e.g., by separating the effect of prompter dissemination from the effect of lower disclosure processing costs).

2.3.7.3. R&D tax credits and innovation boxes

R&D tax credits encourage investment in innovation by reducing the after-tax cost of R&D (see Section 3.4.2.1), although as Figure 3 highlights R&D tax credits may also affect how firms protect their innovations (e.g., if tax authorities are more likely to allow credits for investments that result in patents). Chirinko and Wilson (2008), Kim (2010), and Bloom et al. (2013) provide evidence that state-level R&D tax credits are plausibly exogenous with respect to many outcomes, outside of their effect on R&D investment. However, Kim (2010) and Miller and Richard (2010) find evidence that states endogenously enacted R&D tax credits in response to declining state tax revenues. Further, prior work suggests that changes in R&D tax credits were often part of larger corporate and personal tax reforms (Miller and Richard, 2010), and that state corporate and personal income taxes also affect firms' R&D spending (Ljungqvist et al., 2017 and Armstrong et al., 2019). To address these potential sources of bias, Glaeser (2018a) suggests controlling for firms' effective tax rates and other state taxes (e.g., personal income taxes on top managers, corporate income taxes, and non-R&D tax credits); state economic conditions (e.g., state budget balances, changes in state gross domestic balances); and firm performance (e.g., return on assets, equity market returns).

States implement R&D tax credits in diverse ways. For example, some states recapture (tax) R&D credits, reducing the effective credit rate by the state corporate income tax rate, and some states calculate the credit base on a rolling basis, such that a credit applied today reduces future opportunities to claim a credit. States also differ in terms of eligibility requirements. Consequently, researchers should carefully match the empirical approach to the unique characteristics of a particular state's implementation. Many researchers use the highest tier *effective* R&D tax credit rate to account for these differences in credit design (see, e.g., Wilson, 2009 for a calculation).[22]

Researchers must also determine where to assume state R&D tax credits affect multi-state firms. One approach is to use the distribution of firms' inventors across states as disclosed in patent documents to estimate the geographic distribution of a firm's R&D activities and assume that the effect of R&D tax credits is proportional to the pre-existing level of patenting inventors across states. An alternative is to use the R&D credit in the firms' headquarters state because, as noted above, firms have a strong incentive to locate knowledge workers in their headquarters state (Glaeser et al., 2022a). We recommend using the headquarters state as a baseline approach because doing so does not introduce the endogeneity of patenting inventor location decisions (the headquarters location is likely more exogenous to state R&D tax credits).

A final consideration is whether to use R&D tax credits as an instrument for R&D spending or in the reduced form, essentially as a continuous treatment effect in a differences-in-differences regression.[23] Given the straightforward mapping from reduced form estimates to instrumental variable estimates discussed in Armstrong et al. (2022), we believe the reduced form approach is appropriate in most settings.

[22] Researchers can also incorporate variation in whether firms are eligible for the credit to further refine inferences (e.g., whether the firm has a taxable gain to offset with a credit). However, incorporating firm eligibility requires using endogenous variation in firm profitability, potentially contaminating estimates, and is also subject to measurement error as state-level eligibility data is unavailable for most firms. Consequently, we recommend using the effective credit rate, without considering eligibility, as a baseline approach.

[23] The benefit of using R&D tax credits as an instrument for R&D spending is that it allows the researcher to estimate the elasticity of outcomes to R&D spending. However, the price effects discussed in Section 2.3.1 will partially contaminate this elasticity. One could instead instrument for patenting outcomes rather than for R&D spending to measure "real" responses to the credit, but the endogeneity of the patenting decision would bias the resulting elasticities. Using R&D tax credits in the reduced firm circumvents these issues, at the potential expense of estimating a potentially less interesting treatment effect (e.g., by estimating the effect of the credits themselves, rather than of R&D investment).

While R&D tax credits reward front-end investments in innovation, innovation boxes reward back-end innovation success by applying a lower tax rate to income from qualifying innovations (see Section 3.4.2.2). Back-end rewards encourage investment by increasing expected after-tax payoffs. Some innovation boxes apply solely to patent income, hence the colloquial name "patent boxes." These innovation boxes almost certainly affect how firms protect their innovation (in the case of patent boxes by encouraging firms to use patents to protect their innovation). However, compared to state R&D tax credits we know less about why countries implement innovation boxes, raising concerns about sources of potential endogeneity. Consequently, more work is needed to assess the validity of innovation boxes as potential sources of plausibly exogenous variation.

We conclude our discussion of R&D tax credits and innovation boxes with two notes of caution. First, as with most sources of plausibly exogenous variation, tax incentives affect behavior on the margin, which may limit generalizability.[24] Second, tax incentives may cause spillovers between firms, for example because a firm benefiting from a state tax credit poaches inventors from firms in neighboring states. These spillovers can violate the Stable Unit Treatment Value Assumption (SUTVA; see Glaeser and Guay, 2017 for a discussion). Consequently, researchers using innovation boxes and R&D tax credits as sources of plausibly exogenous variation should discuss the generalizability of their results and model potential spillovers that would otherwise violate SUTVA.

3. Review of accounting literatures on innovation

[24] For example, the marginal investment motivated by R&D tax credits likely has a lower expected return than the average investment, as managers typically undertake their best investment opportunities first. This means that the effect of R&D stimulated by R&D tax credits will not generalize to the average effect (the Local Average Treatment Effect [LATE] issue; see Armstrong et al., 2022 for discussions of the LATE issue by accounting researchers).

3.1. Disclosure and innovation

3.1.1. Patent disclosures and innovation

The patent system is built on a "grand bargain" (e.g., *Eldred v. Ashcroft,* 537 U.S. 186, 216 (2003)). The system grants inventors partial excludability in the form of legal protections to their claimed innovation in exchange for disclosure of the workings of their innovation so that others can nonrivalrously build on it.[25] The USPTO makes the patent disclosure publicly available and requires that it be sufficiently detailed such that someone skilled in the relevant area could recreate the innovation independently of the original inventor (35 USC § 112(a)). This disclosure is meant to spur progress by providing enabling knowledge to other inventors and helping them avoid costly duplication of research efforts. Unlike many financial reporting spillovers that are an unintended consequence of disclosure mandates, knowledge spillovers are an intended consequence of the patent disclosure mandate. The USPTO enforces the disclosure requirement via the patent examination process.

Patent examiners enforce disclosure requirements because patent disclosures impose proprietary costs on the assignee by helping potential competitors invent around the patent or leapfrog the patented innovation in quality. The proprietary costs of disclosure due to the partial excludability of patents are likely familiar to accounting researchers (e.g., Verrecchia, 1983). However, prior literature outside of accounting provides "little empirical evidence as to the extent of [patent] disclosure and its economic impacts" and argues that any patent "disclosure effects are likely to be small" (Hall and Harhoff, 2012, p. 549).

[25] The patent system protects the embodiment (tangible form) of the innovation but not the underlying idea. By requiring public disclosure of the innovation, others can build on the underlying idea if their implementation does not violate the embodiment outlined in the original patent.

Given the centrality of disclosure to the patent system, understanding the role of disclosure is important in assessing the overall design of the patent system. While the patent system also incentivizes investments in innovation by promising valuable legal rights in the event these investments are successful, these rights create deadweight losses due to monopoly pricing and litigation (Kim et al., 2022). Consequently, if the sole goal of the patent system is to incentivize investments in innovation, then alternative mechanisms, such as explicit fiscal incentives, are potentially more efficient because they do not impose the same deadweight losses (Budish et al., 2016). Therefore, understanding whether knowledge spillovers from patent disclosures spur follow-on innovation is important to evaluating the design of the patent system. It is also important to understand whether any follow-on innovation justifies the proprietary costs of patent disclosure to the assignee.

3.1.1.1. Effect of patent disclosure on other inventors' follow-on innovation

Despite the centrality of disclosure to the design of the patent system, until recently relatively few studies examined patent disclosure. One explanation for the dearth of research on patent disclosure is the difficulty empirically separating the effect of patent disclosure from the effect of underlying patent economics. For example, patents with more detailed disclosure could associate with more follow-on innovation because more innovative patents endogenously lead innovation waves and necessitate more detailed explanations. This difficulty is analogous to the difficulty causally linking financial disclosure characteristics to market outcomes.

Accounting researchers have used their expertise addressing the endogeneity of financial disclosures to address the endogeneity of patent disclosures. Kim and Valentine (2021) and Hegde et al. (2022) use different features of the AIPA as sources of plausibly exogenous variation in patent disclosure timing. Kim and Valentine (2021) use firm-level variation in competitors' pre-

AIPA patent disclosure delays and find that prompter peer disclosure causes firms to invest more in R&D and produce more innovation. Hegde et al. (2022) use application-level variation in twin applications filed with both with the European Patent Office (EPO) and the USPTO for the same innovation. Consistent with USPTO dissemination increasing follow-on innovation, Hegde et al. (2022) find that USPTO twin applications receive relatively more citations than their EPO counterparts after the AIPA, and in particular when the EPO patent disclosure is not in English.

The evidence in Hegde et al. (2022) and Kim and Valentine (2021) suggests that the timing of patent disclosure affects follow-on innovation. However, the evidence does not speak to which parts of the patent disclosure, which includes the legal claims, invention description, and various administrative details, affect follow-on innovation. Dyer et al. (2020) fill this gap by examining the effect of the invention description portion of the patent. They find that patents overseen by examiners who are lenient with respect to invention description disclosure requirements provide lower-quality disclosure, as captured by several measures developed in the prior accounting literature (e.g., Li, 2008; Guay et al., 2016). Moreover, they find that patents overseen by disclosure-lenient examiners produce significantly fewer follow-on innovations, consistent with invention disclosures in particular spurring follow-on innovation.

3.1.1.2. Effect of patent disclosure on disclosing innovators' incentives to innovate

While required patent disclosure spurs follow-on innovation, disclosure requirements potentially decrease disclosing innovators' incentives to innovate by reducing the excludability of the knowledge associated with their innovation. Consequently, disclosure requirements that make patent disclosure more timely, detailed, or accessible can reduce focal firm innovation due to proprietary costs of disclosure. For example, Kim and Valentine (2021) find that firms forced to disclose more promptly by the AIPA decreased R&D investment and produced less innovation.[26]

3.1.1.3. Patent disclosure and equity markets

While patent disclosures were not designed with equity markets in mind, several studies find that patent disclosures affect equity market outcomes by providing information about novel innovations. Hegde et al. (2018) and Beyhaghi et al. (2022) find that prompter patent disclosure caused by the AIPA improves the speed of stock price discovery and accuracy of analysts' forecasts. Further, Martens (2021) uses individuals' proximities to patent libraries to provide evidence that retail investors trade on patent filings.

Related to the question of whether patent disclosures provide information to equity market participants is the question of whether firms use information from equity market participants to inform their own innovation activity. Ahci et al. (2022) document evidence that managers learn less from the stock price response to their innovations when the response reflects multiple signals due to the USPTO simultaneously granting more patents to the firm on the same day. Consistent with analyst coverage also affecting innovation information flows, Martens and Sextroh (2021) find that a firm is more likely to cite another firm's patents if they are covered by the same analyst and Canace et al. (2023) find that a reduction in the ability to privately communicate innovation information to analysts causes managers to innovate less (see also Palmon and Yezegel, 2012 who find that analysts provide more informative forecasts for R&D intensive firms).

[26] Chen and He (2021) also examine the effect of the AIPA on the overall level of firms' R&D investment. They measure the relative effect of the AIPA using the number of disclosed applications post-AIPA while controlling for granted or pending applications, implicitly assuming that no applicants disclosed prior to grant in the pre-AIPA period. They find that firms presumably more affected by the AIPA invest more in R&D. Chen and He (2021) argue that positive effect of the AIPA on R&D investment occurs because the AIPA credibly reveals information about R&D payoffs, reducing market-induced managerial myopia and underinvestment. While the results in Chen and He (2021) appear to run counter to the results in Kim and Valentine (2021), it is less clear how to interpret the result in Chen and He (2021) in terms of focal vs. other-firm innovation because Chen and He (2021) do not model spillovers between firms.

3.1.1.4. Manager incentives to disclose patent information

The preceding suggests that patent disclosure affects follow-on innovation and equity market outcomes. However, managers can avoid patent disclosure by protecting their innovations with trade secrecy and, if they do patent their innovations, can exercise discretion over the timing and quality of their patent disclosures. In deciding when and how to disclose patent information, managers face important tradeoffs familiar to accounting researchers. On the one hand, managers may disclose via patenting to satisfy equity market participants' and other stakeholders' demand for information about novel innovations. On the other hand, managers may withhold disclosure to avoid the proprietary costs of disclosing information about partially excludable innovations.

Managers are more willing to bear proprietary costs of innovation disclosure when their horizons are shorter and when they have an incentive to release good news. Managers voluntarily release patent disclosures prior to "bad news" earnings announcements to dampen the stock market reaction to the earnings announcement (Lansford, 2006). To credibly and immediately reveal innovation success to equity markets, short horizon managers rely more on patenting than secrecy (Glaeser et al., 2020). Consistent with investors recognizing managers' incentives, investors discount unpatented R&D to a greater degree when the manager's horizon is shorter. Theoretically, the option to disclose innovation information ambiguously affects short horizon managers' incentives to explore (Chen et al., 2023a).

Several studies argue that competition, in addition to manager horizon, affects the manager's decision to disclose innovation. Glaeser and Landsman (2021) test the predictions of the model of Hughes and Pae (2015) by examining managers' decisions to publish their patent applications. They find that technological competition, defined as competition for novel ideas, causes firms to delay their patent disclosures to avoid revealing proprietary information to technological competitors. However, product market competition, defined as competition for users or consumer spending, causes firms to accelerate their patent disclosures to deter product market competitors by signaling their efficiency or product advantages. Valentine et al. (2023) find that the America Invents Act, which increased technological competition, caused laggards in technological competition to concentrate their patent activities in fewer technology areas and produce more scientific publications to pre-empt competitors' patent filings.

Armstrong et al. (2020) examine how the inventor's incentives, as opposed to the manager's or the firm's incentives, affect patent disclosure decisions. They examine the ruling in *Alcatel v. Brown*, which shifted the assignment of intellectual property rights from inventors to their employers and reduced the risk that inventors would misappropriate innovations. Using a within firm-year difference-in-differences design, they find that affected inventors were less likely to switch employers and employers accelerated affected inventors' USPTO patent disclosures.

3.1.1.5. Patent disclosure challenges and opportunities

Researchers have made progress examining the causes and consequences of patent disclosure. Despite this progress, we know little about the descriptive content of innovation disclosures. For example, who writes the invention description portion of patents, who makes the ultimate disclosure decision, and who decides to protect a given innovation with a patent instead of secrecy or some other means? Our understanding based on discussions with industry professionals is that firms differ in the extent to which individual scientists, managers, and patent lawyers affect patent disclosures.[27] We call for research identifying the relative importance of different decision makers in the innovation process, particularly when it comes to disclosure

[27] Existing research finds that executive incentives affect patenting and disclosure decisions, suggesting that executives influence the process either directly, or indirectly by setting incentives and communicating preferences.

choices, and how their incentives affect outcomes. This research would be particularly timely given the rise of accounting research on individual decision makers (Hanlon et al., 2022).

Many other questions about patent disclosure remain, despite the evidence that patent disclosure fosters follow-on innovation. Do patent applicants strategically under-disclose the details of their innovation in the invention description portion of the patent and over-claim their legal rights in the claim section of the innovation? When, why, how, and who? How widespread and successful is the practice of strategic patent drafting, in which applicants strategically draft their applications to target Art Units that are more lenient with respect to granting patents and approving claims?[28] When, why, how, and which applicants? Do applicants' strategic disclosure choices affect capital market or innovation outcomes (e.g., Schuster and Valentine, 2022 find that burying relevant citations with less relevant ones positively associates with patent grant probabilities)? In addition to potentially improving strategic patent drafting, how has artificial intelligence (AI) changed the patent disclosure process?[29] Accounting researchers are well suited to answer these questions given their focus on disclosure incentives and spillovers. Further, the tools for understanding patent disclosure likely overlap substantially with those developed to examine firm-level disclosure choices more generally.[30]

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[28] Lexis Nexis advertises its patent analytics tools by stating, "The language, terminology and framing used in drafting an application all influence which art unit the USPTO will choose as the best fit for evaluating the application. Before filing, using patent analytics tools, patent practitioners can analyze portions of their application drafts using the LexisNexis PathWays™ tool to determine which art units are likely to be assigned to the application. PatentAdvisor analytics also communicate which of those art units provide users with the best opportunity to receive a statistically favorable examiner. If a user's draft is more likely to be assigned to a difficult group of examiners, PatentAdvisor can suggest the language that should be included and omitted from the document draft to help guide it to an art unit with a more favorable composition of examiners." https://www.lexisnexisip.com/knowledge-center/strategic-drafting-with-patent-analytics-tools/ (accessed May 30, 2022).

[29] For example, cloem (http://www.cloem.com/; access May 1, 2023) uses AI to create tens of thousands of claims and statements of invention using permutated and synonymized patent disclosures in order to create prior art to protect the "white space" around a patent (or prevent competitors from patenting the white space around their own patents).

[30] A potential concern is whether these types of questions fall outside the purview of accounting research. However, innovation disclosure has a natural and significant role in understanding firms' disclosure choices and information environment and likely interacts importantly with disclosure mandated by the financial reporting system.

Another opportunity is examining perhaps the most important and fundamental disclosure choice made by innovators: the choice between secrecy and patenting. Relatively few studies examine the choice between patenting and secrecy, likely due to the inherent difficulty measuring the value and distribution of trade secrets and in identifying individual innovations for which the choice exists between patenting and secrecy (exceptions being Glaeser, 2018b; Breuer et al., 2019; and Glaeser et al., 2020). To move forward, the literature needs to further open the black box of trade secrecy. We call for improved measures of trade secrecy and deeper investigation into the determinants and consequences of secrecy, particularly from the perspective of secrecy as a disclosure choice.

We also call for research documenting how disclosure processing costs affect the relation between patent disclosures and follow-on innovation (Blankespoor et al., 2020). Many innovations are combinations of existing ideas, and these combinations may be the key to how innovation drives growth despite diminishing marginal returns (Jones, 2023). However, there are functionally infinitely many combinations of existing ideas, such that the main constraint on our ability to grow may be our ability to process these potential combinations (Romer, 1993). This raises the question of whether disclosure processing costs affect how innovators process patent disclosures, and innovation disclosure more broadly. Moreover, how will artificial intelligence tools affect innovation disclosure processing?

Related to the question of how innovators process patent disclosures and the choice between patenting and secrecy, is the opportunity to integrate disclosure into the models of innovation and economic growth (e.g., Romer, 1990; Jones, 2023). As noted earlier, traditional models of innovation and growth do not model disclosure. Instead, these models assume that as soon as an inventor discovers an innovation, that innovation enters the knowledge stock. However, in the real world, innovations do not enter the knowledge stock and generate knowledge spillovers until they are disclosed. Integrating disclosure into models of economic growth can reveal important tradeoffs in the design of institutions designed to incent innovation. Integrating disclosure into these models can also highlight key economic parameters of interest (e.g., the relative degree of knowledge spillovers between patenting and secrecy, and the average length of time for which innovators can expect to protect an innovation via secrecy).

Researchers can also examine whether patent disclosures disseminate green innovations. Dissemination of green innovation is particularly important because green innovations are unlikely to materially impact aggregate environmental outcomes absent widespread adoption beyond the borders of a single firm (e.g., an innovation that reduces greenhouse gas emissions is unlikely to materially affect aggregate emissions if it only benefits a single firm). Finally, given the importance of understanding the effects of green innovation, can accounting researchers improve the measurement of green innovation using textual analysis or other methods?

3.1.2. Non-patent disclosures

Several studies examine how innovative firms use non-patent disclosure to communicate or withhold innovation information from external parties. The novelty and partial excludability of innovations creates uncertainty about their value, which results in information asymmetry among investors and between managers and investors. Managers often respond to information asymmetry by providing more disclosure, but in the context of innovation partial excludability creates potentially large proprietary disclosure costs. Consequently, whether innovation increases or decreases a given type of voluntary disclosure depends on the degree to which: (1) the disclosure provides useful information about how the innovation will affect firm value, (2) outsiders demand information about the innovation and managers internalize outsiders' demand, and (3) the disclosure imposes proprietary costs due to partial excludability.

3.1.2.1. Innovation and management earnings forecasts

Manager earnings forecasts likely carry relatively low proprietary costs with respect to innovations because they do not reveal detailed information about specific innovations. Knowing whether future earnings will be higher or lower than expected is unlikely to provide competitors with information that allows them to misappropriate or invent around an innovation. At the same time, earnings forecasts provide information to investors on future profitability and therefore the potential value of undisclosed innovations. Consequently, earnings forecasts may be an attractive way for managers to provide investors the necessary information to value the firm while limiting proprietary costs. Consistent with these arguments, firms provide more management earnings forecasts when relying on trade secrecy or patents to protect their innovations (Glaeser, 2018b; Huang et al., 2021), although short-term forecasts drive this increase (Dube, 2020).

3.1.2.2. Innovation and narrative in mandated disclosures

Narrative in mandated disclosure differs in important ways from management forecasts. On the one hand, managers may be able to tailor narrative disclosures to provide valuable information and limit disclosure of proprietary information. On the other hand, greater qualitative detail potentially increases the risk of revealing proprietary information about partially excludable innovations to competitors. Consequently, the relation between innovation and narrative in mandated disclosures is conceptually unclear *ex ante*.

Several studies in our review attempt to clarify the relation between innovation and narrative in mandated disclosures. Gu and Li (2003) and Jones (2007) examine small, hand-collected samples and find that innovative firms provide more narrative R&D information in their

10-Ks and conference calls. Merkley (2014) develops the most used large sample measure of narrative R&D disclosure and finds that narrative disclosures provide information to equity market participants. Follow-on papers find that firms with more patenting activity release more voluntary 8-Ks discussing patents (He and Lee, 2023) and that over-confident CEOs provide more narrative R&D disclosure (Rawson, 2021). Skinner and Valentine (2023) find that firms with green patents, which are those in technology classes that the International Patent Classification Committee designates as environmentally beneficial, provide relatively more narrative disclosure than do firms with non-green patents.

A significant challenge in interpreting the literature examining narrative disclosure is that firms with more R&D and patents likely differ systematically from other firms in ways that mean they have more information to disclose. One way to mitigate the issue is to examine sources of plausibly exogenous variation in disclosure incentives. Kim et al. (2021) use the staggered adoption of the IDD by US states as a source of variation in proprietary costs of disclosure and find that the IDD caused firms to provide less narrative R&D disclosure.

A related body of literature examines redactions from SEC-required filings. The SEC permits firms to redact "commercially sensitive information," which indicates the presence of significant proprietary costs. All else equal, the increase in proprietary costs associated with innovation should make firms more likely to redact information. Consistent with these arguments, Glaeser (2018b) finds that trade secrecy causes managers to redact information from their 10-Ks and that the overall effect of trade secrecy is an increase in information asymmetry (see also Kim et al., 2021). Similarly, Kankanhalli et al. (2021) find that firms involved in a material patent licensing agreement are more likely to redact information from licensing agreements that include more patents.

3.1.2.3. Innovation and other narrative disclosure

Beyond management forecasts and SEC filings, firms also provide innovation disclosure through other channels that can convey specific information about the nature and development of innovations. Baruffaldi et al. (2023) find that firms publish more articles in scientific journals following increases in information asymmetry, consistent with investor demand driving other narrative disclosure. However, Guo et al. (2004) and Cao et al. (2018) find that the risk of misappropriation by technological competitors due to partial excludability causes firms to withhold innovation-related product information. In contrast, Cao et al. (2022) find that the risk of misappropriation by technological competitors causes firms to provide more specific job postings, consistent with the need to attract workers outweighing any proprietary costs of job postings.

A related literature examines disclosure of clinical trial results for medical innovations. Beginning in 2007, the Food and Drug Administration Amendments Act (FDAAA) requires firms to disclose their phase II and phase III clinical trials on clinicaltrials.gov. Zhang (2020) finds that clinical trial disclosure by strong competitors deters rivals from competing in the same therapeutic area, while disclosure by weak competitors attracts rivals. Capkun et al. (2022) suggest that weak competitors respond to the proprietary costs of clinical trial disclosure by delaying disclosure beyond the mandated one-year deadline. Several studies focus on the effect of clinical trial disclosure on capital markets. Enache et al. (2022) find that the FDAAA caused biotechnology firms to voluntarily provide 10-K product disclosures while Bourveau et al. (2020) show that the FDAAA reduced pharmaceutical firms' bid-ask spreads.

Finally, several studies examine how membership in a Standard Setting Organization (SSO) affects member firms' disclosure.[31] Bushee et al. (2021) find SSO firms provide more

[31] SSOs are groups of competitors that jointly adopt a key technology, such as Bluetooth or Wi-Fi, and thereby ensure their products interoperate. SSO members often attempt to develop "standard essential patents," which the SSO

accurate earnings forecasts, which they argue is due to members sharing information, reducing the proprietary costs of disclosure. Consistent with SSO membership reducing proprietary costs, Chen et al. (2023b) find that members provide more narrative R&D disclosure in their 10-Ks. In contrast, Oh and Yeung (2021) find that SSO members provide less narrative R&D disclosure in their 10-Ks. Oh and Yeung (2021) attribute the differing results to data issues with Chen et al. (2023b). Oh and Yeung (2021) also find that members download each other's accounting disclosures from EDGAR, consistent with SSO members using accounting filings to monitor one another.

3.1.2.4. Non-patent disclosure challenges and opportunities

The literature explores firms' tradeoff between the proprietary costs of disclosing information about partially excludable innovations and the desire to communicate the value of novel innovations to market participants. While the literature has made progress, a fundamental challenge is the many distinct types of disclosure that managers can use and the degree of substitutability and complementarity between them. Studying disclosure mediums in a piecemeal fashion likely obscures important interactions between different disclosures and paints an incomplete picture of the overall information environment. Examining broad measures of the quality of the information environment, such as analyst forecast errors or bid-ask spreads, can help, but these measures comingle the direct uncertainty and information asymmetry effects of an innovation with any disclosure effects.

While challenging, we call for research that takes a more comprehensive approach to examining innovators' non-patent disclosure choices. How does innovation disclosure interact

designates as essential to the technology, and which SSO members must license for a royalty. The prospect of lucrative patent royalties leads to strategic behavior, such as delaying patent filings until after joining the SSO. A managing company often runs the SSO, and this company can frequently access proprietary information about member firms. While managing companies are frequently third parties, they are also sometimes competitors that erect "Chinese walls" within the SSO to protect members' proprietary information.

with more traditional forms of disclosure? To what extent do innovators tailor disclosure for one group (e.g., investors or regulators) to avoid disclosure to another group (e.g., competitors)? We also note that the existing literature is largely limited to publicly traded firms. However, a great deal of innovation occurs outside of publicly traded firms (e.g., private firms, individuals, universities, foundations, and governments). The disclosure incentives of these parties often differ significantly from those of public firms. For example, nonprofit entities, such as governments, universities, and foundations, may *value* knowledge spillovers and ensuring that novel, nonrival information spreads as broadly as possible. Studying entities other than public firms may provide valuable insights into the diffusion of knowledge (Bloom et al., 2021).

The diffusion of knowledge related to green innovations may be particularly important from a societal perspective. This importance raises questions of whether ESG disclosures and reports accurately capture the value and nature of green innovation, help disseminate information about green innovation, or even discourage green innovation due to proprietary costs? Can accountants use ESG disclosures and reports, along with textual analysis of patent disclosures, to improve the measurement of green innovation (see, e.g., Skinner and Valentine, 2023)?

3.2. Financial reporting and innovation

Financial reporting systems struggle with the treatment of innovations because of novelty, nonrivalry, and partial excludability. The novelty of innovations means that they have no comparable asset and hence are difficult to accurately value or audit (Godfrey and Hamilton, 2005). The partial excludability of innovations makes firms hesitant to disclose detail about them because of proprietary costs. The nonrivalry of innovations, particularly paired with their partial excludability, means that the firm does not fully control them, which is typically a prerequisite for asset recognition. Exacerbating these issues, developing, and commercializing novel, and partially excludable assets is risky because of the high chance of failure or misappropriation.

3.2.1. Financial reporting of innovation

3.2.1.1. Innovation, risk, and future returns

In 1974, the FASB released SFAS No. 2, "Accounting for Research of Development Costs," which required immediate expensing of R&D. The FASB argued that prior research "generally failed to find a significant correlation between research and development expenditures and increased future benefits as measured by subsequent sales, earnings, or share of industry sales." Motivated by the FASB's arguments, several studies document evidence that R&D positively relates to market valuations and profits,[32] which is perhaps unsurprising as managers should on-average invest in projects they expect to yield profits and increase firm value.

The FASB also justified expensing of R&D by noting "uncertainty about future benefits of" R&D. In response, researchers examined the risk of R&D. Surprisingly given the uncertainty of developing novel innovations and the partial excludability of successful innovation, these researchers found mixed evidence.[33] Research generally suggests that higher R&D stocks earn higher subsequent returns[34], although this literature is also mixed (e.g., Donelson and Resutek, 2012; Curtis et al., 2020) and it is unclear whether the returns represent compensation for risk or mispricing. There is also some evidence that smaller firms and firms with more interconnected innovation earn higher returns (Lee et al., 2019; Stoffman et al., 2022; and Tseng, 2022).

One explanation for the different correlations between innovation and risk and returns documented by prior studies is that these studies do not base their tests on the unique characteristics

[32] E.g., Sougiannis (1994), Lev and Sougiannis, (1996), Kimbrough (2007), and Xu et al. (2007).
[33] Kothari et al. (2002) and Chambers et al. (2002) find that R&D expenditures positively relates to earnings variability, while Brown and Kimbrough (2011) find that R&D negatively relates to earnings systematic variability.
[34] E.g., Lev and Sougiannis (1999), Chan et al. (2001), Chambers et al. (2002), and Lev et al. (2005).

of innovation and the development cycle of innovation. It seems unlikely that investments in innovation are initially a priced risk. While developing novel assets is uncertain, the uncertainty should be largely idiosyncratic; whether a scientist or engineer succeeds in developing an innovation likely depends little on whether the market is up or down. It is after the scientist or engineer succeeds that their firm becomes exposed to systematic (priced) risk. To maximize returns from its nonrival innovation, the firm needs to commercialize the innovation quickly and broadly. This requires the firm to contract with third parties, raise capital, and form alliances, exposing it to market and misappropriation risk due to partial excludability. Even as it commercializes the innovation, the firm's technology likely spills over to other firms due to partial excludability, leading to correlated outcomes. Consequently, the relation between innovation and priced risk likely depends on the stage of the development cycle, the resources available to the firm, and the extent of spillovers associated with the innovation.

3.2.1.2. Capitalization of R&D

Related to the FASB's decision to disallow capitalization is the question of whether R&D capitalization provides information to capital markets. Expensing R&D potentially leaves "assets" off the balance sheet (Lev, 2008). However, it is not clear that leaving innovation assets off the balance sheet leads to a misallocation of resources (Skinner, 2008, a,b), in particular because doing so attracts information intermediaries such as analysts (Barth et al., 2001). Further, arbitrary capitalization and subsequent amortization could reduce financial statement informativeness given the difficulty making and auditing judgements for novel assets (Barker et al., 2022).

Empirical evidence on the information content of capitalized R&D is scarce given the limited contexts in which it has been permitted. However, there is evidence that R&D capitalization was informative when permitted in the UK (Oswald and Zarowin, 2007) and under

IFRS (Oswald et al., 2017), and simulations predict capitalization is informative (Healy et al., 2002). A related question is whether capitalization affects incentives to invest in R&D. Wasley and Linsmeier (1992) find that managers forced to expense R&D by SFAS No. 2 reduced R&D spending. Similarly, Oswald et al. (2021) find that UK firms required to capitalize development costs increased investment in R&D.

Relatedly, if capitalization were permitted, would managers use discretion to manipulate reported results? Wyatt (2005) finds that misreporting incentives did not appear to dominate truthful reporting in the Australian setting during a period when capitalization was largely unregulated. However, Canace et al. (2018) find that US firms reduce R&D expense near earnings thresholds and increase capital expenditures, consistent with earnings management via opportunistic capitalization (see, also, survey evidence in Canace et al., 2022).[35]

Overall, the literature suggests that R&D expenditures are risky but positively correlate with future performance. Further, R&D capitalization appears to provide information to markets. Misreporting does not appear to dominate truthful reporting overall, but managers may manipulate results when incentives are particularly strong. However, it is difficult to draw causal inference given challenges in developing a convincing counterfactual. An open question is why some managers choose not to capitalize when given the opportunity (Oswald et al., 2021), and whether there are any costs of capitalization. For example, are there proprietary costs to capitalization (note that some models predict that capitalization can provide proprietary benefits by allowing managers to credibly signal advantages to competitors; De Waegenaere et al., 2017).

3.2.2. Financial reporting and innovation production

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[35] US GAAP provides some discretion to capitalize expenditures on certain R&D-related long-lived assets. SFAS 2 indicates, "equipment or facilities that are acquired or constructed for research and development activities and that have alternative future uses (in research and development or otherwise) shall be capitalized as tangible assets when acquired or constructed."

In this section, we discuss how financial reporting could potentially increase or decrease firms' innovation production, along with related evidence (see, also, Simpson and Tamayo, 2020). We consider four channels through which financial reporting could affect innovation production: (1) "capital access," (2) "short-termism," (3) "resource allocation," and (4) "proprietary costs."

The capital access channel operates via financial reports helping firms access capital to fund innovations. Because innovations are nonrival they create economies of scale, suggesting innovators need a great deal of capital to produce and commercialize them. Because of the long horizon of innovation, it may be difficult to fund these capital outlays internally, forcing innovators to rely on external capital. However, to raise external capital innovators must credibly communicate the value of their novel innovations to capital providers to address moral hazard and adverse selection concerns. The potential proprietary costs of disclosure due to partial excludability make it difficult for the innovator to do so without reducing their innovations' value. Audited financial reports can potentially overcome these issues by credibly reporting the value of innovations without requiring innovators to reveal proprietary specifics. Consequently, financial reporting may help innovators access capital, increasing innovation production.

Despite the conceptual appeal of the capital access channel, no studies in our review provide evidence of financial reporting increasing innovation production. This is surprising given the large literature linking financial reporting to firms' access to external capital more generally (see Roychowdhury et al., 2019 for a review). However, the results of that literature do not necessarily translate to the innovation setting given the unique characteristics of innovation relative to other types of investment. For example, financial statements may be ill-equipped to reflect the value of novel assets and managers may be loath to reveal information about partially excludable assets in their financial statements.

While the capital access channel suggests that high quality financial reporting may increase firms' innovation production, several other channels suggest that financial reporting may decrease firms' innovation production. The short-termism channel operates via financial reporting requirements focusing managers on short-term financial results at the expense of the long-term orientation that is key to developing innovation. Consistent with the short-termism channel, Fu et al. (2020) find that firms required by 1970 SEC mandate to produce quarterly rather than semiannual financial reports filed fewer patents and received fewer patent citations. Also consistent with the short-termism channel, several studies document that firms opportunistically cut their R&D spending to meet earnings targets (e.g., Bushee, 1998; Roychowdhury, 2006) or to smooth their earnings (Mande et al., 2000; Baik et al., 2022). Bereskin et al. (2018) find that opportunistic R&D spending cuts reduce firms' patenting activity relative to R&D spending cuts of the same magnitude made for other reasons.

Chang et al. (2013) argue that conservatism, another characteristic of financial reports, reduces the ability of financial statements to communicate the value of innovations. Consistent with their arguments, they find that accounting conservatism negatively relates to firms' patent filings, patent citations, and R&D spending. Similarly, Chy and Hope (2021) find evidence that auditor conservatism discourages innovation by constraining managers' ability to use accruals management to meet earnings goals, forcing them to rely on innovation-decreasing real earnings management. Their results run counter to the predictions of Laux and Ray (2020). In the model of Laux and Ray (2020), conservatism increases innovation by allowing the principal to use higher-powered bonuses that motivate the manager to work harder on innovation projects without giving them incentives to overinvest in these projects.[36]

[36] Laux and Ray (2020) argue that the difference between their predictions and the findings of Chang et al. (2013) lies in the nature of innovation considered. In their model, innovation is a radically new company direction, such as a

Like the short-termism channel, the resource allocation channel suggests that financial reporting could reduce innovation. The resource allocation channel operates via financial reporting requirements diverting resources away from innovation towards complying with financial reporting requirements. The resource allocation channel may be particularly harmful to innovation if the financial reports do not help firms access external capital to fund innovation (Laux and Stocken, 2018) or even harm innovation production due to auditor deficiencies (Kim, 2023). Consistent with the resource allocation channel, Allen et al. (2022) find that firms with negative operating and investing cash flows and positive financing cash flows, or "young life-cycle firms," affected by the Sarbanes Oxley Act (SOX) reduced their R&D investment, filed fewer patents, and received fewer patent citations.

The final channel through which financial reporting could reduce innovation production, the proprietary costs channel, operates via financial reports revealing proprietary information, which reduces firms' ability to successfully innovate and/or discourages investments in innovation. At first blush, the proprietary costs channel may seem inconsistent with the notion that financial reports are ill equipped to reflect the value of innovation. If the proprietary information in financial reports is non-financial, but instead enabling, such as details about how to recreate innovations, it is unclear which required disclosures in financial reports reveal this information. While financial reports may reveal certain types of proprietary information, *ex ante* it seems unlikely that this information would be proprietary with respect to innovation (e.g., it seems more likely that financial reports reveal attractive markets than attractive chemical compounds).

Despite the conceptual arguments against the proprietary costs access channel, several studies document convincing evidence of the proprietary costs channel. Breuer et al. (2019) find

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traditional automobile company choosing to produce only electric vehicles, and not an incremental product improvement. This distinction highlights how the type of innovation can affect inferences.

that plausibly exogenous variation in financial reporting generated by European Union cross-country size-based financial reporting disclosure thresholds cause affected firms to report less innovation in the Community Innovation Survey and spend less on R&D.[37] Mechanism tests suggest that forcing smaller local monopolists to disclose more income statement information attracts larger competitors that misappropriate smaller firms' partially excludable innovations. Also consistent with income statement disclosure imposing proprietary costs with respect to innovations, Berger et al. (2023) find that allowing Korean firms to aggregate cost information allows them to protect cost innovations from rivals.

Chen et al. (2022) and Chawla (2023) suggest that financial reporting by larger US firms can also impose proprietary costs by facilitating competitor innovation. Chen et al. (2022) find that narrative R&D disclosures and accounting information disaggregation in financial statements positively relate to more follow-on innovation by peers. Chawla (2023) and Dambra et al. (2023) show that forcing firms to disclose their financial statements on EDGAR creates more follow-on innovation to the disclosing firms' patents. The results of Chen et al. (2022), Chawla (2023), and Dambra et al. (2023) raise the question of what specific GAAP financial statement disclosures revealed proprietary information, particularly given the difficulty capturing innovation value from GAAP financial statements. Chircop et al. (2020) sidestep this issue by examining pro forma

[37] Several patterns in the data and institutional details suggest that the proprietary costs channel drives the negative relation between financial reporting requirements and innovation production documented by Breuer et al. (2019). Inconsistent with the resource allocation channel driving the results, the disclosure mandates imposed relatively low additional compliance costs because firms required to disclose financial statements had to prepare them for regulatory purposes even before the mandates. Firms required to disclose financial statements also produced more patents and indicated less reliance on secrecy in the CIS survey, consistent with a substitution away from secrecy and towards patenting because of proprietary costs. This substitution could also occur because financial reporting increases managers' short-termism, causing them to forgo secrecy and rely on patenting to credibly reveal the value of their innovations. However, further consistent with the proprietary costs channel, Breuer et al. (2019) find that financial reporting increases competitors' innovation production.

financial reports and document evidence consistent with the proprietary costs channel in the setting of pro forma reporting.

3.2.2.1. Financial reporting and innovation production challenges and opportunities

The existing research suggests a negative relation between mandated financial reporting and innovation production via the short-termism, resource reallocation, and proprietary costs channels. However, the existing research has limits and provides opportunities for potentially important contributions. For example, are there upsides to high quality financial reporting through the capital access channel? As noted above, the limited evidence for the capital access channel in the innovation setting is striking given the extensive literature linking high-quality financial reporting to capital access more generally. In what situations if any does financial reporting increase innovation production via the capital access channel? Does the capital access channel operate, but is subsumed by the other channels, such that the net effect is a negative relation between financial reporting and innovation production? Do private firms, capital constrained firms, or firms that rely on trade secrecy produce high-quality financial reports to access external capital and fund innovations? Does the capital access channel operate through less structured financial reporting, such as pro forma disclosure?

Further, while several studies find that financial reporting negatively affects innovation production on average, these studies argue for different mechanisms and few, if any, robustly identify their proposed mechanisms. More work is needed to convincingly differentiate among the alternative channels. Third, and relatedly, what specific disclosures and/or financial numbers impose proprietary costs with respect to innovation? Do firms attempt to avoid these disclosure requirements and are they successful? Do investors find these disclosures useful, or just technological competitors?

3.3. Management of innovation

3.3.1. Monitoring and management control

Managers oversee the process of producing innovations (i.e., innovating), which typically entails monitoring and directing innovators. In theory, more monitoring and management control could increase or decrease innovation production.[38] Because innovations are novel, they require creativity to develop.[39] Some survey and experimental evidence suggests that monitoring and management control stifle creativity by discouraging experimentation and preventing serendipity (e.g., Campbell et al., 2011; Allen et al., 2015). For example, Alexander Fleming famously discovered penicillin because he failed to adequately clean his lab prior to a vacation. His serendipity might not have occurred in the presence of stricter management control.

Monitoring and management control might also encourage innovation (Davila et al., 2009). Prior work finds that control systems that cut inefficiency and waste can increase productivity (e.g., Baek, 2023). Monitoring and management control may be particularly important in the innovation context because they can prevent employee inventors from misappropriating partially excludable inventions. Monitoring and management control may also help manages implement or commercialize innovations.

3.3.1.1. Management control

Several studies document a positive relation between management control and innovation, although the relation is often specific to a given control. Based on survey results, managers believe

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[38] We define monitoring as managers observing or checking the progress or quality of innovation, and management controls as systems that gather and use information to evaluate the performance of organizational resources. Shields and Young (1994) find that a surprising number of R&D lab members are cost conscious, suggesting they are aware of management cost controls such as budgets and input oversight.

[39] Grabner (2014), Speckbacher (2017), and Kachelmeier et al. (2019) discuss the broader accounting literature on creativity. Creativity is important for innovating given the novelty of innovation, but not all creative outputs are innovations (e.g., art or literature are not innovations).

management control systems broadly, and selection and training-based "personnel" controls specifically, increase innovation production (Abernethy and Brownell, 1997), while accounting controls reduce innovation (Chenhall et al., 2011). Experimentally, activity-based costing systems positively interact with group-based cooperation incentives to encourage innovation, but negatively interact with tournament incentives (Drake et al., 1999). Turning to the question of how managers design control systems, surveys suggest that managers wishing to encourage incremental innovation use performance metrics, while managers wishing to encourage radical innovation avoid performance metrics (Li et al., 2023).

Several studies find that management control systems help managers implement successful innovation.[40] Surveys suggest that implementing and developing innovation require distinct types of management controls (Bedford, 2015) and that performance and behavior monitoring reduce innovation implementation, while value communication increases it (Grabner et al., 2018). Tucker et al. (2021) use the Apollo-13 mission as a case study to highlight how management control can complement creativity, even in life-or-death situations. In one of the few broad-sample studies of innovation and controls, Miller et al. (2022) find that ineffective internal financial reporting controls, which should correlate with ineffective management controls, negatively relate to future patenting activity (see also Allen et al., 2022, who find that top-down governance and controls from SOX adversely affected innovation).

While the preceding suggests that management control correlates with innovation, it is more difficult to establish the direction of causality. In practice, management control systems and innovation endogenously co-evolve (Andreicovici et al., 2023). Overall, studies in our review generally find that management control positively relates to innovation production and

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[40] The process of implementing innovations is sometimes referred to as "exploitation," while the process of discovering innovations is sometimes referred to as "exploration" (see, e.g., Bedford, 2015).

implementation, although there is heterogeneity in the relation, especially across different types of controls. More formal oversight appears to constrain innovation, while more informal oversight increases it. The positive on-average relation likely reflects the fact that managers intentionally design and implement control systems tailored to their innovation goals.

3.3.1.2. Monitoring

Few studies examine how direct monitoring affects innovation production. Zhong (2018) finds that firm transparency, which aids investor monitoring, positively relates to innovation production, and negatively relates to the sensitivity of manager turnover to innovation output (see also Brown and Martinsson, 2019). In contrast, Dai et al. (2021) find that media coverage, a type of monitoring, negatively relates to future patenting activity and that the negative relation is greater for firms with more short-term institutional investors, suggesting media coverage exacerbates short-termism. Baldenius and Yang (2022) show theoretically that allowing managers to directly observe innovation outcomes can reduce experimentation.

Relatively few studies examine the behavior of individual innovators. Glaeser et al. (2022a) find that inventors and R&D facilities located closer to senior managers at headquarters are more productive, and that plausibly exogenous reductions in flight times increase remote inventors' and facilities' productivity and creativity. They argue that proximity increases both innovation production and inventors' creativity by increasing senior managers' ability to guide and advise inventors. Bol et al. (2023) run a Mechanical Turk experiment and find that having peers evaluate the quality of innovative ideas leads to more creativity, while having workers compete for multiple small pecuniary awards, as opposed to a single large award, leads to less creativity.

3.3.1.3. Monitoring and management control challenges and opportunities

We view the literature on monitoring, management control, and innovation as an emerging research area. Overall, the evidence suggests that monitoring and management control can spur innovation but are most effective if they are flexible and permit creativity (Sunder et al., 2017). However, we note several challenges and opportunities. Most research draws inference from smaller sample surveys or experiments. While these inferences are undoubtedly valuable, we call for research triangulating these inferences using broader-sample archival analyses. Another challenge facing the literature is identifying the direction of causality. Our review suggests that management control systems and innovation almost certainly coevolve, raising concerns about potential endogeneity but also creating opportunities to explore mechanisms.

Another opportunity is further exploring how monitoring and management control affect individual inventors. The lack of surveys of inventors is surprising because inventors are potentially the most important players in the innovation process. Admittedly, it is difficult to directly observe the activities of individual inventors. However, there may be an opportunity to survey inventors to better understand theirs incentives and the constraints they face. Patent documents record inventors' names and home addresses, making it possible to contact them directly (and inventors' passion for discovery may make them especially responsive to academic surveys). Researchers could combine patent data on citation flows, invention teams, and assignees with survey data and firm-level accounting and market data to draw deeper inferences.[41] A final opportunity for the literature is documenting how managers evaluate innovative ideas. How do managers direct or help inventors select which ideas to pursue? How do managers select which innovations to commercialize? What is the role of monitoring and control systems in this process?

3.3.2. Compensation and incentives

[41] For example, Grabner et al. (2018) combine patent data with manager survey data to understand how firms design management control systems to encourage innovation.

Incentivizing managers and inventors to commercialize innovations requires navigating difficulties created by the unique characteristics of innovation. The novelty of innovations and their long development horizons makes it difficult to assess their value until they are commercialized and makes contracts written for innovation incomplete (Aghion and Tirole, 1994; Dutta and Fan, 2012). Even if the inventor or manager successfully innovates, they may be concerned that the outcome will be delayed for so long that their principals will terminate them before commercialization. Further complicating incentive contract design for innovation, inventors can misappropriate partially excludable innovations by moving to a competitor or founding a startup.

Studies in our review identify implicit and explicit contractual arrangements that firms use to navigate the above difficulties caused by the unique characteristics of innovation. Some of these contractual arrangements mirror those documented by the broader compensation literature. Innovators' implicit and explicit incentive contracts tie compensation to outcomes to encourage effort (Xue, 2007; Pfister and Lukka, 2019; Laux and Ray, 2020), include convexity to encourage risk-taking (Guay, 1999), and tie compensation to longer-term outcomes to discourage short-termism.[42] However, contracts to encourage innovation also include unique characteristics to overcome contract incompleteness due to novelty and to reduce misappropriation risk due to partial excludability (Erkens, 2011).

Misappropriation risk is largely unique to innovations due to their partial excludability. For example, few managers worry that their builders will misappropriate their buildings, while many managers worry that their inventors will take innovations to a competitor or use them to found a

[42] Dechow and Sloan (1991), Holthausen et al. (1995), and Cheng (2004). In the only empirical study in this section not focused on executive compensation, Cai et al. (2023) find non-innovation task incentives make employees innovate less.

competitor. Misappropriation risk is different from other risks because misappropriation may lead to *negative* payoffs to *successful* investments (e.g., because competitors use misappropriated innovations to compete with the firm). Misappropriation risk also likely evolves over an innovation's lifecycle. Initially, the risk is that a successful inventor does not reveal their innovation to their employer, but instead takes the innovation to an existing competitor or founds a new competitor. Later the risk is that public disclosure of details of the innovation, for example via a patent document or commercialized product, allows competitors to copy the innovation, invent around it, or leapfrog it in quality.

The novelty of innovations can also create implicit incentives largely unique to innovation. Aboody and Lev (2000) find that executives at R&D-intensive firms earn higher profits on their insider trades, suggesting that information about novel innovations provides managers with information rents. Building on these results, Dutta and Fan (2012) model how to delegate decision rights over innovation to a divisional manager in light of the long horizon of innovation and the inability to write a complete contract *ex ante* due to the novelty of innovations. They find that delegation increases the divisional managers' incentives to innovate but reduces headquarters' ability to profit from that innovation. In Feng et al. (2023) a principal contracts with an agent to search for innovative investment projects that arrive dynamically over time. The optimal contract in the face of information frictions includes a finite, progressively declining budget and terminates the agent's employment without pay if there is no investment before the budget is exhausted. Dynamic and the threat of termination induces overinvestment at time-varying degrees.[43]

3.3.2.1. Compensation and incentives challenges and opportunities

[43] See also Gregor and Michaeli (2021) consider the ability of managers to pursue innovative or routine investment opportunities and find that firms end up overinvesting in innovations. To mitigate this concern, shareholders prefer to nominate a more aggressive board of directors, but this board nevertheless does not fully prevent overinvestment in innovation.

The existing literature suggests that firms design compensation contracts considering the unique characteristics of innovation. However, there are remaining challenges and opportunities. Most studies focus on manager incentives rather than inventor incentives.[44] While managers undoubtedly play a significant role in innovation, a primary input into innovation is inventors' time and effort. Understanding how best to incentivize and compensate inventors is important and may be vastly different from incentivizing and compensating other employees (e.g., inventors may have strong nonpecuniary preferences). Our anecdotal understanding is that inventors' contracts often include complex incentive structures. We call for studies examining what motivates inventors and how firms contract with them. Relatedly, most inventors do not work alone; patent documents often list teams of inventors. How do firms incentivize cooperation among inventors (Speckbacher and Wabnegg, 2020)? Are there spillovers among inventors? Do the incentives of one inventor help or hurt their peers' production (e.g., Sprecher, 2022, finds that patent examiner incentives can harm peers' productivity, but this might not hold true for inventors).

Another opportunity is examining how implicit incentives drive behavior. Do inventors sacrifice pecuniary benefits to ensure public acknowledgement through scientific publications and/or patenting? Do boards provide managers with implicit incentives, such as job security, to encourage them to take risks and invest in long-horizon innovation? A final opportunity is documenting how misappropriation risk shapes implicit and explicit contracts for innovation. While Erkens (2011) documents initial evidence that innovative firms use time-based vesting provisions to retain executives and reduce misappropriation risk, our discussions with compensation consultants suggest that firms use many other contractual provisions not studied in the accounting literature (e.g., noncompete clauses and severance pay; see also Laux, 2015).

[44] An exception is Phister and Lukka (2019) who provide case study evidence on creative and innovation activities of global technology firm accounting personnel provided with stretch targets.

A challenge facing the literature is identifying the direction of causality. Few studies examine plausibly exogenous variation in compensation and incentives or in a desire to innovate. To draw stronger conclusions, research should identify the causal effect of innovation on compensation and incentive contract design, and how compensation and incentive contracts affect innovation.

3.4. Taxation and innovation

3.4.1. Effect of innovation on taxation

The nonrivalry of innovation allows firms to "locate" innovations strategically in the corporate structure and reduce their tax bill via intra-company income shifting from high-tax to low-tax jurisdictions. As a simplified historical example, a firm can take an innovation mainly developed by US-based scientists and nominally "locate it" with an Irish subsidiary that faces a lower tax rate on innovation income. The firm could then pay royalties from its US subsidiary to its Irish subsidiary for use of the innovation, lowering its US taxable income and increasing its Irish taxable income by the same amount, but lowering its combined tax bill. Firms can also legitimately develop innovations in low-tax jurisdictions and charge royalties to subsidiaries in high-tax jurisdictions for their use. In either case, firms can aggressively set royalty rates to shift income from high-tax to low-tax jurisdictions.

Tax authorities try to limit firms' ability to shift income via intracompany transfer payments by enforcing the "arm's length standard," which requires that the price charged by related parties match the price charged by unrelated parties. Because there are no comparable prices for a novel asset, tax authorities struggle to accurately evaluate whether transfer payments for an innovation satisfy the arm's length standard. This information asymmetry makes innovations particularly attractive for avoiding taxes via intracompany transactions (De Waegenaere et al., 2012; De Simone et al., 2020). Patents are a particularly useful type of innovation for avoiding taxes because the tax authority can clearly identify them as a basis for transfer payments (Amberger and Oswald, 2020; Cheng et al., 2021). While Dyreng et al. (2019) find that this patent-based income shifting can result in tax uncertainty, Drake et al. (2022) present evidence that foreign employment reduces the tax uncertainty from profit shifting. In total, innovation appears to facilitate relatively low-cost tax planning.

3.4.1.1. Effect of innovation on taxation challenges and opportunities

Existing literature suggests that firms locate innovations and innovation activity to facilitate tax planning. A fundamental question is how much of the employment and investment response to tax incentives is from firms taking advantage of the lower tax rate by expanding production, relocating production, and/or merely creating nominal nexus to justify transfer pricing strategies to tax authorities. Existing estimates often comingle these responses, but the different responses likely justify different policy interventions and hence understanding the magnitude of each response is important. A related question is whether foreign employment or investment attracted by tax incentives crowds out domestic production and employment. A potentially related opportunity is examining how recent efforts to curb intangible-based income shifting, such as the Global Intangible Low-Taxed Income (GILTI) and the base erosion and anti-abuse tax (BEAT) provisions of the 2017 Tax Cuts and Jobs Act, affect innovative firms' tax planning.

A fundamental question is, what are the "real" costs and benefits of innovation-based transfer pricing strategies? Dyreng et al. (2019) suggest that innovation-based transfer pricing strategies impose financial reporting costs, but do these strategies meaningfully affect firms' production, employment, or how firms protect and pursue innovations? Does a desire to tax plan cause firms to produce patentable innovations or patent innovations they would otherwise have kept as trade secrets to facilitate transfer pricing strategies? Do firms locate their most valuable patents in foreign subsidiaries to accomplish transfer pricing goals or will any patent do? How does this tax planning affect firms' production and employment, and that of their peers? Do these strategies cause firms to distort their operations and do any such distortions impose meaningful costs? Do firms vary substantially in the extent to which they use aggressive innovation-based transfer pricing to reduce their tax bills and, if so, why? Do inventor preferences play a role in innovation and tax planning?

3.4.2. Effect of taxation on innovation

Innovations add to the knowledge stock due to their novelty and create knowledge spillovers due to their nonrivalry. The innovator cannot capture all the value created by their innovations due to partially excludable. Consequently, firms will tend to underinvest in innovation relative to the socially optimal amount. Due to potential underinvestment in innovation, governments attempt to encourage innovation by providing favorable tax treatment to innovations. These favorable tax treatments include "front-end" incentives in the form of R&D tax credits and "back-end" incentives for successfully innovating in the form of innovation boxes (Lester, 2021).

It might seem obvious that both up front- and back-end tax incentives would increase innovation production, either by making it cheaper to invest in innovation or by increasing the expected after-tax rewards to innovating. However, tax incentives may not meaningfully increase innovation for at least two reasons. First, managers may not be aware of the tax incentives (i.e., they are not salient). Second, the supply of inputs to the innovation process may be relatively inelastic in the short run, especially because the primary input into innovation is the time and effort of individual innovators (e.g., Goolsbee, 1998). Individuals cannot easily change careers to become innovators and it takes time to train new innovators. Consequently, even if firms respond to tax incentives by investing more in innovation, they may only bid up the price of the largely fixed pool of innovators without materially increasing overall innovation production, at least in the short run. Consequently, how tax incentives affect innovation, and in particular the degree to which they affect real innovation production over shorter horizons, are open empirical questions.

3.4.2.1. R&D tax credits

Several papers investigate the relation between tax incentives and innovation (see also Section 2.3.7.3 for a description of R&D tax credits as a source of plausibly exogenous variation). Using a time-series model of firms' R&D spending around the 1981 federal R&D tax credit, Berger (1993) finds that each dollar of foregone tax revenue led to $1.74 of R&D spending. Examining the stock price reaction of firms unable to take advantage of the credit, he infers that 27% of the increased R&D spending was due price effects in the inputs market rather than real investment.

Klassen et al. (2004) revisit the effectiveness of the US federal R&D tax credit and compare it to the effectiveness of the Canadian federal R&D tax credit, which applies to all R&D rather than mainly incremental R&D. They find that each dollar of foregone tax revenue from the Canadian credit results in $1.30 of additional R&D spending, while each dollar of foregone tax revenue from the US credit results in $2.96 of additional R&D spending. Their results suggest that the US credit is more cost effective than the Canadian tax credit. Klassen et al. (2004) also suggest a larger effect of the US credit than Berger (1993), which could be due to their use of Canadian firms as a control sample or differences across sample periods.[45]

[45] Differences across sample periods can explain the difference in results between Berger (1993) and Klassen et al. (2004) because Klassen et al. (2004) examine a later period (1991-1997) after the federal government renewed the credit renewed several times. The credit was originally set to expire in 1985 but was repeatedly renewed prior to 1991 and four times between 1991 and 1997 (there was no credit from July 1995 to June 1996). Consequently, US firms may have responded more strongly to the credit over time because they increasingly expected it to eventually become permanent (indeed, the credit became permanent in 2015). Consistent with significant uncertainty around the temporary nature of the credit, Hoopes (2018) finds that firms that disclosed using the credit experienced greater

Another explanation for why Klassen et al. (2004) and Berger (1993) estimate different levels of effectiveness of the US federal R&D credit is that both studies use R&D reported on financial statements to measure R&D spending. Because the financial reporting rules for R&D differ between the US and Canada and because the tax and financial reporting rules for R&D differ within each country, using financial statement R&D may lead to inferences that are not comparable. Highlighting the differential treatment of R&D between financial and tax reporting, Brown and Krull (2008) find that stock option exercises by R&D employees, which trigger the R&D tax credit but not financial statement R&D expense, dampen the incentives to use R&D cuts to meet earnings benchmarks.

3.4.2.2. Innovation boxes

Innovation boxes increase back-end returns to innovation by applying a lower tax rate to income from qualifying innovations. Countries may implement innovation boxes to encourage innovation or to attract taxable innovation income and/or economic nexus from other countries.

Several studies examine how innovation boxes affect firm outcomes, generally finding that innovation boxes increase patenting rates (see also Section 2.3.7.3 for a description of innovations boxes as a potential source of plausibly exogenous variation). Bradley et al. (2015) find that innovation boxes rapidly increase domestic inventor patenting rates, likely due to domestic inventors substituting away from trade secrecy and not an increase in the rate of overall innovation. Consistent with innovation boxes creating or attracting economic nexus, Chen et al. (2019) find that they positively relate to capital expenditures. Inconsistent with innovation boxes increasing overall employment, Chen et al. (2019) find that they do not relate to changes in compensation

analyst forecast errors in quarters in which the credit expired. Cowx (2021) documents evidence that uncertainty about R&D tax credit enforcement due to the novelty of innovation affects the willingness of US managers to respond to the US credit. To the extent that credit enforcement uncertainty is greater in Canada, differences in enforcement uncertainty can also explain the difference in credit effectiveness between the US and Canada.

expense or employment levels. In contrast, Borneman et al. (2020) find that Belgium's innovation box, which applies only to income from patents first commercialized after the box's effective date, quickly increased skilled employment, increased patenting rates, and decreased patenting firms' effective tax rates. Finally, Bradley et al. (2021) find that stronger owner development requirements reduce merger and acquisition (M&A) activity by reducing the tax benefits from acquired innovations.

Several studies find that tax incentives indirectly affect innovation production via financial reporting and tax planning effects. Williams and Williams (2021) show that requiring firms to expense and record contingent liabilities for uncertain tax benefits such as R&D tax credits reduced affected firms' R&D investment and patent filing rates. Li et al. (2021) find that firms with a subsidiary in a state that enacts an addback statute, which curbs firms' ability to use innovation-based income shifting to avoid state taxation, produce fewer patent filings, receive fewer patent citations, and invest less in R&D. Their results suggest that an inability to use innovations to reduce taxes can cause firms to produce fewer innovations.

3.4.2.3. Other taxes

Direct tax incentives for innovation are not the only way that taxation can affect the location, ownership, production, and protection of innovation. Corporate and personal income tax rates can directly affect firms' and individuals' innovation decisions by altering the after-tax mean and standard deviation of the payoffs to innovation. Armstrong et al. (2019) show that higher personal income taxes cause managers to invest in R&D, which they attribute to personal income taxes increasing the marginal utility of wealth and reducing the after-tax volatility of investment returns. Glaeser et al. (2022a) find that firms locate their inventors and R&D facilities further from headquarters when the headquarters' state personal and corporate income tax rates are relatively higher and when the headquarters' state R&D tax credit is relatively lower. Their results suggest that managers balance the benefits of close monitoring with tax concerns when locating inventors. Huang et al. (2020) show that firms whose inventors collaborate across national borders alter R&D investment in response to foreign tax rates, consistent with international collaboration allowing firms to obtain tax benefits from R&D. Consistent with the horizon of taxation affecting innovation, He et al. (2022) find that tilting the horizon of country-level capital gains taxes to the short-term leads to less innovation.

3.4.2.4. Effect of taxation on innovation challenges and opportunities

Existing studies find consistent evidence that tax policy affects innovation, but these studies take the tax system as exogenous despite it being unclear why different governments design their tax systems differently. Tax policy probably does not evolve in isolation, raising many questions. Are patent boxes exclusively intended to encourage innovation or are they part of a broader effort at tax competition? How do the various methods of stimulating innovation, such as the patent system, tax credits, patent boxes, education incentives, legal rights, etc., interact? Is there an optimal mix of methods from the perspective of a benevolent social planner? How do recent regulations designed to curb innovation-based income shifting, such as GILTI and BEAT, affect innovation? Relatedly, how socially beneficial is the marginal investment that results from tax incentives and how efficient are tax incentives relative to other methods of spurring innovation?[46] For example, are tax incentives more or less efficient at spurring innovation than

[46] Studies in our review find that R&D tax credits stimulate over a dollar of investment for each dollar of foregone tax revenue, suggesting that credits are more efficient than simply collecting the tax revenue and having the government invest it directly in R&D. However, governments should in theory direct R&D to the socially optimal investment that, for example, produces the greatest knowledge spillovers, while firms will direct their R&D to the privately optimal investment. Consequently, a dollar of government R&D investment may have greater societal returns than a dollar of private investment. Conversely, private investment may be more efficient than government investment due to the disciplining forces of competition and therefore private investment could also result in greater spillovers than government investment.

ESG-style disclosure mandates aimed at attracting individuals from underrepresented groups to careers in science?

Closely related to the efficiency of tax-motivated R&D investment is the question of why estimated magnitudes vary widely across studies. Do governments differ in how they implement tax credits over time? Klassen et al. (2004) highlight major differences between the implementation of the Canadian and US tax credit, but other differences are necessary to explain, for example, why estimates of the US federal credit differ from study to study. Did the salience and/or expected permanence of the credit change over time? Do governments differ in how they encourage uptake of the credit (e.g., do they differ in how they disclose or market tax credits)? Do governments act in isolation or do they strategically respond to changes by other countries (e.g., due to tax competition)?

3.5. Financing and contracting for innovation

3.5.1. Debt contracting and innovation

The novelty of innovations makes contracts written for undeveloped innovations incomplete and makes it difficult to ascertain the value of successful innovations, exacerbating moral hazard and adverse selection concerns when an innovator raises capital. Disclosure of the innovation can potentially alleviate these concerns, but disclosure can also impose proprietary cost due to the partial excludability of innovation. Debt contracting allows firms to privately disclose innovation information to lenders without incurring the proprietary costs of public disclosure (Plumlee et al., 2015). However, lenders find the uncertain payoffs to investments in innovation unattractive because they do not share in the upside (Shi, 2003). Conversely, once innovation investments are successful, lenders find the resulting stable stream of rents attractive,[47] particularly if they can write contracts to ensure successful commercialization (Ma et al., 2022).

The preceding suggests that lenders incorporate borrowers' innovation activity into their lending decisions; a related question is the extent to which the supply of loanable capital affects innovation. If debt financing is an important source of innovation financing, increases in bank lending capacity should increase innovation. Consistent with lending capacity affecting innovation production, Dou and Xu (2021) find that a reduction in banks' Tier 1 capital ratios due to SFAS 166/167 caused more affected banks' borrowers to invest less in R&D and produce fewer patents. Further, Mao (2021) finds that plausibly exogenous increases in the value of firms' real estate portfolios, an important source of corporate collateral, positively relate to the number of patents they file and patent citations they receive.

3.5.1.1. Debt contracting and innovation challenges and opportunities

Existing research suggests that the unique characteristics of innovation affect the design of debt contracts and that the availability of debt financing affects innovation production. This combination of results highlights the potential endogeneity of debt contracts. While our review identifies several sources of plausibly exogenous variation in innovation, identifying the causal relation between innovation and contract outcomes is more complicated than merely incorporating these sources of variation. As discussed in Section 2.3.7, sources of plausibly exogenous variation in innovation, such as tax credits, affect behavior on the margin. The expected risk and return of marginal investments likely differ significantly from those of average investments. For example, in the absence of capital constraints the marginal investment motivated by tax credits is likely negative net present value absent the tax savings. Lenders likely treat these marginal investments

[47] Eberhard et al. (2008), Loumioti (2012), Hsu et al. (2015), Griffin et al. (2018), and Griffin et al. (2022).

differently from the average investment due to their different risks and returns, making it especially difficult to generalize when examining exogenous variation.

Another challenge to using sources of plausibly exogenous variation is identifying the appropriate counterfactual. Is the ideal counterfactual the same firm, but without the innovation? Or the same firm, but protecting the innovation with secrecy instead of patenting? Or the same firm, but with a tangible asset of equal value instead of the innovation? Or the same firm, but having never invested in innovation in the first place? Ideally, the researchers would identify the appropriate counterfactual based on the economic theory underpinning their empirical analysis. However, it is unlikely that a given source of plausibly exogenous variation can precisely isolate any one counterfactual given the range of forces at work. Consequently, researchers should be clear about the ideal counterfactual and how their empirical setting differs from the ideal.

The debt contracting and innovation literature has many opportunities. Few studies examine the relation between unpatented innovation and debt contracting. How do trade secrets, and the related information challenges, affect the composition and structure of lending arrangements? The existing literature focuses on a relatively narrow, albeit important, set of contractual terms, but leaves many features unexamined. How does innovation affect covenant design, loan syndicate structure, the choice of lenders, and other price and non-price debt contract terms? When contracting with innovative firms, are lenders more likely to use short- or long-term debt, and do they include provisions to convert debt into equity given the upside of innovation? What happens to innovations in default and how much of their value is recoverable by creditors? How does the accounting treatment of innovation affect debt contracting?

3.5.2. Firm ownership and innovation

The nonrivalry of innovations means that they can be used in multiple functions and markets simultaneously, which incentivizes firms to commercialize them quickly and broadly. The partial excludability of innovations means that proprietary costs of disclosure are high and the novelty of innovations means that contracts with potential partners are incomplete. These forces can affect the nature and boundaries of the firm.

3.5.2.1. Mergers and acquisitions

Innovative firms are particularly attractive corporate merger and acquisition (M&A) targets because acquiring a firm may be one of the few ways to access the full potential of that firm's innovations. For example, Lin and Wang (2016) find that R&D intensity positively relates to takeover probabilities and that a takeover risk factor subsumes the R&D risk factor in predicting future returns. Beneish et al. (2022) extend Lin and Wang (2016) by demonstrating that many M&A transactions involve a high degree of unpatented innovation and that unpatented innovation significantly increases mergers synergies.

Several studies document evidence that M&A risk affects innovation production. Fang et al. (2014) show that a plausibly exogenous decrease in tick size, and hence an increase in stock market liquidity, increases takeover risk and causes affected firms to file fewer patents and receive fewer patent citations. Sapra et al. (2014) develop an incomplete contracting model that predicts a U-shaped relation between takeover risk and innovation. At elevated levels of takeover risk innovation increases the expected takeover premium, which incentivizes the manager to innovate. At low levels, takeover risk is too small to meaningfully affect the manager's decisions and they simply choose to innovate to maximize expected profits. At moderate levels, the modest takeover premium, coupled with loss of control benefits after takeovers, discourages the manager from innovating. Using variation in state-level antitakeover laws, they find evidence of the predicted U-shape relation between takeover risk and R&D intensity.

Dey and White (2021) consider the relation between M&A risk, limitations on employee mobility due to IDD adoption, and, indirectly, employee innovation incentives. They argue that the IDD exogenously decreases knowledge-workers' ability to move to competitors, causing competitors to acquire affected firms to access their innovations. Dey and White (2021) find that firms respond to the increased takeover risk associated with the IDD by strengthening their antitakeover provisions. Consistent with firms using antitakeover protections to reduce their employees' takeover-related termination risk, firms affected by the IDD are more likely to strengthen antitakeover protections when their employees are otherwise more mobile and when the firm relies more on human capital for value creation.

3.5.2.2. Ownership structure and innovation

Several studies document evidence that characteristics of equity ownership affect innovation. Francis and Smith (1995) show that firms with disperse equity ownership produce fewer patents, are more likely to time R&D expenditures to smooth earnings and are more likely to acquire established intellectual property than to develop it internally, which they attribute to lax monitoring. Relatedly, Cetin (2022) finds that revenue recognition standards that provided more leeway and required more disclosure caused life science firms to enter more strategic alliances to develop innovations.

An important consideration is that many equity owners may not directly monitor their assets, instead relying on intermediaries such as mutual fund managers. Agarwal et al. (2018) provide evidence that the horizon preferences of these intermediaries can affect innovation production. They demonstrate that a 2004 SEC regulation that required mutual fund managers to report their portfolio holdings quarterly instead of semiannually reduced the patent activity of firms with greater mutual fund ownership.

For most firms, the greatest change in equity ownership occurs when they go public. Aghamolla and Thakor (2022) study how innovation affects this choice. They find that biotechnology firms forced to publicly disclose more information about late-development drugs by the passage of the FDAAA in 2007 were more likely to go public. They argue that this is evidence that increased mandatory disclosure due to the FDAAA lowers the proprietary costs of financial statement disclosure. Firms that went public because of the FDAAA disclosure requirements pursued less innovative projects, which Aghamolla and Thakor (2022) interpret as evidence that monitoring from dispersed public owners increases managers' risk aversion.[48]

An aspect of corporate form and innovation that has received relatively little attention is the relation between innovation and internal corporate structure (Cheng and Wang, 2022). In one of the few studies on the subject, Cardinal and Opler (1995) find that diversified firms do not introduce fewer new products per dollar of historical R&D spending. Their evidence runs counter to the argument that diversified firms will produce more innovation since innovation in one segment can facilitate innovation in other segments via knowledge spillovers.

Another aspect of corporate form and innovation that has received relatively little attention is the initial decision to launch a business. Barrios et al. (2022b) find that potential entrepreneurs

[48] While going public involves a drastic change in equity ownership, innovative firms can change the ownership structure for specific innovations by forming a research and development financing organization (RDFO). RDFOs have become uncommon since their peak in the early 1980s, when firms raised over $1 billion using RDFOs (Beatty et al., 1995). To form an RDFO, the firm separates part of its research and sells it to outside investors while including research in progress and patents as collateral. This allows investors to immediately deduct R&D expense. Shevlin (1987) examines the limited partnership form of the RDFO and finds that managers form RDFOs to sell the tax benefits of deducting R&D expense and, to a lesser extent, to move the funding off balance sheet. Beatty et al. (1995) build on Shevlin (1987) by examining all types of RDFOs and find little evidence of a tax motive for RDFOs. They also find that RDFOs are over twice as costly as seasoned equity offerings due to higher transaction costs and investor's concerns about adverse selection and moral hazard, and that RDFOs concentrate among cash-constrained firms.

are more likely to found new businesses when Lyft and Uber provide gig opportunities. Their evidence suggests that financial safety nets and fallback employment options encourage innovation by shielding entrepreneurs from some of the downsides of failure. Barrios et al. (2022a) also examine entrepreneurship and find that initial public offerings trigger local entrepreneurship and argue that this effect occurs due to knowledge spillovers.

3.5.2.3. Firm ownership and innovation challenges and opportunities

Existing literature documents relations between innovation and M&A activity, ownership structure, corporate structure, and new business formation, but opportunities remain. There is less accounting research on one of the most popular methods of developing or commercializing an innovation outside the boundaries of the firm: strategic alliances (Cetin, 2022 is a notable exception). Strategic alliances have become increasingly popular, rely on explicit contracts, incorporate management control systems, and frequently contract on accounting information (Gomes-Casseres and Saada, 2018). Commercial databases, such as the Cortellis database, have allowed researchers outside of accounting to provide insights into strategic alliances. However, gaps in our understanding remain, especially with respect to the role of accounting information in strategic alliances. Similarly, there is limited research on the role of accounting information in the design and monitoring of royalty agreements, another common method of commercializing innovations (see, e.g., the KtMine commercial database). Finally, few studies examine co-patenting, in which two entities jointly develop and patent an innovation.

Related to the need for more research on strategic alliances, royalty agreements, and co-patenting is the broader question of how firms with useful innovation combinations interact. Many innovative products are combinations of existing innovations, and these existing innovations may reside with different firms. How do these firms identify one another and share the rents to their combination (e.g., how do these firms sort between takeovers, alliances, royalty agreements, etc.)? How many worthwhile combinations go unused given the difficulties identifying potential combinations and contracting for them?

In addition, there are opportunities to examine how firms commercialize and fund their innovations in non-US settings, and the role that accounting information plays in that process. Generalizing from the US to international settings is challenging because of differences in institutional attributes such as intellectual property rights, disclosure requirements, and capital markets. For example, Bhagat and Welch (1995) find that determinants of R&D investment differ predictably between the US, UK, Canada, Europe, and Japan. More international research would be especially valuable given the importance of cross-border innovation.

Finally, there is limited research on where firms locate innovation production within the corporate structure and why they do so. How are decisions rights allocated between innovators, direct managers, and senior managers? Are R&D labs integrated with the production function, or kept separate? Who in the organization oversees R&D lab managers and are labs treated as profit or cost centers? Does corporate diversification across product lines or geographic segments help firms develop or commercialize innovation (Cardinal and Opler, 1995)?

4. Conclusion

We review the accounting literature on innovation. The novelty, nonrivalry, and partial excludability of innovation create information challenges that accounting researchers are well suited to study. In Section 2, we review the different approaches to measuring innovation. We conclude that there is no “correct” way to measure innovation, and the most appropriate method depends on the research setting and theory. Even then, any measure will likely have flaws that researchers must navigate. While we do not believe measurement issues should preclude otherwise competently executed empirical work, opportunities remain to improve our measurement of innovation. In Section 3, we review the disclosure, financial reporting, management, tax, and contracting and financing literatures on innovation. These literatures have made considerable progress, but significant opportunities remain. Given the importance of innovation to economic growth and the expertise of accounting researchers in navigating the information and incentive issues created by the unique characteristics of innovation, we call for more accounting research on innovation.

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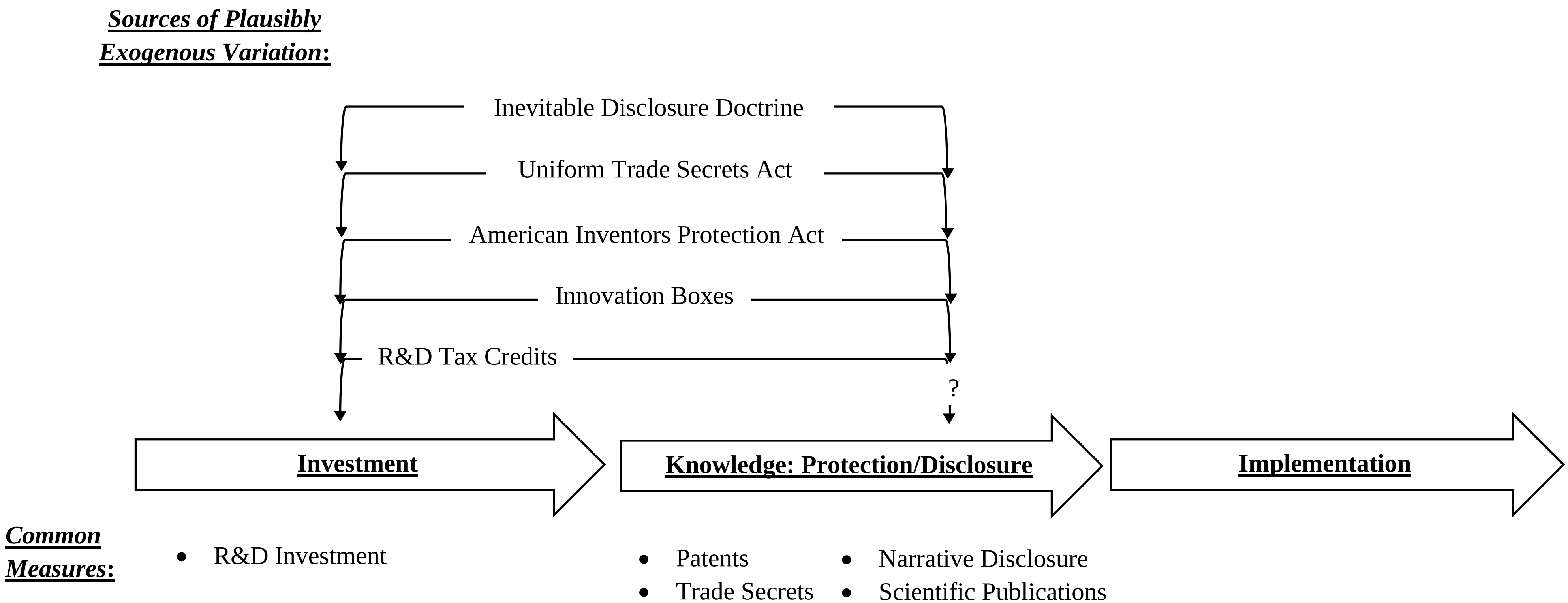
Figure 3: Innovation Lifecycle for Profit Driven Firms



Appendix A – Potentially useful public data sources

Construct	Related Paper(s)	Source
R&D Investment		
- Knowledge stocks and depreciation rates	Ewens et al. (2019)	https://github.com/michaelewens/Intangible-capital-stocks
- R&D employment and use of funds by state and industry.	N/A	https://www.nsf.gov/statistics/industry/
- US Department of Energy R&D funding grants	Myers and Lanahan (2022)	https://www.openicpsr.org/openicpsr/project/158762/version/V1/view
Strategic Alliances		
- Standard setting organizations.	Bushee et al. (2021), Oh & Yeung (2021), Chen et al. (2023b)	https://www.law.northwestern.edu/research-faculty/clbe/innovationeconomics/data/
Patents		
- Environmentally sound technologies (green patents).	Skinner and Valentine (2023)	https://www.wipo.int/classifications/ipc/green-inventory/home
- Market value of patents and matching of patents to public firms.	Kogan et al. (2017); Stoffman et al. (2020)	https://host.kelley.iu.edu/nstoffma/
- Patent inventor disambiguated identities, location, and co-authorship networks.	Li et al. (2011); Akcigit et al. (2022), Glaeser et al. (2022a)	https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/5F1RRI; https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/SR410I
- Patent assignments (including historical to infer ownership transfers).	Marco et al. (2015); Kim and Valentine (2022)	https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/SR410I
- Patent citation similarity.	Kuhn et al. (2020)	https://storage.googleapis.com/jmk_public/Kuhn-Younge-Marco_Patent_Citation_Similarity_2017-10-23.csv

- Patent depository library locations	Furman et al. (2021); Martens (2021)	https://www.aeaweb.org/articles?id=10.1257/pol.20180636
- Patent disclosure attributes.	Dyer et al. (2020)	https://stephenglaeser.web.unc.edu/data/
- Patent examiner prior art search notes.	Baek and Ko (2021)	https://ped.uspto.gov/peds/#!/
- Patent filings, abandoned applications, pending applications.	Marco et al. (2015); Glaeser and Landsman (2021)	https://www.uspto.gov/ip-policy/economic-research/research-datasets/historical-patent-data-files
- Patent litigation data (including data on non-practicing entities ["patent trolls"]).	Marco et al. (2017); Glaeser et al. (2022b)	https://www.uspto.gov/ip-policy/economic-research/research-datasets/patent-litigation-docket-reports-data; https://npe.law.stanford.edu/
- Patent maintenance fees.	Schuster and Valentine (2022)	https://developer.uspto.gov/product/patent-maintenance-fee-events-and-description-files
- Patent novelty.	Arts et al. (2021)	https://zenodo.org/record/3515985#.ZBJ903bMLn8
- Patent pilot program designated judge districts.	Kim et al. (2022)	Kim et al. (2022) Table 1, Panel B
- Patent scope.	Kuhn and Thompson (2019)	http://jeffreymkuhn.com/index.php/data/
- Textual similarity of patents.	Arts et al. (2017, 2021); Schuster and Valentine (2022); Bekkerman et al. (2023)	https://zenodo.org/record/3515985#.ZDhF03bMKQI; https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/JO2DQZ; https://figshare.com/s/d0319b79c316b034f72a;
Trade Secrets		
- Reliance on secrecy and other protection methods by state and industry.	N/A	https://www.nsf.gov/statistics/industry/
- Trade secret discussions in 10-Ks	Glaeser (2018b)	https://stephenglaeser.web.unc.edu/data/

Narrative Disclosure		
- Narrative R&D disclosure key words	Merkley (2014)	publications.aaahq.org/accounting-review/article-supplement/3609/pdf/10_2308_accr-50649_s1/
Scientific Publications		
- Scientific publications matched to firm-years.	Arora et al. (2021); Baruffaldi et al. (2023)	https://zenodo.org/record/4320782
Startups/Entrepreneurship		
- New business registrations	Guzman and Stern (2020); Andrews et al. (2022b); Barrios et al. (2022a,b)	https://www.startupcartography.com/
Trademarks		
- Trademark applications.	Hsu et al. (2022)	https://www.uspto.gov/learning-and-resources/electronic-data-products/trademark-case-files-dataset-0
- Trademark ownership.	N/A	https://www.law.northwestern.edu/research-faculty/clbe/innovationeconomics/data/
R&D Tax Credits		
- R&D tax credit effective rates.	Wilson (2009), Akcigit et al. (2022), Glaeser et al. (2022a)	https://www.frbsf.org/wp-content/uploads/sites/4/RDusercost.xls; https://dataverse.harvard.edu/dataset.xhtml?persistentId=doi:10.7910/DVN/SR410I
Inevitable Disclosure Doctrine		
- Inevitable Disclosure Doctrine recognition.	Klasa et al. (2018)	Klasa et al. (2018) Table 1
Innovation Boxes		
- Innovation box regimes.	Chen et al. (2019); Bradley et al. (2021)	Chen et al. (2019) Appendix A; Bradley et al. (2021) Table 1

Uniform Trade Secrets Act		
- Uniform Trade Secrets Act recognition.	Glaeser (2018b)	Glaeser (2018b) Appendix A
Other		
- Marginal personal income tax rates on high earners.	Feenberg and Coutts (1993); Armstrong et al. (2019)	http://users.nber.org/~taxsim/state-rates/; http://accounting-faculty.wharton.upenn.edu/dtayl/wp-content/uploads/sites/5/2020/02/ManagerRate.xlsx
- Technology and product market spillovers.	Lucking et al. (2019); Glaeser and Landsman (2021)	https://drive.google.com/file/d/1-sVWcdZZQM158dvR8KngncBhLUrbZ-P7/view
- "We own what you think" invention assignment precedence.	Armstrong et al. (2020)	Armstrong et al. (2020) Appendix A