Corporate Innovation, Macroeconomic Risk, and Stock Returns[1]

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Abstract

We show how combining R&D investments and patents granted can explain stock returns more than each dimension taken separately, particularly the long-run component of these returns. Firms with low exposure to contemporaneous macroeconomic shocks (also short-run macroeconomic risk) tend to invest more intensively today in R&D activities because there is a low probability of losing a large proportion of their investments in the short term. Yet, these relatively large investments make future profits more exposed to future economic conditions (or long-run macroeconomic risk), inducing higher returns because the latter source of risk has a stronger positive impact on stock returns. This novel finding shows that higher R&D translates into higher returns, confirming that R&D is a source of risk for firms. Next, we develop portfolios by ranking firms based on their innovation level and find a negative but weak connection between patents awarded and stock returns, as patents have a negative association with future economic conditions. We further sort firms on both R&D and patents, we obtain that the positive relationship between R&D and returns is reduced, especially among firms that produce more patents because of their attenuating effect on firms' exposure to long-run risk.

JEL: G12, G30, G31, O31

Keywords: Corporate innovation, Risk exposures, Short-run risk, Long-run risk, Stock returns, Equity risk premium

1. Introduction

Investing in innovation is a widely acknowledged strategy as effective in facing an increasingly competitive and uncertain business environment. Traditional consumption-based asset pricing models postulate that the short-run systematic risk (SRR) should be the main driver of equity risk premium. However, prior studies (e.g., al., Bansal, at al., 2004) suggest that long run systematic risk (LRR) is capturing most of the equity risk premium. Recently, (Dorion et. al., 2020) show that long-run risk represents, on average, 81.6% of equity risk premium in periods of economic downturns. This means that investors aversion to future economic uncertainty (long-run risk) seems to outweigh the aversion to the current correlation between consumption and a firm's cash flows (or short-run risk). In this paper, we investigate firms' exposure to macroeconomic risk in the context of corporate innovation activities. In particular, we examine whether some firms are more exposed to short-run and long-run risk than others are; if so, what are the firm-level characteristics that explain exposure differences. We argue that some innovative firms persistently exhibit greater exposure to long-run risk, while others present greater exposure to short-run risk.

Innovation activities are risky, unpredictable, idiosyncratic, and long-term process because they could fail, particularly with the presence of strong rivals that could win the innovation race (Gu, L. 2016). Using various types of U.S patent applications from 1947 to 1981, for example, (Basmann et al., 2007) show that 38% of them were failed. In a similar spirit, (Chkir, I., et al., 2024) study U.S. patent applications filed between 2001 and 2020 and show that firms diminish their subsequent investments in innovation inputs (i.e., R&D investment) when they fail to obtain successful patents. However, when innovation inputs lead to successful innovation output (i.e., granted patents), the risk of the firm is shifted to non-innovator rivals in the industry (Chun et al., 2008), and thus, such patents lead to lower risk. This means that the risk of infrequent innovators should be cyclical: the risk is high at the beginning of the innovation activity, then the risk becomes low with a successful innovation project. For frequent innovators, we believe that the risk is persistently low as they continuously (frequently) engage in successful innovation activities. Therefore, the risk should be higher than average for infrequent innovators and lower than average for frequent innovators.

In this paper, we investigate the relationship between the firms' innovation inputs (i.e., R&D expenditures), innovation outputs (i.e., granted patents), macroeconomic risk, and stock returns. To better understand this connection, we employ two important factors—consumption growth, i.e., short-run risk (SRR), and expected economic conditions, i.e., long-run risk (LRR)—that, when considered together, are missing from the existing literature on corporate innovation, risk exposures, and stock returns. We are able to obtain a number of interesting results based on the interaction of these different variables of corporate innovation and macroeconomic risk in determining the firms' stock returns. Perhaps most interesting is the role the exposure to the long-run risk plays with R&D investment in determining/generating higher stock returns/risk premia for firms.

We first examine the relationship between R&D expenditures and betas to economic shocks (i.e., SRR), expected economic growth (i.e., first moment of LRR), and expected economic growth fluctuations (i.e., second moment of LRR). The betas are by the exposures of firms returns to consumption growth, economic growth forecast, and economic growth forecast dispersion respectively. Using the United States Patent and Trademark Office (USPTO), over the period 2000-2019, we find that the R&D is strongly negatively correlated to economic shocks (i.e., SRR), but positively correlated to expected economic conditions (i.e., LRR). Then, we examine the connection between R&D investment and risk premium, as R&D spending shows a strong positive relation with the firm's exposure to the LRR. The results show that firms with higher size-adjusted R&D investment exhibit higher stock returns/risk premiums, confirming that these returns are driven exposure to the LRR.

Next, we investigate the relationship between the firm's innovation outputs (i.e., patents granted) and exposures to economic shocks, expected economic growth, and fluctuations. Contrary to R&D expenditures, we find a positive association between patents and short-term shocks, a negative connection between patents and expected economic conditions, and a strong and positive connection between patents and future economic uncertainty. The last two findings indicates that more (and frequent) patents are associated with low exposure to the LRR. We then sort firms in groups based on the number of patents awarded and quantify each group average exposures to LRR and returns. Firms with more patents have lower exposures to future macroeconomic uncertainty and higher returns.

We further explore the relationship between patents, R&D spending, risk exposures, and returns by developing strategies that double-sort firms into two dimensions: R&D spending and patents granted. First, we examine the risk exposures of firms with similar R&D spending levels and find that the risk exposures decrease in each group category as the number of patents rises. When we look at firms with similar numbers of patents awarded per year, we find that the more a firm invests in R&D, the higher its exposure to future macroeconomic conditions. Second, with regards to the firms with different levels of R&D spending, we found that the more firms are exposed to future economic conditions, the higher the expected return. Then, we went back to analyze the relationships between patents-returns and R&D-returns and discovered that although returns increase with the number of patents, the increase is less pronounced than the increase for R&D spending. In summary, our results highlight the short-run risk exposure effects of corporate innovation activities on firms' stock returns and equity risk-premia, as well as the long-run risk exposure effects on firms' future innovation inputs and outputs.

Our paper contributes to the literature on corporate innovation, macroeconomic risk, and stock returns in at least four ways, which sets it apart from previous research. First, using unique data on R&D expenses, granted patents, and patent citations, we develop strategies that double-sort firms into two dimensions, and provide evidence of their importance as drivers to explore/analyze to a greater degree the relationship between R&D spending, patents and their citations, macroeconomic risk, and stock returns. Notably, our measurement strategies transcend traditional methods by linking these four important variables. Second, by employing different innovation characteristics—innovation input (i.e., R&D) and innovation output (i.e., patents)—in our analysis, we add to prior findings—who applying these measures separately—by showing that such inputs and outputs, jointly, have different implications for a firm's exposure to the short- and long-run risk, as well as its stock return.

Third, by examining multiple levels of corporate innovation activities (i.e., different R&D spending levels and numbers of patents across firms), our paper highlights the importance of interactions between core corporate innovation activities (i.e., R&D expenditures) and their highly successful results (i.e., granted patents) in light of short- and long-run risk exposures. Finally, while most of the previous studies mainly examine the relation between innovation, risk-uncertainty, and firms' performances, we provide better understanding of the risk exposure-level variation with respect to the impact of macroeconomic short- and long-run risk exposures on corporate innovation, which is a valuable addition to prior studies on the connection between risk exposure—the uncertainty of outcomes—and corporate innovation decision-making (see e.g., Coiculescu, et al., 2023; Chemmanur, et al., 2019; Sabrina, 2017; Bernstein, 2015; Lerner, et al., 2011).

Our work is closely related to a growing strand of the literature that studies the relation between risk and corporate innovation activities (see e.g., Atanassov et al., 2024; Parker et al., 2023; Lee et al., 2022; Xu, 2020; Wang et al., 2017; Gu L, 2016; Kung et al., 2015; Bartram et al., 2012; Lin X, 2012; Czarnitzki et al., 2011; Lerner et al., 2011; Eberhart et al., 2008, 2004). In contrast to the existing literature, which focuses on R&D investment and expected stock returns, this paper goes beyond that by exploring the relationship between corporate innovation inputs and outputs, firms' exposures to macro-risk in the short- and long-run, and stock returns, as well as equity risk premia. This study is also particularly related to (Hirshleifer et al., 2013, 2018), who suggested that long-term consumption risk be applied in future related research. In light of this, we address the link between the macroeconomic factors not only in the long run but as well as in the short run and how their interacts with firms' innovation activities, stock returns, and equity risk premia.

The remainder of the paper is organized as follows: Section 2 reviews the literature with respect to corporate innovation, risk-uncertainty, risk exposures, stock returns, and equity risk premium. Section 3 introduces the data, key variables, our hypotheses. Section 4 presents the empirical results of the interactions between R&D expenditures, granted patents, risk exposure, and equity risk premia. We conclude in Section 5.

2. Review of Related Literature

Corporate innovation is risky, unpredictable, idiosyncratic, and long-term process (Cohen et al., 2013; Manso, 2011; Holmstrom, 1989), and thus involves a high probability of failure (Chkir et al., 2024). A large body of literature in economics and finance uses granted patents and R&D expenditures as proxies for corporate innovation activities (e.g., Fehder et al., 2025; Babina et al., 2023; Farre-Mensa et al., 2020; Sabrina T, 2017; Luong et al., 2017; Bena et al., 2014). Another line of research examines the determinants of corporate innovation decisions and, more precisely, uses risk (or, more generally, uncertainty) as a determinant of innovative activity (see, e.g., Bena et al., 2024; Audretsch et al., 2023; Xu, 2020; Wang et al., 2017; Biais et al., 2015; Lee et al., 2010; Bloom, 2007; Berk, et al., 2004). The focus of all these models, however, is on the dynamics of risk rather than exposures to risk. The dynamic of risk means changes over time—i.e., its behavior, fluctuations, and interactions—whereas exposures to risk indicate the degree to which a firm, for example, is subject to economic risk at a given time (e.g., macroeconomic factors). In addition, the method in these studies differs from ours; it precludes a study of exposures to short- and long-run risk and their effects on corporate innovation activities and stock returns, which is what we focus on. Our goal, therefore, is to investigate the relationship between corporate innovation—by using two innovation measures: R&D expenditures and granted patents and their citations—short- and long-run risk exposures, and equity risk premium.

2.1 Corporate Innovation (R&D Expenditures) and Risk-Uncertainty

The activity at the heart of this section is firms' investments in R&D and the impact of risk-uncertainty. Given that R&D investment is one of the main sources of innovation that drives a firm’s long-term viability (Yu et al., 2016; Hall et al., 2010) and, more importantly, provides a significant contribution to a firm’s innovation (Dodgson et al 2008) and economic output (Gumus et al., 2015; Cohen et al., 2013), the proper allocation of R&D investment is a vital task of the corporations. This task, however, becomes difficult by the fact that R&D investment is a highly uncertain activity. (Dang et al., 2018; Cohen et al., 2013) indicate that R&D investment is indeed associated with considerable uncertainty. The latter is a broad concept, including uncertainty over the path of macroeconomic phenomena (Ludvigson et al., 2021; Bloom et al., 2018; Bloom N, 2014). Moreover, R&D investments have the property that a significant portion of their value is associated with future cash flows. The uncertainty inherent in these investments includes two distinct types. There is purely unsystematic risk associated with the decision of technical uncertainty. There is also risk related to cash flows after the decision is made, which will have a systematic component. (Baker et al., 2016) point out that recent uncertainty in the US and Europe may have harmed macroeconomic performance.

More recently, several articles in finance and economics have studied the relationship between R&D expenditures and risk-uncertainty using firm-level data, yet they show mixed results (see e.g., Atanassov et al., 2024; Chemmanur et al., 2019; Wang et al., 2017; Czarnitzki et al., 2012). For instance, (Van Vo et al., 2017) study the influence of uncertainty on R&D investment and find that firms invest more in R&D when they face higher uncertainty. Likewise, (Stein et al., 2013) investigate the impact of uncertainty on firms' R&D spending and demonstrate that uncertainty encourages R&D spending. Recently, (Atanassov et al., 2024) analyzed whether political uncertainty can stimulate innovation, focusing on R&D investment as a strategic response. The authors challenge the prevailing view that uncertainty hinders firms' R&D investments by providing compelling evidence that uncertainty actually fosters firms to increase R&D spending. Exploiting close U.S. gubernatorial elections as an exogenous shock, they show that high uncertainty leads firms to increase R&D spending. Thus, firms with high uncertainty may expedite their R&D investment to capture market share and achieve sustainable growth.

Another stream of the literature argues that R&D investment's response to fluctuations in uncertainty differs and exhibits two-way findings. Bloom (2007), for example, examines how fluctuations in uncertainty shape firms' R&D investment decisions. The results indicate that the effect of uncertainty on R&D will be positive if firms reduce R&D investment, while the effect of uncertainty on R&D will be negative when firms increase R&D investment. Coiculescu et al. (2023) investigate how two distinct types of uncertainty—risk, defined by outcome volatility, and ambiguity, defined as uncertainty over outcome probabilities—affect innovative activity, particularly in their investments in R&D. By developing an empirically implementable measure of ambiguity derived from firms' stock return distributions, they demonstrate that ambiguity consistently and negatively impacts R&D spending, whereas risk increases R&D. Using data from Chinese listed companies of the Shanghai and Shenzhen stock markets from 2005 to 2016, Beladi et al. (2021) study the relationship between cash flow uncertainty and innovation. They find that firms with higher cash flow uncertainty invest more cautiously in R&D investment, whereas firms with lower cash flow invest more boldly in R&D investment. These last three articles, which present two-way findings, emphasize that uncertainty makes R&D investment more inertial, affecting the nature of innovation across economic cycles.

Contrary, (Czarnitzki et al., 2011; Goel et al., 2001) find that high uncertainty reduces firms' investments in R&D. Similarity, (Xu, 2020) investigates the relationship between uncertainty and innovation and shows that higher uncertainty hinders R&D investment. In the same spirit, (Wang, et al., 2017) examine the effects of policy and market uncertainties on the firm's R&D investment. Using a sample of Chinese firms, they show that both policy and market uncertainties can negatively affect the firm's R&D. They pointed out that uncertainties associated with potential changes of government policy have significant implications for corporate innovation. (Carvalho et al., 2018) indicate that in the presence of higher uncertainty, innovations are more likely to be undone in the future. Likewise, (Czarnitzki at al., 2007) explore the impact of product market uncertainty on firm-level R&D investment. They show that product market uncertainty reduces R&D investment. In other words, higher risk-uncertainty may lead to a drop in R&D investment because of irreversibility. Thus, these articles suggest negative effects of risk-uncertainty on firms' innovation in general and on R&D investments in particular. In this paper, we demonstrate that firms' exposures to macroeconomic risks, particularly the long-run components, affect R&D investments.

Overall, earlier studies use R&D expenditures—as proxy of innovation—to measure corporate innovation. According to the National Research Council (Fealing et al., 2014), although a reasonable proxy, R&D expenditures cannot adequately substitute for the innovation output. First, R&D expenditures are an input to innovation along with human and physical capital, employee and managerial effort, and creativity (Atanassov, 2013). High R&D expenditures, hence, are less likely to result in successful patents when other inputs are not used effectively. Second, many firms do not include R&D expenditures in their financial statements due to differences in accounting standards among countries. However, missing R&D data does not necessarily mean that firms are not engaged in innovative endeavors. Therefore, rather than just R&D expenditures, we also use patents and their citations—as proxies of successful innovation and their quality—to capture corporate innovation outcomes. Finally, our use of patents captures an important dimension of innovation and, thus, is complementary to the use of R&D expenditures in measuring innovative activities—i.e., firms that conduct a lot of R&D tend to patent more. And ordinarily, reducing the investment in R&D will hinder more patents.

2.2 Risk, Corporate Innovation (R&D and Patents), and Stock Returns

Innovation is a central characteristic of superior firms and a significant factor of competitiveness; yet, it also involves considerable risk due to the uncertainties inherent in both the inputs and outputs of innovation. Risk—the lack of certainty in outcomes—assumes a unique, known distribution of future outcomes. We concentrate on innovation and risk for several reasons. First, although prior research demonstrates the influence of uncertainty on firms' investment and other operations, the impact on corporate innovation is still not well covered. Second, growing evidence indicates that economic factors (e.g., macroeconomic risk) influence innovation and other investments differently, due to the unique features of R&D investment. Third, R&D investment is more sensitive to uncertainty, and that is because it is risky and takes a long time to yield fruitful outcomes. In this section, however, we must first shed light on previous work regarding the interaction between innovation inputs and outputs before linking this dimension to risk and stock returns.

One strand of literature analyzes the impact of R&D on patents (see e.g., Hegde et al., 2023; Brander et al., 2017; Hunt, 2006). For example, (Faleye et al., 2014) show that firms invest more in R&D receive more and higher quality patents. (Farre-Mensa et al., 2020) show that successful applications (i.e., granted patents) foster firms' investment in R&D. Others investigate how firms expand their R&D abroad and whether this has an effect on the firms' number of patents. In fact, many firms internationalize their R&D activities to obtain new knowledge and capabilities available in other countries. In light of this, (Penner et al., 2005) examine the international R&D activities and patent output and find that, only when firms have domestic R&D investments, foreign R&D has a positive impact on the firms' innovative output. Likewise, (Bertrand et al., 2013) study the differences between internal and offshore R&D (i.e., external R&D) and their impact on a firm's innovation outputs. They find that absorptive capacity from internal R&D allows for more offshore R&D and leads to more positive innovative outputs. These studies also suggest that success in innovation, as measured by granted patents and citations, enhances a firm's future investment in R&D. Therefore, R&D appears to always have a positive effect on a firm's patents. Nevertheless, not all innovations are eventually patented, as no one can guarantee that a firm's investments in R&D will automatically result in successful patents. This indicate that some of firm's R&D could turn to sunk costs.

Another strand of literature relating to innovation, risk, and stock returns focus on the interacts of either the input (i.e., R&D investment) or the output (i.e., patents) of innovation "separately" and reveals positive results (e.g., Parker et al., 2023; Hirshleifer et al., 2013; Czarnitzki et al., 2011; Eberhart et al., 2008, 2004; Lev et al., 2005). Our paper differs in focusing on both innovation measures "jointly". Using a dynamic equilibrium model with production, (Lin X, 2012) examines whether endogenous technological progress—driven by firms' own innovation activities, i.e., R&D—can explain the variation in risk and stock returns across firms. The author develops a general equilibrium model in which firms invest in R&D to enhance productivity, and this technological progress influences expected returns through its impact on risk exposure. He shows that firms with higher R&D investment earn higher expected returns, reflecting compensation for bearing innovation-related risks. Similarly, using a range of risk-adjustment techniques, (Chan et al., 2001) investigate whether the stock market properly values R&D expenditures and how these investments are reflected in firms' stock returns. They show that firms with higher R&D expenditures predict higher future stock returns, particularly when these firms are small and face information asymmetry. This evidence indicates that the market often undervalues R&D investments, treating them as immediate expenses rather than long-term value creators—a main topic we address in this paper.

Furthermore, some studies also indicate a negative relation between risk and stock market returns due to varying firms' R&D investment levels, which in turn affect future stock returns. For example, (Bartram et al., 2012) investigate why U.S. equities exhibit higher volatility compared to stocks in other developed markets. The results indicate a strong negative relationship between idiosyncratic risk and the stock market, particularly with the bond market, as the result of stock markets is ambiguous. One of the examinations in their paper is whether such excess volatility increases with differences in exposure to macroeconomic risk factors. Their findings reveal that market-specific factors, such as greater exposure to idiosyncratic risks, are driving volatility of U.S. stocks. One of the examinations in their paper is whether such excess volatility increases with differences in R&D investments and exposure to macroeconomic and global risk factors. Their findings demonstrate that market-specific factors, such as greater exposure to idiosyncratic risks and firms' high investment in R&D, are driving volatility of U.S. stocks. Using French firms, (Cazavan-Jeny et al., 2006) indicate a negative correlation between R&D and stock returns when the risk is high. Others explore whether R&D expenditures could mitigate the negative effects of risk on economic performance, which reflect investors' expectations about future stock market returns. (Lee et al., 2022), for example, find that the effect of the interaction between R&D and uncertainty is significantly high on economic performance. This suggests that promoting R&D may have a strong effect on mitigating the negative impact of risk-uncertainty.

In this paper, we propose a simple argument to explain our findings. We demonstrate that firms with higher size-adjusted R&D investment exhibit higher stock returns/risk premiums. Then, we investigate the relationship between firms' innovation outputs and exposures to macroeconomic uncertainty. We show a positive association between patents and short-term shocks, a negative connection with expected economic conditions, and a strong and positive connection with future economic uncertainty. Thus, in comparison to prior work, we argue that our findings are novel, go beyond these previous results, and roughly cover broader macroeconomic factors than those identified by, for example, (Hirshleifer et al., 2013, 2018). This suggests that our approach identifies a unique and previously undetected pattern in the cross-section of stock returns associated with the firms' short- and long-run risk exposures in the context of corporate innovation activities.

2.3 Corporate Innovation, Short- and Long-Run Risk Exposures, and Equity Risk Premia

In the finance and economics literature, most attempts to explain the equity risk premiums of the U.S. market are based on macroeconomic variables. The empirical analysis suggests that the equity risk premium—the expected higher return that investors require for holding equities relative to a risk-free asset or compensation for taking on equity market risk—is a central component of every risk and return model in finance (e.g., Azimi et al., 2024; Damodaran A, 2013). Moreover, equity risk premium reflects fundamental judgments we make about how much the risk we perceive in an economy or market, along with the price assigned to that risk, influences the expected return on all risky investments. It is surprising, considering its importance, that this crucial aspect of corporate finance and financial economics has not received more attention from scholars in the finance and economic literature, particularly in light of corporate innovation. Thus, examining how episodes of macroeconomic risk (i.e., in the short and long run) and return interact with the equity risk premium in the context of firm innovation is a novel link in the corporate finance literature.

Accordingly, our paper uniquely focuses on the joint analysis of both measures of innovation—i.e., R&D expenditures and patents—, firms' short- and long-run risk exposures, and how this relationship interacts with equity risk premia. As far as we know, this is the first study in the relevant literature discuss such a mechanism through which macroeconomic factors affect corporate innovation, which in turn results in high/low equity risk premiums. We begin this section by reviewing the earlier studies considered firms' R&D expenditures, equity risk premium, and different types of risk; it will conclude with a look at the firms' granted patents.

2.3.1 R&D Expenditures

Empirically, is there a relationship between R&D expenditures, risk exposures, and equity risk premium? The evidence is generally skewed. First, during times of financial and economic uncertainty—when equity risk premiums are high—decisions about future R&D projects may be temporarily delayed. Second, when firms resume their investments in R&D, any negative relation between corporate innovation activities and the equity risk premium may seem problematic because such a result may reduce firms' investments in upcoming R&D projects. Finally, the high expected return, which arises from investors' expectations of firms' innovation-related profits and the firms' efforts to meet these expectations, has led to an increased demand for premiums. If innovation outcomes have become less informative overall, it is reasonable for equity investors to demand large equity risk premiums for future R&D investments to offset the increased uncertainty.

Differences in risk exposures in both the short and long run may be one reason why investors demand larger risk premiums in some firms than in others. After all, exposures to risk and its measures vary widely among firms, as investors often have divergent interpretations of these measures. For instance, using data from 1973 to 2018, (Damodaran A, 2019) looked at the relationship between equity risk premiums and macroeconomic variables, including economic growth and inflation rates. The results indicate that equity risk premium is negatively correlated with GDP growth and is positively correlated with inflation. Note, however, that their study focused mainly on the interaction between equity risk premiums and macroeconomic volatility, not on short- and long-run risk exposures of innovative firms. Nonetheless, there are several studies in the finance literature that link corporate innovation inputs (i.e., R&D) with equity risk premiums and reveal inconsistent findings. For example, (Gu L, 2016) examines the joint effect of product market competition and R&D investment on stock returns—an R&D premium. The study hypothesizes that R&D-intensive firms should command higher expected stock returns—equity risk premium—reflecting the high risk and uncertainty inherent in innovation. (Gu L, 2016) assumes that this premium is especially pronounced in competitive industries, where innovation efforts face a high failure risk, increasing risk-based premium. The results document a positive correlation between R&D intensity and expected stock returns—an R&D premium—suggesting that competition has a significant impact on R&D-intensive firms' risk-and-return profiles and thus independently drives a significant portion of the equity risk premium.

In a similar vein, (Lin X, 2012) indicates a positive relation between R&D investment and expected premiums, which reflects compensation for the higher systematic risk associated with technological innovation. Others investigate the R&D-return relation via the interaction between financial constraints and R&D investment. In his research, (Li D, 2011), for instance, investigates how financial constraints impact the relationship between R&D investment and stock returns. The study demonstrates a positive relation between R&D investment and the risk premium. In other words, the constraints-expected return relation among high R&D investment firms is positive and is much stronger than that among low R&D investment firms. This return premium is largely attributed to the higher risk associated with uncertain innovation outcomes under financial constraints. These results indicate that R&D-related risks are not completely diversifiable when firms face binding financing constraints.

Contrary, by integrating patents and R&D into a real business cycle model with recursive preferences, (Kung et al., 2015) examine how innovation-driven long-term growth uncertainty affects asset pricing and risk premia, and they show that uncertainty in innovation-driven growth has a negative impact on asset prices and risk premia: when innovation prospects weaken, long-term growth uncertainty increases, leading to higher risk premia, whereas strong innovation expectations reduce risk and support higher asset prices. Likewise, (Audretsch, et al., 2023) indicate that macroeconomic episodes of high equity risk premia (ERP) hinder R&D investments due to high discount rates. Others use industry concentration to examine the relationship between innovation and equity risk premiums. (Hou et al., 2006), for example, investigate the connection between the concentration premium and risk-based explanations, such as innovation risk—measured by R&D—or distress, by examining their time-series characteristics. They argue that sectors characterized by higher innovation risk and distress risk should yield higher expected returns, and that one of these risk factors is probably responsible for the concentration premium. The empirical results exhibit that firms in more concentrated industries consistently earn lower returns, even after controlling for other risk factors. This suggests that the return premium linked to industry concentration is independent from other asset pricing factors and that controlling for industry concentration is important for understanding the cross section of stock returns.

As these contrary arguments suggest, the relationship between R&D expenditures, risk, and equity risk premiums is complex. More precisely, higher R&D spending should lead, ultimately, to higher equity risk premiums. However, precision in this context must be defined in terms of what level and period of risk exposure can tell us about high/low equity risk premiums. Consequently, it is possible that investing more in R&D in the future may create more uncertainty about future equity risk premiums (i.e., high or low), given that investors frequently disagree about how best to interpret these returns.

2.3.2 Patents Granted

Compared to other corporate investment activity, several attributes of the innovation process suggest that the relationship between innovation outputs (i.e., patents) and equity risk premiums should be even more pronounced. In other words, patents granted signal future cash flow potential but may also show exposure to high levels of risk, as well as market mispricing due to their complex valuation. Consequently, investors may demand a higher expected return—an innovation premium—to offset bearing additional risk, making the relationship between patent activity and risk premiums a critical dimension for understanding asset pricing patterns. The earlier work rarely revealed this phenomenon, with mixed outcomes. Recently, (Audretsch, et al., 2023) investigate the relationship between corporate patenting activity and the equity risk premium for a sample of publicly traded U.S. firms from 1977 to 2018. The authors document strikingly strong positive correlations between equity risk premium and the aggregate number of patent grants. This implies that during periods of high equity risk premium, while some firms reduce innovation, others intensify their patenting activity. Thus, periods of high equity risk premiums are often associated with more aggregate patenting but a shift toward patents of varying quality, with exploratory patents often showing greater technological impact.

In the same spirit, (Hirshleifer et al., 2018) look into the possibility that innovative originality can be used as a priced equity premium and use granted patents as a proxy for firms' innovative originality. In other words, if a firm’s patents cite previous patents belonging to a wide set of technologies, its originality score will be high. The authors argue that firms exhibiting high innovative originality may consistently outperform their competitors due to the market power granted by their original innovations. The findings reveal that firms with high innovative originality have significantly higher future equity premiums up to five years. This suggests that when uncertainty about the future stock value is higher, investors should optimally place a greater weight on innovative originality when forming posterior beliefs about value. This, in turn, raises the demand for future premiums. (Hsu P. H, 2009) examines how aggregate technological innovations, as measured by aggregate patents and R&D, systematically influence the expected market returns and premiums. The results show that patent and R&D shocks have positive effects on expected returns and equity risk premiums in the U.S. market. This bridging link between innovation economics and asset pricing theory suggests that tracking aggregate innovation indicators (i.e., patents and R&D) could improve forecasting models for equity risk premiums and expected returns. More importantly, the study pointed out that since the mid-1970s, these two indicators (i.e., premiums and returns) have more explanatory power than other macroeconomic and financial variables.

These findings together suggest that an increase in the equity risk premium goes along with an increase in the value of patents. Firms will, however, concentrate their efforts on particular promising innovation projects with high technological impact and high expected returns because of the increase in both the equity risk premium and innovation-related values. This pattern of innovation outputs and equity risk premium is consistent with (Manso et al., 2023), documenting that firms tend to focus on exploration during contractions and exploitation during booms.

Others demonstrate opposite results. (Bena et al., 2024), for instance, explore how traditional asset pricing premiums—specifically, the value, investment, and profitability effects—apply to firms with high patent intensity. By using the classification of patentors and non-patentors, the authors show that profitability premiums are significantly weaker or even reversed for patentors compared to non-patentors. This result suggests that the market struggles to adequately price the innovation premium associated with technological innovators. Even so, most of the prior studies in the related literature use data for US firms, and, as far as we are aware, none of the US studies have ventured into the analysis of short- and long-run risk exposures as a different basis from dynamics of risk for enhancing firms' patents and, ultimately, increasing stock returns and risk premia, although there is work on risk-uncertainty as a determinant of innovative activity (e.g., Xu, 2020; Biais et al., 2015; Lee et al., 2010).

3. Empirical Strategy and Data

3.1 Persistent Short-Run Risk for Frequent Innovators:

In this section, we demonstrate the ongoing and cyclical risk for frequent as well as infrequent innovators. The graph below presents the continual risk (high or low) for the frequent innovators over time. The S_0 marks the starting point of R&D investment, while the distance from T_1 to T_N indicates the average time lag of patents, typically ranging from three to five years. The green arrows illustrate the level of risk exposure during each innovation period for frequent innovators.

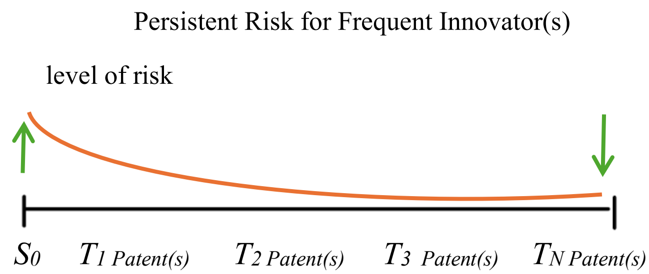

Fig. 1. The frequent innovators' exposure to both short-run and long-run risk.

We argue that the risk is high when firms invest in R&D for the first time (S_0). However, when firms obtain first granted patents (T_1), they become more strategic and acquire more experience with the patent examination process and its outcomes, thus, the risk declines. Furthermore, when firms continuously engage in innovation activities and, more importantly, generate more successful patents and significant returns (T_2, T_3, T_N), the risk becomes lower in the short run for each period of investment, which motives them to increase their future R&D investments as they become more creative. In other words, the more firms engage in successful innovation activities, the lower their exposure to short-run macroeconomic risk becomes; however, this appears not to be true for long-run macroeconomic risk, which is characterized by slow-moving economic changes and fluctuations in market conditions that may impact frequent innovators. Although the latter have low exposure to short-run macroeconomic risk, invest heavily in R&D, and obtain patents, they still face high long-run risk exposure for each period of innovation due to enduring uncertainties.

3.2 Cyclical Short-Run Risk for Infrequent Innovators:

For the infrequent innovators, the cyclical risk (high, low, and high again) is shown in the graph below. The distance from S_0 and T_1 indicates the average time lag of patents. The green arrow illustrates the level of risk exposure during the innovation period for infrequent innovators.

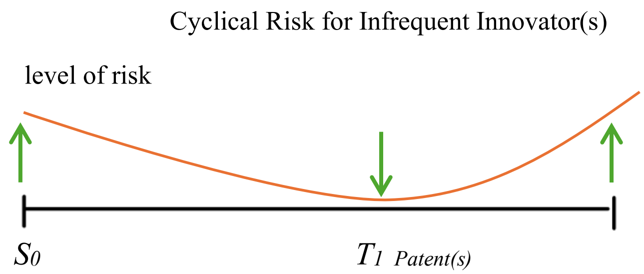

Fig. 2. The infrequent innovators' exposure to both short-run and long-run risk.

As shown above, the risk is high for infrequent innovators when they start their R&D investments at (S_0). This may take three to five years before they receive the final decision from the patent examiner. At this stage, such innovators continue to be highly exposed to both short-run and long-run risk. If firms' applications are granted successful patents, they gain more experience with the patent examination process and its outcomes, generate high returns, and, more importantly, their exposure to the subsequent short-run risk period decreases, which encourages them to continue investing in R&D. In other words, the more the infrequent innovators involve in innovation activities, the lower their exposure to the next period of short-run macroeconomic risk become. However, such firms are not frequently engaging in innovation activities because their business models rely less on long-term innovation and more on stable, predictable operations. Therefore, their exposure to short-run macroeconomic risk depends on how frequent their future investment in R&D, while their long-run macroeconomic risk is always significant. In summary, firms' exposure to both long-run and short-run risk in the context of corporate innovation is yet ambiguous.

To test our predictions, we employ several empirical models that examine the relationship between R&D spending and different measures of risk horizon.

3.3 Data sources and Sample Selection

3.3.1 Data sources

We combine a variety of data sources to create the sample we use in this study. Particularly, our sample is compiled from the following four different sources: the United State Patent and Trademark Office (USPTO), CRSP, COMPUSTAT, and The Survey of Professional Forecasters. We at first step download all COMPUSTAT firms with patent data in USPTO. The dataset offers details on each patent, such as the USPTO filing and issuance dates, the number of forward citations the patent received up until the end of the sample period, and an estimate of the patent's value based on market-adjusted firm returns during the three days after the patent issuance date. We then collect data on Research and Development spendings (R&D) and Market Equity Values (ME) from COMPUSTAT. Asset Prices for our sample are from CRSP. Finally, to compute our risk factors, we use survey data from the quarterly Survey of Professional Forecasters, maintained by the Federal Reserve Bank of Philadelphia.

3.3.2 Sample selection

To construct our sample, we first total the number of granted patents for each firm in a given year, aggregating the patent-level data to the firm level. We then compare the firm-level patent data with the financial statement and macroeconomic risk factors. We follow the literature and do not include firms in the utilities or financial services sectors. We drop observations that do not have sufficient financial statement information to construct our control variables. We also remove observations that contain missing information on sales, EBITDA, the annual fiscal closing price, common/ordinary equity, R&D expenditures, and common shares outstanding. The resulting final sample consists of about 219,688 firm-quarter observations representing around 4,618 firms spanning the period from 1990 to 2019, due to the average time lag of patents, which ranges from three to five years.

3.4 Hypotheses and Empirical Models

Fig. 3. Conceptual framework of the study.

First, the existing literature, such as (Gu, L. 2016), generally suggests that R&D-intensive firms tend to be riskier. This is because these firms often engage in innovative activities with uncertain outcomes, which can lead to greater variability in returns. However, our approach challenges this conventional view by arguing that the sensitivity of R&D spending to risk may vary depending on the time horizon of the risk factor. Specifically, we propose that R&D-intensive firms are more exposed to long-run risk, characterized by slow-moving economic changes and shifts in market conditions that impact the firm over an extended period. These firms invest heavily in innovation, which may not yield immediate returns but can lead to significant payoffs (or losses) in the future. Therefore, their risk profile is more aligned with long-term uncertainties.[2] In contrast, we believe that low-R&D firms, which do not invest as much in innovative activities, are more likely to exhibit short-run risk. These firms may be more sensitive to immediate market fluctuations and short-term economic conditions, as their business models are less dependent on long-term innovation and more on stable, predictable operations. By testing this hypothesis, we aim to refine the understanding of how R&D spending influences a firm's risk profile, particularly in distinguishing between short-run and long-run risk factors. The above argument leads to the first hypothesis:

***H1** Firms with low exposure to short-run macroeconomic risk invest more intensively in R&D, expecting substantial future returns.*

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[2] Low exposition to SRR can lead to high propensity to invest more in R&D. Thus, we invest more today because we are less exposed to SRR. At the same time, investing in R&D lead to more exposure to LRR.

Next, following (Gu, L. 2016), we measure R&D intensity using the ratio of R&D spending over total equity. A proportion of past R&D spending may still be productive in the current year. Assuming the productivity of each dollar spent declines linearly by 20% (Chan, et al., 2001), the total amount of R&D still productive at a given year is a combination of previous and current R&D spendings. Therefore, the following approximation is used.

$$R\&D\ capital_{it} = R\&D_{it} + 0.8 \times R\&D_{it-1} + 0.6 \times R\&D_{it-2} + 0.4 \times R\&D_{it-3} + 0.2 \times R\&D_{it-4} \qquad (1)$$

We divide R&D spending by total market equity to obtain our measure of R&D intensity (RD/ME). To study the connection between R&D capital and macroeconomic risk, we propose the following regression model, which consists of three independent variables that are associated to excess stock returns:

$$R\&D\ capital_{it}/ME_{it} = a_{it} + b \times \beta_{it}^{\Delta c} + c \times \beta_{it}^{GF} + d \times \beta_{it}^{GD} + \varepsilon_{it} \qquad (2)$$

The betas are obtained from the following time series regressions. Hence, for each firm i, we compute the time-series of the risk exposures (with a 36-month rolling window) $\beta_{it}^{\Delta c}, \beta_{it}^{GF}$, and β_{it}^{GF}:

$$StoctRet_{it} - R_{ft} = a_{it} + \beta_{it}^{\Delta c} \times \Delta c_t + \varepsilon_{it}, \qquad (3)$$

$$StoctRet_{it} - R_{ft} = a_{it} + \beta_{it}^{GF} \times GF_t + \varepsilon_{it}, \qquad (4)$$

$$StoctRet_{it} - R_{ft} = a_{it} + \beta_{it}^{GD} \times GD_t + \varepsilon_{it}, \qquad (5)$$

Contemporaneous consumption growth, Δc, represents the SRR factor, while both economic growth forecasts (GF) and the forecast dispersion (GD) are the two LRR factors. The results presented in Table 3 suggest that higher values of SRR (the beta based on consumption growth) are associated with lower levels of R&D (as measured by RD/ME) but with higher values of LRR (see Columns 2 and 3).

Second, we delve into the relationship between R&D intensity and firm returns by examining whether R&D-intensive firms outperform low-R&D firms in terms of returns. The literature posits that firms with greater exposure to risk tend to have higher returns, as investors demand compensation for bearing additional risk. Consequently, firms with higher R&D spending, which are often perceived as riskier due to the uncertain nature of innovation, should theoretically be rewarded with greater returns compared to firms with lower R&D spending. In this section, we demonstrate that the observed risk-return relationship is primarily driven by the long-run component of risk (LRR), rather than short-run risk (SRR). However, this relationship is particularly relevant for firms that have high R&D spending. This suggests that the positive R&D-return relationship documented in prior studies is more closely associated with long-term risks that materialize over extended periods, rather than short-term fluctuations. Based on our testable argument and relevant literature, we can hypothesize:

***H2** Firms that invest more in R&D, due to their low exposure to short-run macroeconomic risk, face higher exposure to long-term macroeconomic risks, resulting in significant returns.*

Following insights from Table 2, we investigate the R&D-risk relationship for firm with high and low level of granted patents. Innovation inputs, such as R&D projects, inherently carry significant risk due to the uncertainty of outcomes. This risk is amplified in competitive environments where strong rivals are also pursuing similar innovative endeavors. The fear of losing the innovation race to these competitors increases the likelihood of failure, as resources and efforts may not yield the desired breakthroughs (Gu, L. 2016).

However, the landscape changes when these innovation activities successfully translate into concrete outputs, such as patents. At this stage, the risk dynamic shifts. The firm that secures innovation outputs gains a competitive advantage, while the risk burden transfers to its non-innovating competitors. These rivals, having not achieved comparable innovation successes, face increased pressure and uncertainty as they struggle to keep pace with the advancements (Chun et al., 2008). As a result, the firm that achieves innovation output not only strengthens its market position but also experiences a reduction in its own risk profile, as it has effectively outpaced its competitors and capitalized on its R&D investments. First, we investigate whether a relationship exist between innovation output and each of our sources of risk. We perform regression analogue to model (1):

$$Patents_{it} = a_{it} + b \times \beta_{it}^{\Delta c} + c \times \beta_{it}^{GF} + d \times \beta_{it}^{GD} + \varepsilon_{it} \qquad (6)$$

Risk is either the beta of consumption growth (SRR), the expected consumption growth (LRR) or the volatility of the expected growth (LRR). Controls are firms fixed effects. The results presented in column 1 of Table 5 indicate that innovation output, as measured by the number of patents, tends to be higher during favorable economic conditions, as reflected by the short-run risk (SRR) coefficient. This suggests that firms are more likely to produce significant innovation outputs when the economic environment is strong and stable. However, the findings in columns 2 and 3 reveal a more complex relationship between future economic conditions and innovation output. Specifically, while there is no significant relationship between expected economic growth and the number of patents, the expected volatility in economic conditions is positively and significantly associated with patent production. This implies that firms may be more motivated or better positioned to innovate in environments where future economic conditions are uncertain or subject to greater fluctuations.

In Table 6, we sort firms by patents and construct four portfolios. For each portfolio, we average the measure of SRR and LRR. We can see no apparent relationship between patents and returns, nor do we see a supporting relationship between patents and SRR and LRR. Following these ambiguous results, we delve into the relationship between R&D spending and risk across different levels of innovation output, aligning with hypothesis 3. By examining this relationship, we aim to uncover how the risk profile of firms varies depending on their success in generating innovation outputs, thereby providing deeper insights into the R&D-risk dynamic.

H3 *Conditional on having similar level of size-adjusted R&D spending, firms with a greater level of patents awarded have a lower exposure to future economic conditions.*

H4 *There exists a positive but weak relationship between the number of patents awarded and stock returns.*

Having established that R&D-intensive firms are likely to show more exposition to future economic conditions, we move forward to analyse the innovation output (its size) effect on the documented (see above) R&D-risk relationships. To perform this, we double sort by R&D and by innovation output (number of patents). We present the results in Table 4. For each portfolio sort on RD/ME, we construct 4 portfolios sort on yearly patent number. We argue that although R&D spending bears high risk, firms with successful innovation activities (patents) will have a relatively lower risk than firms with more unsuccessful or lower patent numbers. Looking at consumption growth (SRR) in Panel A, we see no clear relationship between patents and betas for none of the portfolios sorted on RD/ME. In Panel B, for expected economic conditions (LRR), for portfolios 3 and 4 sorted on RD/ME, we observe a decrease in the risk factor from the first quartile of patents to the fourth quartile. This suggests that firms with high innovation output tend to be less risky, particularly of the are R&D-intensive firms (those pertaining to the last two portfolios of RD/ME sorting). Results of Panel C, support those of Panel A, on average. The betas of the future economic conditions' volatility increase from column 1 to 4 for all portfolios sorted on RD/ME, although such a decrease is not monotonic. Overall, results from Panels B and C support hypothesis 3.

4. Main Empirical Results:

In this section, we detail our findings regarding the relationship between R&D investments, patents granted, and stock returns. Our approach differs from previous works because it introduces consumption growth (SRR) and expected economic conditions (LRR) as missing risk factors in understanding this relationship comprehensively.

Table 1 Descriptive Statistics on the Main Variables: This table displays summary statistics for the key variables from 2000 to 2019. For each variable, the mean, minimum, maximum, standard deviation, and number of year-observations are also displayed in the table. The description of all variables is given in Appendix.

Variables	Obs	Mean	Std.Dev	Min	Max	P1	P99	Skew	Kurt
b cons growth	405119	0.004	0.079	-.0550	0.489	-0.194	0.218	0.150	4.422
b cons foreca	387832	0.004	0.035	-0.422	0.320	-0.193	0.111	0.285	8.466
b cons volat	388661	-0.020	0.211	-1.725	1.962	-0.593	0.548	0.046	6.080
RD/ME	323573	0.153	0.277	0.000	2.474	0.000	1.463	3.730	21.061
Patents	327400	15.510	80.657	0.000	3465.000	0.000	285.000	15.563	382.888

Table 2 presents the results from portfolios sorted based on the R&D-to-market equity ratio (RD/ME). These results corroborate the findings in Table 2. Specifically, in column 2, we observe that the SRR betas tend to decrease from the first quartile (lowest RD/ME) to the fourth quartile (highest RD/ME), although this trend is not strictly monotonic. This implies that firms with lower R&D intensity exhibit greater exposure to short-run risk, whereas high R&D firms are less sensitive to these immediate market variations. Conversely, expected (future) economic growth (the LRR betas) in column 3 show a consistent, monotonic decrease from the first quartile portfolio to the fourth quartile portfolio, indicating a strong positive relationship between long-run risk and

RD/ME (as further detailed in column 3). This finding is reinforced by future economic conditions' volatility, which also align with the patterns observed in Table 2. Additionally, firms with high RD/ME in the fourth quartile achieve higher returns compared to firms with low RD/ME in the first quartile.

Table 2 Correlation for all variables: This table shows the correlation coefficients for the variables used in our regressions.

Variables	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**
(1) b cons growth	1.000				
(2) b cons foreca	-0.011	1.000			
(3) b cons volat	0.127	**-0.192**	1.000		
(4) RD/ME	0.007	0.084	0.013	1.000	
(5) Patents	-0.013	-0.004	0.008	0.010	1.000

Overall, the results from Table 2 suggest a robust relationship between RD/ME, expected economic conditions and stock returns. In contrast, the connection between RD/ME, current economic shocks, and stock returns appears less clear, further emphasizing the importance of long-run risk in explaining the R&D-return relationship.

4.1 Are R&D intensive firms more exposed to macroeconomic risk?

We first investigate the link between investment and risk. The literature mostly views R&D spending as a source of risk for the firm because part or most of the amount invested could be lost without producing the intended results (e.g., Edmans et al., 2017; Manso, 2011; Holmstrom, 1989) or leading to patents granted. The literature finds mixed results (e.g., Brander et al., 2017; Hunt, 2006). For example, (Faleye et al., 2014) show firms that invest more in R&D receive more and higher quality patents. Likewise, (Farre-Mensa et al., 2020) show that granted patents foster firm's investment in R&D. We measure firms' betas to economic growth (SRR), expected economic growth (LRR), and expected economic growth volatility by the exposure of their returns to consumption growth, economic growth forecast, and economic growth forecast dispersion. First, the three types of betas are obtained for each firm in our sample, then we regress each firm size-adjusted R&D on their betas and find the R&D strongly negatively correlated to short-run risk (economic growth), but positively correlated to long-run risk (expected economic conditions). We do not observe a strong correlation between R&D and expected economic growth volatility. One unit increase in size-adjusted R&D translates into a reduction of 0.074 in economic growth beta, an increase of 0.165 in expected economic growth beta, and a decrease of 0.012 in expected economic uncertainty. R&D spending negatively correlates with short term risk and positively correlates with long-run risk. This reveals that firms spend more in R&D when they have a lower exposure to short-term risk. By investing more today, they will likely face higher exposures to future economic conditions. We can conclude that R&D can be viewed as a risk factor as documented in the literature (Jensen, 1993; Cheng, 2004). This result is confirmed by the result in column (4) with the joined estimation (see Table 3).

Table 3 The table presents the link between R&D and betas to economic growth, expected economic growth, and expected economic growth volatility

	(1) **R&D**	(2) **R&D**	(3) **R&D**	(4) **R&D**
B-Cons Groth (SRR)	**-.074***** **(.007)**			**-.066***** **(.007)**
B-Forecasts (LRR)		**.165***** **(.017)**		**.146***** **(.017)**
B-Volat			**-.012***** **(.003)**	0.00 (.003)
Cons	.144*** (0.001)	.146*** (0.001)	.147*** (0.001)	.142*** (0.001)
Observations	101,524	107,346	107,346	101,524
Fixed effects	Y	Y	Y	Y

4.2 R&D investment and risk premium

In the previous section, we found that there exists a positive association between R&D spending and exposure to expected economic conditions. Does it mean that R&D investment is positively correlated with risk premium? To provide an answer to this question, we create a portfolio sorting with firms being ranked by the level of size adjusted already invested and compute the average betas of exposures to consumption growth, expected consumption growth, and expected consumption growth volatility. The results are reported in Table 4. As we can see, firms with higher size-adjusted R&D investment also exhibit higher stock returns or risk premiums. We have created four (4) portfolios, but portfolios 1 can be ignored in this analysis because it contains firms with close to 0 R&D spending. Portfolios 2, 3, and 4 average returns are respectively 8%, 11%, and 14%. This confirms that R&D investment represents a risk factor for firms in the long run.

Table 4 The table presents the link between RD/ME and (monthly) returns

	1	2	3	4	5
Ranked by R&D/ME	**R&D/size**	**B-Cons Groth**	**B-Forecasts**	**B- Forec Disp**	**Returns**
1	0.000	0.003	0.003	-0.007	0.009
2	0.028	**0.005**	**0.005**	**-0.000**	**0.008**
3	0.110	**0.004**	**0.006**	**-0.011**	**0.011**
4	0.468	**0.002**	**0.008**	**-0.012**	**0.014**
4-1	0.468	-0.001	**0.005**	-0.005	0.005
tstat		-1.488	**5.491**	-1.760	1.753
*p*_value		0.138	**0.000**	0.079	0.080

Here we go further by looking at which source of risk can explain this finding. When we compute the average risk exposures to economic shocks - Column 1, we get that short-run risk is decreasing as we increase our R&D spending, confirming our results in this Section 5.1. Interestingly we find that the level of exposure to the expected economic growth is increasing with R&D spending. With this result we can conclude that the association between R&D and stock return is at least partly determined by Investors seeing higher investment spending as a long-term risk. The *t*-statistic of the high minus low exposure to the expected economic conditions is 5.49. Thus, by connecting R&D to current in future economic conditions, we are able to explain why R&D spending can be viewed as a risk factor and it connection to stock returns. Overall, the results from Table 2 suggest a robust relationship between RD/ME, expected economic conditions and stock returns. In contrast, the connection between RD/ME, current economic shocks, and stock returns appears less clear, further emphasizing the importance of long-run risk in explaining the R&D-return relationship.

4.3 Patents, Risk Exposure, and Stock Returns

Table 5 shows the regressions of patents granted on exposures to economic shocks, expected economic growth, and expected macroeconomic uncertainty. Contrary to R&D spending, we find a positive association between patents and short-term shocks and a negative connection between patents and expected economic conditions (a strong and positive connection between patents and future economic uncertainty (see Column 3 of Table 5). The intuition behind this finding is that the more patents a firm gets, the less exposed it gets to the future uncertainty, as the firm will have superior earning growth due the exclusivity in the use of the patents for several years. Investors see firms that obtain more patents as being more capable of live through future uncertainty than other companies.

Table 5 reports the regressions of innovation outputs (i.e., patent granted) on exposures economic shocks, expected economic growth, and expected macroeconomic uncertainty

	(1)	(2)	(3)	(4)
	Patents	**Patents**	**Patents**	**Patents**
B-Cons Groth (SRR)	**13.708*** (1.612)**			**12.091*** (1.652)**
B-Forecasts (LRR)		.962 (3.465)		4.934 (3.634)
B-Volat			**3.939*** (.550)**	**3.752*** (.596)**
Cons	22.011*** (.102)	21.433*** (.103)	21.39*** (.098)	21.901*** (.108)
Observations	102,740	108,664	108,664	102,740
Fixed effects	Y	Y	Y	Y

In Table 6, we have the returns and risk exposures of the portfolios build with respect to the level of patents granted. Again, because Portfolio 1 contains firms with zero patents we do not include it in the analysis. Portfolios 2, 3 and 4 returns are respectively 8%,10%, and 11% monthly, their levels of exposure to short-term risks uncorrelated to the patterns awarded, and their betas to future economic growth are strongly negatively correlated with the number of patents granted. This confirms a firm that gets more patents reduces its exposure to long-run risk as it becomes more resilient and produces more stable profits over the business cycles. Predict, however, as can be seen in second column of Table 6, average portfolio returns increase with the average number of patents, in apparent contradiction with what is anticipated. To solve this, double-sorted portfolios are created, allowing for analyze to a greater degree the relationship between patents, R&D investments, risk, and returns.

Table 6 shows the returns and risk exposures of the portfolios built with respect to the level of patents granted.

Ranked by Patents	Patents	B-Cons Groth	B-Forecasts	B-Forec Disp	Returns
1	0.000	0.005	0.005	-0.010	0.010
2	1.143	0.004	**0.009**	0.018	**0.008**
3	2.916	0.006	**0.007**	-0.013	**0.010**
4	62.990	-0.001	**0.004**	-0.004	**0.011**
4-1	62.990	-0.006	-0.000	0.006	0.001
tstat		-13.545	-2.615	5.718	0.908
p-value		0.000	0.009	0.000	0.364

4.4 Patents, R&D spending, risk exposure, and stock returns

So far, we found that firms with higher size-adjusted R&D are more exposed to future economic conditions and have higher returns. These firms also tend to exhibit lower exposures to current economic shocks. We then quantified firms exposures to future economic conditions for different levels of patents received and discovered that firms with more patents have lower exposures to future macroeconomic uncertainty but have higher returns.

To explore further the relationship between patents, R&D spending, risk exposures, and returns, we develop strategies that double sort firms into two dimensions. First, we consider R&D spending and patents granted. A 4-by-4 matrix is created, and each group's average level of exposure to expected economic growth on one hand and volatility on the other is computed. When we look at firms with a similar number of patents awarded per year, we find that the more a firm invests in R&D the higher the exposure to future macroeconomic conditions. This confirms our finding in Section 5.1. Next, we analyze risk exposures for firms with a similar level of R&D spending and find that in each group category, the risk exposures are reduced as the number of patents increases.

The mitigating impact of the patents is greater for the groups with greater size-adjusted R&D spending in accordance with what we found in Table 4. This attenuating effect varies between 25 to 75%. See Table 7.

Table 7 shows the annualized returns (Panel A) and risk exposures (Panels B–D) of firms with a similar level of R&D spending and number of patents granted per year. Firms with low R&D activities (less than the twentieth percentile) are removed. Betas are multiplied by 100 to account for the fact that consumption dynamics are smoother than stocks**.**

Panel A: Returns

	PATENTS					
R&D/ME	1	2	3	AVERAGE	(2) – (1)	(3) – (2)
1	0.106	0.129	0.139	**0.125**	0.026	0.015
2	0.113	0.141	0.160	**0.138**		
3	0.167	0.175	0.163	**0.168**	0.009	0.002
4	0.196	0.206	0.222	**0.208**		
AVERAGE	**0.146**	**0.163**	**0.171**			

Panel B: Beta exposure to economic shocks

	PATENTS			
R&D/ME	1	2	3	Average
1	0.700	0.300	0.100	0.367
2	0.600	1.000	0.100	0.567
3	0.900	0.100	0.100	0.367
4	0.700	-0.200	-0.100	0.133
AVERAGE	**0.725**	**0.300**	**0.050**	

Panel C: Beta exposure to expected economic growth

	PATENTS			
R&D/ME	1	2	3	Average
1	0.300	0.300	0.200	**0.267**
2	0.400	0.400	0.300	**0.367**
3	0.600	0.400	0.200	**0.400**
4	0.600	0.500	0.600	**0.567**
AVERAGE	**0.475**	**0.400**	**0.325**	

Panel D: Exposure to expected economic uncertainty

	PATENTS			
R&D/ME	1	2	3	Average
1	-0.300	-1.200	0.500	-0.333
2	-1.300	-0.200	0.200	-0.433
3	-1.700	-1.800	0.500	-1.000
4	0.500	-1.200	-0.200	-0.300
AVERAGE	-0.700	-1.100	0.250	

Panel D': Exposure to expected economic uncertainty (average of firms in R&D groups 3 and 4 in Panel D above)

	PATENTS			
R&D/ME	1	2	3	Average
1	-0.300	-1.200	0.500	**-0.333**
2	-1.300	-0.200	0.200	**-0.433**
3	-0.600	-1.500	0.150	**-0.650**
AVERAGE	**-0.800**	**-0.700**	**0.350**	

Second, within firms with different levels of size-adjusted R&D spending, we compute the average return of three groups with low, medium, and high exposure to future economic conditions. Table 8 shows these results. As expected, we found that the more firms are exposed to future economic conditions, the higher the expected return. Motivated by this observation, we went back to analyze the relationships between patents-returns and R&D-returns and discovered that although returns increase with the number of patents, the increase is less pronounced than the increase for R&D spending, clearly showing the mitigating effect of patents granted on the risk posed by higher R&D spending. The average returns for Portfolios 2, 3, and 4 are 8, 11, 14% when sorted by R&D and 8, 10, and 11% when sorted with the number patents. Thus, the increase in return for firms with more patents is due to the fact that the risk of investing heavily in R&D does not completely offset the average gain from obtaining patents. It may be that this is the case in some industries or over a much longer time period, which is beyond the scope of this paper.

Table 8 displays returns (annualized) based on a double sorting of size-adjusted R&D spending (rows) and exposures to economic shocks (Panel A), expected economic conditions (Panel B), and expected economic uncertainty (Panel C). Firms with a size-adjusted R&D spending that is lower than the twentieth percentile are removed (these firms have either none or very low R&D activities).

Panel A	**Beta exposure to economic shocks**			
R&D/ME	1	2	3	Average
1	0.123	0.178	0.127	**0.143**
2	0.154	0.147	0.147	**0.149**
3	0.139	0.130	0.184	**0.151**
4	0.112	0.178	0.159	**0.150**
Average	0.132	0.158	0.154	

Panel B	**Beta exposure to expected economic growth**			
R&D/ME	1	2	3	Average
1	**0.135**	0.130	0.151	0.139
2	**0.139**	0.143	0.171	0.151

3	**0.146**	0.122	0.163	0.144
4	**0.154**	0.168	0.135	0.152
Average	0.144	0.141	0.155	

Panel C		**Beta exposure to expected economic uncertainty**		
R&D/ME	1	2	3	Average
1	0.110	0.099	**0.100**	**0.103**
2	0.152	0.137	**0.102**	**0.130**
3	0.143	0.132	**0.133**	**0.136**
4	0.149	0.136	**0.137**	**0.141**
Average	**0.139**	**0.126**	**0.118**	

5. Conclusions and Implications for Future Research

Overall, we investigate firms' exposure to long-run as well as short-run risk. In particular, we examine whether some firms are more exposed to long-run risk than others. We argue that some firms persistently exhibit greater exposure to long run risk, while others present greater exposure to short run risk. We measure firms' betas to economic growth (SRR), expected economic growth (LRR), and expected economic growth volatility by the exposure of their returns to consumption growth, economic growth forecast, and economic growth forecast dispersion. We find the R&D strongly negatively correlated to short-run risk (economic growth), but positively correlated to long-run risk (expected economic conditions). We also show that firms with higher size-adjusted R&D investment exhibit higher stock returns or risk premium. Contrary to R&D spending, we find a positive association between patents and short-term shocks and a negative connection between patents and expected economic conditions (a strong and positive connection between patents and future economic uncertainty).

Further, we develop strategies that double-sort firms into two dimensions to explore the relationship between patents, R&D spending, risk exposures, and returns. We analyze risk exposures for firms with similar and different levels of R&D spending and patents granted. With regards to the similar level of R&D and patents, the findings document that the risk exposures decrease in each group category as the number of patents rises. When we examine the firms with a similar number of patents granted per year, we find that the more a firm invests in R&D, the higher its exposure to future macroeconomic conditions. For firms with different levels of R&D spending and patents, we find that the more firms are exposed to future economic conditions, the higher the expected return. When we look at the patent returns and R&D returns, we find that although returns increase with the number of patents, the increase is less pronounced than the increase for R&D spending.

The results of this paper suggest the following new directions for future research. First, our paper highlights that innovative firms are different in terms of their exposures to short-run risk and long-run risk. Future research can focus on studying why innovation is a key driver of risk exposure and whether and how frequent innovators benefit more from these exposures than infrequent innovators. Second, we demonstrate that exposure to long-run risk, particularly, enhances firms' innovation outcomes in the long term and increases stock returns, as well as risk premiums, consistent with the value creation of innovation. Investigating whether such successful innovation outcomes—due to long-run risk exposures—help develop new corporate mechanisms that encourage and facilitate the realization of innovation gains will be important. Finally, future research can also benefit from our results by investigating other types of macroeconomic risks associated with corporate innovation activity. Ignoring the impacts of short- and long-run risk exposures may lead to erroneous characterizations/evaluations of the effectiveness of under- or over-innovation investment (i.e., R&D spending) and their outcomes (i.e., successful patents), as well as stock returns. The fact that the stock market fails to adequately disclose/incorporate this type of information raises important questions about the consequences of macroeconomic risk exposure in general and long-run risk exposure in particular for corporate innovation activities, as well as the economy.

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