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Finance and Corporate Innovation: A Survey*

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Abstract

Corporate innovation is an increasingly important topic that has attracted great attention from academic researchers in financial economics in recent years. Although the top three finance journals (i.e. the *Journal of Finance*, the *Journal of Financial Economics*, and the *Review of Financial Studies*) together published a total of only five papers on corporate innovation from 2000 to 2008, the number of such papers published by these three journals skyrocketed to 56 from 2009 to the third quarter of 2017. The purpose of this survey is to provide a synthetic and evaluative monograph of academic papers that examine the drivers and financing sources of corporate innovation.

Keywords Corporate innovation; Finance; Survey; Patents; Citations; R&D

JEL Classification: G10, G30, G31, G32, G34

1. Introduction

This article aims to review the recent, fast-growing literature on finance and corporate innovation. It addresses the following questions: How is corporate finance motivated and financed? To what extent do financial markets and systems shape the initiation, process, features, and outcomes of technological innovation by

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corporations? These questions are particularly important to investors, business practitioners, social scientists, policy makers, and the like due to the fact that technological innovation is vital for a country's economic growth (Schumpeter, 1911; Solow, 1957; Romer, 1986) and a firm's long-term competitive advantage (Porter, 1992). According to a report issued by the OECD (2015), innovation (including technological progress embodied in physical capital, investment in knowledge-based capital, increased multi-factor productivity growth, and creative destruction) accounts for approximately 50% of a country's total GDP growth, with influences varying depending on the country's level of economic development and the phase of its economic cycle. Economists have estimated that 85% of a nation's economic growth is attributable to technological innovation (Rosenberg, 2004). Chang *et al.* (2016) document that a one-standard deviation increase in patent stock per capital is associated with a 0.85% increase in GDP growth. Given the important roles played by technological innovation, more and more financial economists have started exploring a wide spectrum of firm-, market-, and country-level determinants of corporate innovation over the past few decades. The purpose of this survey is to provide a synthetic and evaluative monograph of academic research that examines the drivers and financing of corporate innovation. By doing so, we hope readers can obtain a comprehensive perspective on the recent development of this line of research, understand the differences and interconnectedness among various topics, and have a better clue as to the direction of future research.

In recent years, corporate innovation has become an increasingly important topic that has attracted tremendous attention and research effort from academic researchers in all kinds of disciplines including finance, economics, accounting, marketing, management, and so on. This is especially true in the last decade, largely because of the availability of high-quality patent and citation data that capture a country's or a firm's innovation output.[1] To obtain a clear idea of the growth of the finance and innovation literature, we searched "innovation" in the titles, abstracts, and key words of academic papers that were published in the top six accounting and finance journals listed on the University of Texas at Dallas' "The UTD Top 100 Business School Research Rankings" website (i.e. the *Journal of Finance* (JF), the *Journal of Financial Economics* (JFE), the *Review of Financial Studies* (RFS), the *Accounting Review* (TAR), the *Journal of Accounting and Economics* (JAE), and the *Journal of Accounting Research* (JAR)).[2] We read these papers to ensure that they were indeed about corporate innovation and then named them "innovation

[1]Before that, the majority of academic studies on innovation rely on a firm's voluntarily reported research and development (R&D) expenses to infer about its innovation input, which has several limitations, to be discussed in detail later in the survey.

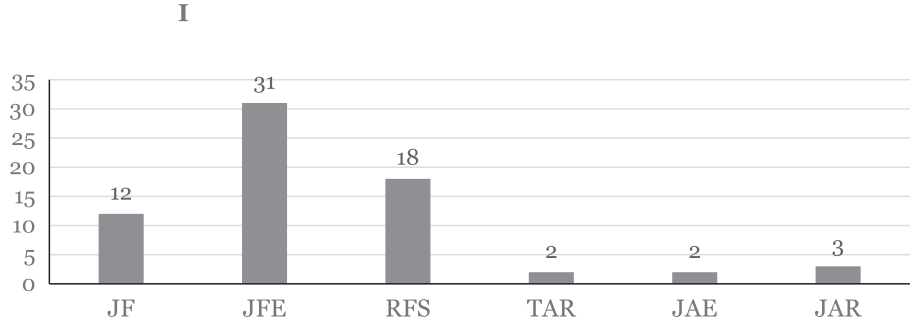
[2]The website is http://jindal.utdallas.edu/the-utd-top-100-business-school-research-rankings/

publications." We found that there were a total of 68 innovation publications between 2000 and the third quarter (Q3) of 2017.[3]

Figure 1 shows the distribution of the innovation publications across these six journals. Finance journals publish far more papers on corporate innovation than accounting journals (i.e. 61 papers versus seven papers). Of the finance journals, the JFE publishes about half of such papers (i.e. 31) followed by the RFS (18) and the JF (12). Innovation publications are evenly distributed across the three accounting journals.

Regarding the time-series distribution of innovation publications in these six journals, Figure 2 shows a fast-growing trend in the number of published papers on corporate innovation in recent years. If we split the sample into two time periods, we find that there is a total of only nine such papers published in these top accounting and finance journals between 2000 and 2008. This number, however,

Figure 1 Distribution of innovation publications across top accounting and finance journals between 2000 and 2017Q3



soars to 59 (about 6.5 times as large as the previous one) in the second half of the sample period between 2009 and 2017Q3. This dramatic increase in the publication volume is phenomenal and could be partially explained by the researchers' awareness of high-quality patent and citation databases made available during the last decade.

Figure 3 reports the distribution of innovation publications across three academic fields: asset pricing, corporate finance, and macroeconomics. In each field, we distinguish between theoretical and empirical studies. Since there are six papers that contain both theoretical and empirical analyses, we double counted them when drawing the figure, which leads to 74 reported observations. As we can see, corporate finance is the most popular field in which papers on technological innovation are published, with a total of 59 publications that include 13 theoretical studies and 46 empirical ones. There are nine papers published in asset pricing and six papers published in macroeconomics, with a slightly larger number of empirical studies being published compared to theoretical ones (i.e. nine versus six).

We further break down the 46 innovation publications in empirical corporate finance into seven categories based on the main subject of study: private firms, start-ups, entrepreneurs, firms recently going public (IPO firms), publicly listed firms, firms involved in mergers and acquisitions (M&As), and firms going private, and report their distribution in Figure 4. Studies focusing on innovation activities in public firms dominate as they account for 60% of the empirical corporate finance studies on corporate innovation. This pattern is probably due to the relatively easier access to accounting, financial, and stock trading data of public firms. The next two popular categories are the papers on innovation undertaken by IPO firms and

Figure 3 Distribution of innovation publications across different fields between 2000 and 2017Q3

entrepreneurs. They account for 12% and 10% of the total pool of
rate finance studies, respectively. Owing to limited data
innovation activities of start-ups and those goin
categories.

innovative projects, they can use a variety of long-term incentive-inducing compensation methods such as stock options with long vesting periods, option repricing, or golden parachutes. His theory has implications for various aspects of a firm's operating environment that are likely to affect corporate innovation, and motivates many follow-up studies discussed later in this survey.[5]

There are three other survey papers closely related to ours. Ederer and Manso (2011) review theoretical and empirical work that explores the motivation of innovation from an optimal contracting perspective, and they focus in particular on the implications of contracting for innovation activities under different scenarios such as bankruptcy, corporate governance, and compensation schemes. Hall and Lerner (2010) and Kerr and Nanda (2015) review the literature on the financing of R&D investment and corporate innovation. Kerr and Nanda (2015) especially focus on the role of debt financing in the innovation process. They also highlight the new literature on learning and experimentation across multi-stage innovation projects and how such behaviors affect optimal financing designs. However, unlike these survey papers, we review studies that examine a broader set of research questions related to corporate innovation and mainly focus on research papers published in top accounting and finance journals.

This survey consists of four sections. The first section reviews the literature that links micro-level firm characteristics and innovation activities. We discuss papers that explore how venture capital (VC) and entrepreneurship, as well as firms' internal and external characteristics, influence the process, features, and outcomes of innovation. The second section covers studies examining the relation between market-wide economic forces (such as product market competition, import penetration, banking deregulations, market conditions, etc.) and firms' incentives to engage in innovative investments. The third section analyzes the literature on how macro-level social or country characteristics (such as a nation's institutional features, laws and policies, financial market development, etc.) affect corporate innovation. Finally, we provide our views on potential directions for future research on this important topic.

2. Firm-Level Characteristics

We first review the finance and innovation literature that examines various firm-level determinants of innovation, such as VC backing and ownership structures, factors that can be controlled by shareholders like corporate governance and compensation schemes, as well as economic forces that are largely beyond the control of shareholders like analyst coverage, institutional investment, and stock liquidity.

[5]Ederer (2016) extends Manso's analysis to a multi-agent setting with social learning and shows that optimal incentives for innovation not only feature tolerance for failure, but also reward team and group performance to internalize informational spillovers.

2.1. Venture Capital and Entrepreneurship

As an internal engine that drives a nation's long-term economic growth and competitive advantage, corporate innovation takes place at every stage of a firm's life cycle. When a young entrepreneurial firm launches its business ventures, it has a strong incentive to invest in new technologies and revolutionary products because it needs to surmount the hurdles set by the incumbents in its industry and establish itself as an independent, viable company. However, its lack of a track record and physical collateral shuts the door to typical financiers, such as banks and public equity investors, resulting in the young start-up company imposing substantial financial constraints on its investment scope, thus preventing it from fully pursuing its innovation activities. In the meantime, privately held entrepreneurial firms may suffer less from typical agency conflicts between widely dispersed shareholders and firm managers and are more capable of protecting their confidential information and business secrets, which might give such firms stronger incentives to engage in long-term, risky, innovative projects. In this subsection, we review academic articles that explore how one unique feature of private firm financing, namely, VC, influences corporate innovation, as well as those articles that examine the tradeoffs among different types of ownership structure (i.e. remaining privately held, being an independent public firm, or being acquired by another firm) and their relation to R&D investment and innovation outcomes.

Owing to the difficulty of raising capital from banks or public equity investors, a large number of entrepreneurial firms resort to VC, which plays both a financing and advisory role during the process of corporate innovation. Examining 20 industries in the US manufacturing sector between 1965 and 1992, Kortum and Lerner (2000), for the first time in the literature, document a positive association between VC and patenting. To address the concern regarding omitted variables, such as the arrival of technological opportunities, they conduct two identification tests. First, they use the US Department of Labor's clarification of the Employee Retirement Income Security Act in 1979 as an instrument for the supply of VC. Second, they assume that R&D expenditures can partially control for the arrival of unobserved technological opportunities and thus examine the effect of VC on the patent–R&D ratio, rather than on patenting itself. Using both methods, they conclude that VC may have accounted for 8% of industrial innovations from 1983 to 1992, even though the average ratio of VC to R&D during the same period is <3%.

Motivated by theoretical studies that argue for the necessity of tolerance for the failure of innovation (e.g. Holmstrom, 1989; Manso, 2011), Tian and Wang (2014) examine whether failure-tolerant venture capitalists enhance innovation by using a sample of VC-backed IPO firms between 1985 and 2006. They first develop a new measure of failure tolerance for each VC firm in their sample based on its past investment pattern towards underperforming entrepreneurial firms in its portfolio. Using this measure, they find that IPO firms backed by more failure-tolerant VC investors tend to generate more patents and patents with more future citations, and that this pattern is more prominent for firms that face higher failure risk. Finally,

they adopt a number of identification strategies to show that these results are unlikely driven by the endogenous matching between failure-tolerant venture capitalists and entrepreneurial firms with greater innovative abilities.

While the above two papers examine the role played by independent venture capital (IVC) firms (i.e. those drawing funds mainly from limited partners and remaining independent of other entities) in the young start-up innovation process, a growing trend in the VC industry is the development of corporate venture capital (CVC) firms that are a subsidiary of established industrial companies from which they obtain funding and mainly serve the strategic goals of their parent companies. As Fulghieri and Sevilir (2009) argue, firms, facing increasing competition from the industry, may optimally choose to undertake their innovation projects outside of firm boundaries in collaboration with specialized firms while still offering financing from their own internal funds in the form of CVC.

However, ex ante, it is unclear whether CVC is more efficient than IVC in promoting innovation. On the one hand, CVCs have longer investment horizons, and unlike IVCs, they do not only chase financial returns. Moreover, CVCs do not adopt the typical performance-based compensation structures as IVCs do. These unique characteristics of CVCs allow them to be more tolerant of failure, which is beneficial to the success of technological innovation. Meanwhile, CVCs have superior industry and technology expertise inherited from their parent companies, which could also enhance their ability to promote corporate innovation. On the other hand, as corporate subsidiaries, CVCs are more subject to centralized resource allocation problems and thus cannot finance entrepreneurial endeavors as freely as IVCs do. Further, higher powered compensation schemes and specialized industry expertise may make IVCs superior than CVC fund managers in nurturing innovation. Hence, the horse race between IVCs and CVCs in promoting innovation is an empirical question.

Using a sample of 2129 VC-backed firms that went public between 1980 and 2004, Chemmanur *et al.* (2014) find that while CVC-backed firms are younger, riskier, and less profitable than IVC-backed firms, they are more innovative in the sense that they generate more patents and patents with higher future citations received. Further, their analysis identifies two possible channels through which CVCs benefit innovation: (i) the technological fit between CVCs' parent firms and the start-up companies backed by them; and (ii) CVCs' greater tolerance for failure than IVCs.

Venture capital investment structure affects innovation as well. Mao *et al.* (2016) examine a unique feature of VC financing, namely, stage financing, on the innovation output of the IPO firms it funds. Stage financing refers to the stepwise disbursement of capital (rather than a lump sum capital infusion upfront) from VC investors to entrepreneurial companies. While VC staging can enhance corporate innovation by mitigating the agency and hold-up problem with regard to the entrepreneur, it may also hurt incentives to innovate if too much pressure is exerted on the young firms to meet short-term performance measures (so as to receive follow-up funding). To empirically test the two competing hypotheses, Mao *et al.* (2016)

exploit the plausibly exogenous variation introduced by staggered passage of the Inevitable Disclosure Doctrine (IDD) across states, which prevents a firm's employees who have knowledge about the firm's trade secrets from working for another firm, and find that VC staging has a negative, causal effect on IPO firms' patenting activities. They also find that staging hurts innovation more when the R&D task is harder to achieve and when VCs have less industry-related experience.

After operating as privately held firms with some form of private financing (e.g. VC or bank loans), many start-up companies eventually attempt to obtain more efficient access to external capital by either going public or by being acquired by another (usually larger) firm. The latter point is often referred to as the point of "exit," since many insiders may exit the firm at this stage, either partially or completely, by selling their own equity in the firm. Previous studies have analyzed both the determinants and ramifications of such exit decisions for product market performance, such as total factor productivity, sales growth, market share, and capital intensity (see, e.g. Poulsen and Stegemoller, 2008; Bayar and Chemmanur, 2012; Chemmanur *et al.* 2016a).

Ferreira *et al.* (2014) theoretically model the impact of public and private ownership structures on firms' incentives to innovate, and argue that the former is more beneficial for exploiting existing ideas while the latter is more conducive to the exploration of new ideas. The central intuition in their model is that managers in private firms, which are less transparent to outside investors than public firms, are more tolerant of early failures and thus more likely to engage in innovative projects due to their ability to time the market by choosing an early exit strategy after receiving bad news. In contrast, such a strategy is unprofitable under public ownership because cash flow is already observable for public firms. Therefore, there is no tolerance for failure in public companies. Moreover, the stock prices of public companies react quickly to good news, which gives rise to myopic behavior that focuses on conventional projects given such projects' higher probability of early success. Consequently, Ferreira *et al.* (2014) show that the optimal ownership structure of a firm changes with its life cycle and depends on whether the exploitation of existing knowledge or the exploration of new territories is more desirable.

Using a firm-year panel data set of all VC-backed biotechnology firms founded between 1980 and 2000, Aggarwal and Hsu (2014) examine how entrepreneurial exit choices, namely, IPOs versus acquisitions, affect patenting outcomes. To address the possible self-selection problem, they make use of coarsened exact matching, and two additional empirical designs. First, they compare firms that filed for an IPO (or announced a merger) with those not completing the transaction for reasons unrelated to innovation. Second, they adopt an instrumental variable approach. With the help of these two identification strategies, they find that innovation quality, as measured by patent citations, is the highest under private ownership and the lowest following an IPO exit, with the intermediate level following an acquisition exit. They also find a drop (increase) in patent counts after IPOs (acquisitions). They further argue that their results are consistent with an information

confidentiality story: going public entails the largest information disclosure and thus reduces the marginal benefit of conducting innovation to the greatest extent, followed by being acquired by another firm, with remaining private involving the least information disclosure.

Other than losing privacy and confidentiality, going public may impose short-term pressure on managers to focus more on quarterly profits rather than on long-term earnings potential, leading to the "managerial myopia" problem predicted by Stein (1988). In this sense, private rather than public ownership of a firm may be more conducive to firms' incentives to engage in innovative activities. To test this theory, Lerner *et al.* (2011), using a sample of 472 leveraged buyout (LBO) transactions, empirically examine whether going private via an LBO can relieve managers of short-term pressure, prompting them to invest more in long-term innovative projects. They find that while the level of patenting does not significantly change after an LBO transaction, firms pursue more influential innovations, as measured by patent citations, in the years following private equity investments. In terms of the fundamental nature of the innovative activities, they do not find significant changes in the originality or generality of the patents that are generated under different ownership structures. Finally, going private via LBOs seems to motivate firms to refocus innovative portfolios in their core business areas. One limitation of the above study, however, is that they cannot fully rule out selection as a potential alternative explanation for their results.

A follow-up study by Bernstein (2015) examines the other side of the coin: how going public via an IPO affects corporate innovation. Taking one step closer to drawing a causal interpretation, he compares the innovation activity of firms going public with that of firms withdrawing their IPO filing due to NASDAQ fluctuations during the book-building period. He finds that the quality of internal innovation declines post-IPO (with no changes in the quantity of innovation), which is a result of losing skilled inventors and a decrease in the productivity of inventors who do not leave. Meanwhile, public firms are able to attract new inventors and obtain patents from the acquisition of other companies. He concludes that going public changes firms' strategies in pursuing innovation. Finally, the paper finds support for an agency explanation: out of career concerns, managers are averse to innovative projects, which are long term and highly risky in nature. Since public firms face more severe agency conflict than closely held private companies, their managers are more likely to divert resources away from corporate innovation.

Acharya and Xu (2017) point out that reliance on external financing is an additional channel through which public listing affects corporate innovation. Using a large sample of public and private firms between 1994 and 2004, they find that public firms engage more in R&D activities and generate more patents with higher impact than similar private companies in external financing-dependent industries, where financial dependence is measured by the median fraction of capital expenditures not financed through internal cash flows across all firms in a particular industry-year. In contrast, public firms in internal financing-dependent industries are not

more successful in their innovation endeavors than private firms. Finally, their analyses suggest that innovative firms that are in greater need of external financing benefit more from listing in public equity markets whereas the innovation activities of firms without such needs could be hampered due to the intensified short-termism imposed by the stock market.

Closely related to Acharya and Xu (2017), Gao *et al.* (2017) directly compare innovation strategies of public and private firms based on a sample over the period 1997–2008. They find that public firms tend to do more exploitative innovation as their patents rely more on existing knowledge. In contrast, private firms tend to do more exploratory innovation as their patents are broader in scope. The underlying mechanism that explains their main findings is the shorter investment horizon associated with the public equity market.

Several papers study how firm boundaries and their ownership structures via mergers and acquisitions affect both the input and output of innovative investments. Using a quasi-natural experiment based on failed mergers to generate exogenous variation in acquisition outcomes, Seru (2014) finds that firms acquired in diversifying mergers pursue fewer innovative investments and generate fewer patents or citations than failed targets do. The negative effect of a conglomerate organizational structure on innovation is more pronounced when the acquiring firm has a more active internal capital market, consistent with the idea that managers in conglomerate firms are afraid of initiating innovative projects because researchers may manipulate the information transmitted to the central office after such projects start in order to compete for internal corporate resources. Further, he finds that the dampened innovation activities in acquired targets are largely driven by inventors becoming less productive after the merger rather than as a result of inventors leaving the firm.

In a related paper, Zhao (2009) explores a firm's joint decision on technological innovation and acquisition, and finds that the two strategic decisions are highly correlated. Specifically, he finds that firms making acquisitions are less innovative to start with, with a decreasing amount of innovation activities during the period before the takeover bids. Further, those less innovative bidders are more likely to complete a deal and benefit more from their successful acquisitions in terms of innovation output quality. These findings indicate that corporate innovation both affects and is affected by firms' acquisition decisions.

While Seru (2014) focuses on target firms and Zhao (2009) on acquirers, Bena and Li (2014) examine how innovation activities in both target and acquiring firms affect merger outcomes. Using a sample of patent-merger data from 1984 to 2006, they find that firms with larger patent portfolios but lower R&D expenses tend to become acquirers and firms with higher R&D expenses but which are slower in generating patents are more likely to become targets. Moreover, the proximity in patent portfolios between the target and acquirer firms has a positive effect on the likelihood of their pairing up. Finally, acquirers whose patent portfolios are closer to those of target firms experience an increase in patenting activity afterwards. In

conclusion, their results indicate that the technological synergies between the target and the acquirer have important implications for both the takeover outcomes and the future innovative capacity of the merged firm.

In a similar spirit, Liu *et al.* (2016b) examine how a firm's acquisition activities affect its subsequent innovation output and find a positive relation between the two. Further, acquiring innovative target firms with better existing patent portfolios seems to be more beneficial to the acquirer in terms of announcement returns and long-term post-merger stock returns. Overall, Liu *et al.* (2016b) focus on the implication of M&A for acquirers' innovative activities and suggest that acquiring innovation might be an important motive for taking over other firms.

2.2. Firms' Internal Characteristics

In this subsection, we turn our attention to the innovation activities of publicly listed firms. In particular, we review articles that explore in depth the firm-level determinants of corporate innovation, especially those that can be largely controlled by shareholders, the owners, and ultimate residual claimers of the benefits associated with innovative investment.

Chief executive officers (CEOs) are the most important decision makers for public firms, responsible for allocating corporate resources, designing corporate strategies, and ultimately generating profits and financial returns. As a result, their incentives, management styles, and even personal characteristics might exert substantial influence on the direction, focus, and progress of corporate innovation activities. Hence, we first review academic studies that explore the relation between innovation and a variety of CEO characteristics.

Using a novel measure of CEO overconfidence developed by Malmendier and Tate (2005a,b), Galasso and Simcoe (2011) examine how managerial overconfidence influences corporate innovation. Specifically, they classify a CEO as being overconfident if he or she holds highly in-the-money stock options after they are fully vested, and hypothesize that overconfident CEOs tend to underestimate the likelihood of failure and are thus more likely to pursue inherently risky and uncertain innovative projects. Examining a sample of 450 large US publicly listed firms between 1980 and 1994, they find evidence consistent with the above conjecture: firms run by overconfident CEOs have higher citation-weighted patent counts and this effect is more pronounced in more competitive industries.

In a contemporaneous study that examines a more comprehensive sample (over 1500 US public firms between 1993 and 2003), Hirshleifer *et al.* (2012) also find that firms with overconfident CEOs have greater return volatility, invest more in R&D projects, generate a larger number of patents and patent citations, and exhibit higher innovation productivity. In addition to the option-based measure of CEO overconfidence described above, they examine an alternative measure that is based on press coverage. Specifically, following Malmendier and Tate (2005b, 2008), they calculate the fraction of press releases that discuss CEOs and mention words related to overconfidence or its opposite in proximity. Using both measures, they find that

overconfident CEOs not only pursue more innovative investment but are also better at translating external growth opportunities into firm value. However, unlike Galasso and Simcoe (2011), they find that overconfident CEOs promote corporate innovation only in innovative industries.

Another article that explores the role of CEO personality traits in innovation is Sunder *et al.* (2017). Using a sample of 1200 CEOs with 4494 firm-year observations between 1993 and 2003, they find that a CEO's hobby of flying airplanes is positively associated with the innovation activities of the firm that he or she is managing. In particular, they find that firms run by pilot CEOs generate more patents and citations, exhibit higher innovation efficiency, and pursue more diverse and original innovative projects. They argue that their finding highlights the important role of CEO sensation seeking, which does not simply reflect risk tolerance but also captures a desire to try new experiences in the initiation and process of innovative investments. To partially address the endogeneity problem concerning the nonrandomness in CEO-firm matching, the paper examines changes in innovation outcomes around CEO turnover and finds that, keeping the firm constant, pilot CEOs are associated with higher patent and citation counts.

A CEO's skill set, in addition to his or her personal attributes, could also contribute to the success of corporate innovation. Custodio *et al.* (2017) explore this topic. They define generalist CEOs as those who gain general managerial skills over their lifetime working experience and examine how such CEOs influence the innovation activities of the firms they manage. Using a sample of 2005 CEOs covering 1464 firms between 1993 and 2003, they find that generalist CEOs spur innovation by leading their firms to generate more patents with higher future citations, and to engage more in exploratory rather than exploitative innovation strategies. Finally, they find that the main reason for which generalist CEOs promote innovation is that such CEOs are more tolerant of failure due to their superior abilities to apply their general management skills elsewhere in the labor market when the innovative ventures happen to fail. Therefore, an efficient managerial labor market is likely to contribute to overall innovation success.

Further, a CEO's network connection is important for his or her firm's innovation as well. Faleye *et al.* (2014) explore the effect of CEO network connections on corporate innovation using a sample of 2366 CEOs and 1532 firms between 1997 and 2006. They find that firms with better-connected CEOs engage more in innovative activities and generate more and higher quality patents. They then show that the two main channels through which this happens are the labor market insurance effect of personal network connection on CEOs' risk-taking incentives as well as the access to innovation-related information via personal networks.

Other than personal traits and skill sets, CEOs' compensation schemes and incentives are also believed to be very important in regulating their behavior and influencing their management styles as well as the corporate strategies they design. We now review the literature on how CEO compensation and incentives affect corporate innovation.

In a controlled laboratory experiment conducted by Ederer and Manso (2013), 379 human subjects are provided with different types of incentive plans and then asked to perform a task that involves tensions between the exploration of an untested new approach and the exploitation of a well-known approach. They find that relative to fixed wages or standard pay-for-performance compensation contracts, those incentive plans that involve tolerance for early failures and reward for long-term successes are the most effective in motivating exploratory (i.e. innovative) actions and better performance. They also find that the threat of contractual termination can reduce the subjects' incentives to innovate, but golden parachutes can somewhat alleviate such adverse effects. Their results are more pronounced for more risk-averse subjects whose propensity to explore is much lower under pay-for-performance compensation.

Given the above findings, it is interesting to know how firms, especially those engaging more in innovative investments, design their compensation packages for CEOs and top executives to motivate innovation, which has the special features of being idiosyncratic, unpredictable, and long-term in nature. Using a sample of newly public US firms between 2001 and 2004, Baranchuk *et al.* (2014) test whether the combination of tolerance for failure and rewards for long-term success can enhance CEOs' incentives to invest in innovative projects empirically. Consistent with the predictions of Manso (2011), they find a significantly positive association between firms' innovation activities and "innovation friendly" incentive schemes, namely, the length of the vesting period of a CEO's unexercised and unexercisable options, the proportion of the CEO's compensation in deferred compensation, and the stringency of antitakeover provisions. Although the direction of causality is not explored in the study, the evidence is consistent with an equilibrium matching between a firm's intention to engage in innovation and its tendency to provide its CEO with more incentive compensation, longer vesting periods, and greater protection from early termination.

Related to the above two papers, Mao and Zhang (2017) find that CEOs' risk-taking incentive induced by their compensation structure (i.e. vega) has a positive, causal effect on their innovation activities. For identification, they make use of compensation changes triggered by the FAS 123R accounting regulation in 2005, which mandated stock option expensing at fair values. They further find that the reduced managerial risk-taking incentive after the implementation of FAS 123R decreases the production of patents related to a firm's core businesses and explorative inventions.

Looking deeper into the compensation packages of CEOs, González-Uribe and Xu (2015) document a within-firm cyclical pattern for innovative activities, with the length of the cycle coinciding with that of the CEO's employment contract. Using a sample of 571 CEOs during the 1994–2008 period, they find that CEOs with more years remaining in their contracts pursue more influential, broad, and varied innovation, and that this finding is not driven by changes in compensation structures. After investigating various potential explanations for this pattern, the

authors argue that the most plausible reason is that longer-horizon contracts allow managers to take on innovative projects without worrying too much about the pressure to meet short-term performance benchmarks. They conclude that a policy effort to reduce legal CEO contract length, as proposed in some European countries, can have adverse consequences for the real economy in terms of curbing corporate innovation. Hence, their paper illustrates that the length of CEO contract, in addition to its incentive components, can serve as a key ingredient in motivating CEOs to engage in innovative activities.

Since innovation is a long, unpredictable, and risky process, it entails the effort not only from a firm's CEO, but also from its non-CEO executives as well as its lower-ranked employees. Several recent papers have therefore examined how the incentives of non-CEO executives and rank-and-file employees shape a company's investment policy in innovative projects. For example, Chang *et al.* (2015) find a positive effect of non-executive employee stock options on the quantity and quality of innovation outcomes. Their identification strategies suggest that the main results are likely causal. They also argue that the main channel through which these stock options encourage innovation is its positive effect on the risk-taking incentive (i.e. vega) rather than on the performance-based incentive (i.e. delta).

In a related study, Jia *et al.* (2016) focus on team-based compensation designs and examine the effect of synergistic incentives among executives on corporate innovation performance. Building on Edmans *et al.* (2013) and Bushman *et al.* (2016), they use dispersion in pay performance sensitivities (PPS) among top executives as a proxy for the synergy component of a management team's incentive. They set up a model to estimate the optimal PPS dispersion and use residuals from this model to capture deviations from the optimal dispersion. They then show that innovation performance deteriorates when PPS dispersion is above the optimal level, but this declining performance disappears when PPS dispersion is below the optimal level. These results are consistent with the notion that the inequality perceptions of some executives in an interdependent work context could hinder corporate innovation. They also show that deviations from optimal PPS dispersion have a negative effect on the innovation productivity of individual executives.

Another paper that examines the innovative-related incentives of individual non-executive employees is Sauermann and Cohen (2010), who, adopting a psychologically grounded approach, study the relation between innovation performance and various types of motives of employees who actually work in the R&D division. Using a sample of more than 1700 scientists and engineers holding PhD degrees, they find that different motives affect innovation outcomes differently. While motives related to intellectual challenge, independence, and money are positively associated with innovative output, those concerning responsibility and job security seem to be negatively related to innovation performance. Moreover, they find that the main channel through which motives match innovation performance is not the amount of effort spent on R&D activities but rather other dimensions (i.e. characters) of innovative effort. Without any identification tests, however, their study only

documents an equilibrium matching between employee motives and innovation outputs but does not differentiate between a treatment effect and a selection effect.

In a related study, Dutta and Fan (2012) conduct a theoretical investigation into how centralized and delegated forms of investment decision making can motivate a firm's divisional managers to better implement innovation strategies. In their model, the manager faces a classic holdup problem in the sense that the headquarters would take away his/her rent via ex post opportunistic behavior, and thus would reduce his or her ex ante incentives to exert effort on innovation. The manager's holdup problem is more severe under the centralized investment structure because headquarters exploits the information provided by a central monitoring system to limit managerial rents. In contrast, this problem is less severe under a delegated form of investment because headquarters effectively commits to providing the manager with more rents from his/her innovation efforts by not putting in place any monitoring technology. Hence, they find that in equilibrium, the level of innovation activity under the delegation scheme would be higher than that under centralization. Overall, they argue that one essential element that contributes to the effort exerted on innovative investments and thus their success rate is the tradeoff between ex post investment efficiency and ex ante innovation incentives.

Other than providing suitable incentives for innovation to top and divisional managers as well as rank-and-file employees, shareholders could directly influence the scale and scope of a firm's innovation activities through changing the functional attributes of the board of directors, which plays a vital role in monitoring and advising corporate managers.

Using regulatory changes that force the adoption of independent boards in early 2000s, Balsmeier *et al.* (2017) find that firms that transition to independent boards generate more and better-cited patents but focus on more crowded and familiar areas of technology in the sense that the citation increase comes mainly from incremental patents in the middle of the citation distribution. Meanwhile, these firms do not exhibit significant changes in the number of uncited or highly cited patents, suggesting that they are not actively exploring new territories or pursuing risky innovation strategies. The paper concludes that greater oversight by the corporate board might improve the focus and productivity of managers but does not help investment in new, unexplored technologies.

Besides examining the roles played by "internal" governance (such as designing proper incentives for managers via contracting, form of delegation, and board monitoring) in influencing innovation, it is also interesting to explore how the "external" form of governance through an active takeover market affects the agency conflicts within a firm and thus shapes the innovation incentives of CEOs and key executives. On the one hand, an active takeover market may reduce the moral hazard problem by disciplining the managers who, if not monitored, have a tendency to shirk or invest in projects with quick but safe returns. In this way, the external threat of being taken over and having their jobs replaced may incentivize the managers to work harder and improve their innovative efforts.

On the other hand, due to incomplete contracts, managers might be reluctant to put down their human capital for innovative projects, which are long-term in nature, because they fear being ripped off by hostile takeover bidders who reap the profits of the innovative projects without paying the initial costs. Moreover, managers might be unwilling to invest in innovative projects that tend to be opaque to outside investors because by doing so, their firms might be undervalued, triggering hostile takeovers and any disciplining actions associated with them. If the arguments for incomplete contracting and asymmetric information are valid, an active takeover market might deter managers from pursuing innovation. Therefore, how external governance through takeovers affects innovation is an empirical question.

Using a sample of 13 339 US firms over the 1976 to 2000 period and a difference-in-differences methodology, Atanassov (2013) finds that firms incorporated in states that pass antitakeover laws, and experience an exogenous decrease in the threat of hostile takeovers, not only generate fewer patents but also experience a decrease in the quality of the patents they generate, compared to firms incorporated in states that do not pass antitakeover laws. Further, he finds that the negative effect of antitakeover laws on innovation activities is mitigated but not completely eliminated by the presence of alternative governance mechanisms such as large blockholders, pension fund ownership, financial leverage, and product market competition. Overall, his evidence is more consistent with a disciplinary role played by the external takeover market. The findings reported in Atanassov (2013), however, have recently been challenged by Karpoff and Wittry (2017), who point out that it is problematic to use state anti-takeover provisions as a shock to firm-level exposure to the takeover threat because some states' anti-takeover provisions do not raise (but rather reduce) the barriers to takeovers for firms incorporated in these states.

In a related paper that finds somewhat different results, Chemmanur and Tian (2017) instead explore the impact of firm-level antitakeover provisions (ATPs) and find that they have a positive, causal effect on innovation outcomes (patents and citations). For identification, they use a regression discontinuity approach that relies on locally exogenous variation generated by shareholder proposal votes. Moreover, they find that the positive effect of ATPs on innovation is more pronounced in firms that face a greater degree of information asymmetry and operate in more competitive product markets. They conclude that ATPs help enhance managerial effort in innovative investments mainly because they can protect managers from the short-term pressure associated with public equity markets. Finally, they document that the number of ATPs increases firm value for those engaging more in innovation activities.

To examine the relative strengths of internal versus external governance mechanisms in influencing corporate innovation, Sapra *et al.* (2014) develop a theoretical model and find a U-shaped relation between innovation and external takeover pressure, which arises from the interaction between the private benefits of control and expected takeover premia. In their model, choosing a more innovative project

increases the firm's likelihood of being taken over and thus increases the manager's expected loss of control benefits. Meanwhile, choosing the more innovative project would imply a larger expected takeover premium because it has a higher likelihood of being taken over and the ex post assessments of its quality are more variable. These tradeoffs give rise to the predicted U-shaped pattern. The authors also find evidence consistent with their prediction that innovation is enhanced either by an efficient market for corporate control or by very severe antitakeover laws.

While most of the studies that analyze how innovation is affected by firms' internal incentive structures focus on the role played by the firms' organizational capital, little is known about the relative importance of this organizational capital and that of the human capital of the employees in the process of innovative endeavors. Whether the "horse" or the "jockey" matters more for innovation is both an important and intriguing research question. Hence, a growing line of research has been dedicated to this topic.

Using a sample of over 200 000 inventors who work for 5722 firms from 1970 to 2003, Liu *et al.* (2016a) run a horse race between organizational capital and inventor human capital in explaining the success and features of corporate innovation, and find that relative to the former, the latter explains most of the variation in innovation performance (i.e. the quantity and quality of patenting) but much less in innovation strategy (i.e. whether the patents are exploratory or exploitative).

(2016a) by demonstrating that human capital by both top managers and individual inventors matter for corporate innovation.

Using the same management quality measure above, Chemmanur *et al.* (2017a) find that higher quality management teams in private firms enhance the investment and productivity of their innovation projects before they go public. Further, they show that entrepreneurial firms with greater pre-IPO innovation activities and higher management quality tend to go public at a younger age and can enjoy higher valuations both on the IPO offer date and in the secondary market immediately following the IPO. Such firms' post-IPO operating performance also experiences more rapid growth relative to those non-innovative firms with lower quality management teams.

Kerr (2013) provides a literature review on academic work regarding the effects of global migration on innovation and entrepreneurship. The work reviewed in his paper argues that most immigrants in the US who are in the science, technology, engineering, and mathematics (STEM) fields are better trained for this work than natives, but that they are comparable to each other conditional on educational choices. He also looks into literature on the aggregate consequence of higher immigration to the US for innovation and concludes that immigration is associated with higher levels of innovation for US firms and that the short-run employment consequences for natives are minimal (while the long-run impact is less understood). Overall, the papers reviewed in Kerr (2013) suggest that immigrants possess unique human capital that benefits a nation's innovation and entrepreneurship.

2.3. Firms' External Characteristics

In this subsection, we discuss literature that explores how the external environment of a firm and those firm-level characteristics largely beyond the direct control of shareholders influence the process and outcomes of corporate innovation. We start by reviewing studies that examine various kinds of financial market intermediaries, such as financial analysts, institutional investors, and hedge funds, and then move on to discuss articles studying the effect of stock market trading, prices, as well as stakeholders, on corporate innovation.

While previous literature mostly focuses on the positive role played by financial analysts in terms of their information production and dissemination activities, He and Tian (2013) reveal a potential "dark side" of financial analysts in the case of corporate innovation. Specifically, they find that the more a firm is being covered by financial analysts, the fewer patents it produces and the fewer future citations it receives for the generated patents. To explore the causal relationship between analyst coverage and innovation, they make use of a difference-in-differences approach that relies on the quasi-natural experiment of brokerage mergers and closures, as well as an instrumental variable approach. Their results suggest that financial analysts might have exerted too much pressure on managers to meet short-term earnings targets, prompting them to cut investment in long-term innovative projects. As such, the paper identifies a previously unknown adverse effect of analyst coverage:

its promotion of managerial myopia and the consequent reduction in innovation activities.

In a related paper, Goldman and Peress (2016) argue that innovation (i.e. knowledge about technology) and financial analysis (i.e. technology about knowledge) are mutually reinforcing. They first develop a theoretical model to show a positive relation between innovation incentives (i.e. R&D expenditures) and a firm's information environment. They then test this relation empirically by using the staggered implementation of R&D tax credits by US states as an exogenous shock to R&D expenditures and brokerage mergers and closures as an exogenous shock to a firm's information environment. However, since R&D tax credits increase a firm's earnings in addition to its incentives to innovate, it is unclear whether the staggered implementation of R&D tax credits by US states influences a firm's information environment only through its effect on innovation incentives. Similarly, brokerage mergers and closures could influence both the information environment of a firm and the short-term pressure that analysts tend to put on firm managers (He and Tian, 2013), and thus their effect on R&D expenditures may reflect the net effect of both economic forces.

Given the growing importance of institutional investors in corporate governance and decision making, how different types of institutions shape the innovation process is a natural question to explore. This strand of literature begins with Aghion *et al.* (2013). Using a sample of firm-years between 1991 and 1999, they find an overall positive association between institutional ownership and innovation outcomes such as citation-weighted patents per dollar of R&D expenses. This result is consistent with both a monitoring story, in which institutional investors discipline managers by forcing them out of their "quiet life," and a career concern story, in which the increased monitoring of institutions can insulate managers from reputation damages in case the risky innovation leads to bad outcomes. To distinguish between the two alternative explanations, the authors develop a theoretical model and find evidence mostly consistent with the career concern channel.

Brav *et al.* (2017) focus on the role played by hedge funds, a special type of activist institution, in the innovation process. They find that firms targeted by hedge fund activists are able to enhance their innovation efficiency following the intervention by reducing R&D expenditures while alsoo increasing innovation output. Further, the positive influence of hedge fund activism on innovation is more pronounced for firms with more diversified innovation portfolios. They also find that the main channels through which hedge funds induce innovation efficiency gains are the reallocation of innovative resources and the redeployment of human capital, which contribute to the refocusing of the innovation scope.

Yang (2017) examines how shareholder–creditor conflicts affect corporate innovation by using a new proxy for the degree of shareholder–creditor conflicts: the simultaneous holdings of a firm's debt and equity by the same institutional investor (dual-holder). He finds that firms with dual ownership (which have smaller shareholder–creditor conflicts) generate fewer but more valuable patents, suggesting that

institutional dual-holders can mitigate shareholder–creditor conflicts and curb excessive risk taking (i.e. risk shifting). Finally, he finds that the lower sensitivity of managerial incentive compensation to stock price volatility is a plausible channel.

In a related paper, Chemmanur *et al.* (2017b) explore the role of institutional cross-blockholders in the formation of strategic alliances and corporate innovation. They first find that the number of same-industry peers sharing common institutional blockholders with a firm is positively associated with the number of strategic alliances it enters into, and then document a positive, causal effect of strategic alliances on innovation. Moreover, they examine the influence of alliance-induced networks on innovation and find that alliance partners share patent rights via the practice of "co-patenting." Finally, they argue that an important mechanism through which strategic alliances enhance corporate innovation is their efficient redeployment of inventors across alliance partners.

Analyzing activism via a more general group of shareholders, Qi (2016) finds a negative effect of shareholder intervention on managerial incentives to innovate. She argues that innovation may cause stock prices to reflect less accurate information about a firm's fundamentals, which triggers shareholder intervention and associated disciplinary actions against managers. Thus, under the threat of shareholder intervention, firm managers would refrain from taking innovative projects in the first place. Consistent with this hypothesis, Qi (2016) finds that the negative effect of shareholder intervention on innovation is less pronounced for firms with more efficient stock prices through higher institutional ownership and/or greater analyst coverage.

In a similar fashion but in a different setting, Gu *et al.* (2017) examine the effect of bank interventions on corporate innovation in the case of debt covenant violations. They find that bank interventions have a negative effect on innovation quantity, but not on innovation quality. Moreover, they find that the decrease in innovation outputs is largely unrelated to the violating firm's core business, which in fact helps these firms refocus their innovation strategies and ultimately improves firm value. Finally, they find that the main channel through which the above "restructuring" effect occurs is human capital redeployment.

Using a sample of approximately 2800 Spanish manufacturing firms between 1990 and 2006, Guadalupe *et al.* (2012) examine the relation between foreign ownership and firm innovation. After verifying that more productive firms are more likely to be targeted by foreign acquirers, they find that acquired firms become more innovative after transitioning into foreign ownership. Further, they find that the higher levels of innovation by foreign subsidiaries are mostly driven by exporting through a foreign parent. Overall, their evidence suggests that multinational subsidiaries innovate more because they enjoy greater benefits from innovation due to their existing market scale and not just because their innovation costs are lower than domestic firms.

In a related paper, Luong *et al.* (2017) study the influence of foreign institutional investors on firm innovation. Using data from 26 non-US countries from

2000 to 2010, they find a positive, causal effect of foreign institutional ownership on corporate innovation. Moreover, they show that foreign institutional investors' active monitoring, more tolerance for failure, and the facilitation of knowledge spillovers from high-innovation economies are three possible channels through which foreign institutions improve firms' innovative efforts.

Other than institutional investors, short sellers are another group of market participants that might affect firms' incentives to innovate because their active trading behavior could generate both useful information (if the short sales are fundamental driven) or downward price pressure (if the short sales are driven by hedging needs or other non-fundamental related factors). He and Tian (2017) examine whether short sellers encourage or hinder firms' innovation activities by adopting the quasi-natural experiment of Regulation SHO, which removes the short-selling constraints on a randomly chosen subsample of Russell 3000 firms. They find that the quality, market value, and originality of patents generated by treatment firms improve significantly more than control firms surrounding Regulation SHO, suggesting that short sellers are able to mitigate managerial myopia and enhance the quality of corporate innovation. Further, they find that patenting-related litigation risk from short sellers might be a plausible channel through which short sellers help improve innovation quality. Their paper identifies an unintended real effect of short sellers on corporate innovation.

Another paper that documents the real effect of secondary market trading on innovative investments is Fang *et al.* (2014). Using a difference-in-differences approach based on the exogenous variation in liquidity generated by regulatory changes (mainly decimalization in 2001), they show a somewhat surprising result that stock market liquidity in fact impedes firm innovation. They further argue that the two possible mechanisms for the negative effect of liquidity on innovation are increased exposure to hostile takeovers and greater presence of non-dedicated institutional investors.

are under greater scrutiny by lenders. Further, firms pursue more risky innovation investments with greater originality and higher economic value after the initiation of CDS trades. Finally, they argue that the main channel through which CDS trading enhances firms' incentives to undertake corporate innovation is its boost of lenders' risk tolerance and the corresponding increase in borrowers' risk-taking behavior in the innovation process.

Other than financial analysts, institutional investors, stock market traders, and CDS market investors, some recent literature has found that important firm stakeholders could also exert influence on firms' innovation strategies. For example, Chu *et al.* (2017) explore how supplier–customer relationships affect suppliers' innovation activities. Adopting a difference-in-differences framework, they show that knowledge spillovers, measured as the geographical distance between a supplier and its major customers, appear to have a positive, causal effect on supplier innovation. Further, they find that this positive influence is more pronounced when the customers are more innovative themselves and have patent portfolios closer in the technology space to those of the suppliers.

Another paper, Flammer and Kacperczyk (2016), also analyzes the impact of stakeholder orientation on innovation. To explore exogenous variation in stakeholder orientation, the authors make use of the enactment of state-level constituency statutes that permit the board of directors to consider stakeholders' interests when making business decisions. They find that the enactment of such constituency statutes gives rise to more innovation output, and that the positive effect of stakeholder orientation on innovation is more pronounced in consumer-oriented and less eco-friendly industries. Finally, they argue that stakeholder orientation spurs innovation by encouraging experimentation and boosting employees' innovative productivity.

Given that the patenting process requires intensive interpersonal interactions between firms and patent officers, a firm's accessibility to the United States Patent and Trademark Office (USPTO), an important intermediary in the US innovation ecosystem, is critical to the materialization of the firm's innovation effort. Jia and Tian (2018) use a firm's distance to the USPTO to capture accessibility and show that an increase in accessibility to the USPTO results in a shorter time-to-patent grant and an increase in the quantity and exploration of the firm's innovation. Markets react positively to the opening of the USPTO's regional offices for innovation-intensive firms that enjoy easy accessibility to the USPTO. Their results illustrate the importance of accessibility to patent officers in fostering an effective innovation ecosystem.

3. Market Characteristics

After discussing various firm-level determinants of corporate innovation, we now turn our attention to the general economic environment in which a firm operates and assess how different market-wide forces influence the process and outcome of the firm's innovative investment.

Since corporate innovation ultimately gives the innovating firms a competitive edge in the product market, it is both interesting and important to understand how product market dynamics interact with the innovation process and firms' incentives to innovate under various market circumstances.

In an early attempt to address this research question, Aghion *et al.* (2005) find an inverted-U relationship between product market competition and innovation. They first develop a model in which competition in an industry discourages laggard firms from pursuing innovation but incentivizes neck-and-neck firms to invest in innovative projects, which gives rise to a non-linear effect of product market competition on innovation. They then conduct empirical analyses to test this prediction using panel data and find supporting evidence. Finally, they find that the average technological distance between leaders and followers increases with the level of product market competition and that the inverted-U relationship is more pronounced when an industry has more neck-and-neck competing firms.

In a related study, Desmet and Rossi-Hansberg (2012) examine why private firms are willing to invest in innovation if perfect competition eliminates all the possible profits. They argue theoretically that in the presence of nonreplicable factors of production (such as land), perfect competition in the product market together with competition in the input markets can lead to optimal innovation even if no single firm possesses any market power. The central intuition is that if a firm bids for land with a plan to innovate and wins the bid, the firm would benefit from the innovation since no one else can produce in that location except the firm itself. The firm will thus invest in innovation as long as the gains from these investments outweigh the costs, which explains the coexistence of perfect competition and innovative investments.

Yung (2016) proposes another reason for why firms in a competitive market are still willing to invest in risky and costly innovative projects rather than simply waiting and copycatting. In his model, internal financing leads to an equilibrium in which all firms wait for others to innovate first because innovation involves costly investment and useful information could be revealed by observing others' innovation activities. This equilibrium is changed when firms finance their projects with external financing because the terms of financing now depend on the investor's perception of the firm's quality, which can be partially reflected in its innovation activities. As a result, in equilibrium, firms with higher quality would optimally take the lead in innovation to signal their ability while those with lower quality would wait longer before doing so. His paper thus offers an information-based explanation for firms' innovation endeavors as well as some key features of market-wide innovation waves.

In a similar vein, Spulber (2013) theoretically explores the implications of competition and intellectual property (IP) protections for innovation, and finds that these two are complements to increase incentives to innovate. He shows that when there is a market for innovation products, both the competition among producers (i.e. the demand side of innovation) and the competition among inventors (i.e. the

suppliers of innovation) lead to more innovation outcomes. This is because competition in the product market increases inventors' ability to realize the market value of their innovations by reducing the rents extracted by producers. Similarly, competition in the market for inventions mitigates the inventor's incentive to reduce innovation output in order to extract monopolistic profits. On the other hand, when IP is not fully appropriable, he shows that competition reduces incentives to innovate, resulting in lower economic welfare. Overall, his findings indicate that antitrust policy and IP protections are complements.

Bloom *et al.* (2013) develop an empirical framework to identify two different types of R&D spillovers from rival firms in the same industry: the technological spillover effect, which tends to enhance the productivity of firms operating in similar technological areas, and the product market rivalry effect, which tends to steal away businesses from competitors. They first distinguish a firm's position in the technology space and the product market space and then examine multiple indicators of performance such as market value, patents, and R&D expenditures. Applying this empirical framework to a panel of US firms during the period between 1981 and 2001, they find that both types of R&D spillovers are present and that R&D activities by a firm's product market competitors are a strategic complement to its own innovation effort.

Using a sample of biopharmaceutical firms, Thakor and Lo (2016) examine the interaction between competition, R&D investment, and the financing choices of innovative firms. They first develop a theoretical model to predict that innovative firms will, in response to an increased competitive pressure from the industry, increase their R&D investment relative to investment in assets-in-place, carry more cash, and keep a lower level of net debt. In the meantime, firms under such circumstances would experience a decline in their stock betas but an increase in total stock return volatility due to the strategic complementarity in R&D investment. They then test these predictions using a panel of biopharmaceutical firms and find empirical support for the model.

standing in terms of technological level in the sector as well as the competitiveness of the sector. Using these designs, the paper finds that competition positively affects R&D investments by neck-and-neck firms but negatively affects innovative efforts

the effect of bank credit supply on corporate innovation. Chava *et al.* (2013) focus on how bank deregulations affect young and private startup companies. They find that state-level intrastate banking deregulation in the US, which enhances the local market power of banks, has a negative effect on the innovation efforts made by young, private firms. In contrast, interstate banking deregulation in the US states, which reduces the local market power of banks, promotes such firms' innovation.

Cornaggia *et al.* (2015), on the other hand, analyze the impact of bank deregulation on both public and private firms. Specifically, they find that banking competition induced by the deregulation of interstate bank branching decreases state-level innovation outcomes by public firms headquartered in deregulating states. In the meantime, the success rate of innovation improves among private firms that rely on external financing and those with limited access to credit from local banks. They argue that banking competition is beneficial to small, innovative firms because it allows them to avoid being acquired by public corporations. As such, the supply of innovative targets is reduced, leading to the smaller proportion of state-level innovation carried out by public firms.

Another paper in this area, Amore *et al.* (2013), focuses on manufacturing firms' innovative outcomes and finds that interstate banking deregulation during the 1980s and 1990s significantly increased the quantity and quality of innon. n activities by these firms, especially for those highly dependent on external capital and located closer to entering banks. Moreover, they argue that the main channel through which this effect arises is the greater ability of deregulated banks to geographically diversify their credit risk.

Similarly, Hombert and Matray (2017) study how relationship lending affects the financing of innovation. Using intrastate banking deregulation as a negative shock to relationships, they find that the shock has an adverse effect on small innovative firms, especially those that depend more on relationship lending. Further, they show that an important channel through which this credit supply shock negatively impacts innovation is the departure of productive inventors from the small firms in the affected regions.

A closely related paper by Saidi and Zaldokas (2017) explores the relation between innon. n and relationship lending. They focus on the trade-off between

in innovation. For example, using the Great Depression as their setting, Nanda and Nicholas (2014) find that bank distress negatively impacts the quantity, quality, and trajectory of corporate innovation, particularly for innovative firms operating in capital-intensive industries. However, they fail to find a negative effect in aggregate because a large number of innovative firms were either located in countries with lower levels of bank distress or operating in less capital-intensive industries. Their results help explain why US firms continue to be innovative even after large historical shocks to the country's banking system.

Mao (2017) pushes this line of inquiry further and shows that credit markets could affect corporate innovation through a collateral pledging mechanism. Specifically, she finds that collateral shocks affect the patents and citations of a firm mainly through three channels: in-house R&D, the acquisition of innovative targets, and CVC investment. This paper's identification comes from two sources. First, the paper compares the innovation of land-holding firms across different MSA areas with different local real estate price growth. Second, the paper compares the innovation of firms with different levels of real estate holdings within one MSA area. These methods allow the author to control for aggregate economic fluctuations and local economic conditions that could be correlated with innovation.

Some earlier studies also explore how financing affects firms' R&D investments. For example, Brown *et al.* (2009) find that the availability of internal and external (public) equity financing affects the amount that young US public firms spend on R&D. Specifically, they argue that most of the dramatic 1990s R&D boom can be explained by a finance supply shift. In a related paper, Brown *et al.* (2012), using a large sample of European firms, find that financial constraints and access to external financing have a considerable effect on firms' R&D investments, suggesting the significant influence of stock market development on economic growth.

In addition to the market structure and the banking system, taxes are another important macro-level economic force that is largely out of the control of corporate managers but may affect their incentives to innovate. On the one hand, a smaller size of the pie among stakeholders due to heavier taxes may reduce the incentives of managers and employees to pursue innovation. Higher taxes may also reduce the after-tax cash held by innovative firms, leading to a lower level of failure tolerance that is crucial for innovation. On the other hand, more taxes may allow local governments to enhance education and other infrastructure support, which, in turn, enhances firm-level innovation.

Two contemporaneous studies analyze how corporate taxes affect innovation using the same identification strategy. Using a differences-in-differences methodology, Atanassov and Liu (2016) empirically document that large state income tax increases (decreases) reduce (enhance) firms' patenting activities. Further, they find their results are stronger for more financially constrained firms, those with weaker corporate governance, and those that avoid taxes more. Using the same state-level staggered changes in taxes, Mukherjee *et al.* (2017) arrive at a similar conclusion. In addition to the quantity of innovation inputs (R&D expenses) and outputs

(patents), they find that taxes affect new product introductions. Hence, the results from the two papers are consistent with the idea that higher corporate taxes hinder innovators' incentives by discouraging risk-taking.

Exploring the same question in a different setting (i.e. policy changes to the asset-based size thresholds for eligibility for R&D tax subsidies), Dechezleprêtre *et al.* (2016) find, based on a sample of UK firms, that taxes have a significant effect on both R&D expenses and patenting. They show that in the absence of the tax relief scheme, the aggregate R&D expenses by the sample firms would be significantly lower. They also find that the additional R&D expenditures induced by the tax policy have a positive spillover effect on other innovative firms. The findings of this study are consistent with those of the above two papers. Further, using a broad sample of OECD countries, Brown *et al.* (2017) study the cross-country effects of R&D tax credits and find that more generous tax credits are associated with more R&D in low-tech (but not high-tech) industries.

Some people have argued that technological innovations, like many corporate events such as M&As and IPOs, tend to cluster by time periods. Two recent papers analyze this phenomenon of innovation waves from a theoretical perspective. Sevilir (2017) develops a model in which firms learn from each other's innovations. In the model, innovation by one firm incentivizes peer firms to make innovative investment in subsequent periods, generating an innovation wave. The intuition is that as innovations reach more and more peer firms, it becomes less profitable for each of them to expropriate the innovation but more profitable to invest in innovation on their own. Sevilir (2017) thus predicts that a concentrated mass of interconnected firms that both compete and learn from each other as well as a quick flow of innovative ideas from one firm to another could give rise to an innovation wave. Finally, her analysis predicts that a series of consolidating mergers in an industry will reduce incentives to innovate.

Dicks and Fulghieri (2017) make use of the concept of uncertainty aversion to explain innovation waves. In their model, investors need to decide whether to fund an innovative project with limited knowledge of the odds of success. They then show that uncertainty-averse investors have a more favorable opinion about an innovation project if they can also make investments in other innovative projects at the same time. As a result, uncertainty aversion makes investments in innovative projects a strategic complement, leading up to an innovation wave. They also show that innovation waves may start with some positive technological shocks in one sector and then spill over to other sectors via uncertainty-averse investors.

Market-wide litigation risk could also affect corporate innovation. Cohen *et al.* (2016a) document that patenting-related litigation risk drives innovators to shield themselves by shifting their place of conducting innovation from industry (i.e. public and private firms) to universities. Specifically, the litigation risk by non-practicing entities (NPEs) that behave as opportunistic patent trolls (Cohen *et al.*, 2016b) pushes innovators to focus on technological areas with reduced potential litigation

threat, and this effect is more pronounced in industries with more aggressive NPE litigation.

Finally, while public firms in many countries are required to file reports and disclose their earnings on a quarterly basis (with a few exceptions, such as the European Union, which removed such requirements in 2013 to combat short-termism), this was not the case in the US. The Securities and Exchange Commission required annual financial reporting of publicly listed firms in 1934, increased the frequency to semi-annual reporting in 1955, and increased it further to quarterly reporting in 1970. These regulatory changes in financial reporting frequency could also affect public firms' incentives to innovate. Fu *et al.* (2017) explore this question and find that a higher financial reporting frequency reduces a firm's innovation output. Further, this negative effect is more pronounced for firms with higher price–earnings sensitivities and those with more severe financial constraints. The explanation they offer is that frequent reporting imposes short-term pressure on managers and induces managerial myopia.

4. Institutional Features of a Society/Country

In this section, we consider some characteristics of a society or nation that are even broader than within-country market conditions. We first review papers that explore how laws related to shareholder protection, IP rights, labor protection, bankruptcy, and insider trading affect firms' incentives to innovate. Then, we discuss studies that examine how a nation's overall financial development, financial liberalization, accounting system, and international trade rules relate to the investments in innovative projects. Finally, we review papers that study whether other aspects of a country, such as its policy uncertainty, government subsidy, economic growth, and demographic and social traits, can influence the process and success of corporate innovation, and if so, in what way.

4.1. Laws and Policies

This subsection considers the effect of a country's legal system and government policies on its innovation activities. Ever since the theoretical framework of Aghion and Tirole (1994), which analyzes the organization of innovation activity under incomplete contracts, several economics papers have explored how IP protection rules and regulations influence the incentives to innovate.

Analyzing 177 major patent policy shifts in 60 nations over the past 150 years, Lerner (2009) examines how IP protection laws affect innovation. After adjusting for the overall trend in patenting, he finds a surprisingly negative impact of such law changes on the number of patents generated. To explain this puzzling result, he discusses three possibilities. First, the patent-based measure of innovation may not fully capture the true extent of innovation output. Second, there might be confounding policy changes in some of the sample countries. Third, the common wisdom among economists that patent protection can encourage innovative actions might be over-exaggerated.

Williams (2013) empirically explores how IP on an existing technology affects subsequent innovation efforts, which is unclear from a theoretical perspective. Specifically, he analyzes the sequencing of the human genome by the public Human Genome Project and a private firm called Celera, and studies the influence of Celera's gene-level IP on subsequent innovations. Employing different approaches, Williams (2013) finds that Celera's IP leads to reductions in subsequent scientific research and product development outcomes, suggesting that short-term IP on existing technologies has persistent negative effects on subsequent innovation.

Focusing on Chinese firms, Fang *et al.* (2017) examine how IP rights protection affects innovation in China around the privatization of state-owned enterprises (SOEs). They find that innovation increases after SOE privatizations, and this increase is more pronounced in cities with strong IP rights protection. Their results suggest that IP rights protection is beneficial to firms' innovative incentives but this positive effect mainly exists among non-SOE firms rather than SOEs.

Using data from 60 countries from 2000 to 2013, and analyzing the implemen-

For example, wrongful discharge laws, which protect employees against unfair firing/layoffs, limit firms' ability to hold up innovating employees after the innovation turns out to be successful. Hence, by mitigating the possibility of hold-up risk faced by R&D employees, such laws increase their incentives to innovate and in turn boost the employers' innovation output. Using the staggered adoption of wrongful discharge laws across US states, Acharya *et al.* (2014) formally test the above intuition and find that wrongful discharge laws indeed have a positive impact on innovation and new firm creation. Following the same intuition, Acharya *et al.* (2013) compare labor dismissal laws with other laws in influencing firm innovation. Exploiting country-level changes in dismissal laws in the US, the UK, France, and Germany, the paper finds that more stringent dismissal laws spur innovation, particularly in innovation-intensive industries, but other labor laws do not do so.

Related to the above two papers, Bradley *et al.* (2017) analyze how a unique feature of organized labor, namely, unionization, impacts on firm innovation. Adopting a regression discontinuity design framework that relies on locally exogenous variation generated by union elections that pass or fail by a small margin of votes, they document a negative effect of enhanced labor power on both the quantity and quality of innovation. In response to unionization, firms move their innovation activities away from those states where union elections win. Reductions in R&D expenditures, shirking by existing inventors, and departures of talented inventors are three plausible underlying channels.

Besides laws concerning innovators and employees, a series of papers looks into the effect of bankruptcy laws, which protect the interests of creditors, on firms' incentives and efficacy in the innovation process.

Acharya and Subramanian (2009) argue that when the bankruptcy code is friendly to creditors, innovative firms might be discouraged from pursuing innovation for fear of excessive liquidations. In contrast, a debtor-friendly bankruptcy code may lead to more innovation by promoting continuation upon failure. Using time-series changes within a country as well as cross-country variation in creditor rights, they find evidence consistent with the above conjectures. Further, they find that the negative effect of a creditor-friendly bankruptcy code on innovation is more pronounced for firms in technologically innovative industries. When creditor rights are stronger, such industries use relatively less debt and grow disproportionately slower.

In a closely related work, Cerqueiro *et al.* (2017) examine the effects of regional and temporal variation in US personal bankruptcy laws on innovation, and arrive at a somewhat different conclusion from that of Acharya and Subramanian (2009). Specifically, they find that bankruptcy laws that offer stronger debtor protection reduce, rather than increase, the number of patents generated by small firms. In the meantime, stronger debtor protection also decreases the average quality as well as the variance in the quality of innovation. Further, they find that the negative effect of the stronger debtor protection on innovation may be driven by the reduced

supply of debt financing and that such effect is stronger in industries with a high dependence on external financing.

From a somewhat different angle, Mann (2017) shows that patents are frequently pledged as collateral to raise significant debt financing, which indicates that the pledgeability of patents might help financing innovative activities. Exploiting court decisions as a source of exogenous variation in creditor rights, he finds that when creditor rights to patents are strengthened, innovative firms raise more debt and invest more in long-term, risky R&D projects, giving rise to greater innovation outputs.

Another type of law explored by the recent literature is the universal demand (UD) law, which makes it harder for shareholders to file derivative lawsuits and thus reduces a company's shareholder litigation risk. For example, using the staggered passages of UD laws in 23 US states between 1989 and 2005, Lin *et al.* (2017) find that firms experience an increase in their innovation activities and outcomes following the adoption of the UD laws. Moreover, the main channel through which the passage of UD laws encourages innovation is the reduction in the external pressure imposed by shareholder litigation risk, which tends to deter managers from investing in long-term, exploratory innovative projects.

Other than laws, several papers examine how innovation is influenced by a country's institutional features characterized by its shareholder protection, legal origin, corporate contracting environment, and privatization of the economy.

Using a large sample of firms in 32 countries between 1990 and 2007, Brown *et al.* (2013) find that strong shareholder protections and better access to stock market financing have a positive impact on innovative investments, particularly for small firms. In the meantime, they find no evidence of a connection between the access to stock market financing and fixed capital investment. On the other hand,

Focusing on China and making use of its unique institutional setting, Tan *et al.* (2016) study the real effect of privatization on technological innovation. Specifically, they examine a quasi-natural experiment, China's split share structure reform, which mandatorily makes nontradable shares tradable and starts the privatization process of SOEs in China. Adopting a difference-in-differences approach, they find that better prospects for privatization encourage managers of SOEs to innovate more, possibly by better aligning the interests between controlling and minority shareholders and by enhancing stock price informativeness.

Instead of focusing on particular rules and policies imposed by governments, Bhattacharya *et al.* (2017) explore whether the uncertainty of government policies also affects corporate innovation. Using data from 43 countries, they find that it is not policy per se, but policy uncertainty that affects technological innovation to a greater extent. Specifically, they find that patenting outcomes significantly decrease during times of policy uncertainty as measured by national elections, especially for more innovation-intensive industries. Finally, they argue that the decrease in the number of inventors in periods of policy uncertainty might explain their result.

Some studies have also explored the role played by government spending and subsidies in the process of generating innovation. For example, Bayar *et al.* (2016) develop a theoretical framework to analyze how governments and non-profit agencies can use subsidy schemes and incentivizing prizes to spur the development of fundamental innovations, which have positive social value but have negative net present values to the developing firms. They also study how government-funded venture capitalists, which hold a diversified portfolio of innovating firms and other firms (in the user industries), help stimulate socially desirable fundamental innovations. Empirically, Kong (2017) shows that firms headquartered in states with increases in government spending experience a significant decline in their innovation. The plausible reasons for this finding include resource reallocation from innovative to non-innovative activities by firms and individuals as well as the substitution of government innovation for corporate innovation.

Howell (2017) uses data on ranked applicants to the US Department of Energy's Small Business Innovation Research grant program to examine the role played by government subsidies. She finds that an early-stage government subsidy has a significantly positive effect on an entrepreneurial firm's patenting and revenues, especially those that are financially constrained. She also rules out certification (i.e. selection) as a likely reason for this effect.

A related study by Jaffe and Le (2015) uses a large sample of New Zealand firms between 2005 and 2009 to examine a similar research question. They find that the receipt of an R&D subsidy significantly increases a firm's propensity to apply for a patent but does not affect the probability of applying for a trademark. They also find a positive influence of R&D support on the introduction of new goods and services, but only a weak effect on process innovation and product innovation.

4.2. Financial Market Development

In this subsection, we analyze how a nation's overall financial development in terms of financial market accessibility, financial liberalization, accounting system, and international trade rules affect firms' innovation incentives and outcomes.

A growing line of research explores the implication of financial market development for a country's innovation activities. Using a panel of 10 manufacturing industries across 34 countries over the period 1980–1995, Tadesse (2006) compares the innovation outcomes of industries operating in countries with bank-centered financial systems with those in countries with market-based systems. He finds that while market-centered systems have a positive effect on innovations in almost all industrial sectors, bank-centered countries contribute more to innovation in information-intensive sectors. He concludes that the two distinct types of financial system have differential effects on a country's innovative landscape according to the industrial structure of the economy.

Along this same line of research, Hsu *et al.* (2014) use a data set that includes 32 developed and emerging countries to examine the effect of financial market development on firm innovation. Adopting a fixed effects identification strategy, they find that industries with more dependence on external financing and those that are more high-tech-intensive appear to be more innovative in countries with better developed equity markets. In contrast, they find a negative effect of credit market development on innovation outcomes in such industries.

Focusing only on developing economies, Ayyagari *et al.* (2011) analyze a large sample of firms, both public and private and across different size ranges in 47 developing economies, and find that easier access to external financing is associated with greater firm innovation, measured by the introduction of new products and technologies, knowledge transfer, or new production processes. They further identify several boosters of innovation, including managerial education level, family or individual ownership, as well as exposure to foreign competition.

Another strand of literature explores the implication of international trade rules for technological innovation. Examining a large panel of firms during the 1996–2007 period, Bloom *et al.* (2016) study the impact of Chinese import competition on innovation and productivity in 12 European countries. For identification, they make use of the removal of product-specific quotas after China joined the WTO. They find that the trade pressure induced by more Chinese imports stimulates firms to upgrade their technology and reallocate employment towards more innovative firms. In contrast, import competition from developed economies seems to have no significant effect on innovation.

In a related paper, Kueng *et al.* (2016) examine how a sample of Canadian firms adjust their innovation activities and other business strategies following the larger increase in Chinese imports between 1999 and 2005. Unlike Bloom *et al.* (2016), they actually find a negative effect of import competition on innovation, with a more adverse effect on process innovation than on product innovation.

Regarding the effect of foreign direct investment (FDI), Gorodnichenko *et al.* (2015) examine firm- and industry-level data from 18 countries and find that FDI and international trade have a strong, positive spillover effect on the innovation activities of domestic firms in emerging markets. Further, the effect is stronger if the FDI is made by firms from more economically developed economies.

Similarly, Coelli *et al.* (2016), using firm-level patent data in over 60 countries, analyze how trade policy during the Great Liberalization of the 1990s affected innovation. Exploiting ex-ante differences in firms' exposure to countries and industries to construct firm-specific measures of tariffs, they find that trade liberalization has a positive, causal effect on corporate innovation in terms of new knowledge generation. They further argue that improved market access and more import competition might be two possible channels.

Other than trade liberalization, some studies have shown that financial liberalization, which removes restrictions on foreign investors and allows them to participate in domestic equity markets, also plays an important role in affecting corporate innovation. For example, Moshirian *et al.* (2015), using a sample of 51 developed and emerging economies between 1980 and 2008, find that industries relying on external equity financing produce more innovation output after financial liberalization. Moreover, they find that underlying mechanisms through which financial liberalization spurs innovation include the relaxation of financial constraints, the utilization of human capital, and the transmission of foreign technology.

Financial accounting regulation has been examined in this literature as well. Li *et al.* (2016) explore how International Financial Reporting Standards (IFRS) affect corporate innovation, using a large sample of more than 140 000 firm-year observations across 38 countries over the 2001–2009 period. They find that mandatory IFRS adopters experience a substantial increase in innovation output during the post-IFRS adoption period. Relaxed financial constraints and improved managerial learning from stock prices induced by IFRS appear to be two plausible underlying economic mechanisms.

Also exploring the implication of information releases for innovation, Brown and Martinsson (2017) show that both the inputs and outputs of innovation are higher in more transparent information environments. They find that an increase in transparency is associated with more innovation, with relatively stronger effects in industries that are more dependent on arm's-length financing.

4.3. Demographic and Social Traits of a Country or a Region

Some papers relate demographic or social traits in a country or region to perceived as well as actual investment in innovation. While Bénabou *et al.* (2013), using international country-level data, document a negative association between religiosity and patents per capita, a follow-up paper by Bénabou *et al.* (2015) examines a related question at the individual level. Specifically, they use a broad set of pro- or anti-innovation attitudes in all five waves of the World Values Survey (1980–2005)

and find that greater religiosity is associated with less favorable opinions about innovation.

Some recent research shows that sexual orientation could also affect corporate innovation. Making use of US state-level Employment Non-Discrimination Acts (ENDAs), which prohibit discrimination based on sexual orientation and gender identity, Gao and Zhang (2017) find that such laws encourage corporate innovation. They further argue that the underlying mechanism is that ENDAs match innovative firms with pro-gay employees who are typically more creative than anti-gay employees.

In addition, the gambling preferences of local investors and managers have been shown to influence corporate innovation in two papers. In particular, using the ratio of Catholics to Protestants to capture local attitudes towards gambling, Chen *et al.* (2014) and Adhikari and Agrawal (2016) find that firms headquartered in countries in which gambling propensity is higher tend to undertake riskier projects, spend more on innovation, and generate greater innovative output. The rationale is that investment in innovation makes a company's stock price more lottery-like, which is a feature desired by individuals who love gambling. Hence, local managers' and investors' gambling preferences influence firms' innovative endeavors.

Using a large sample of firms in 57 countries, Ayyagari *et al.* (2014) find that innovating firms pay more bribes than non-innovating firms, especially in those countries with more bureaucratic regulation and weaker governance. Further, the bribing innovators do not seem to benefit from better services or a better chance of engaging in other opportunistic activities such as tax evasion, so they are more likely to be the victims of corruption. This paper suggests that a corruptive culture or political system may hurt innovation by placing extra burdens on the innovators.

5. Future Directions for Studies on Finance and Corporate Innovation

In this section, we discuss a few of our observations and views on the future direction of research exploring the relation between finance and corporate innovation.

First, we think that it is important to develop new empirical proxies that better capture the extent of corporate innovation activities than self-reported R&D expenditures and patenting-based measures. Self-reported R&D expenditures (especially those reported in a public firm's financial statements) used to be the primary proxy for a firm's innovation activities in the economics and finance literature due to data availability and their direct link to theoretical models as "action" variables. This proxy, however, has several limitations. First, R&D expenditures only capture one particular observable quantitative input (as argued by Aghion *et al.*, 2013) and cannot capture the different dimensions of a firm's innovation strategies (as argued by Manso *et al.*, 2017). Second, R&D is sensitive to accounting norms such as whether they should be capitalized or expensed (as argued by Acharya and Subramanian, 2009). Third, information on self-reported R&D expenditures contained in financial

statements (e.g. those from the Compustat database) is unreliable, which may introduce a significant measurement error problem. Specifically, more than 50% of firms do not choose to report R&D expenditures in the Compustat database. The fact that a firm does not report its R&D expenditures, however, does not necessarily mean that the firm is not engaging in innovation activities: the firm may do so out of strategic concerns or an intention to make use of accounting leeway. Koh and Reeb (2015) show that 10.5% of firms with missing R&D information file and receive patents, and that this number is 14 times greater than firms actually reporting zero R&D expenditures. Hence, a common practice in the existing literature, namely, replacing missing values of R&D expenditures with zeros, introduces noises that could bias the estimation.

Given the limitations of self-reported R&D expenditures, researchers have been trying to explore viable alternative measures for innovation. In the past decade, patenting has been frequently used as an alternative proxy to capture corporate innovation. In fact, the vast majority of the studies reviewed in this survey use patent-based measures to gauge the extent of corporate innovation activities. Superior to R&D expenditures that only capture one particular observable input of innovation and thus fail to account for many other (equally or even more important) observable and unobservable inputs (such as the allocation of talent, effort, and attention to innovative projects and internal incentive schemes, especially non-monetary ones such as public acknowledgements), patenting is an innovation output variable, which encompasses the successful usage of all (both observable and unobservable) innovation inputs. Owing to the richness of the patenting data, researchers could analyze not only the quantity of innovation outputs but also the quality and fundamental attributes of them, such as their impact (citations), generality, originality, and their relevance for a firm's core businesses. In addition, patent data are available not only for publicly traded firms, but also for privately held firms, organizations, and even individuals.

Patenting, however, is not a perfect proxy for innovation either. First, existing literature (e.g. Lerner, 2009) has pointed out that patent-based measures of innovation may not fully capture the true extent of innovation output after observing a few puzzling empirical findings with regard to patent-based measures. Second, patenting is just one way to protect a firm's intellectual property, which largely depends on its own discretion and strategic plans. For example, many corporate innovation outputs take the form of trade secrets because their developers do not want to file for patents. This is especially true for process innovation as opposed to product innovation: while the USPTO accepts applications for process innovation, the final granted patents overwhelmingly capture product innovation. Finally, as pointed out by Lerner and Seru (2015), patent data itself have a few problematic features, such as truncation issues, the difficulty of adjusting for technology classes, the vast disparity in innovative activities across regions, and misleading assignment practices, etc., which may lead to erroneous conclusions if these issues are not properly addressed.

In light of the above concerns, a few attempts to develop new innovation measures have been made in recent years. For example, Kogan *et al.* (2017) propose a new way of measuring the value of innovation outcomes, that is, the market-perceived value of patents at the time of granting. Specifically, they examine the cumulative abnormal returns for a firm during a short window surrounding the date when its patents get granted and then multiply this return with the size of the firm's market capitalization to estimate the patents' economic value in dollar terms. They find that their proposed value measure is positively related to the scientific value of the granted patents, as measured by their future citations. Further, they argue that their market-price-based measure contains additional information relative to the citation-based value measure because the relation between the new measure and firm growth is much larger. This proxy, however, relies on an implicit assumption that the market is able to fully evaluate the granted patents and attach value to them correctly. Owing to the research design, this newly developed proxy can only measure the value of patents filed by publicly traded firms.

Another recent attempt is by Cooper *et al.* (2017). Drawing cues from the management literature, they propose a firm's R&D quotient, defined as the firm-specific output elasticity of R&D expenditures, as an alternative corporate innovation proxy. After comparing their R&D quotient measure with patent-based measures used in the literature in their relation to important asset pricing and corporate finance variables, they conclude that the estimation results from previous literature using their new measure are more consistent and statistically significant than the results using patent-based measures. Further, they argue that the R&D quotient measure is a more universal and uniform measure of innovation. Similar to the measure developed by Kogan *et al.* (2017), this measure can only be used for public firms, and more particularly, can be used only for firms with non-zero R&D expenditures.

Taking a quite different route, Bellstam *et al.* (2017) deviate from using R&D-based or patent-based measures and instead develop a new proxy for corporate innovation by conducting a textual analysis of financial analysts' reports. Specifically, they first fit the Latent Dirichlet Allocation (LDA) model to a large number of analyst reports and then measure the level of a firm's corporate innovation by the intensity with which analysts write about the innovation topic. They argue that their new text-based measure of innovation not only strongly correlates with patenting efficiency, but also captures innovation activities by firms that do not generate patents. For example, they find that the text-based innovation measure forecasts better performance and higher growth rates for both patenting and non-patenting firms. One limitation0-1l t394403.6(t393)-341.8(meas)-8.2(u91)-465.886s grantass. to captur

returns as an alternative way to capture corporate innovation activities. The above two papers provide good examples for the search of new innovation measures.[6]

Another fruitful direction for future research is to examine the real and stock market consequences of corporate technological innovation. The vast majority of the literature reviewed in this survey studies how a variety of firm-, market-, and country-level characteristics affect corporate innovation. A natural question is whether and how corporate innovation affects a firm's real and financial performance, as well as its ownership structures and key firm characteristics. For example, do innovative firms grab more market share from their major product market rivals, and are they more likely to enter a new market and enjoy higher operating performance? Do they hire more productive workers and managers with better skills? In turn, do innovative firms exhibit faster long-term growth, better stock returns, and higher market valuation? Also, are innovative firms suitable for certain ownership/governance structures and financial policies, and do they want more or less publicity? In terms of labor market consequences, do innovative firms spawn entrepreneurs and especially spur local entrepreneurship? Finally, how does corporate innovation at the aggregate level affect a region's or a nation's entrepreneurship, employment, financial development, and economic growth?

While some of the existing papers address a few of the above issues to certain extent (e.g. Hall *et al.*, 2005; Cohen *et al.*, 2013; Hirshleifer *et al.*, 2013, 2017; Balsmeier *et al.*, 2016; Farre-Mensa *et al.*, 2017; Fitzgerald *et al.*, 2017; Frydman and Papanikolaou, 2017), more research along this line is needed and would be fruitful. In particular, future studies should look for clean empirical settings and develop clever identification strategies to identity the causal effect of corporate innovation on the real economy and financial markets.

6. Conclusion

In recent years, finance and corporate innovation has become an increasingly important topic that has attracted a great deal of attention from academic researchers in financial economics. The number of papers published in the top three finance journals (i.e. JF, JFE, and RFS) and accepted for presentation at top academic conferences (e.g. American Finance Association meetings, Western Finance Association meetings, and National Bureau of Economic Research group meetings) has experienced a tremendous growth in the past few decades. This new strand of research is generally centered on two themes: (i) how to best motivate corporate managers to invest in innovation, and (ii) how to finance innovative projects efficiently. In this survey, we provide a synthetic and evaluative monograph of academic papers that examine the drivers and financing sources of corporate innovation. We also provide

[6]Further, a recent paper by Faurel *et al.* (2017) argues that trademarks measure product development innovation.

our observations and views on potential directions for future research on finance and corporate innovation.

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