ESSAYS ON FINANCE AND CORPORATE INNOVATION

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ABSTRACT

This thesis consists of two essays on corporate innovation, CEO compensation, firm performance, macroeconomic risk, and stock returns. The first empirical work sheds light on the relationship between failure in innovation, CEO compensation packages, firm performance, and other additional tests. Compensation packages serve as an instrument to motivate CEOs to achieve high performance. On the one hand, CEOs may engage in a reckless shopping spree to build an empire without penalty for poor performance. On the other hand, if the penalty is severe, CEOs will be reluctant to extend the firm's investment in innovation, which is long-term, unpredictable, idiosyncratic, and involves a high probability of failure. To strike a balance between investing in innovation projects and risk aversion, our study suggests that firms might need to design optimal incentive packages that are more tolerant of CEOs who experience failures in innovation. We measure innovation failures by a firm’s non-granted patents (NGPs) per year. The results show that there is a significant reduction post-NGPs year in CEOs’ short-term incentives (jointly and separately). In particular, when we look at the relationship between NGPs and the changes in salary and bonus separately, we find a negative and significant correlation between these factors and NGPs, with more impact on bonus (with a higher Pearson’s r) than salary. This is because bonus schemes are dependent on earnings. In other words, the bonuses of CEOs, particularly those in firms actively engaged in innovation, are associated with the success of these innovations. When we join these two components of CEO compensation, we discover a negative and significant correlation between a CEO’s cash compensation (the sum of both) and NGPs, but with less impact compared to the separate tests. The log we use on total cash compensation may weaken the results.

When we examine the relationship between NGPs and the CEO’s long-term incentives, we find a negative and significant correlation between the subsequent CEO’s stock-based compensation and firms’ NGPs. However, we did not observe any significant correlation between NGPs and the changes in other components of the CEO’s long-term compensation, such as option-based compensation. In addition, we computed several compensation variables, including short- and long-term compensation, stock and options, etc., to investigate the same relationship. Our findings show that there is no significant relationship between the changes in these variables and NGPs. The first study also includes a significant section that explores the changes in the firm's performance after the NGP year. We find that the changes in subsequent firm performance, as measured by ROA and ROE, have a significant negative correlation with the NGPs. Furthermore, we set up two supplementary empirical models to investigate the relationship between innovation failure and (1) CEO departure (given that almost 24% of CEOs left their positions post-NGPs) and (2) the changes in R&D investments, as the rest of the CEOs held their positions for a minimum of three years. The results indicate that NGPs have no direct impact on CEO departure following the failure in innovation. Regarding the changes in R&D, we find that R&D is negatively and statistically significantly in response to NGPs. This finding indicates that CEOs tend to sharply reduce the firm’s subsequent investment in R&D, particularly when they face failures in obtaining patents.

The second empirical work explores how firms' exposure to macroeconomic risk can help explain the relationship between firms' R&D investment (i.e., innovation input), patents granted (i.e., innovation output), and stock returns. To understand the relationship between these variables, we introduce two critical macro-level risk factors that are missing in the literature: exposure to economic growth, or short-run risk (SRR), and exposure to expected economic growth and uncertainty, or long-run risk (LRR). The latter has two components that capture economic conditions: expansion (high economic growth and/or low economic uncertainty) or recession (low economic growth and/or high economic uncertainty). We first examine the relationship between firms' exposure to SRR and LRR and R&D expenditure. We find that firms with low exposure to SRR engage more in R&D spending, making their future earnings more exposed to LRR. As compensation for LRR dominates, these firms also have higher stock returns. This result shows that firms with higher size-adjusted R&D investment have higher stock returns or risk premiums, providing a risk-based analysis of why R&D investment is considered a risk factor in the literature.

We then examine the relationship between patents granted and exposure to SRR and LRR. In contrast to R&D expenditure, we find a positive relationship between patents and SRR and a strong and negative relationship between patents and LRR (i.e., a negative relationship with expected economic growth and/or a positive relationship with future economic uncertainty). This confirms that firms that are frequent innovators have low betas to economic fluctuations, so that patents reduce firms' exposure to future uncertainty. Despite being less exposed to long-term risk, we do not find that their stock returns are lower on average, but higher.

To further investigate the reason for the latter result, we develop strategies that double-sort firms into the two innovation dimensions, R&D spending and patents granted, in order to compute the corresponding average stock returns and the betas of SRR and LRR for each category. First, we examine the risk exposure of firms with similar levels of R&D spending and show that the decrease in beta to LRR (specifically economic growth) is driven by firms with higher R&D investment. Looking at firms with similar numbers of patents granted per year, we find that the more a firm invests in R&D, the higher its exposure to future macroeconomic conditions. Second, within firms with different levels of R&D spending, we find that there is no relationship between patents granted and stock returns. However, when analyzing the relationship between patent returns and R&D returns, we find that although stock returns increase with the total number of patents, the increase is less pronounced than the increase in R&D expenditure. This shows that the long-term risk of investing in R&D is reduced, but not completely offset, by the granting of patents.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

This introductory chapter first presents the motivation for my thesis, which focuses on analyzing the consequences of innovation failure on two specific aspects of a firm's operations. The two aspects are the firm's compensation packages and firm performance. Next, this chapter outlines the research objectives and contributions made by the two empirical studies. I conclude by providing a thesis outline for my doctoral dissertation.

1.1.1 Motivation

Overall, my PhD dissertation explores the unexpected and dark side of non-granted patents and their potential impact on firms' activities, both in the short and long term. Previous studies on failure in innovation using the USPTO database have been very limited. For instance, (Basmann et al., 2007) study the impact of patents on technical change in the U.S. from 1947 to 1981, using various types of U.S. patent activity variables, including unsuccessful patent applications, as instruments for the technology changer. The findings indicate that 38% of patent applications are unsuccessful, yet they have a significant and positive effect on the marginal rate of technical substitution (MRTS). In a similar spirit, (Sampat et al., 2019) collect both successful and unsuccessful patents submitted to the USPTO. However, their study concentrates on individual patents held between 2001 and 2010. With special access to the USPTO's internal databases, (Farre-Mensa et al., 2020) have recently examined successful and unsuccessful applications. Their study, however, is limited to startups that filed their first-time patent application with the USPTO between 2001 and 2013.

Together, these results support the argument that many firms use their patents more extensively for strategic purposes such as blocking other firms, improving the reputation of the firm, improving position in negotiations with other firms, creating incentives for their R&D employees (Hall et al., 2009), as well as measuring firm performance (Kapoor et al., 2015). Motivated by the theoretical and empirical literature that suggests possible links between failure in innovation and various aspects of a firm's operations, the first empirical chapter sheds light on the role of non-granted patents and their potential effects on CEO compensation packages and firm performance.

Theoretical and empirical literature (e.g., Manso, 2011; Holmstrom, 1989) show that innovation, in the form of R&D spending, is an idiosyncratic, unpredictable, and risky process. From the shareholder perspective, investing in R&D will maximize their wealth in the long run by increasing the value of their stocks, especially if the firm obtains a patent and, more importantly, converts it into a product. However, this is based on the firm's level of exposure to risk in both the short and long run, as the decision whether to invest in R&D is "entirely under managerial control." The existing literature has yet to directly examine the relationship between R&D investments, patents granted, and stock returns, particularly in the presence of exposure to risk. Therefore, the second empirical chapter addresses this gap.

1.1.2 Research Objectives

The first empirical chapter examines how failure in innovation could impact the CEO's compensation package and firm performance. The first objective is to identify whether such a relationship essentially exists. The following goal is to determine how non-granted patents, a measure of innovation failure, affect the CEO's compensation. The third goal is to link this failure to the firm's short-term performance. In specific, I aim to determine whether firms reduce their CEOs compensations following the non-granted patents. If so, how could this impact the firm's future performance? The results would provide evidence of whether failure in innovation affects the firm's CEO compensation and future performance.

The second empirical chapter examines the relationship between the firm's innovation inputs (i.e., R&D investments), the firm's innovation outputs (i.e., patents granted), and stock returns. The first objective is to examine the relationship between R&D expenditures and 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. The second objective is to explore the links between the firm's granted patents and exposures to economic shocks, expected economic growth, and expected macroeconomic uncertainty. The results would provide empirical support for the hypotheses that both short-term and long-term exposure to risk are crucial for firms to enhance their patent output and, more importantly, increase stock returns in the long run.

1.1.3 Contribution

The first empirical study has the following contributions. First, while it has been known that the effects of success in innovation on many different aspects of firm activities, we are among the first researchers to shed new light on the failures in innovation using the USPTO-PatEx database and provide strong evidence for the empirically underexplored conjecture that the changes in the CEOs compensation packages and firm performance are related to the failures in firms' innovation. These findings are relevant to all areas of finance and innovation literature. Second, we propose a useful proxy variable to measure firms' failures in innovation, which strictly represents patents that received a final decision with rejection from USPTO examiners. We named our measure non-granted patents (NGPs). Third, in contrast to previous research, we provide robust evidence that NGPs, as a negative result of innovation, have an impact on a CEO’s compensation, a firm’s performance, and R&D investment at the firm level, thereby contributing to the literature on the corporate outcomes of innovation.

Fourth, our sample period of 2001–2020 is long enough to capture the effects of NGPs that could appear in both the short and long run. In doing so, we not only integrate new knowledge with prior studies, but we also go one step further and address a set of interesting characteristics of firms and management that reflect the impact of NGPs on corporate innovation activity. Finally, this study, in general, contributes to the body of research on the "dark side" of corporate innovation—why scholars only look at success in innovation when studying patenting activity and ignore the role of unsuccess in innovation, which seems to have a significant impact on many firms' activities —by determining the scope of patent activity, classifying the NGPs recognized by the USPTO, and showing the direct effects of NGPs. The main contribution of the second empirical study is to demonstrate that expected returns can be determined based on the firm's level of R&D investments, risk exposure—consumption growth (SRR) and expected economic conditions (LRR)—as well as granted patents per year. This specific mechanism is missing in the relevant literature.

1.1.4 Thesis Outline

The remainder of the thesis proceeds as follows. Chapter 2 is the first empirical chapter examining the relationship between failure in innovation, CEO compensation packages, and firm performance. Chapter 3 is the second empirical chapter investigating the relationship between the firm's innovation inputs (i.e., R&D investments), the firm's innovation outputs (i.e., patents granted), and stock returns. Chapter 4 summarizes two empirical studies.

CHAPTER 2

CORPORATE INNOVATION, CEO COMPENSATION PACKAGES, AND FIRM PERFORMANCE – THE CONSEQUENCES OF NON-GRANTED PATENTS: EVIDENCE FROM THE US PATENT DATA

2.1 Abstract

Innovations have always been a crucial factor in a firm's long-term success. The declared purpose of innovation is to develop new products or process enhancements that have not yet been developed. As a result, there is a growing need to understand the consequences of corporate innovation activities with a more comprehensive view. In contrast to the existing research on the corporate innovation, this paper documents a “failure gap" in corporate innovation and examines its impact, as measured by non-granted patents NGPs, on CEO compensation packages and firm performance using data from the U.S Patent and Trademark Office - USPTO over the past 20 years. We find that there is a significant negative correlation between CEO's changes in short-term incentives (jointly and separately) and NGPs. We also find a significant negative correlation between the CEO's subsequent stock-based compensation and NGP. Similar results hold for changes in the firm's performance, as measured by changes in return on assets (ROA) and return on equity (ROE). However, we do not observe any correlation between NGPs and changes in ROI. To conclude, the results from using the USPTO data support our suggestion that NGPs have a negative association with CEO compensation packages and firm performance in the following year, and more importantly, help in understanding the consequences associated with failure in innovation by providing new information on the U.S. corporations.

Note that this is not a call for US firms to avoid innovation activity; rather, it is a recommendation to consider the implications of failures in innovation.

Keywords: Corporate innovation, Failure innovation, Patents activity, CEO compensation packages, Firm performance.

2.2 Introduction:

This paper studies the correlation between failure in innovation, CEOs compensation packages, and firm performance in the last two decades. Innovation is vital for a country's economic growth (Romer, 1986) as well as a firm's long-term competitive advantage (Porter, 1992). The focus of innovation is on generating, accepting, and implementing new ideas, processes, products, or services (Thompson, 1965) as a foundation for generating wealth from an invention (Gao et al., 2018; Gomez-Mejia et al., 2010). Economists have estimated that 85% of a nation's economic growth is attributable to technological innovation (He, J. J et al., 2018). Given that the firm is the central mechanism for converting innovation into economic action, comprehending the nature, process, and outcome of innovation requires understanding at the level of the firm (Dodgson, 2017). Therefore, exploring the effects of 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 economics, finance, management, and so on. This is particularly true in the last decade, mostly because of the availability of granted patent data that measure countries and firms' innovation output. In addition to patent counts, the number of citations is frequently used to measure the impact of innovation as well as to adjust for patent quality. The availability of the two above factors—granted patents and number of citations—which are powerful tools for understanding innovative activity (Lerner et al., 2017), is mainly due to open innovation and social efficiency (Kim et al, 2019). Yet, scholars have not devoted sufficient attention to the dark and unexpected side of patents that have not been granted and whether such patents impact firms' activities in the short and long term.

To be granted, however, applicants must go through a series of sequential and selective steps, such as the examination process and early fees before obtaining the final decision from the patent office. In 1975, the United States Patent and Trademark Office (USPTO) started keeping track of patent information in a digital format, considerably enhancing academics' access to this information. Nevertheless, it must be emphasized that prior to the reform on November 29, 2000—which in fact began publishing patent applications in 2001 under the 18 months publication provisions of the American Inventors Protection Act of 1999 (AIPA) (P.L. 106-113)[1]—was not possible to gather and classify non-granted patents (NGPs) from the USPTO database. This is the main reason why, in the literature of economics, finance, and management, the vast majority of studies on corporate innovation focus on success in innovation activities, which measured by R&D and later patents granted and their citations, while only a few studies look at the phenomenon of failures in innovation and mostly rely on the databases from European Patent Office EPO. We are more interested in failures than success in innovation, especially at the "firm level".

The USPTO database, on the other hand, has been instrumental in creating a patent system for various levels, including firm-level databases. Yet, acceptance of the difficulty of accessing and classifying patent applications that the USPTO rejected has meant that this logic is rarely challenged. In particular, prior research analyzing unsuccessful patents using the USPTO database have been very limited. For instance, (Sampat et al., 2019) collect both successful and unsuccessful patents submitted to the USPTO. However, their research focuses on patents that held by individuals in the period of 2001-2010. With special access to the USPTO's internal databases, (Farre-Mensa et al., 2020) have recently examined successful and unsuccessful applications. Their study, however, is limited to startups that filed their first-time patent application to USPTO between 2001 and 2013. In addition, we know from the existing literature that CEO compensation is often linked to innovation, with studies suggesting that short-term CEO compensation is related to metrics like patent counts and R&D spending (see section 2.3.2.1). High compensation aims to mitigate the conflict of interest between the CEO and those of shareholders, potentially encouraging greater risk-taking in R&D, which could result in more patents (Balkin et al., 2000). However, what remains unclear is whether firms tolerate/adjust CEO compensation when innovation efforts fall short, such as when there is a lack of successful patents, and whether such patents influence a firm's performance in the short-term. This is a significant knowledge gap given the growing problems surrounding innovation activity. Exploring this relationship could offer insights into the effectiveness of the board, CEO entrenchment, and the overall quality of corporate innovation/governance. The objective of this paper is to close this gap by answering the following research questions:

First, does failures in innovation, represented by USPTO- Non-granted patents NGPs, have an effect on the compensation package of a CEO in both the short and long term?

Second, if so, do NGPs impact the performance of a firm in the short-term?

Third, more generally, do NGPs influence other firm's characteristics, and - if this is the case - do these characteristics play a significant role in the corporate innovation process?

These are the substantive questions that we intend to investigate and to provide an analysis of the failure in innovation and its potential consequences on firm activities.

Furthermore, due to the lack of systematic data about NGPs, we initially decided to use the Derwent database World Patents Index DWPI (formerly known as Thomson Innovation) because it contained extensive data on innovations. Unfortunately, data on NGPs for US firms is not readily accessible in the Derwent database, making it unreliable for our research purposes. Even today, with data much more accessible of patent activity, the available data on NGP is still quite limited. Showing that NGP is a reliable measure of failure in innovation activity is an interesting accomplishment on its own merit. Likewise, using the USPTO data to understand what can be explored with NGPs is a valuable resource for scholars addressing finance and innovation-related subjects. Therefore, in order to investigate the consequences of failure in corporate inventive activity, we extract the number of NGPs using utility applications from the USPTO Patent Examination Research Dataset PatEx (formerly referred to as Public PAIR data), which contains data on NGPs for the past two decades. We use the latest and most recent version of USPTO-PatEx data (updated in 2022) for US patent applications filed between 2001 and 2022. The sample of this study, however, ends in 2020 due to the average time lag of patents, which is typically three to five years. Our final collection of data for the period 2001-2020 covers 723 firm-year observations and consists of 2,003 applications of unsuccessful patents for 256 firms. More importantly, although we faced enormous obstacles in collecting and categorizing NGPs, using of USPTO data provides us with deep insight into what is happening in various domains of related literature, as well as in more detail than is possible to observe from other patenting data. Plus, we had the opportunity to engage in deep discussion with internal USPTO experts, enabling us to accurately interpret and efficiently present our findings.

More specifically, the study explores whether firms tolerate innovation failures. To measure "firms' innovation failures," we apply NGP because at any given point, innovation firms have granted patents (indicating success in innovation), NGP (indicating failure in innovation), and pending applications. This measure captures innovation firms' response toward failure by gauging their tolerance for their CEOs' compensation packages, as well as their willingness to continue investing in innovation activity despite past poor performance (i.e., obtaining NGPs) before they "pull the plug" (i.e., stop investing). We follow the definitions provided by (Farre-Mensa et al., 2020; Sampat et al., 2019; Lemley et al., 2008) defining failure in innovation as "*patent applications that are submitted to the USPTO and ultimately rejected by USPTO examiners*."[2] We aim to investigate whether firms tolerate such innovation outcomes.

Therefore, we do not deal with applications that are still pending, as they may have potential value in the future (i.e., it may be granted and cited). Nor we use granted patent applications due to the numerous studies that have been conducted in this area. Rather, we try, in this paper, to show why we think NGPs are "exclusively" interesting despite all the difficulties that arise in their availability and interpretation. To do so, we will first describe the nature of patents (granted and non-granted) and their process. We will next review some of the prior work on patenting activity, the types of data employed by researchers, as well as some of the current issues in the corporate innovation literature that are related to this research paper. Then we will cover the previous assessments linking CEO compensations and firm performance to innovation activities. Thus, the research on CEO remuneration and firm performance that related to other than innovation activities will not be discussed. We will not be able, however, to do all the prior work justice, as there are other good studies examined unsuccessful patents from a different perspective, but we hope to provide an important addition to the relevant literature. Finally, we will discuss the hypotheses, methods, and results of the current study.

To conduct this study, we use a two-stage analysis on our selected sample. First, we aim to empirically investigate the entire data collection, which consists of 723 firm year-observations for all variables spanning the year prior to, during, and following the occurrence of the NGPs, to analyze the correlation between NGPs, CEO compensation packages, and firm performance. Or put it differently, we aim to examine on whether CEO compensation packages and firm's performance measurements reduce in the post-NGPs year. With that data, and consistent with our hypotheses, we find that NGPs have a significant negative effect on all short-term incentives (i.e., salary, bonus, and total cash compensation, which is the sum of both) in the year following NGPs. Similarly, stock-based compensation, in terms of long-term incentives (i.e., options, stocks, and other long-term incentives plans), is significantly and strongly negatively impacted by NGPs in the year after NGPs. The outcomes of our analysis on whether NGPs affect firm performance, as measured by return on equity ROA, and, as a robustness check, return on assets ROE, and return on investment ROI, show a strong and significant negative impact on ROA, ROE, but we did not observe any influence on ROI solely. However, when we add control variables to the model, the result indicates that NGPs significantly negatively associated with the change in ROI. Moreover, prior work uses research and development R&D expenditures to measure innovation output, and others rely on granted patents for the same purpose. However, they disregard the fact that R&D expenditures, which is the primary input into the innovation process, do not offer any details on the “success of the innovation” (Brander et al., 2017; Kleinknecht et al., 2002). NGPs, on the other hand, provide information on the firm's “unsuccess of the innovation”. Hence, to explore the relationship between our primary variable to measure failures in innovation, NGPs, and R&D activities, we examine the impact of NGPs, innovative outputs in our study, on firms' investment in R&D, innovative inputs, in the year following the appearance of NGPs. We find that NGPs have a strong and significant negative effect on R&D investments in the subsequent year for the US firms. We use the ordinary least squares (OLS) technique to run all these models.

In addition, we observed that in our entire dataset, almost 24% of all Chief executive officers (CEOs) (i.e., 95 out of 401) were departed the year following the occurrence of NGPs. Consequently, we investigate the correlation between firm’s failures in innovation and the departures of the CEOs. Our analysis, using a binary variable and logistic model, shows that the NGPs do not influence the departure of CEOs. We intend, however, to dig into this outcome further by gathering the motives for the departure of CEOs, as the databases we rely on do not encompass all the relevant information on CEOs' departures. The logic behind this collection is to identify a direct link, if any, between the effect of NGPs and the reasons of a CEO's departure so that we can suggest some directions for future research and theory building. We find that “resignation” was the main cause of departure for 70% of CEOs who left their positions (i.e., 67/95) in the year following NGPs (Section 3.3 provides more details). Our conclusions suggest that innovation failure could be a contributing factor—considering the long tenure of these CEOs and their high number of NGPs—but it is obviously not the main reason innovation firms replace their CEOs. Therefore, if more innovation firms, especially those with a high number of NGPs, exhibit a tendency to replace their CEOs in the year subsequent NGPs, our hypothesis of CEO departure could potentially gain acceptance, and, more importantly, open a new area of future research about the role of failures in innovation and its effects on the decision-making process of a firm's board of directors.

Second, as a further robustness check, we tighten our data by considering only the CEOs who had their tenures extended after the occurrence of the NGPs and excluding those who left, resulting a total of 628 firm year-observations consists of 306 CEOs and 1,823 cases of NGPs. Then, we run the exact models in the first stage in order to examine the consequences of NGPs on CEO compensation packages and firm performance, as well as firm’s R&D investments. In this stage, however, we are unable to analyze the relationship between NGPs and the departure of the CEOs, as we do in the first stage, due to limitations in our dataset in this level, which only includes CEOs who were in the position one year before, during, and after the NGPs occurred. These CEOs represent 87% of our total data on CEOs. We argue that CEOs who have been reappointed bear full responsibility for the firm's patent applications from the time they start the filing process until the firm receives the final decision from the USPTO examiner. In specific, since these CEOs remain in their positions for at least three years and show failure in innovation, by obtaining NGPs, such result could have a negative effect on their short-and long-term incentives in the subsequent year. As a result, the firm's performance and the observable characteristic of firm innovation, R&D investment, may also reduce in the year following the NGPs. The effect on the latter variable is particularly relevant as it is the only input into the innovation process that is “entirely under managerial control". In other words, if CEO compensation packages decrease, due to failure in innovation, their motivation to invest in R&D is most likely to decrease.

We confirm from an OLS regression that the empirical results we obtain in the second stage support the findings of the first stage across all models (*failure in innovation, in the form of NGPs, is associated with decrease in the CEO short-term incentives and stock-based compensation, which, in turn, is associated with decrease in both firm performance and investment in R&D in the post-NGPs year*). Particularly, the results indicate a significant negative impact of NGPs on all components of CEO short-term incentives. With CEO long-term incentives, the findings show that stock-based incentives in the year after NGPs are less effective than stock-based incentives in the year before NGPs. Likewise, the outcomes show a significant negative effect of NGPs on ROA and ROE, while there is no impact on ROI with regards to firm performance measurements. The findings of the second stage also confirm that NGPs have a significant negative impact on a firm's investments in R&D in the post-NGPs year. Overall, all these empirical models from the "two-stages" demonstrate that firm's failures in innovation have a significant and direct influence on various aspects of firm operations. The results, therefore, suggest hitherto unexplored effects of the USPTO-NGPs on US firms. As far as we know, the current study is the first to link "exclusively" the innovation failures of firms with compensation packages of CEOs and performance of US firms, as well as their R&D investments.

Some may argue that this exclusive focus on NGPs is exaggerated and that other types of patents, such as those that are pending, are of equal if not greater importance. Nevertheless, our study attests to the robust results (this is the second level) that NGPs demonstrate. This study makes several contributions to the literature. First, while it has been known the effects of success in innovation on many different aspects of firm activities, we are among the first researchers to shed new light on the failures in innovation using our analysis on the USPTO-PatEx database and provide strong evidence for the empirically underexplored conjecture that the changes in the CEOs compensation packages and firm performance, as well as firm's R&D investments are related to the failures in firms' innovation. These findings are relevant to all areas of finance and innovation literature. Second, we propose a useful proxy variable to measure firms' failures in innovation, which strictly represents patents that received a final decision with rejection from USPTO examiners. We named our measure non-granted patents (NGPs). Third, empirical research, in general, uses R&D investment and latter patents granted and citations to investigate firms' innovative activities. Yet, the effect of NGPs, within the context of innovative activities, is still ambiguous. Therefore, this study contributes to the existing body of literature by linking the failure in innovation —particularly the role of NGPs—with CEOs' remuneration packages and the performance of US firms, as well as their R&D investments.

Fourth, our study also contributes to the literature on the causal effect of innovation outputs. Existing literature (e.g., Mao et al., 2018; Baranchuk et al., 2014; Lerner et al., 2007; Makri et al., 2006) has focused on patents granted and R&D investments. We take advantage of NGPs to explore their causal effect on all short-and long-term CEO compensations as well as on commonly used measures of firms' performance. Fifth, in contrast to previous research, we provide robust evidence that NGPs, as a negative result of innovation, have an impact on CEO's compensation, firm's performance, and R&D investment at the firm level, thereby contributing to the literature on the corporate outcomes of innovation. Sixth, our sample period of 2001–2020 is long enough to capture the effects of NGPs that could appear in both the short and long run. In doing so, we not only integrate new knowledge with prior studies, but we also go one step further and address a set of interesting characteristics of firms and management that reflect the impact of NGPs on corporate innovation activity. Finally, this study, in general, contributes to the body of research on the "dark side" of corporate innovation—why scholars only look at success in innovation when studying patenting activity and ignore the role of unsuccess in innovation, which seems to have a significant impact on many firms' activities —by determining the scope of patent activity, classifying the NGPs recognized by the USPTO, and showing the direct effects of NGPs.

We conclude that, despite being relatively inconsequential for most of the US firms, we initially predicted that NGPs might only affect compensation of CEOs and firm performance in the "long-term." Interestingly, our study shows surprising outcomes on the two stages of analysis, indicating that, except for stock-based compensation, the effects of NGPs are actually significant for the "short-term." From managerial perspectives, these results can therefore be valuable to firm administrators in determining whether these patents require more attention. Plus, they suggest that firms ought to carefully consider the importance and potential economic value of NGPs in the long run, especially if the firm seeks re-evaluation and the USPTO examiner approves to review and, eventually, grant them in the future. They also offer guidelines for policy makers regarding the implications of strategic decision-making in innovation.

The remaining of the study is organized as follows: Section 2 discusses the background and related literature of innovation, CEO compensations, and firm performance. It additionally describes the classifications of NGPs and the interaction between patent applicants and examiners of the USPTO. Sections 3 summarizes our expectations. According to the literature, when patents are granted, they frequently result in positive effects on various aspects of firms' operations. In contrast, we hypothesize that NGPs will have negative consequences on both CEO remuneration and firm performance, including some other potential negative effects on firm innovation activities, like lower investment in R&D. Section 4 describes data and methodology, including sample, measures, models, and data analysis. Section 5 presents the empirical results and robustness. Through our analysis we find support for our primary hypotheses related to impacts of NGPs. Our analysis, however, does not find effect on all components of long-term incentives for CEOs. Section 6 concludes the study.

2.3 Literature Review:

In order to use the USPTO data effectively, particularly our main independent variable, NGPs patents, it is necessary to understand a little about the prior studies conducted on both granted and non-granted patents in the related literature. Most of these studies have relied on R&D investments, granted patents, and citation patents to represent corporate innovative performance. This part, however, reviews current research on the interaction of corporate innovation with CEO compensation packages and firm performance.

2.3.1 Innovation Activity: Patents examinations, Granted Patents, and Non-Granted Patents

2.3.1.1 Patents examinations:

A patent is a legal document, issued by recognized governmental agencies, granting the right to exclude anyone else from the production or use of a particular new device, apparatus, or process for a stated number of years (Griliches, 1990, 1998). The main objective of the patent system is to promote innovation and technological development by allowing the inventor a temporary monopoly for the inventor and requiring early disclosure of the information necessary for the production of this product or the operation of the new process. The inventor of the device or process receives the grant after an evaluation that considers both the uniqueness of the claimed item and its potential value. Moreover, applicants must go through a series of sequential and selective steps, such as the examination process and early fees, before obtaining the final decision from the patent office, which, at best, can last three years (Schettino et al., 2009). Failing to meet the obligations in due time, however, the patent is considered to be withdrawn.

Furthermore, the USPTO examiner is a public officer who is legally required to grant a patent if the inventor met the criteria for patentability established by the US Congress and federal courts. The USPTO uses five criteria to determine whether to grant a patent application: patent eligibility, novelty, non-obviousness, utility, and the text of the application satisfying the disclosure requirement. More precisely, the USPTO sends the applications to the “art unit”, a group of patent examiners, for review. The examiner, with relevant expertise, makes an initial assessment of patentability based on the above-mentioned criteria. Most often, this assessment is just the first in a series of revisions carried out in collaboration with the applicant. Notably, there are only two participants: the examiner and the applicant. In other words, there is no possibility for other interested parties to submit evidence during the initial review that could influence the decision to grant the patent. After the initial review, which is estimated to cost a patent examiner only eighteen hours on average to decide on each application (see, e.g., Burk et al., 2002), the applicant receives an official letter detailing the examiner's initial decision.

At this stage, the applicant can revise the claims to meet the demands of the examiner, and another same round of revisions may follow. If the patent reaches an advanced stage —most likely to be in pending —there is a substantial chance to be issued. Otherwise, the applicant will receive a final rejection. We find thousands of applications pending and obtain 2,003 applications with final rejection between 2001 and 2020. Three months following the final rejection, however, the USPTO applicant has the right to respond and decide on one of the three options: *request a re-examination* with compelling justifications for why the applicant persists in believing their application should be accepted; *appeal against the final decision* if the applicant perceives that the examiner may have missed a crucial component of the application during the patent examination process; or *abandon the application* when there is a little chance to issue the patent if the applicant proceeds.

We argue that the term "final rejection" seems inappropriate at this point because the applicant should not take any further action following such a determination. We also argue that the USPTO ought to consider the disparity between these phrases to avoid any misunderstanding when researchers try to employ them. The final accept/refuse decision task takes approximately 3 years on average. However, the delay in the granting process may be substantially longer due to the rise in patent applications, which can be largely associated with applicants' increasing use of strategic patenting (see, e.g., Hall et al., 2009). Half of the US patents granted in 1996 spent approximately 20 months in pendency, while, in sharp contrast, half of the patents granted in 2011 spent more than 36 months in pendency (Zahringer et al., 2018).

2.3.1.2 Granted Patents:

The likelihood of success in obtaining a patent varies significantly between countries. (Boubakri, et al., 2021) show that corporate innovation is more prevalent in countries with an indulgence orientation. (Griliches, 1990) noted that the success rates of obtaining patent protection were 90% in France, 80% in the UK, 35% in Germany, 65% in the U.S during 1970s (approximately two out of three applications in the U.S are ultimately granted), and 73% in 1988. Since then, the patenting activity has grown substantially in the U.S. (Cohen et al., 2000), for example, indicating that the total number of U.S patent grants has increased 78% between 1983 and 1995. (Schuster et al., 2020) recently reported that, out of over 3.9 million applications using U.S. data, 68.8% resulted in patent issuance between May 22, 2001, and March 22, 2016. Other studies (see, e.g., Carley et al., 2015), however, argue that the U.S grants patents easily, and many such patents granted hinder, rather than promote, the U.S. innovation system. This disparity is mostly due to the differences in the economic conditions, procedures, and resources used by various patent offices, resulting in variations in the quality of a granted patent between countries and periods. These results indicate that the more experience in the process of patenting (granted), the higher the chance to reduce the risk of failure (NGPs).

In the past decade, patenting has been frequently used as an alternative proxy to capture corporate innovation (He J.J et al, 2018). Several studies in the field of finance and patenting literature have looked at the effect on firm innovation due to mergers and acquisitions (Bena et al., 2014), bankruptcy (Bai et al., 2020; Acharya et al., 2009), banking deregulation (Hombert et al., 2017; Cornaggia et al., 2015; Amore et al., 2013; Chava et al., 2013), going public (Bernstein, 2015), stock market liquidity (Fang et al., 2014), and stock volatility (Bartram et al., 2012). Others have examined the impact of litigation (Choi et al., 2017; Galasso et al., 2013; Haslem, 2005; Allison et al., 2004; Hall et al., 2004), unions (Bradley et al., 2017), and other factors on firms' innovation. In all of these studies, researchers use granted patents as a main variable to measure corporate innovation at the firm level because such patents have value to the firms that obtain them. There is no study, however, in the empirical literature of patents, at least what we read, that captures "perfectly" innovation.

Previous research has used firm-level data and specifically examined the impact of granted patents. For instance, (Agarwal et al., 2010) estimate the patent premium using an empirical approach and suggest that the presence of granted patents increases the returns to an invention by around 40 to 50 percent on average. In a recent study, (Farre-Mensa et al., 2020) demonstrate that obtaining a patent not only boosts the number of subsequent patents granted to the firm (by 56.5%), but also improves the quality of these patents (the average number of citations per subsequent patent increases by 33%). (Brander et al., 2017) investigate the correlation between employee relations (ER) and innovation, as measured by granted patents and patent citations. They use the

NBER Patent Data File over the period 1991 to 2010 and find that patents granted have a positive relationship with both real R&D and the number of employees. In contrast, (e.g., Hall et al., 2010; Crosby, 2000) show a negative relationship between patents granted and innovation activities. Whether the patents granted reflect true innovation or not, it is still of interest to assess the factors that contribute to successful patenting.

2.3.1.3 Non-Granted Patents:

The prior empirical literature in this area is relatively sparse, perhaps due to the difficulty and limited resources of comprehensive data. Until recently, publicly available data sets, such as NBER or Harvard Business School, only covered patents granted (Lerner et al., 2017). Even today, public disclosure of patents that have not yet been granted is insufficient, according to the patenting literature. Therefore, we conducted extensive research, excluding irrelevant studies, and found that no previous research "exclusively" studied the effects of NGPs patent applications over the period 2001-2020. This part, however, focuses on the reasons given in the literature for NGPs patents and the various consequences they have. We divided the relevant studies into three groups according to their common reasons: lack of technological merit, examination decision differences, and market value estimation.

One of the reasons that a patent application is rejected is a lack of technological merit. According to US patent laws, technology may be deemed to lack novelty if it is either obvious, thereby lacking technological merit, or if it was made publicly available more than a year prior to the application being filed. (Carley et al, 2015), for example, use USPTO's databases from 1996 to 2005, which include granted and rejected applications, and show that applications in the high technology fields such as drugs and medical and computers and communication are least likely to be successful, with a sharp decline at 55.8%. This result is consistent with a previous study (Frietsch et al., 2013) that use the European Patent Office EPO Worldwide Patent Statistical Database (PATSTAT) and reveals that patents rejected are more in the high technology fields (specifically, electrical engineering and chemistry) than those in the medium or low technology fields (mechanical engineering). In a similar spirit, (Basmann et al., 2007) study the impact of patents on technical change in the U.S. from 1947 to 1981, using various types of U.S. patent activity variables, including unsuccessful patent applications, as instruments for the technology changer. The findings indicate that 38% of patent applications are unsuccessful, yet they have a significant and positive effect on the marginal rate of technical substitution (MRTS). Likewise, (Sampat et al., 2019) use administrative data on successful and unsuccessful patent applications at the individual level and suggest that, on average, gene patents have had no quantitatively important effect on follow-on innovation. These outcomes together support the argument that patents are used more extensively for strategic reasons such as blocking other firms, preventing inventing around, improving the reputation of the company, improving position in negotiations with other firms, creating incentives for its R&D employees (Hall et al., 2009), and measuring firm performance (Kapoor et al., 2015).

Differences in patent examination decisions are another reason why patents are not granted. In practice, the examiners make their examination decision by comparing the patent application with certain criteria, which include the state of existing knowledge, the patent application's novelty, the nonobvious of the patent, etc. If the application does not match the criteria, the examiner issues an "office action," rejecting the application as not patentable and explaining the reasons for that rejection. Hence, the decision to grant or non-grant the application should be the same across offices for the same patent. (Palangkaraya et al., 2011) use granted and refused patents to investigate the misclassification in patent examination decisions made at the European Patent Office (EPO) and the Japanese Patent Office (JPO) between 1990 and 2004 on a matched sample patent application. Besides the EPO and JPO, the authors use data from four different databases: the Triadic Patent Family (TPF), NBER, USPTO, and the EPO Worldwide Patent Statistical Database to examine the determinants of misclassification. The results display a 6.1% probability of refusing a true grant application, and a 9.8% probability of granting a true refusal application. Consequently, differences in examiner skills, staffing levels, office procedures, and country-specific legal texts may explain differences in decisions, but they should not serve as justification. In a similar vein, (e.g., Batabyal et al., 2008; Cockburn et al., 2002) find that examiners in the USPTO make too many errors in the process of evaluating the strengths of individual patent applications. These errors can result in rejecting a deserving patent application or accepting an undeserving patent application. These findings suggest that the USPTO's management should be significantly involved in controlling examiners' idiosyncratic aspects when granting patent rights. Because both applicants and examiners participate in the patent examination process, it is important to comprehend how applicants behave strategically. A further study (Graham et al., 2018) use USPTO data over the period 2003–2012 to identify the impact of nonpublication requests on the characteristics of patent records included in PatEx. In general, applications can be unpublished for two main reasons: applicants can take advantage of the American Inventors Protection Act (AIPA) opt-out provision for nonpublication, and applications may be abandoned or granted prior to the pre-grant publication date. However, the authors find that the majority of unpublished applications, approximately two-thirds, include a request for nonpublication. This result suggests that a large share of the applications do not meet the requirements for publishing, thus will not be granted.

Others argue that the market value estimation (that is, the market-perceived value of patents) plays a significant role in determining whether patents succeed or fail by increasing or decreasing their value. Many of the studies in this area of the literature have regarded the U.S. context (e.g., Farre-Mensa et al., 2020; Balasubramanian et al., 2011; Lanjouw et al., 2004), demonstrating significant effects of market value on granted patents than NGPs patents as it has met the criteria of novelty, technological height, and commercial applicability (Neuhäusler et al., 2011). Some other research shows similar findings for the European firms (e.g., Hall et al., 2007; Toivanen et al., 2002). Two decades earlier, (Guellec et al., 2000) use two factors related to the technological value and legal rights conferred to the patentee and demonstrate that the patents granted have a higher private value than the ones that are withdrawn or refused. Other researchers have confirmed the patents granted–market value link in other contexts. For example, (Kogan et al., 2017) use a novel measure of the economic value of new innovations that is based on stock market reactions to the U.S. patents granted between 1926 and 2010. Specifically, they estimate the private value of the patent by exploiting movements in stock prices following the days patents are issued to the firm. Their findings reveal a higher volatility in returns on patent grant days compared to days without any patent grant announcement, , indicating the release of valuable information to the market. In contrast, (Yang et al., 2019) use data for 22 countries and show that market value has a significant negative influence on the patenting activities of emerging countries. Similarly, (Fang et al., 2014) suggest that the stock market has a negative causal effect on firm innovation (measured by granted patents). Another paper in this area (Walsh et al., 2016) use information from US patents and show that 30% of non-use patents (including failed patents) are due to the market environment reducing the value of the invention. These findings highlight two important points: First, the misleading values of the patents may lead to wrong conclusions if they are not properly addressed. Second, the low-value granted patents could potentially influence the future value of NGPs (if they issued later) for the same invention. In sum, these issues of lacking technological merit, examination decision differences, and market value estimation are determinants of patents' success or failure and have often received considerable critical attention from researchers. Besides this background and with an eye on the limited empirical evidence on NGPs, in this study, however, we are interested in establishing facts about the effects of NGPs on CEO compensation packages and firm performance by focusing on North American patent data.

2.3.2 CEO Compensation Packages:

CEOs are the most important decision-makers for firms (Faleye et al., 2014), responsible for allocating corporate resources (Coles et al., 2006), designing corporate strategies (McDonald et al., 2008), and ultimately generating profits and financial returns (He et al., 2018). In a modern firm where ownership and control are separate, providing compensation to managers mitigates misalignment between managers' and shareholders' interests and motivates them to invest in innovations (e.g., Roe, 2013; Koo et al., 2019). Thus, firms wishing to pursue innovation would provide their CEOs with more compensation (Baranchuk et al., 2014). However, CEOs are risk-averse and favor short-term earnings, especially when it comes to innovation, partially due to the high failure rate (Biggerstaff et al., 2019; Edmans et al., 2017; Holmstrom, 1989), as well as the risk of being fired (Aghion et al., 2013). We know little about how failure in innovation, in the form of NGPs, affects a firm's CEO's incentives. The current study addresses these two issues: the CEO's failure to innovate and the CEO's departure.

Our compensation sample is formed from US firms with CEO compensation data available on BoardEx. The BoardEx database's structure indicates that a CEO's compensation package consists of two main components: First, short-term incentives (STIs) are the total cash compensations—the sum of salary and bonus. Second, the total equity at risk—the sum of the stocks, options, and the long-term incentive payment (LTIP)—indicates long-term incentives (LTIs). We focus on these two main compensation measures, as well as each of their components separately. Prior studies, which we discussed below, have mostly linked one or two components of CEO compensation to innovation activity. In our study, however, we intend to link all of the short- and long-term components to corporate innovation, both jointly and separately. The literature on CEO compensation packages consists of two sections. The first section reviews the literature that links short-term CEO compensation and innovation activities. We discuss studies that explore how successful innovation, in the form of granted patents, influences the CEO's total cash incentives, salary, and bonus. The second section covers studies examining the relationship between long-term CEO compensation (stock, options, etc.) and innovation activities. We will also discuss the relationship between these two main compensations and the innovation failure.

2.3.2.1 Prior research linking short-term CEO compensation to corporate innovation.

Given the high rate of innovation failures, CEOs may avoid innovation investment decisions and devote attention instead to other firm strategies that enhance their personal career objectives. In this case, most firms intervene by adjusting compensation packages to encourage CEOs to engage more in innovative activities and generate more granted patents, as well as to affect the riskiness of their decision-making (Graffin et al., 2020). However, in practice, other CEO incentives, such as stock and options, are not always achievable. The shareholders, thus, can only offer the CEO a short-term compensation, even though the cost of short-term incentive is higher than the cost of long-term incentive (Manso 2011). Such short-term compensation is most likely to be linked to profitability (Incentive-based performance). Moreover, One of the most widely cited papers that investigate CEO short-term schemes is (Healy, 1985). The author describes different forms of compensation, including both salary payment and bonus plans, and indicates that bonus schemes depend on earnings. Many subsequent researchers have pointed to Healy's study as evidence that CEOs' bonuses are associated with profitability. For example, (Makri et al., 2006) use a sample of 206 firms from 12 US manufacturing industries to explore the relationship between innovation activities and CEO incentives in technology firms. The findings indicate a stronger correlation between bonuses and financial results. They further suggest that R&D-intensive firms should reward CEOs for financial results with annual bonuses. Therefore, rewarding a CEO with annual bonuses linked to earnings reinforces their focus on continuous innovation.

Prior literature presents mixed results concerning the relationship between innovation activity and CEO short-term incentives. For instance, (Brick et al., 2006) use a sample of 1441 firms over the period 1992–2001 to examine, besides other investigations, the association between the CEO's cash compensation and R&D. The authors document a strong positive correlation between the CEO's cash compensation and R&D after controlling for monitoring proxies. Using sample data between 1992 and 2004, (Sheikh, 2012) examines whether the structure and design of CEO compensation has any effect on firm innovation. In particular, the author empirically examines how incentives from compensation contracts affect two observable characteristics of firm innovation: R&D expenditures and patents and citations to patents. The results indicate that the CEO's cash compensation is positively related to investment in R&D, number of patents, and citations.

In a similar spirit, (Shen et al., 2013) focus on both short-term incentives and equity-based compensation to study which CEO compensation can influence corporate investment efficiency and hence impact shareholder wealth. They use a sample of 843 cases in which firms increased their R&D investments by an economically significant amount during 1995–2006. They also point out that increases in R&D investment tend to increase investor opinion divergence, resulting in greater stock return volatility. They find a positive and strong correlation between CEOs with higher cash compensation and increased R&D investments. This finding is consistent with prior work (e.g., Guay, 1999), which discussed that a CEO's risk aversion is related to how much of that CEO’s personal income is earned within the firm. In other words, increasing the CEO's cash compensation would be a motivation to invest more in R&D projects, which, in turn, would generate more patents and vice versa.

In an empirical study on the duration of CEOs' compensation, (Gopalan et al., 2014) develop a measure of pay duration that directly captures the mix of short-term and long-term compensation. More precisely, their measure explicitly considers the length of the vesting schedule for each component of the CEO's compensation, of which there are often many during a given compensation year. Since cash compensation can produce incentives for a CEO to take high risks, R&D investment (Roe, 2013), the authors indicate that, based on their data, 30% of CEOs compensation consists of salary and bonus, which vest immediately (we know that the non-cash components, long-term incentives, typically vest within five years if a CEO remains in the position). That is because most of these CEOs have longer-duration pay contracts, in which most of their compensation comes from equity-based incentives. They show overall a positive correlation between CEO cash compensation (salary and bonus) and R&D investment. In particular, CEOs with long pay durations have significantly higher salary compensation but lower bonus compensation. These results support the literature that indicates a positive relationship between both short- and long-term contracts with innovation.

In contrast, (Cheng, 2004) examine the relationship between innovation, in the form of R&D, and CEO compensation. Based on the data from 160 Forbes 500 firms in R&D-intensive industries over the period 1984–1997, the main hypothesis suggests a positive correlation between changes in R&D and changes in CEO compensation. In contrast to changes in long-term incentives, the results show that changes in cash compensation (salary and bonus) are significantly negatively associated with changes in R&D. In other words, when the firm faces a small earnings reduction or small loss, its R&D is likely to be sharply reduced or cut in the subsequent year (Hayes et al., 2012). The decline in the firm's earnings will negatively affect the CEO's cash incentives. As the firm forms strong long-term incentives for its CEO to prevent any reduction in such incentives, the correlation between the decline in the firm's earnings and long-term incentives is positive, especially when the CEO approaches retirement.

Likewise, (Mao et al., 2018) use a sample consisting of 15,741 firm-year observations between 1992 and 2008 to explore how the risk-taking incentive derived from CEO compensation affects firm innovation. They apply compensation changes made by the FAS 123R accounting regulation in 2005, which mandated stock option expensing at fair values. Based on their baseline ordinary least squares (OLS) results, there is a significant positive relationship between CEOs' risk-taking incentive (i.e., vega) and innovation output (patents granted and citations). Further, they examine the relationship between the CEO's short-term incentives (salary and bonus) and innovation activities in an OLS regression framework. The findings demonstrate a negative relationship between the CEO's short-term incentives and innovation following the implementation of FAS 123R. This negative result indicates that firms use pay-for-performance-based compensation when they use the FAS 123R law. In a similar spirit,.

In short, salary and bonus (total cash compensation) are part of CEO total compensation packages, and both are contingent upon the year-on-year performance of a firm and are agreed upon ex-ante. Bonuses, for example, reward CEOs with additional payments on top of a base salary when they show good performance (e.g., generating more patents). In other words, short-term incentives motivate CEOs to shift attention to the short term and focus only on less risky investments that have sufficient potential to guarantee meeting the objectives tied to their short-term compensation. Yet, when a firm fails to obtain patents, such failures might influence its CEO's subsequent bonuses and, consequently, the CEO's entire short-term incentives. Overall, prior studies have mainly focused on the positive role that successful innovation plays in the CEO's short-term incentives, and they neglected the potential negative consequences of innovation failure, which may directly affect the CEO's future compensation from salary, bonus, and total cash incentives. Hence, this study seeks to fill this gap.

2.3.2.2 Prior research linking long-term CEO compensation to corporate innovation.

We now review the literature on how corporate innovation affects a CEO's long-term incentives (i.e., stock, options, LTIP). Scholars (e.g., Manso, 2011; Holmstrom, 1989) argue that incentive contracts should provide a long-term commitment and protection from failure to motivate managers to invest in the exploration of new ideas rather than exploiting existing ones. Recently, there has been a call from academics and commentators for a more comprehensive empirical investigation into the relationship between CEOs' long-term compensation and corporate innovation (e.g., Mazouz et al., 2019; Shen et al., 2018; Laux, 2015; Baranchuk et al., 2014; Shen et al., 2013; Manso, 2011; Lerner et al., 2007; Ryan et al., 2002). These studies summarize the results of this line of research by stating that successful innovation, which is mostly measured by granted patents, has a positive relationship with the CEO's long-term incentives. (Francis et al., 2010), for example, use a sample of 1,106 firms during 1992–2005 to explore the relationship between the long-term compensation and innovation activity, as measured by the number of patents filed and citations. The findings indicate a positive relationship between the CEO's long-term incentives (options and stock) and the firm's innovative activities. Their results provide evidence consistent with the theory that contracts that offer a high tolerance for failure motivate CEOs to invest more in innovation.

Since R&D has assumed a greater importance in corporate innovation and the efficiency of R&D projects has more significant influence on firms' future performance, several recent papers have therefore explored the potential impact of R&D investments on CEO compensation. In this context, (Shen et al., 2013) focus on R&D investments in corporate innovation and investigate whether the sensitivity of the CEO long-term compensation affects the propensity for, and especially the efficiency of, R&D investment. They use a sample of 843 cases in which firms increased their R&D investments by an economically significant amount during 1995–2006. The results prove that firms with higher sensitivity of CEO long-term compensation value to stock volatility (i.e., vega) are more likely to have large increases in R&D investments. They further suggest that shareholders should frequently monitor the level of CEO risk incentives and decrease CEO compensation vega that is excessively high to prevent the potential overinvestment problem associated with excessively high vega. Likewise, (Lin et al., 2011) examine the roles of managerial incentives and CEO characteristics in a firm's innovation activities, as measured by R&D investments. The data they use includes 1088 manufacturing firms in 18 Chinese cities. They highlight that weak manger incentive schemes and restricted decision-making power plague China's firms with agency problems. This is what motivated the researchers to explore the impact of these factors on corporate innovation activities in China. They find that firms that provide CEOs with significant shareholding and performance-based compensations are more likely to invest in R&D and tend to invest more in R&D. These findings demonstrate that CEOs with high compensations would have stronger incentives to engage in long R&D investments, which are tangible in cost but intangible in benefits.

Additional evidence is constructed by (González-Uribe, 2017) who study the relationship between the long-term incentive and innovation quality as measured by, respectively, CEO contract horizon and granted patents citations. Using a sample of 1,262 firms headed by 1,346 CEOs during the 1993–2008 period, they find that firms with longer CEO horizons produce more important patents. In a related paper, (Nguyen, 2018) uses a sample of 1,900 firms between 1992 and 2006 to find out whether the CEO's long-term incentive plan LTIP (restricted stock and unvested option) is higher in firms that work in industries and product markets where innovations are more urgent. Building on (Manso, 2011), he further investigates whether, in specific, unvested options-based incentives spur corporate innovation. Regarding the first question, the author documents that long-term incentives are significantly higher among firms in innovative industries as well as among firms facing strong product market competition. In regard to the second question, the results from the baseline specification indicate that the higher level of CEO long-term incentives is associated with not only a higher number of patents but also a higher impact of patents generated in the subsequent year.

Another paper that examines the innovative-related incentives of CEOs is (Mazouz et al., 2019) who study whether takeover protection affects the ability of CEOs long-term incentives (equity-based compensation) to spur innovation. When both incentives and protection are considered, the latter may hinder the ability of the former to motivate innovation. Using a large sample of US firms over the period 1996–2014, they find that long-term incentives have a stronger influence on innovation when combined with takeover threats. That is because risk-averse CEOs tend not to engage in innovation when a takeover threat is imminent due to the high level of uncertainty about the expected payoff. Therefore, without appropriate protection, equity-based compensation may not provide CEOs with sufficient incentives to engage in high-risk investment. Finally, they suggest that the discipline of takeover markets is crucial for CEOs who receive high long-term incentives to perform as intended.

Given that innovation is a long-term, unpredictable, idiosyncratic, and risky process, it requires effort not only from a firm’s CEO but also from its non-CEO executives. Therefore, several studies have investigated how the incentives of non-CEO executives impact firms' innovative activities. For instance, (Chang et al, 2015) examine the effect of non-CEO executive stock option on corporate innovation. The findings indicate a positive effect of non-executive stock options on patents and citations. They also argue that the main channel through which these compensations encourage innovation is their positive effect on the risk-taking incentive (i.e., vega) rather than on the performance-based incentive (i.e., delta). Furthermore, they argue that the main way in which these compensations promote innovation is their positive influence on the risk-taking incentive (i.e., vega) rather than on the performance-based incentive (i.e., delta).

Upon delving deeper into the long-term compensation of CEOs, other streams of research reached opposing conclusions. For example, (Biggerstaff et al., 2019) use the implementation of FAS 123R as a quasi-natural experiment to investigate the relationship between option-based compensation and corporate innovation. Although they find a decline in CEO's long-term compensation, such a decline does not impact the level of patent applications around FAS 123R. These findings suggest that long-term incentives (i.e., option-based compensation) do not drive corporate innovation. In a similar spirit, (Koo et al., 2019) use a sample of 3281 granted patents over the period 1996–2005 to investigate whether lucky grants to CEOs impact firm innovations. Building on (Kogan et al., 2017), they also use patent citations as a proxy variable for innovation. The 'lucky grant' is a term used by (Bebchuk et al., 2010) to describe how CEOs leverage the opportunistic timing of stock option grants to increase their compensation—or stock options issued to CEOs when the price is low. They find that if CEOs receive lucky grants in the previous year, firm innovation decreases. Finally, the authors suggest that lucky grants may reduce the incentive for CEOs to engage in risky projects and negatively affect firm innovation.

Overall, the evidence on how long-term incentives negatively impact innovative firm activities remains surprisingly scant in the corporate finance literature. We conjecture that our main independent variable (NGPs) might have an effect on the CEO's long-term incentives, especially stock-based compensation, because it is more sensitive to risk (failures in our study) than other long-term incentive types, such as option-based compensation. If so, our result will then be consistent with the literature that argues that long-term incentives hinder corporate innovation. In sum, theory suggests that CEO compensation contracts suited for innovation should include two key features: they should provide a long-term commitment to the CEOs, and they should offer protection from failure. The above discussions mostly reveal a positive association between a CEO's long-term incentives and successful innovation. To date, however, relatively less attention has been devoted to understanding how innovation failures could impact the CEO's subsequent long-term incentives. To fill this void, we use a sample of 2,003 cases of NGPs from the USPTO for 256 US firms over the period 2001–2020 to investigate the correlation between failure in innovation and the CEO's subsequent long-term incentives (i.e., options, stock, and LTIP).

2.3.3 Firm Performance:

2.3.3.1 Prior research linking firm performance to innovation activities.

There is consensus that firms' ability to promote and exploit their innovative strengths is crucial for performance (Nemlioglu et al., 2017; Bloom et al., 2002; Day et al., 1994). Yet, there is no wide consensus in the relevant literature about the impact of innovation activity on firm performance, which can be indicated by results in the estimation of this relationship. We list just a few examples that make use of innovation and show a positive effect on firm performance (e.g., Farre-Mensa et al., 2020; Zhang et al., 2019; Rodríguez et al., 2016; Atanassov, 2013; Pandit et al., 2011; Ehie et al., 2010; Hull et al., 2008; Mann et al., 2007; Cho et al., 2005; Bloom et al., 2002; Ernst et al., 2001; Murphy et al., 1996; Morbey, 1988). For instance, (Del Monte et al., 2003) examine the relation between innovation and firm performance by using a firm-year panel data set between 1989 and 1997 on a sample of 500 firms. They report a positive relationship between the variable measuring innovation activity (R&D) and the firm's performance. In their pioneering empirical study of patents and firm performance, (Bloom et al., 2002) look at the effect of patents granted on firm performance and prove that patents have a strong and significant impact on firm-level productivity. (Zaheer et al., 2005) investigate how innovative capabilities—both those of focal firms and those they access through their networks—impact the performance of Canadian firms. The results reveal that the firm's innovative capabilities and its network both foster firm performance. Likewise, (Mann et al., 2007) construct further evidence and find significant and positive correlations between patenting and the firm's performance.

Based on the analysis of 8,313 cases for the 5-year period, (Eberhart et al., 2004) point out that firm's R&D increases are profitable investments but that the market is somehow slow to realize the extent of this profit. The authors also provide strong evidence that when a firm increases its innovation activities through R&D, this has a positive impact on the firm's long-term performance. In one of the highly cited papers on innovation activities, (Gunday et al., 2011) use a sample of 184 manufacturing Turkish firms to explore innovations and their effects on firm performance by focusing on various aspects of firm performance, such as innovative and financial performance, including ROA and ROI. The results demonstrate the positive effects of innovations on firm performance. Motivated by two empirical studies that reveal evidence for the effect of corporate innovation on firm financial performance, (Hull et al., 2008) examine whether innovation enhances firm future performance by using a sample of 69 firms between 1998 and 2001. They first develop a more complex model of the innovation-financial performance relationship and measure the firm's financial performance by ROA. Using this measure, they find that innovation has a positive impact on the firm's performance. Finally, they suggest that other robust models, which have received ambiguous empirical support, should incorporate innovation as a moderator.

Likewise, (Hirshleifer et al., 2018) examine the relationship between a firm's innovative originality and its future profitability, as measured by ROA and ROE. They proxy a firm's innovative originality by the USPTO granted patents over the period of 1981-2006. The findings show a strong positive association between the firms' granted patents and their future profitability for both measures, ROA and ROE. Additional evidence is constructed by (Maresch et al., 2016) who investigate whether patenting has an impact on the subsequent performance of patenting firms. The results indicate that the number of patents granted contributes positively to the firm's performance. In a similar spirit, (Nemlioglu et al., 2017) examine whether managerial practices explain the innovation and firm performance relationship by using firm-level data over the period of 1992–2014. They find that firms with better managerial practices and innovative activities benefit favorably. Specifically, following the crisis, firms with high R&D activity experienced a positive effect of intangibles on performance because total assets became more important in improving firm performance than intangibles that did not reflect their true valuation in the pre-crisis period. In one of the earlier studies on corporate innovation (Scherer, 1965), use a firm-year panel data set between 1955 and 1960 on a sample of 365 firms and find a positive relationship between patents granted and performance.

Moreover, using a sample of Japanese manufacturing firms during the period of 2001–2010, (Lee et al., 2015) examine the effect of green R&D investment for eco-innovation on financial performance. Eco-innovation is defined as the efforts of a firm to reduce negative environmental impacts. They point out that, as a part of a sustainable development strategy, eco-innovation can be viewed as the cultivation of distinctive, long-term focused green capabilities, supported by top management, eco technologies, and R&D investment. The results exhibit that green innovation has a positive impact on performance at the firm level. Likewise, in their empirical study on green innovation and firm performance, (Tang et al., 2018) use a sample of 188 manufacturing firms in

China to examine the relationship between green innovation and firm performance. The findings confirm that green process innovation and green product innovation both significantly and positively boost firm performance. (Zhang et al., 2019) corroborate these findings by investigating data from the China Stock Market and Accounting Research Database (CSMAR) over the period of 2000–2010. Specifically, they investigate whether green patenting influences a firm's subsequent performance. The findings prove a positive and significant relationship between green patenting and firm performance. Such positive relationship is observed mainly after 2006, when the government started formally supporting the green industry through legislation.

In addition, other studies have attempted to show the reverse relationship between the firm's innovation and its performance. However, such a link appears to only work in the service industry. For example, using a longitudinal firm-level dataset of 735 service firms for the period 1993–1998, (Cainelli et al., 2006) investigate the two-way relationship between innovation and performance in services. They emphasize that the relationship between innovation and performance should be conceptualized as being two-way as well as potentially cumulative. They identify three different mechanisms to analyze the complex nature of this relationship: innovation as a determinant of economic performance; economic performance as a determinant of innovation activity; and a two-way dynamic link between innovation and economic performance. In line with their empirical agenda, they label the latter mechanism "evolutionary." The findings indicate that firms that were involved in innovation activities in the past tend to perform better in the future, and firms that performed well in the past tend to carry out more innovative activities.

Conversely, the literature indicates a somehow negative relationship between corporate innovation and firm performance. For example, (Artz et al., 2010) point out that firms' ability to generate a continuous stream of innovations may be more important than ever in allowing a firm to improve profitability and maintain competitive advantage. Their research explores several issues that are central to an examination of firms' innovation activities, including the effects of R&D and patents on firm performance, as measured by ROA. Drawing from a sample of 272 firms between 1986 and 2004, they show a negative relationship between granted patents and ROA. Although this finding is intriguing, it has some support in the literature (e.g., Arora et al., 2008; Griliches et al., 1991) suggesting that many patents were created only for strategic reasons unrelated to the firm's own innovation efforts. The authors further suggest that such patents may enhance firm performance indirectly via their positive impact on product introductions. In fact, such benefits are unexpected, as not all patents are actually converted into products. In other words, firms are more likely to invest in patents that may turn out to be commercialized than those with limited success.

Using a firm-year panel data set between 1973 and 1980 on a sample of 340 firms, (Griliches et al., 1991) explore the relationship between innovation activities and firm performance, particularly focusing on how patents, as a firm's innovative output measure, can enhance the firm's performance. The authors highlight that while patents correlate positively with the firm's R&D, they are an imperfect indicator of innovation and show no positive impact on the firm's performance. Likewise, (Bloom et al., 2013) use firm-year panel data from US firms between 1981–2001 to examine the impact of innovation (as measured by R&D) on performance through spillovers. They develop a general framework showing that spillovers have testable implications for a range of firms' performance indicators. Because the predictions differ across performance indicators, they provide identification for spillover effects. The results reveal that firm performance is affected by two countervailing innovation spillovers: the positive impacts from technology spillovers and the negative business-stealing impacts from R&D by product market competitors.

In a related study, (Aghion et al., 2013) examine a range of innovation and performance indicators such as granted patents, R&D, market value, and profitability by using data on US firms over the period of 1980-2001. They obtain patents data from the NBER data archive match with USPTO, which contains detailed information on almost three million US patents granted between 1963-1999. The results show that when institutional investment is low in innovation, stock performance will decline. That is due to the fact that positive stock performance is associated with increased innovation. In addition, (Kline et al., 2019) use a new linkage of US patent applications to US business and worker tax records between 2001-2011. The empirical strategy of the study focuses on contrasting firms that receive an initial allowance to other firms that applied for a patent but received an initial rejection. Building on (Kogan et al., 2017) analysis, (Kline et al., 2019) set up a model to extrapolate their estimates to non publicly traded companies and to NGP applications. Their results, among others, indicate that patents with low predicted value have economically small and statistically insignificant effects on firm performance and worker compensation.

In addition, others point out that the association between firm innovation activities and performance is dependent on several local and environmental factors. In a study of innovation strategy (e.g., Li et al., 2001), use a firm-year data set on a sample of 300 new technology firms in China to investigate the impact of product innovation strategy on the performance of technology firms. All sampled firms were eight years old or younger, which is consistent with the accepted definition of a new venture in the literature. The findings demonstrate that the innovation-performance link is contingent on some environmental factors, including institutional support. In other words, without government institutional support, the success of the firm's innovation strategy declines, which, in turn, affects firm performance. Contrary to empirical findings in the West, (e.g., Li et al., 2001) suggest that relationship-based strategies do not enhance the effectiveness of a new technology firm's innovation strategy and thus hinder the firm's performance.

While it appears to be well established that firms' innovation success, in the form of granted patents, tends, mostly, to positively impact firm performance, the relationship between failure to innovate, in the form of NGPs, and firm performance, empirically, is still ambiguous. This gap in the patenting literature is particularly notable. Therefore, the current study addresses this shortcoming. The following sections expand upon the above literature and propose several hypotheses to be examined in this study.

2.4. Hypotheses Development

As demonstrated in the introduction section, failures in a firm innovation, measured by NGPs, might reduce the CEO's compensation package and, thus, the firm's performance in the short-term. In the following sections, we first introduce the dependent variable with our key independent variable—NGPs—for each hypothesis. We then propose our hypotheses in light of the relevant arguments in the literature.

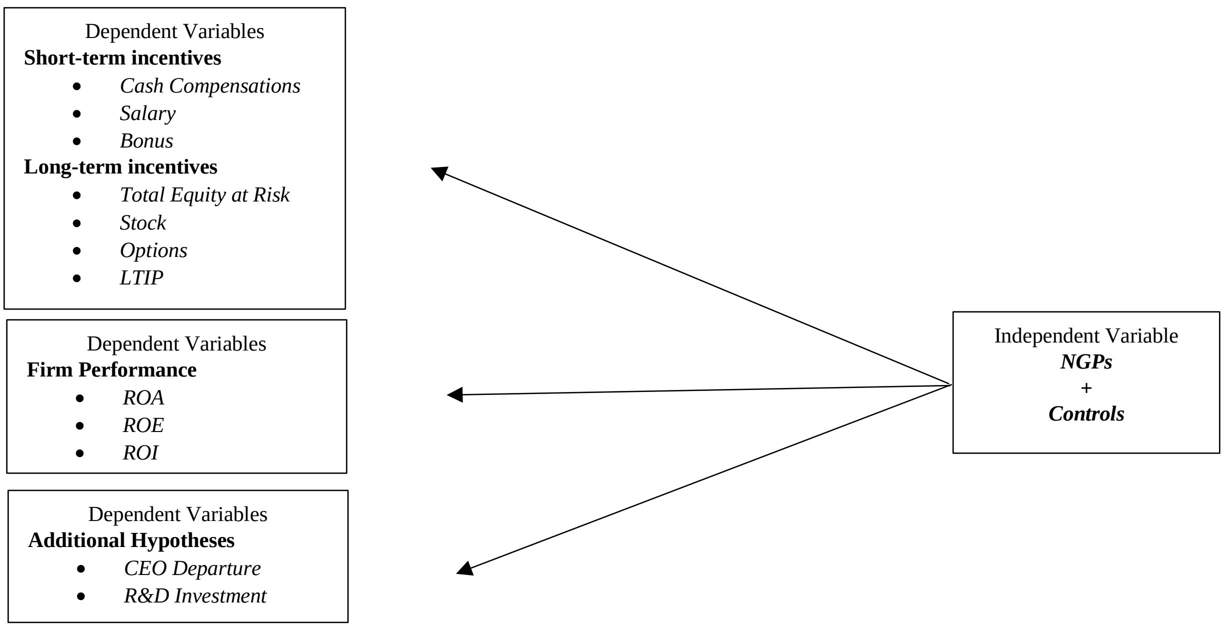

Fig. 1. The Impact of the Key Independent Variable on Three Groups of Dependent Variables[4].

2.4.1 CEOs Compensation Packages and Firm's Failure in Innovation

CEO compensation is directly under a firm's control and, hence, is critical in directing CEO behavior, particularly with regards to innovation activity. In fact, the CEO's compensation package is most closely linked with performance, and the future compensation of a CEO is also tied to this relationship. Prior studies have focused on the effects of successful innovation on CEO compensation while ignoring the potential impacts of failures in innovation. This omission is critical if differences in the results of innovation help to determine the future CEO's compensation package. A long tradition of empirical studies has established only one side of this fact, the effects of success in innovation. In the current study, we are more interested in failures than success in innovation, especially at the "firm level".

Based on the structure of the BoardEx database, the compensation package of a CEO is composed of two main parts: First, short-term incentives (STIs) are the total cash compensations—the sum of salary and bonus. Second, the total equity at risk—the sum of the stocks, options, and the long-term incentive payment (LTIP)—indicates long-term incentives (LTIs). We focus on these two main measures of compensation and each of their components separately. We further compute other dependent variables, including the total stock and option (the sum of stock and options), long-and short-term incentives (the sum of bonus and LTIP), and CEO total remunerations (the sum of cash compensation and equity at risk). The Appendix B-Level 1 and 2 includes all of the hypotheses, models, and regression results for the last three variables that we calculated.

2.4.1.1 CEO Short-Term Incentives and Non-Granted Patents NGPs

In this section, we discuss the potential effects of NGPs on the subsequent changes of the CEO's cash compensation. We will also discuss how NGPs may directly affect changes in the other components of the CEO's cash compensation. In general, CEOs consider the advantages and disadvantages of innovative activity. Hence, they involve in such activity only when they expect the personal profits will be mora than the losses. Their expected losses of innovation include failure and its potential negative impact on their future short-term compensations and, thus, the CEO total remuneration. The potential negative impact of innovation failure on the CEO short-term compensations is due to the fact that, according to (Cheng, 2004), CEOs consider R&D investment, which is the key factor to firm's innovation, as less favorable compared to other investments, in terms of the influence of investments on short-term compensations. As a result, R&D investment may not fully reflect the "current benefits" of CEO's cash compensations. Therefore, CEOs concerned with a decline in their cash compensations may reduce the firm's R&D investment, which is entirely under their control, to increase investments with benefits fully reflected in their current cash compensations. Moreover, CEOs may prefer not to engage in risky and potentially disruptive R&D projects that have a negative short-term effect on their compensation (Faleye et al., 2014; Coles et al., 2006). This preference from CEOs is seemingly consistent with empirical results that R&D investment may not necessarily represent its potential outcome (Atanassov, 2013). In a similar vein, (Jensen, 1993) suggests that increased R&D can simply reflect managerial spending on domestic and/or more ordinary projects rather than significant investments in corporate innovation. Because risky R&D investments can negatively impact CEOs short-term compensations, CEOs with this preference are likely to less invest in R&D in order to avoid any potential reduction in their "future benefits". However, this could ultimately lead to failures in firms' innovation, as success innovation requires a high R&D investment.

In addition, salary is an important portion of CEO's cash compensation and represents the fixed and relatively riskless portion of CEO's total remuneration (Cohen et al., 2013; Healy, 1985). According to (Murphy, 1999), the CEO's compensation often includes a guaranteed minimum increase in base salary over a five-year period. Similarly, the annual bonus is a significant component of a CEO's compensation (Holthausen et al., 1995). In fact, firms reward their CEOs with annual bonuses to maintain their focus on financial outcomes under extreme time pressures. R&D-intensive firms, for example, are more likely than others to use higher bonus-to-base pay ratios to direct CEOs attention toward the innovation outcome (Makri et al., 2006). Therefore, from a BoDs perspective, using innovation outcomes to prompt bonuses for a CEO may be a better option in the short term than other monitoring factors, since bonuses are less ambiguous and more controllable by BoDs. Following the method of previous studies (Gormley et al., 2013; Manso, 2011; Brick et al., 2006; Guay, 1999) we focus on changes in cash compensation variable and its components (i.e., salary and bonus) to examine their potential negative correlations with NGPs. While these prior studies aggregate salary and bonus into one category, we test salary and bonus separately.

In sum, prior studies have recognized the importance of successful innovation and its impact on determining the CEO's short-term incentives, but they have neglected the potential effects of failure in innovation. We have collected data on firm-level of 2,003 cases of unsuccessful patents for 256 firms, which makes it possible to examine the potential impact of firm's failure in innovation on the CEO's compensation packages. More precise, our hypotheses of compensations are based on the following argument: if the CEO's compensation package is determined based on the expected profits of the firm's innovation success (i.e., outcome-based compensation), where firms are active in innovative activity, then failures in innovation could have a negative effect on the CEO's short-term compensation. In other words, a negative correlation between NGPs and changes in CEO's cash compensation may result in a reduction in all other components of short-term incentives, which, in turn, may discourage CEO to innovate. Therefore, the above argument leads to the first set of hypotheses:

Hypothesis 1 (H1): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the change that occurred in the CEO's total cash compensation at time (t+1).*

Hypothesis 2 (H2): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the change that occurred in the CEO's salary at time (t+1).*

Hypothesis 3 (H3): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the change that occurred in the CEO's bonus at time (t+1).*

2.4.1.2 CEO Long-Term Incentives and Non-Granted Patents NGPs

In this section, we turn our attention to address the CEO's long-term incentives (i.e., total equity at risk) based on how BoardEx, the database we use, has structured them. In specific, we follow the method of (Borisova et al., 2018) to examine the association between changes in the CEO's total equity at risk and NGPs. For the purpose of this study, we test each component of the total equity at risk separately (i.e., stock, options, and LTIP). We expect that each incentive component, which is a portion of the CEO's total remuneration, will show a negative correlation with NGPs, specifically, stock compensation. According to (Core et al., 2003) and others, CEO's incentives come almost entirely from changes in the CEO's stocks and options. From a CEO perspective, however, obtaining these incentives requires a long-term contract. (Manso, 2011; Holmstrom, 1989) suggests that to encourage CEOs to invest in the exploration of new ideas rather than exploiting existing ones, incentive contracts should assure a long-term commitment (that is a three-to five-year contract) and protection from failure. Investing in R&D for innovation, for example, does not necessarily imply that CEOs have invested in a novel idea or that the investment will result in a successful innovation. Therefore, as innovation is long-term, unpredictable, idiosyncratic, and involves a high probability of failure, the CEOs may pass up innovative ideas for less risky projects to maximize their own benefits.

Nevertheless, (Manson, 2011) further argue that incentive contracts that encourage CEOs to innovate should have a high tolerance for failure. That is because if a CEO is penalized for innovation failure, he/she faces consequences that extend beyond the short-term incentives to include the long-term incentives. They might also lose motivation to engage in future innovation endeavors. Building on Manso, we intend to explore this relationship between firms' innovation failures and the changes in their CEOs' long-term incentives. Several studies (e.g., Mazouz et al., 2019; Shen et al., 2018; Laux, 2015; Gopalan et al., 2014; Yanadori et al., 2006), however, have noted the positive relationship between firms success in innovation (patents granted and citations) and the long-term incentive-based compensation. For instance, (Lerner et al., 2007) indicate that more long-term incentives are associated with more patent awards and more heavily cited patents. (Francis et al., 2010) show a positive relationship between the CEO long-term incentives and firm innovative activities (R&D, patents granted, etc.). In a similar spirit, (Manso, 2011) argues that the use of stock-based compensation provides CEOs with the necessary incentives to invest in innovation. (Chang et al, 2015) corroborate these findings from empirical study by examining the relation between option incentives, as a crucial component of long-term compensation, and patents granted. They find that patents activity drives by option-based compensation.

However, we argue that this only applies to a CEO who receives full protection from failures. In other words, a CEO with a long-term incentive-based compensation and a high level of protection would likely be less concerned with being fired—and, hence, less concerned about failures. In this context, (Baranchuk et al, 2014; Ederer et al., 2013) examine whether the combination of tolerance for failure and rewards for long-term success prompts the CEO to adopt more innovative paths for the firm. They suggest that firms wishing to pursue innovation and obtain patents should offer their CEOs more incentive compensation and more protection from early termination. The idea that "tolerance for failure" boosts firm innovation activities is also supported by the evidence in (Tian et al., 2014). Taken together, these outcomes seem to suggest that such combination enhances CEOs to exert more effort for firm innovation over the long run. Missing from our study, though, is any consideration that these characteristics of the long-term incentives may play complementary roles in motivating CEOs to pursue innovative activities. This is because complementarity is critical when it comes to the CEO's long-term incentives.

In short, in the previous section (3.1.1), we predict that a negative correlation between NGPs and changes in the CEO's cash compensation may result in a reduction in all other components of short-term incentives. That is based on the argument: if the CEO's compensation package is determined based on the expected profits of the firm's innovation success (i.e., outcome-based compensation), where firms are active in innovative activity, then failures in innovation could have a negative effect on the CEO's short-term compensation. Consistent with this argument, CEOs may receive lower equity-based compensation in the year following NGPs than the year before. To clarify, a negative correlation between NGPs and changes in the total equity at risk may lead to a decrease in all other components of long-term incentives (i.e., stock, options, and LTIP). The same arguments also hold for changes in CEO total remuneration, total stocks and options, and short-and-long-term incentives (which we do not present here for brevity). Based on our testable argument and relevant literature, we can hypothesize:

Hypothesis 4 (H4): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the CEO's total equity at risk change that occurred at time (t+1).*

Hypothesis 5 (H5): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the CEO's stock-based compensation change that occurred at time (t+1).*

Hypothesis 6 (H6): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the CEO's option-based compensation change that occurred at time (t+1).*

Hypothesis 7 (H7): *The firm's failure to innovate in the form of NGPs at time (t) is negatively related to the CEO's long-term incentive plan LTIP change that occurred at time (t+1).*

2.4.2 Firm Performance and Failures in Innovation

In the second main part of our study, we argue that the firm's failure to innovate could impact the firm's performance in the subsequent year, measured by return on assets ROA, and, for robustness, return on equities ROE, and return on investments ROI. These performance measures seem appropriate as they represent the profitability of the firm with respect to the total set of assets, equities, and investments under its control. Consistent with prior empirical research (Cao et al., 2019; Gunday et al., 2011), we further apply the return on sales (ROS) for three basic reasons. First, ROS determines the decline in a firm's sales in the future (Tangen, S. 2003). Second, CEOs frequently consider sales and their return as one of the key factors in their decisions (Rodríguez et al., 2016). Third, ROS is less sensitive to accounting methods than other performance measures (Artz et al., 2010). The hypothesis of ROS is not reported here for brevity (Appendix B—Levels 1 and 2 presents the hypothesis, model, and result of ROS).

2.4.2.1 ROA, ROE, ROI Measures and Non-Granted Patents NGPs

In the literature on innovation activity and firm performance, a major assumption is that innovation enhances firm performance. However, we identify two streams in the related literature. The first stream is from studies reporting a positive relationship between innovation activities and firm performance (e.g., Zhang et al., 2019; Hirshleifer et al., 2013; Pandit et al., 2011; Hull et al., 2008; Bloom et al., 2002; Murphy et al., 1996). These studies use diverse proxies of innovation (R&D, patents granted and citations) and firm's performance (ROA, ROE, etc.). For instance, (Eberhart et al., 2004, 2008) test a sample of 8,313 cases for the 5-year period between 1951 and 2001 and use the ROE to measure the firm's performance. They find evidence that when a firm increases innovation activities through their R&D, this has a positive impact on the firm's performance in the long run. Using a firm-year panel data set between 1984 and 1992 on a sample of 50 firms, (Ernst, 2001) examine the relationship between patents and subsequent changes in firm performance. He reports a positive correlation between patent applications and subsequent changes in performance variables at the firm level.

In an empirical study, (Cho et al., 2005) apply structural equation modeling techniques to explore the relationship between innovation and performance at the firm level. They use three performance measures: ROA, ROE, and ROI. The results of their structural equation demonstrate that innovation has a positive impact on profitability, as it influences quality, which, in turn, influences profitability. Besides other investigations, (Aghion et al., 2013) investigate how innovation impacts firm performance, particularly focusing on the role of financial constraints and competition. ROA is one of the measures used to measure firm performance and they show that innovation can significantly enhance ROA, especially in competitive markets with less stringent financial constraints. In a related paper (Hirshleifer et al., 2013), examine the relationship between innovation efficiency and the subsequent performance of firms, as measured by ROA and ROE. Innovative efficiency is defined as a firm's ability to generate granted patents (innovative output) and citations per dollar of R&D investment (innovative input). The results show that firms that are more efficient in innovation on average have superior future performance.

Another stream is from studies showing a negative (e.g., Artz, 2010) or insignificant (e.g., Macdonald, 2004) association between innovation activities and firm performance, while others prove that at different levels (e.g., Kancs et al., 2016) and with spillovers (Bloom et al., 2013). For example, (Griliches et al., 1991) use a time series-cross section of US manufacturing firms (340 firms between 1973 and 1980), to study the impact of innovation activities on firm performance. They find that no relationship exists at all between innovation and performance, as measured by ROE. (Li et al., 2001) investigate the influence of innovation strategy on the performance of new technology. They demonstrate that innovation, as measured by R&D, has an insignificant impact on a firm's performance, as measured by ROA and ROI. In addition, a firm may only present a strong correlation between its innovation activity and various performance measures after reaching a certain level of investment or knowledge. From this perspective, (Kancs et al., 2016) examine the relationship between the firm's R&D investment and performance by explicitly modeling non-linearities in the R&D-performance relationship and more especially on productivity. They suggest that the influence of the firm's R&D investment on its productivity varies depending on the firm's R&D level. In particular, there is a highly non-linear relationship between the firm's R&D and its productivity that only materializes after a specific critical mass of knowledge accumulates. According to this result, firms are unable to apply new knowledge effectively without sufficient existing knowledge, which leads to less benefit from their R&D investment. These findings indicate a negative relationship between corporate innovation and firm performance, shedding new light on this relationship. This is due to the higher probability of intangible investment failure compared to tangible investments. Furthermore, managers are risk-averse and favor short-term earnings; they may avoid R&D investment, which is, although completely under their control, long-term, unpredictable, and idiosyncratic.

We follow (Hirshleifer et al., 2013; Hull et al., 2008; Cho et al., 2005) to measure firm’s performance in our dataset using three separate measures: ROA, ROE, and ROI. These measures together appear appropriate as they reflect the profitability of a firm innovation with respect to the total equities, assets, and investments under its control. Because most of these measures tend to be highly correlated with one another (Cho et al., 2005), we use their ratios as indicators of a firm’s overall profitability performance. However, ROA remains our key measure of performance and, as a robustness check, ROE and ROI. Researchers have used ROA to measure performance across various fields, including finance (Hirshleifer et al., 2013), economics (Aghion et al., 2013), and management (Zajac et al., 2000). We apply ROA at time $t+1$, which we define as (net income$_{t+1}$/total assets$_{t+1}$). It is also specifically appropriate for our study because our innovation failure measure captures the subsequent changes in a firm return. With regards to ROI, theoretically, it is expected to be generated over several subsequent periods, starting from $t + 1$, since an investment is often made when a firm's expected net present value (NPV) is positive at year *t*. Therefore, we expect an insignificant correlation between NGPs, which occurred in the year *t*, and ROI in the subsequent year (Section 4.3 and 5.2.2 provide more details).

Nevertheless, insights into the relationship between firm innovation activities and firm performance are still contradictory due to the multi-disciplinary nature of this relationship. Adding to this, innovation through R&D investments involves a very high risk of failure. A large part of R&D may have no return at all, and it is not clear at the outset whether the innovative activity has a positive impact on firm performance. That is due to the fact that R&D investments have some characteristics that make such activities especially uncertain. Furthermore, R&D, by definition, is concerned with pre-unknown results, and hence the risk of failure is higher than in the case of ordinary investment processes (see, e.g., Hall, 2002). None of the above studies, however, attempted to investigate whether failure to innovate matters to a firm's performance. In summary, our hypotheses of firm performance are based on the following argument: if we might expect a positive impact of success innovation on firm performance—as generally recognized in the literature, in the short run, the firm's failure to innovate could determine a significant negative effect on performance measures (i.e., ROA and ROE). Thus, consistent with the theory and outcomes discussed above, we investigate the potential negative correlation between the firm's innovation failures and its performance subsequent changes. All this leads to formulate our second set of hypotheses:

Hypothesis 8 (H8): *The firm's number of NGPs at time (t) is negatively correlated to the change that occurred in the firm's performance, represented by return on assets ROA, at time (t+1)*

Hypothesis 9 (H9): *The firm's number of NGPs at time (t) is negatively correlated to the change that occurred in the firm's performance, represented by return on equities ROE, at time (t+1)*

Hypothesis 10 (H10): *The firm's number of NGPs at time (t) is negatively correlated to the change that occurred in the firm's performance, represented by return on investments ROI, at time (t+1)*

2.4.3 CEO Departure and Firm's Failure in Innovation:

Our data indicates that almost 24% of all firms' CEOs (i.e., 95 out of 401) departed after the year of NGPs, while 76% (i.e., 306 out of 401) were renewed their positions. Such observation was interesting and motivated us to examine whether the CEO's departure is correlated with the firm's failure in innovation. We also dug into this observation further by looking at the reasons for the CEOs departures. Since the databases we use do not include all the relevant details on CEOs' departures, we manually collected the missing information using annual reports, proxy statements, and SEC Form 10-K for US companies, as well as corporate websites. The logic behind this collection is to identify a direct link, if any, between the effect of NGPs and the reasons of a CEO's departure so that we can suggest some directions for future research and theory building. We observe that *resignation* was the main reason for 70% of CEOs who left their positions in the year after NGPs (i.e., 67/95); 27% went for retirement (i.e., 26/95); and 2 died.

Moreover, based on our data set, three additional observations are worth mentioning regarding to the above two main reasons for the CEOs' departures. First, in the event of the CEO's retirement, mainly due to aging or stumbling, the successor typically offered a long-term contract—that is, a three-year contract, and the retried CEO is expected to notify the board of directors (BoDs) of his decision to retire a year or two years earlier. Previous studies (e.g., Dechow et al., 1991) show a negative relationship between CEOs close to retirement and firm's innovation activity, measured by R&D expenditures. (Xu et al., 2014) proves this finding by examine the impact of CEO retirement on corporate innovation, measured by patents and citations. They show that firms obtain a few granted patents at the end of CEO tenures, and these patents obtain fewer subsequent citations. Moreover, the newly hired CEO to “succeed the retired CEO”, in most cases, is from outside the firm. Such replacement often does not have a significant impact on the firm’s innovation activity in the long run, as the firm has sufficient time to appoint the most qualified successor before the CEO departs (Dechow et al., 1991). Under this process, decision-making authority is progressively passed to the successor in the years before the CEO changes. The retired CEO, then, has less power to alter the firm's innovation strategy since the succeeding CEO shares many of the decision-making rights and has motives to control the retired CEO's decisions.

Second, in the event of the CEO's resignation, the BoDs typically appoints an interim CEO with a short-term contract—that is, a one-year contract or less. That interim successor CEO is most likely an internal member of the BoDs, and their tenure as CEO might be extended if they show good performance. This is especially true because, from an overall perspective, hiring an external CEO is more costly than appointing an internal CEO who is also a member of the BoDs, is expected to be aware of the firm's innovation strategy, and strives to avoid prior failures. In an empirical study, (Balsmeier et al., 2015) compare the innovative behavior of CEOs hired from inside and outside the firm. They report that inside CEOs are associated with significant higher innovative activity compared with their outside hired colleagues. (Cummings et al., 2018) also asserted that a firm's innovation decays under external CEOs relative to that of internal CEOs. Conversely, research by (Wong et al., 2018) shows that, because of their diverse backgrounds and networks, external CEOs in family firms have more innovative value than the internal. (Atallah et al., 2021) show that firms have a higher innovative activity with outside CEOs. It is somewhat surprising that we could not find many studies on the impact of external CEOs on firm's innovation. Nevertheless, in most cases, our data indicates that the BoDs hire new external CEOs on a long-term contract—that is, a three-year contract, rather than internal CEOs. This observation upheld the result of (Murphy et al., 2007), who find that more than one third of all CEOs are hired from outside the firm in the US.

Third, our data also indicates that there are some cases where firms hire CEOs with long-term contracts to replace their interim internal CEOs, even when they show good firm performance during their tenure. In fact, these interim internal CEOs often replace the CEOs with poor performance and their contracts basically on short-term. Yet, with considering the success of the interim CEOs with short tenure, such replacement could impact firm’s innovation activity. Prior work (e.g., Lee et al., 2020; Ahuja et al., 2008;) document that previous CEOs are better managers of innovation than new CEOs and suggest that such a CEO replacement may have significant negative ramifications on firms’ innovation performance. In the same vein, (e.g., Wu et al., 2005) examine the relationship between a CEO's time in office and firm inventive activities. They find that shorter tenured CEOs are more innovative than longer tenured CEOs. In contrast, (González-Uribe, 2017; Barker et al., 2002) report that longer tenured CEOs increase firm's innovation. (Cho et al., 2017) use data from 681 US firms and assert that CEOs with short tenures tend to produce fewer breakthrough innovations. In their empirical study, (Zona et al., 2016) examine the impact of CEOs tenures in different stages on firm's innovation and demonstrate that CEOs at the later stage decrease firm's innovation while CEOs at the early stage increase firm's innovation. Overall, two main debates are raised when comparing the innovative firm activities of internal CEOs with short-term contracts versus external CEOs with long-term contracts. From the BoDs point of view, the external CEOs with three-year contracts are more likely to bring new vital ideas and alter firm innovation strategy due to their presumably broader outside experiences. In contrast to internal CEOs, external CEOs might not have the critical firm-specific knowledge and skills required to manage the firm's innovation process, which could lead to a decrease in the firm's innovative activities. These arguments suggest there are complex trade-offs in selecting a CEO successor, as both have support in the literature. Therefore, it is not surprising that the empirical results on the comparison between internal and external CEOs are inconsistent.

In spite of that, we observe that resignation was the primary reason for the CEOs who departed their positions in the post-NGPs year. We build interpretations, that is, as a way to account for our observations. Therefore, the word "*resignation*" can be interpreted as firing or pursuing other interests. We interpret resignation as firing due to poor performance—since we try to analyze the effects of failures in innovation. However, we argue that this interpretation is limited to the unsuccessful outcomes (resignation following the innovation failures). With this in mind, we also argue that when the CEO of a firm is reluctant to engage in innovation activity or invests less than what would otherwise be, this may result in a high probability of failure in innovation. Such failures, consequently, may eventually lead the firm to replace its CEO, especially those with a high number of NGPs. Therefore, ceteris paribus, we formulate the following testable hypothesis:

Hypothesis 11 (H11): *The firm's number of NGPs has a negative impact on the CEO departures in the following year.*

2.4.4 Innovative Input, Output, and Failure in Innovation:

The existing literature on the input (i.e., R&D investments) and output (i.e., granted patents) of innovation can be divided into two streams. First, several studies investigate the effect of innovative input or output separately on different aspects of firm operations. On the innovative input side, R&D investment is one of the major sources of innovation (Zona et al., 2016; Hall et al., 2010) that drives a firm's long-term viability (Yu et al., 2016) and provides a significant contribution to firm's innovation (Dodgson et al 2008). At the same time, the innovation success of firms is mainly based on the level of investing in R&D, hence forcing them to invest heavily in R&D. From this point of view, R&D is always expected to have a positive impact on firms operations as validated by many studies (e.g., Rodríguez et al., 2016; Ehie et al., 2010; Kerr et al., 2008; Del Monte et al., 2003). For example. (Morbey, 1988) indicates a strong correlation between firm's R&D and performance after analysis of 800 US firms. Similarity (Eberhart et al., 2004, 2008) report significantly positive operating performance following substantial R&D raises. These studies suggest that R&D drives innovative firms as it allows them to establish efficient processes, cultivates new knowledge, create new products, and obtain more patents, which in return encourage firms to increase their future investment in R&D. Others (e.g., Cruz et al., 2013; Zhang et al., 2010) reveal that R&D expenditure includes the employment cost of R&D employees, such as salary, bonuses, and other allowances. More precise, R&D spending improves, indirectly, such payments in the long run, especially when firms obtain patents (Mao et al., 2018; Lerner et al., 2007; Makri et al., 2006). Therefore, R&D investment has always been at the center of debate among scholars in an attempt to boost innovation efforts. On the innovative output side, patents granted are typically found to have a positive effect on firm operations as they represent successful innovation that is protected from the possibility of being misappropriation (e.g., Maresch et al., 2016; Helmers et al., 2011; Czarnitzki et al., 2010; Kafouros et al., 2008; Mann et al., 2007; Bloom et al., 2002) . For example, (Helmers et al., 2010) find evidence of the positive impact of patenting on firm performance. (Ernst et al., 2001) examines the relationship between patent applications and subsequent changes of firm performance. He finds that patent applications positively affect firm sales for the period of 1984 to 1992. In the same vein, (Pandit et al., 2011) indicate that patents granted are positively related to the firm's operating performance. In addition, (Zhang et al., 2019) report a positive and significant relationship between granted patents and firm performance.

Second, there is yet another important research stream in the innovation literature (e.g., Hegde et al., 2023; Brander et al., 2017; Hunt, 2006) examine the relationship between innovative input and innovative output, and suggest that both are expected to have a positive impact on one another. For instance, (Faleye et al., 2014) show that firms invest more in R&D receive more and higher quality patents. (Brander et al., 2017) indicate that patents strongly correlated with firm's R&D investments. Similarity (Farre-Mensa et al., 2020) show that successful applications (i.e., granted patents) foster firm's investment in R&D. Others investigate how firms expand their R&D abroad and whether this has an effect on the firms' number of patent. In fact, many firms internationalize their R&D activities to obtain new knowledge and capabilities available in other countries. In light of this, (Si et al., 2021; 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 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 firm's future investment in R&D. Accordingly, R&D appears to always have a positive effect on a firm's patents, since it is the most significant factor of innovation. However, not all innovations are eventually patented as no one can guarantee that a firm's investments in R&D will automatically result in successful innovation. This suggest that some of firm's R&D could turn to sunk costs. It is important to understand that the R&D experience of a firm is enriched by trial and error. Thus, R&D that generates failures in innovation should also have a positive impact on firm's patents because, in the long run, the firm will learn from its failures, gain more experience with the patent system, and become more innovative.

In short, it is typically that these two innovation activities are complementary—firms that conduct a lot of R&D tend to patent more. And ordinarily, reducing the investment in R&D will hinder more patents. Yet, if firms are active in their R&D, failures in obtaining patents may result in less R&D in the future. Overall, even though prior research reveals that R&D activities have a positive impact on firm's innovation success and vice versa, it is still ambiguous whether innovation failures (i.e., NGPs) affect firms to boost their R&D investment in the future. In other words, do firms strive to enrich their R&D experience, even when they face failures in innovative output, in order to become more familiar with the patent process and more creative in the future? We find no evidence in the relevant literature suggesting such link between failures in innovation at time *t* and R&D investments at time *t+1*. Moreover, we expect it to matter not just whether the firms attempt to innovate—and not just whether they generate more innovative output, but whether they are able to constantly invest in innovation while experiencing a decline in the number of granted patents. On this basis, firms engaging in R&D activities have to decide whether to pursue their R&D experience, depending on the availability of resources and capabilities, of course. This does not imply the elimination of R&D investments, due to firms' innovation failures, but rather "less R&D investments than would otherwise occur". These arguments lead us to propose the following hypothesis:

Hypothesis 12 (H12): *The firm's number of NGPs at time (t) is negatively related to the change that occurred in the firm's research and development R&D at time (t+1)*

2.5 Data and Methodology:

2.5.1 Data sources and Sample Selection

The data set we established for our study is determined by the joint availability of data on the United States Patent and Trademark Office USPTO, the BoardEx database, and the North American Compustat database for the period of 2000-2020. Table 1 reports the sample size, sources, and other details on NGPs at the stage 1.

2.5.1.1 USPTO-PatEx – Non-Granted Patents NGPs

We start our sample selection procedure by focusing on NGPs based on the records of the US Patent and Trademark Office, Patent Examination Research Dataset (USPTO-PatEx) (available at https://www.uspto.gov/ip-policy/economic-research/research-datasets/patent-examination-research-dataset-public-pair). PatEx data is formerly referred to as Public Patent Application Information Retrieval—Public PAIR data, which is a data source established by USPTO following the US Congress passing the American Inventors Protection Act (AIPA), 1999. AIPA does, however, have some implications that may affect PatEx users. In particular, the legislation dramatically increased the share of prior unpublished patent applications that became accessible after 2001 but also included "an opt-out provision", which means, in order to properly use this data, researchers need to be aware of the selectivity issues that this data contains. PatEx data was created by the USPTO in 2014 to provide information on US patents, patent applications, and their examination process, dating from the 1910 to present. Even though the USPTO updates and makes the PatEx data available, some categories of patents and patent applications—such as those that have not been awarded—were only released from 2001. In this study, we employ the latest version of PatEx (the 2022 release) which includes details that have not been disclosed in prior updates (that is in 2014 and 2019), including data on patent inventors (particularly for NGP applications).

We take a novel approach to collect our data on patents that have not been granted. However, it is not a simple matter to determine which patent is rejected, as thousands of patent applications are filed and issued annually by the USPTO. As (Lemley & Sampat, 2008) mentioned that we cannot know exactly how many patents have been rejected by the USPTO in the past two decades. But knowing the process of the USPTO and what applicants are actually doing is a prerequisite to inform debate on this issue. By scrutinizing how patent applications are assigned to an examiner group in the USPTO and, eventually, assigned to individual patent examiners for search and examination, we first observe an ambiguity in both the examination process of patents and the applicants responses. We also observe duplicates in some definitions and descriptions in the PatEx file related to patent classifications, especially those that have not been granted. Therefore, we engaged in an intensive conversation with experts managing the USPTO-PatEx file, discussing all these issues. Further, we provide some suggestions regarding the initial and final decisions made by USPTO examiners, and recommend considering our suggestions in the future update of PatEx file, allowing researchers interested in collecting and analysis such data.

Rather than looking at all filings patents to gather the NGPs, we first establish a group of patent applications, which we then pursue through the process. In particular, as in the prior studies on innovation, our research concentrates only on utility patent applications, at the firm-level, which consist of approximately 90% of USPTO patent documents in recent years. We exclude patents from the other two types of USPTO data, plant and design applications, as well as patents applications owned by non-profit organizations, governments, and individuals. We also omit firms incorporated outside of the United States and firms with no stock price data. Next, disambiguation of firm names presents a major challenge, since patent documents are not required to contain the assignees (owners) of the patents. Prior work (e.g., Kline et al., 2019) indicate that approximately 50% of patent applications in USPTO are missing assignee names. We worked with the USPTO available data to fill in assignee names (i.e., owners/firms), not inventions, for our sample data of NGPs. We also follow the literature (e.g., Kline et al., 2019; Balsmeier, B et al., 2017; He, J.et al., 2013), and eventually assign a patent application to the *location* and *year* it was applied for. Following disambiguation, we only left with applications titled pending, abandoned, rejected, or withdrawn.

After that, we eliminate patents that are pending because they are being processed and may eventually be granted. We also ignore withdrawn patents that their applicants withdraw before receiving the first action from the examiner. Rejected patents that have not been abandoned (i.e., repeat application) by their owners will return to pendency, because USPTO applicants always have the right to appeal and claim that the examiners should re-evaluate their patent applications. Of course, the request must be approved by the examiner, and the applicant is required to pay an examination fee for each application filed, whether initial or repeat. If the examiner refuses the appeal, however, the final decision will be implemented. Such patents are also excluded from our final NGP sample (additional information is provided in the measure section). Then, we gathered patents that have gone through the examination process, abandoned by their owners, and received a final decision of rejection from the USPTO examiner between January 2001 and December 2020. Our final collected data, thus, contains 723 firm-year observations, with a total of 2,003 NGPs for 256 firms. Finally, the NGPs we collected are matched with other databases: ExecuComp, BoardEx and North American Compustat.

2.5.1.2 CEO Compensation Packages

Rather than using the ExecuComp database to collect information on the US CEO compensation package, we use the BoardEx database—compiled by Management Diagnostics Limited, which is a private research company specializing in gathering and disseminating information on company officials of public and private companies in many countries, including the US—for two reasons. First, BoardEx indicates more observations than ExecuComp when we separately merge them with the USPTO data (the merge section below provides more details). Second, we find that the BoardEx approach is more useful than ExecuComp for collecting and classifying the missing data. In unreported results with the first match between USPTO and compensation data from the two databases, we find that measuring compensation for US CEOs using BoardEx rather than ExecuComp supports the main findings of our study. More importantly, BoardEx includes detailed data on various components of CEO compensation—including salary, bonus, cash compensation, option, stock, and other long-term payments. BoardEx not only contains data on CEO compensation but also provides comprehensive biographic information on CEOs and other executives for many countries, even those without obligatory regulations for disclosing CEO compensation. BoardEx started collecting data in 1999 and began gathering information on US companies in 2003. In 2005, however, BoardEx's sample of US firms dramatically increased to cover US public companies prior to 2003 and add new companies. Currently, BoardEx database contains information on US companies for more than 20 years. As mentioned earlier, however, when we merged our USPTO data with BoardEx, we missed many observations on the compensation packages of US companies (more details below in the merge section). To supplement the BoardEx data, we manually collect the missing data using annual reports, proxy statements, and SEC Form 10-K for US companies, as well as corporate websites. As shown in Table 1, Panel A, 512 firm-year observations with manually gathered data are included in our final sample, which consists of 723 firm-year observations on 256 firms for the period 2000–2020.

2.5.1.3 Firm Performance

We obtain firm-level financial data from COMPUSTAT database, which is the primary source of accounting data on American corporations. Yet, some firms in our main NGPs data from the USPTO-PatEx file lack financial information from the Compustat database, such as R&D, age, sale, and other firm-specific variables. To complete the financial data, we gather it manually using annual reports, proxy statements, and SEC Form 10-K for US companies, as well as corporate websites. Our unique hand-collected dataset on US firms enables us to investigate the potential effect of NGPs on CEO compensation and firm performance. Table 1, Panel A provides information on the missing and collecting financial variables.

2.5.1.4 Merging Data

To merge our final sample of 723 firm-year observations of USPTO data with the compensation and financial databases, we use a method of matching the GVKEY and CUSIP codes, as well as company names. We manually review these identifiers to verify the accuracy of the match. We also conduct online searches when the names are not exactly the same, and we only include the observation if we are confident that the names match. Following this procedure, we first merge the NGPs data we collect from the USPTO-PatEx with the CEO compensation data from the

ExecuComp database. We, initially, consider the match of eight components that cover the short- and long-term compensation package: salary, bonus, cash compensation (salary + bonus), option, stock, other long-term incentives LTIP, and total equity at risk (option, stock, LTIP), as well as the total CEO remuneration. We later compute other dependent variables, including total stock and option (TST&TOP) and long-and short-term incentives (LT&ST), as well as other incentives for CEOs.

This method obtains a sample of 169 firm-year observations, of which 554 firm-year observations are missing in ExecuComp. Then, we apply the BoardEx database to improve the CEO compensation data. Although we could not match all the firm-year observations of our USPTO data, BoardEx shows slightly better match results than ExecuComp. The result increases the sample of CEO compensations to include 211 firm-year observations and decreases the number of missing data to 512. After a manual review of the observations we obtained from the two databases, we find that the BoardEx outcomes cover almost all of the observations from the ExecuComp. We further look at the Bloomberg database, but the variables we need to investigate are not classified as BoardEx databases. Therefore, we rely on BoardEx and its approach for obtaining the missing data of compensation packages consistent with the prior research (see, for example, Borisova et al., 2018; Fernandes et al., 2013; Fracassi et al., 2012). After that we merge the above sample of USPTO unsuccessful patents and BoardEx compensation packages with the financial data from COMPUSTAT for the control variables. This results in a total sample of 407 firm-year observations, of which 316 firm-year observations being missing. Finally, we manually collect the missing observations on both compensation package and financial data, such as salary, bonus, cash compensations, options, stocks, total compensation, R&D expenditure, total assets, and other related variables. We use annual reports, proxy statements, and SEC Form 10-K for the firms with missing information. However, we face difficulties in extracting certain information about CEO's compensation package of many companies, including the restricted and unrestricted stocks and exercisable and unexercisable options, as they do not disclose such information. Thus, the option and stock variables we consider in our sample are the annual totals. Our final sample represents only firm-year observations where data for all variables included in the analysis are available between 2001 and 2020. In Panel B of Table 1, we present the yearly distribution of our final sample. We also follow the extant literature to include a number of control variables—such as firm size, R&D, firm age, market value, CEO age, and others—that may interact with data quality and affect the study's outcomes.

In summary, due to the fact that USPTO database does not provide information on patents that have not been awarded prior to 2001 and the time lag before applicants receive a final decision on whether or not their patents grant (3–5 years), this results in significantly truncated data for NGPs. We recognize, thus, that our sample from USPTO between 2001 and 2020 may not cover the most cases of NGPs at the firm level. This is actually in line with prior studies (see, for example, Hegde et al., 2018) on the required disclosure of inventions to the public, whether or not been granted. Likewise, ExecuComp and BoardEx do not include data on all US public firms between 2000 and 2020, leading to a lack of information on many CEOs compensation packages in our sample of firms with NGPs. ExecuComp, for instance, only covers firms that are listed on Standard & Poor's (S&P) 1500, which comprises firms listed on the S&P 500, S&P 400 Mid-Cap, and S&P 600 Small-Cap. Nevertheless, after the manual collection, our final sample seems to be reasonably comprehensive. Table 1, panel A displays the sample and all firm year-observations in our data.

Table 2.1: Sample and Distribution

Panel A: Sample Distribution by Year, Observation, and number of NGP

This table displays all firm year-observations in our sample (including the missing variables of compensation packages and financial data) and USPTO NGPs per year using period from 2000 to 2020.

Year	Observations	Percentage %	N	Percentage %	Databases
2000	20	0.0276	90	0.0449	USPTO + BoardEx + Compustat
2001	33	0.0456	137	0.0683	USPTO + BoardEx + Compustat
2002	33	0.0456	174	0.0868	USPTO + BoardEx + Compustat
2003	30	0.0414	159	0.0793	USPTO + BoardEx + Compustat
2004	45	0.0622	152	0.0758	USPTO + BoardEx + Compustat
2005	52	0.0719	140	0.0698	USPTO + BoardEx + Compustat
2006	44	0.0608	119	0.0594	USPTO + BoardEx + Compustat
2007	54	0.0746	135	0.0673	USPTO + BoardEx + Compustat
2008	37	0.0511	125	0.0624	USPTO + BoardEx + Compustat
2009	35	0.0484	100	0.0499	USPTO + BoardEx + Compustat
2010	31	0.0428	87	0.0434	USPTO + BoardEx + Compustat
2011	36	0.0497	94	0.0469	USPTO + BoardEx + Compustat
2012	39	0.0539	81	0.0404	USPTO + BoardEx + Compustat
2013	30	0.0414	57	0.0284	USPTO + BoardEx + Compustat
2014	26	0.0359	56	0.0279	USPTO + BoardEx + Compustat
2015	31	0.0428	63	0.0314	USPTO + BoardEx + Compustat
2016	29	0.0401	46	0.0229	USPTO + BoardEx + Compustat
2017	32	0.0442	62	0.0309	USPTO + BoardEx + Compustat
2018	26	0.0359	32	0.0159	USPTO + BoardEx + Compustat
2019	41	0.0567	61	0.0304	USPTO + BoardEx + Compustat
2020	19	0.0262	33	0.0164	USPTO + BoardEx + Compustat
Total	**723**	**100%**	**2,003**	**100%**	USPTO + BoardEx + Compustat

Note: The highest number of observations occurred when the financial crisis hit in the winter of 2007 and continued in 2008. However, comparing the three years prior to and following the 2007 financial crisis, we observe that the number of observations was reduced. Additionally, the number of NGPs was also mitigated in the subsequent years of 2007. Some prior studies on unsuccessful patents end their samples in 2006 to avoid having their results affected by the financial crisis. Our results, however, remain unaffected when we include the years subsequent to 2007. Likewise, the lowest number of both observations and NGPs (19 and 33) happened during the COVID-19 pandemic, which began in late 2019 and early 2020. Taken together, we reveal an interesting twofold reason for such a reduction "when crises occur": (1) USPTO's examiners may accelerate the level of the patenting process; and (2), more importantly, grant more patents at the firm level in order to boost innovation activities and, eventually, revive the economy.

Panel B: Frequency Distribution of NGPs Sequence Number with Year Observations

The table shows the serial number of NGPs, firm year-observations, total number of NGPs for firm year-observations, and its percentage of the 2,003 total in our sample. The most frequent number of NGPs in our sample is 1, which has 480 firm year-observations and 480 unsuccessful patents that have received a final decision from the USPTO's examiners. This number constitutes 24% of the 2,003 NGPs total. Number 2 is next, with 106 firm year-observations and 212 NGPs, which accounts for almost 11% of the 2,003 NGPs. Firms with 11 NGPs, in contrast, have the lowest NGP total—only one firm year-observation and 0.5% of the total 2,003 NGPs; followed by firms with 12 NGPs, which have one firm year-observation and 0.6% of the total 2,003 NGPs.

Serial Number of NGPs	Firm Year-Obs	N	Percentage %
1	480	480	0.2396
2	106	212	0.1058
3	29	87	0.0434
4	30	120	0.0599
5	22	110	0.0549
6	5	30	0.0149
7	12	84	0.0419
8	8	64	0.0319
9	8	72	0.0359
10	2	20	0.0099
11	1	11	0.0054
12	1	12	0.0059
13	2	26	0.0129
14	1	14	0.0069
15	1	15	0.0074
16	1	16	0.0079
17	1	17	0.0084
18	1	18	0.0089
19	1	19	0.0094
21	1	21	0.0104
22	1	22	0.0109
27	1	27	0.0134
30	1	30	0.0149
34	1	34	0.0169
36	1	36	0.0179
57	1	57	0.0284
65	1	65	0.0324
73	1	73	0.0364
101	1	101	0.0504
110	1	110	0.0549
Total	**723**	**2,003**	**100%**

Descriptions of variables

Table 2.2: This table describes some variables with short names. All variables are in logarithms except for CEO Dep. Appendix A includes all variables definition.

Variable	Description	Database
NGPs	Non-granted patents from the USPTO-PatEx	USPTO
Cash.Comp	Total cash compensation (salary + bonus)	BoardEx
TotAtRisk	Total compensation at risk (stock, option, and long-term incentive pay)	BoardEx
LTIP	Long-term incentive payment (restricted stocks + unvested option)	BoardEx
STIP	Short-term incentive payment (bonuses)	BoardEx
TST&TOP	Total stock and option	BoardEx
LT&ST	Long-term and short-term compensation	BoardEx
CEO Total.Rem	Total CEO remuneration (cash compensation + total at risk)	BoardEx
CEO Dep	CEO departures (i.e., CEO with a renewed position after the NGP event)	BoardEx
R&D	Firm investments in Research and development	Compustat
ROA	Return on asset	Compustat
ROE	Return on stock	Compustat
ROI	Return on investment	Compustat
MV	Market value	Compustat

Table 1, Panel A displays all the firm year observations, databases, and the number of NGPs from the USPTO along with their yearly percentages from 2000 to 2020. Some observations of pay packages and financial data are missing. As we demonstrated in Section 4.1, we start with the USPTO-PatEx database to gather NGPs from 2000 to 2020. Then, we merge it with Execucomp and BoardEx for connection data. The BoardEx data provides more observations of CEO compensation than Execucomp. After that, we merge USPTO and BoardEx with Compustat for the control variables. Next, we manually collect the missing observation variables from annual reports, proxy statements, and SEC Form 10-K, following the BoardEx database structure. Finally, our final sample contains 723 firm-year observations for NGPs, CEO compensation, and financial data from 2000 to 2020.

Table 2 lists the names, data sources, and a brief description of some of the variables we used in the study. Each variable is represented on a logarithmic scale to solve the skewed problem. We provided further detail on these variables in the hypotheses development section. We also include three variables, which we computed specifically for the CEO compensation model, in the Appendix, as they do not provide evidence to support our hypotheses. These variables are the total CEO's stock and option, long-term and short-term compensation, and the total CEO's remuneration.

2.5.2 Measures:

2.5.2.1 Dependent variables

2.5.2.1.1 CEO Compensation Packages:

Our sample consists of 256 US publicly traded firms, provided by the USPTO database, with CEO compensation data tracked in BoardEx. In the two stages of analysis, we follow the prior work (e.g., Hung et al., 2019; Borisova et al., 2018; Fernandes et al., 2013) to investigate the change in the two main variables of CEO total remuneration package (CEO TotRem) in BoardEx: first, the short-term compensation, including base salary and bonus, which is measured by ΔCEO cash compensation. This measure represents the change in the CEO's cash compensation in the year following the NGPs. Then, we split the short-term compensation to look at the changes in salary and bonus, as both together constitute the overall cash compensation. Second, the long-term incentive (i.e., stocks, options, and the long-term incentive plan LTIP) is measured by ΔCEO total equity at risk, which represents the change in the CEO's long-term incentives subsequent to the occurrence of NGPs. Further, separate tests are conducted on each of the three components that form this variable. We also calculate the CEO total remuneration (CEO Total.Rem) by adding the CEO's annual short- and long-term income (cash compensation + total at risk). Each of these components in the two main variables is a ratio of the CEO total remuneration. In addition, we calculate and run three other variables besides the above eight components of compensation: the total stock and option TST&TOP and the long- and short-term incentives LT&ST (total remuneration - salary), as well as other payments for CEOs, as indicated in each of the sample firm's annual reports (Appendix A presents the definitions of all these variables, while Appendix B—Levels 1 and 2—contains the results of the last four variables: CEO Total.Rem, TST&TOP, LT&ST, and others, which are not reported for brevity). We employ the logarithmic transformation in the CEO compensations to mitigate the impact of outliers and use the first change as our dependent variable in both short- and long-term CEO compensation, each as a ratio of the total CEO remuneration package (Δl-r-compensations).

2.5.2.1.2 Firm Performance:

Firms face increasing pressure to maximize their performance (Hull et al., 2008). Giving that performance is a multidimensional concept (Murphy et al., 1996), we employ three performance measures that are widely used in financial models, derived from accounting information obtained from the North American Compustat database, that is, the hypotheses developed in Section. 3 refer to the potential impact of the independent variables, NGPs and controls, on the dependent variables, performance of firms, in the subsequent year of NGPs. In keeping with the prior work on firm performance and innovative activities (e.g., Rodríguez et al., 2016; Gunday et al., 2011; Ehie et al., 2010; Cho et al., 2005), we consider the change in the return on assets (ROA), and, as a robustness check, return on equities (ROE) and return on investments (ROI). In line with (Cao et al., 2019), we later applying return on sales (ROS) for three basic reasons. First, ROS determines the decline in a firm's sales in the future (Tangen, S. 2003). Second, CEOs frequently consider this factor in their decisions (Rodríguez et al., 2016). Third, ROS is less sensitive to accounting methods than other performance measures (Artz et al., 2010). With this in mind, we test the potential impact of NGPs on ROS in the subsequent year (Appendix B - Levels 1 and 2 include the result of ROS in the two-stages as it's not reported here for brevity). We define these measures, respectively, as the ratio of net income divided by total shareholders' equity, the ratio of net income divided by book value of total assets, the ratio of net income divided by total invested capital x 100, and the ratio of net income divided by total sales. The natural logarithm of the ratios of these four measures is also employed (Δl-r-performance).

Appropriate performance measures can ensure that Innovative firms adopt a long-term perspective and allocate the firms' resources to the most effective innovative activities, which, eventually, increase their profitability. Our measures appear appropriate as they reflect the profitability of a firm innovation with respect to the total equities, assets, and investments under its control. Hence, we use ROE, ROA, and ROI ratios as indicators of a firm's overall profitability performance, because most of these measures tend to be highly correlated with one another (Cho et al., 2005). Our expectation is that NGPs will have a negative effect on firm performance measures in the subsequent year, particularly ROA and ROE. Or put it differently, we expect a decline in the firm's performance, as measured by ROA and ROE, in the year following the NGPs. With regard to ROI, an investment *I*, which takes place in year *t* and increases a firm's total assets by *It* in year *t*, is typically made when the expected net present value (NPV) of a firm is larger than *It*. However, ROI is expected to be gradually generated and distributed across several periods in the future, starting from $t + 1$. So, we do not expect an impact of NGPs, which occurred at year *t*, on ROI in the subsequent year. This argument does not apply to the ROA, our key measure of performance, nor to the ROE, which we use to corroborate our findings.

2.5.2.2 Independent variables

2.5.2.2.1 Failure in Innovation Activity:

The core of our data set is patents that have eventuality not been granted, obtained from PatEx file in the USPTO database. As we stated earlier that determining which patent is rejected in order to measure failure in innovative activity at firm-level is not a simple matter. In fact, the applicant always has the option to go back and request the USPTO examiner reconsider her patent application; if the examiner approves, the application becomes pending rather than refused. Therefore, it can be difficult to distinguish between pending patents, whether initial or repeat, and patents that are finally rejected. We managed to determine not pending patents but rejected patents in order to construct a key measure for failure in innovation, which we named NGPs—that is, the total number of patents that are "ultimately denied" and abandoned by their owners (i.e., firms in our sample). In other word, this measure captures the quantity of "unsuccessful innovation output" of a firm *i* in year *t*, and is based on the update of PatEx database that consists detailed information of all USPTO-NGPs. In the current research, we employ the 2022 version, which is the most recent PatEx update. Since the distribution of NGPs is skewed, we also use the natural logarithm to reduce the skewness in our regressions (l-NGPs).

A few issues about our measure of failure in innovation, NGPs, deserve further reminder. First, using USPTO data to measure firm innovation activities, particularly patents that have not been granted, has been adopted in some previous studies (e.g., Farre-Mensa et al., 2020; Kline et al., 2019; Balsmeier, B et al., 2017; He, J.et al., 2013; Lemley & Sampat, 2008; Basmann et al., 2007). Under the territorial principle in US patent laws, individuals who seek to claim exclusive rights over their inventions must file US patent applications. Following earlier studies (e.g., Hsu et al., 2014), we assume that all important inventions have been filed to and evaluated by the USPTO, as the US has been the world's largest market for technology consumption in recent decades. Second, we do not include individuals, governments, or non-profit organizations, rather, we only focus on firm-level data because it is more valuable than other types of data.

Third, all pending patents—initial or repeat—are not included in our sample. The vast majority of repeat applications, for which their applicants decided to restart the examination process, have already received a final decision, yet their owners (i.e., firms) have not abandoned them, so they remain eligible for future grants. They fall into one of two categories: requests for continued examination (RCEs), which are essentially extensions of the same application, and continuation applications, considered a new application. Prior work (e.g., Sampat et al., 2010) emphasize that RCEs are useful in pursuing arguments with an examiner who is hesitant to approve a patent, and find that 57% of repeat applications were RCEs. Others (Frakes et al., 2015) show that 63% of repeat applications are filed with RCEs. Both groups, however, used for the same purpose: restarting the examination process of a "refused patent application". Finally, we assign NGPs to their owners (i.e., firms) instead of inventors because our goal is to measure the failure in innovative activities for US firms. Doing so eliminates any potential sampling bias because some firms in the USPTO own a larger pool of patent applications, whether awarded, rejected, or pending, than others..

2.5.2.3 Control variables:

Following the prior literature (Balsmeier et al., 2017; Kung et al., 2015; Fang et al., 2014; Atanassov, 2013; Welch et al., 2011; Makri et al., 2006), we control for several firm and CEO characteristics that could confound the relationship between a firm's innovative unsuccess and its performance and CEO compensation packages. We compute all variables for firm *i* over its fiscal year *t*. In particular, we include *firm size* (log of a firm's book total assets), *research and development* (ratio of firms' R&D to total book assets), and *leverage* (total debt to total assets). We also control for *firm age* (the number of years since the initial public offering IPO date), as older firms may look in older technological areas, and *market value* (the annual close price x the total number of outstanding shares). Moreover, firm performance, as proxied by returns on assets *ROA*, returns on equities *ROE*, and returns on investments *ROI*, enters a few regressions (e.g., the regressions of CEO departures and R&D) to control for differences in profitability. In the finance literature on innovative activities, these performance variables are frequently used as controls. We employ a logarithmic transformation for the above control variables to account for the skewness of the distribution.

In addition to firm-specific variables, three variables are used to capture CEO-specific characteristics. Specifically, following (Islam et al., 2020; Cao et al., 2019; Mao et al., 2018), we control for *CEO age*, *CEO tenure*, and *CEO's gender* (male or female sex scaled by percentage) because these variables can potentially impact our regression results. Finally, various other controls have sometimes been used in our study. We find, however, that such controls are not statistically significant and have little impact on our results, thus, we do not include them for brevity.

Table 2.3: Descriptive Statistics – Level 1. This table displays summary statistics for the key variables for a sample of all 256 US firms from 2000 to 2020 consist of 723 firm-year observations. For each variable, the mean, median, standard deviation, and number of year-observations are also displayed in the table. The CEO compensation-related variables are reported in US dollars (000s). The description of all variables is given under the table and in Appendix A. We also consider subsample data of level 2 in Appendix B-Level 2. Data source: Own calculation based on BoardEx database.

Variables	Number	Mean	Median	Standard Deviation
***Panel A:* Failure in Innovative**				
NGPs	723 Y-Obs	0.445	1.000	0.778
***Panel B:* CEO Compensation Package**				
Sohrt-Term Components: **($ thousands)**				
Δ Cash.Comp	723 Y-Obs	-1.351	-1.252	1.790
Δ Salary	723 Y-Obs	-1.540	-1.456	1.792
Δ Bonus	723 Y-Obs	-2.306	-2.853	2.081
Long-Term Components: **($ thousands)**				
Δ TotAtRisk	723 Y-Obs	-0.420	-0.360	1.711
Δ Stock	723 Y-Obs	-11.141	-11.453	3.216
Δ Option	723 Y-Obs	-1.292	-1.336	2.094
Δ LTIPs	705 Y-Obs	-1.303	-1.357	2.027
***Panel C:* Firm Performance**				
Δ ROA	723 Y-Obs	0.773	0.013	8.605
Δ ROE	723 Y-Obs	-3.449	-3.279	3.055
Δ ROI	723 Y-Obs	8.678	9.435	1.659
***Panel D:* CEO Characteristics**				
CEO age	723 Y-Obs	52.733	53.000	8.203
CEO stays one year after NGPs – binary	723 Y-Obs	0.869	1.000	0.338
***Panel E:* Firm Characteristics**				
Δ R&D	723 Y-Obs	3.942	4.205	2.889
Leverage	723 Y-Obs	- 4.338	- 4.258	3.034
Size	723 Y-Obs	6.324	6.369	3.193
Firm Age	723 Y-Obs	2.533	2.708	0.959
MV	723 Y-Obs	13.347	13.726	3.667
R&D	723 Y-Obs	3.916	4.130	2.869

Note: Variable Definitions: *NGPs* = patent applications that are submitted to the USPTO and ultimately rejected by USPTO examiners. *Cash.Comp$* = natural logarithm for the sum of CEO's salary and bonus. *Salary$*= natural logarithm for the CEO's salary. *Bonus* = natural logarithm for CEO's *bonus$*. *TotAtRisk$* = natural logarithm of the CEO's total compensation at risk (i.e., the sum of stock, option, and LTIP). *Stock$* = natural logarithm of the CEO's stock-based compensation. *Option$* = natural logarithm of the CEO's option-based compensation. *LTIPs$* = natural logarithm of the CEO's long-term incentive payment (i.e., restricted stocks + unvested option). *ROA* = natural logarithm of the return on assets divided by total assets. *ROE* = natural logarithm of the return on equities divided by total equities. *ROI* = natural logarithm of the return on investments divided by total invested capital x 100. *CEO age* = the age of the CEO of a firm. *CEO tenure* = the number of years the CEOs have been in the chief executive position at the current firm. *CEO gender* = male or female sex scaled by percentage. *R&D* = natural logarithm of the change in research and development. *Leverage* = natural logarithm of the total debt to total assets. *Size* = natural logarithm of a firm's book total assets. Firm age = natural logarithm of the number of years since the IPO date. *MV* = the annual close price x the total number of outstanding shares. R&D = natural logarithm in research and development at time *t*. Results using total stock and option, long-and-short-term incentives, other payments, and total CEO remuneration as dependent variables indicate a positive or insignificant correlation with NGPs. These results are not reported for brevity. We also separately computed total stock and option (TST+TOP), long and short incentives (LT+ST), and other CEO's compensations as dependent variables. NGPs, however, have insignificant effects on each of these variables. The Appendix B-Level 1 and 2 includes all of the regression results for these variables.

Table 2.4: CEO sample for two-stages

Panel A: Period of observations

Table 4 presents firm year-observations for CEOs who remain and those who departed when NGPs occurred, as well as other CEO's characteristics between 2000 and 2020.

Three-Year Contract	Level 1	Level 2	Data
Firm-Year Observation	723	628	USPTO + BoardEx + Compustat
Total CEOs	401	306	USPTO + BoardEx + Compustat
CEOs left after NGP	-	95	USPTO + BoardEx + Compustat
CEOs stay after NGP	-	306	USPTO + BoardEx + Compustat
CEO average age	52	53	USPTO + BoardEx + Compustat
CEO male %	100%	100%	USPTO + BoardEx + Compustat
CEO nationality	US	US	USPTO + BoardEx + Compustat

Note: In level 1, we run all of our models using the whole dataset, which consists of 723 firm year-observations, including all of the CEOs in our sample. Then, in level 2, we exclude those who departed after the occurrence of the NGPs, and run the models with 628 firm year-observations. The Appendix B-Level 2 includes all of the regression results.

Table 3 provides a breakdown of the summary statistics for failure in innovation, CEO compensation package, firm performance, CEO characteristics, firm characteristics, and other variables from the final sample. Panel A shows that, on average, the firm has one NGP. As previously mentioned in the introduction section, we have gathered 2,003 instances of NGPs from 256 US firms. All these firms have faced failures in innovation, and some have not received any patents at all. Turning to Panel B, the changes on CEO's short-term incentives (i.e., cash compensation, salary, and bonus) are, respectfully, \$1.351, \$1.540, and \$2.306. The panel also shows the changes in the second main part of CEO compensation, the long-term incentives (i.e., stock, option, LTIP, and their total). We observe a significant change in the stock-based compensation, with an average value of 11.144. The compensation from stock shows a significant negative correlation with NGP. As shown in panel C of table 3, return on equities shows the highest change among the form performance measures with approximately USD 3.449, and the mean return on equities is 3.279. Panel D of table 3 indicates that the average age of the CEOs is 53, and, on average, the chance for a CEO to renew his position is almost 87%. We show in detail that among 401 CEOs, almost 24% (i.e., 95) left their position motivated by different reasons (resignation, retirement, etc.). Panel E in table 3 indicates that the mean firm's change in R&D is \$3.942, which reveals a significant negative association with our main independent variable, NGP. The median firm has \$13.7 market value, 2.5 age, and 3.9 R&D. Furthermore, the median firm's size, which is scaled by total assets, is 6.369.

Table 4 reports the CEO sample for both levels 1 and 2. We manually gathered most of this information after merging three different databases (USPTO, BoardEx, and Compustat). Panel A presents the sample of Level 2, which includes 628 firm-year observations. All our regression analyses in Level 2, as shown in the robustness section and Appendix B, use 628 firm-year observations. This sample includes 306 US CEOs, representing 76% (306/401) of the CEOs who have remained in their positions for at least three years, including the year following the NGPs. Table 4 also reports a total of 95 US CEOs who departed after NGP occurred (as demonstrated in the introduction, these CEOs account for 24% of all the CEOs in our data). For each fiscal year in the sample period, we cover demographic details on each CEO of US companies, including age, gender, and tenure. We observe that all of the CEOs are men, all from the United States of America.

2.5.3 Empirical Models:

This section presents the two main empirical models that we created—CEO compensation packages and firm performance—to investigate their correlation with our main variable, NGPs. Specifically, these models test the changes of several dependent variables in the subsequent year of NGPs. We begin by considering whether CEO compensations packages reduce in the year following NGPs. To do so, based on a number of firm characteristics that have been demonstrated to be determinants of CEO compensations, we specify an empirical model, includes our primary factor and controls, that better deals with the level of changes in CEO compensation. Then, we test whether firm performance—as measured by ROA, ROE, and ROI—decreases the year post-NGPs by establishing a new empirical model and adjusting a set of parameters. Further, we identify two additional empirical models: the first investigates whether firm's R&D investments reduce following the NGPs year; the second examines the relationship between NGPs and CEO departures, since many CEOs left their positions after the occurrence of NGPs.

2.5.3.1 CEO Compensation Model

To test hypotheses 1–3 on whether CEO short-term incentive packages reduce in the post-NGPs year, we use the following three regression models:

Test of H1

$$\Delta\text{log-Cash.Comp}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{NGPs_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, R\&D_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, MV_{i,\,t} + \varepsilon_{i,\,t} \quad (1)$$

Test of H2

$$\Delta\text{log-Salary}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{NGPs_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, R\&D_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, MV_{i,\,t} + \varepsilon_{i,\,t} \quad (2)$$

Test of H3

$$\Delta\text{log-Bonus}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{NGPs_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, R\&D_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, MV_{i,\,t} + \varepsilon_{i,\,t} \quad (3)$$

where $\textit{Cash.Comp}_{i,\,t+1}$, $\textit{Salary}_{i,\,t+1}$, and $\textit{Bonus}_{i,\,t+1}$ are the natural log of CEO short-term incentives for firm *i* at year *t+1 minus – t*. *NGPs* is the failure in innovation for firm *i* at year *t* but started from *t-3*, the average time lag of patents. Prior studies (e.g., Hung et al., 2019; Borisova et al., 2018; Huson et al., 2012) on CEO compensations use a change model to capture differences in the compensations that firms pay from year *t* to year *t+1* or year *t-1*. Thus, we employ a change regression to test all the hypotheses in our study using (OLS) except for the CEO departure hypothesis, as we use a different regression method. In particular, we measure the change for each dependent variable we use in the regression analyses from *t* to *t+1*. We provide a complete set of data for US firms over 2 years (*t and t+1*) during our sample period of 2001–2020 to analyze changes in all dependent variables. We expect that NGPs, our key independent variable, will have a negative impact on cash compensation, salary, and bonus at year *t +1*. In addition, we use controls that represent a set of variables known to influence particular compensation. We also expect to find a significant correlation between the changes in short-term compensations at year *t+1* and the two primary controls in the literature—the firm's research and development (R&D) and firm size (F-Size)—. In keeping with the prior work (e.g., Islam et al., 2020; Atanassov, 2013; Welch et al., 2011; Frydman et al., 2010; Zaheer et al., 2005), along with R&D and firm size, we include additional control variables—firm age (*F-Age*), debt (*Leverage*), market value (*MV*), CEO-specific characteristics (*CEO-age*), and ε as a random error term—to mitigate the possibility that the impact we expect to find on the short-term compensations is in fact driven by these variables.

We then use the following four regressions for the same model to test hypotheses 4–7 regarding whether CEO long-term incentives decrease in the year following NGPs:

Test of H4

$$\Delta\text{log-TotAtRisk}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(4)}$$

Test of H5

$$\Delta\text{log-Stock}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(5)}$$

Test of H6

$$\Delta\text{log-Option}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(6)}$$

Test of H7

$$\Delta\text{log-LTIP}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(7)}$$

where $\textit{TotAtRisk}_{i,\,t+1}$, $\textit{Stocks}_{i,\,t+1}$, $\textit{Options}_{i,\,t+1}$, and $\textit{LTIP}_{i,\,t+1}$ are the natural log of CEO long-term incentives for firm *i* at year *t+1 minus – t*. BoardEx defines CEO long-term incentives as total equity at risk or total equity proportion of total compensations, which is the sum of stock, options, and long-term incentive plan (LTIP) awarded during the period, divided by total CEO remunerations (TotAtRisk/Total CEO remunerations). Following the previous research (e.g., Borisova et al., 2018; Manso, 2011; Frydman et al., 2010) we test and analyze total equity at risk. In addition, we conduct separate tests on each of the three components (i.e., stocks, options, and LTIP). According to BoardEx, while stocks include restricted and unrestricted stocks, options consist of both exercised and unexercised options. LTIP component represents the sum of cash, equity, and equity matched and option-based LTIPs and its value is calculated using the closing stock price of the selected annual report date. We do not expect that NGPs will have a significant effect on the CEO's total equity at risk at year *1 + t*. Rather, we expect that NGPs will have a negative impact on stock-based compensation, in particular, because previous research (e.g., Mao et al., 2018) often shows a positive relationship between innovation activity at the firm level and the other two components of CEO total equity at risk, especially option-based compensation. In addition, it is widely known in the literature that stock-based compensation is more sensitive to risk (NGPs in our case) than option-based compensation. For controls, we apply the same control variables in short-term regression model. However, we do not expect a significant association between changes in CEO total equity at risk at year *t+1* and both firm's R&D and firm size. Overall, we focus our analysis on the levels of CEO total short-term incentives —in the form of cash compensation—and CEO total long-term incentives—in the form of equity at risk—and their components because these two main measurements cover the potential broad consequences of most CEO remuneration packages. By using these compensation models, we expect the effect of failures in innovation—in the form of NGPs—will be stronger on the CEO's short-term incentives than long-term incentives.

2.5.3.2 Firm Performance Model

We employ the following three regression models to test hypotheses 8–10 on whether ROA, ROE, and ROI decline in the year after NGPs:

Test of H8

$$\Delta\text{log-ROA}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{ROI}_{i,\,t} + \beta_3 \textit{F-Age}_{i,\,t} + \beta_4\, \textit{Leverage}_{i,\,t} + \beta_5\, \textit{CEO-age}_{i,\,t} + \beta_6\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \qquad \textbf{(8)}$$

Test of H9

$$\Delta\text{log-ROE}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{ROI}_{i,\,t} + \beta_3 \textit{F-Age}_{i,\,t} + \beta_4\, \textit{Leverage}_{i,\,t} + \beta_5\, \textit{CEO-age}_{i,\,t} + \beta_6\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \qquad \textbf{(9)}$$

Test of H10

$$\Delta\text{log-ROI}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{ROI}_{i,\,t} + \beta_3 \textit{F-Age}_{i,\,t} + \beta_4\, \textit{Leverage}_{i,\,t} + \beta_5\, \textit{CEO-age}_{i,\,t} + \beta_6\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t} \qquad \textbf{(10)}$$

As dependent variables, $ROA_{i,\,t+1}$, $ROE_{i,\,t+1}$, *and* $ROI_{i,\,t+1}$ are the natural log of firm performance measurements for firm *i* at year *t+1 minus – t*. *NGPs* is the failure in innovation for firm *i* at year *t* but began from *t*-*3*, the average time lag of patents. These measures seem appropriate as they represent the profitability of the firm with respect to the total set of assets, equities, and investments under its control. The prior studies (e.g., Zhang et al., 2019; Rodríguez et al., 2016; Hirshleifer et al., 2013; Gunday et al., 2011; Zaheer et al., 2005) mostly show a positive association between innovation—using diverse proxies of innovation performance—and firm performance as measured by ROA and ROE. In this study, however, we expect that our key measures of firm performance, ROA, and the robustness, ROE, will show a negative association with failures in innovation, represented by NGPs, in the following year. Theoretically, ROI is expected to be generated over several subsequent periods, starting from *t + 1*, since an investment is often made when a firm's expected net present value (NPV) is positive at year *t*. Therefore, we expect an insignificant impact of NGPs, which occurred at year *t*, on ROI in the subsequent year. We rather control for ROI in our regressions of firm performance. Nevertheless, to test on whether ROI reduces in the post-NGPs year, we run the same regression model of firm performance with ROI as dependent variable and we control for our key performance variable, ROA (Section 5.2.2 provides details). We include a set of control variables in the three regressions—return on investments (*ROI*), firm age (*F-Age*), debt (*Leverage*), CEO-specific characteristics (*CEO-age*), market value (*MV*), and ε as a random error term—to reduce the possibility that the effect we expect to observe on the firm's performance measures is actually impacted by these factors.

2.5.3.3 Additional Models

2.5.3.3.1 CEO Departure Model:

We also examine whether the CEOs who run the firm for at least a year or two prior to the NGPs will remain in their position the following year.

Test of H11

$$CEO\text{-}Dep_{i,\,t+1} = \beta_0 + \beta_1\, Innovation\ Failures_{i,\,t}\{NGPs_{(i,\,t-3)}\} + \beta_2\, F\text{-}Size_{i,\,t} + \beta_3\, R\&D_{i,\,t} + \beta_4\, ROA_{i,\,t} + \beta_5\, ROE_{i,\,t} + \beta_6 F\text{-}Age_{i,\,t} + \beta_7 Leverage_{i,\,t} + \beta_8\, CEO\text{-}age_{i,\,t} + \beta_9\, MV_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(10)}$$

where $CEO\text{-}Dep_{i,\,t+1}$ is a binary variable taking value 1 if the firm renews its CEO contract the following year of NGPs, rather than replace the CEO, and 0 otherwise for firm *i* at year *t+1*. We observe that almost 24% of all firms' CEOs (i.e., 95 out of 401) left their positions the year following NGPs in our data set. Such observation is what motivated us to examine whether the CEO's departure is correlated with the firm's failure in innovation. As we previously stated, resignation was the main reason for 70% of CEOs who departed in the year after NGPs (i.e., 67/95), followed by retirement with 27% (i.e., 26/95), and 2 died. The purpose of this model is to determine whether there is a correlation between firms' innovation failures and the departures of their CEOs in order to provide new insight into this relationship and, more importantly, open a new area of future research about the role of failures in innovation and its effects on the decision-making process of a firm's board of directors. We argue that when the CEO of a firm is reluctant to engage in innovation activity or invests less than what would otherwise be, this often results in failures in innovation. Such failures, consequently, may eventually lead the firm to replace the CEO, especially those with a high number of NGPs. Therefore, we expect that NGPs could impact the firms' CEOs' departures.

2.5.3.3.2 Firm's R&D Investments Model:

We test whether firms' R&D reduce in the post-NGPs year by modifying firm performance model as shown below:

Test of H12

$$\Delta\text{log-R\&D}_{i,\,t+1} = \beta_0 + \beta_1\, Innovation\ Failures_{i,\,t}\{NGPs_{(i,\,t-3)}\} + \beta_2\, Cash.Comp_{i,\,t} + \beta_3\, TotAtRisk_{i,\,t} + \beta_4\, ROI_{i,\,t} + \beta_5 F\text{-}Age_{i,\,t} + \beta_6\, Leverage_{i,\,t} + \beta_7\, CEO\text{-}age_{i,\,t} + \beta_8\, MV_{i,\,t} + \varepsilon_{i,\,t} \quad \textbf{(11)}$$

Our dependent variable, $\text{R\&D}_{i,\,t+1}$ is the natural log of firm's research and development, in which *i* represents a given firm at year *t+1 minus – t*. The independent variables include the failure in innovation *(NGPs)* for firm *i* at year *t* but began from *t-3*, which is the average time lag of patents, total cash compensation (*Cash.Comp*), which is the sum of salary and bonus for firm *i* at year *t*, total equity at risk (*TotAtRisk*), which is the sum of stock, option, and long-term incentive plans for firm *i* at year *t*, return on investments (*ROI*), firm age (*F-Age*), debt (*Leverage*), CEO-specific characteristics (*CEO-age*), market value (*MV*), and ε as a random error term. As we demonstrated earlier (in Section 3.4), prior studies (e.g., Brander et al., 2017; Bertrand et al., 2013; Hunt, 2006) that illustrate the relationship between firms' innovative input (i.e., R&D investments) and innovative output (i.e., patents granted) indicated strong positive results. They further suggest that R&D—the main sources of innovation—drives innovative firms as it enables them to establish efficient processes, create new products, and obtain more patents, which in return spurs firms to increase their future investment in R&D. Moreover, R&D investment not only increases the output of innovation but also improves the quality of patents. It is typically that these two innovation activities are complementary—firms that conduct a lot of R&D tend to patent more. And ordinarily, reducing the investment in R&D will hinder more patents. Unlike much of the previous research, we find it important to test on whether "failures in innovation" at time *t* discourage firms from reinvesting in R&D at time *t+1* (Section 5.2.3 provides details), since there is no empirical evidence of such a relationship in the literature.

2.5.3.4 Model Analysis

We analyzed our collected data using ordinary least squares regression (OLS). To examine the impact of the key variables and control variables, we build four models. In model 1, we separately model several CEO compensation components with a set of controls. In model 2, we model firm performance as measured by ROA, and for robustness, ROE and ROI, with a new set of control variables. In model 3, we model the firms' R&D investments by modifying models 1 and 2. Finally, we model the CEOs departures with additional control variables and use a logistic regression model, as OLS is not appropriate for such types of regressions. We examined all our models for clarity issues, and we conclude that there is no significant concern with our models.

2.6. Main Results:

2.6.1 Correlations

2.6.1.1 The Impact of Failure in Innovative on CEO Compensation Package, Firm Performance, R&D Investments, and CEO Departure- Level 1

In Panel A of Table 5, we present Pearson correlations between the variables that we use in the short- and long-term compensation model. Consistent with our expectations for the CEO's short-term incentives, we find a negative and statistically significant correlation between NGPs and *ΔCash.Comp* (-0.096*, p = 0.010), *Δsalary* (-0.123***, p = <.001), and *Δbonus* (-0.126***, p = <.001). For the long-term incentives, we also find a negative and statistically significant correlation between NGPs and *Δstock-based compensation* (-0.128***, p = <.001). However, we do not find any correlation between NGPs and the rest of the long-term compensation (i.e., *ΔTotAtRisk*, *ΔOptions*, and *ΔLTIP*).

In Panel B of Table 5, we show the correlations between NGPs and the firm performance measures. Specifically, the results indicate that NGP is negatively and significantly correlated with

ΔROA (-0.100**, *p* = 0.007) and *ΔROE* (-0.142***, *p* = <.001). Yet, as we predicted, we do not observe a correlation between NGPs and *ΔROI* in the subsequent year, *ΔROI* (0.020, *p* = 0.596).

In Panels C and D, we present additional tests for the correlation between NGPs and *CEO departure*, for which we use a binary variable = 1 if the CEO remains in the position in the year following the NGP event and 0 otherwise, and *ΔR&D*. The former result with NGPs is the opposite of our expectations and reveals no correlation between firm failure in innovation and CEO departures (0.068, *p* = 0.068). However, the later demonstrates a negative and statistically significant correlation with NGPs (-0.123***, *p* = <.001), which is consistent with our projections.

Table 2.5: Correlation for all variables used in the four models

Panel A: Pearson and P-value Correlations for the Variables Used in the CEO Compensation Model – Level 1.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
(1) NGPs	1													
(2) ΔCash.Comp		1												
Pearson's r	-0.096*													
P-value	0.010													
(3) ΔSalary			1											
Pearson's r	-0.123***	0.987***												
P-value	<.001	<.001												
(4) ΔBonus				1										
Pearson's r	-0.126***	0.527***	0.534***											
P-value	<.001	<.001	<.001											
(5) ΔTotAtRisk					1									
Pearson's r	-0.072	0.676***	0.664***	0.534***										
P-value	0.053	<.001	<.001	<.001										
(6) ΔStock						1								
Pearson's r	-0.128***	0.546***	0.526***	0.534***	0.775***									
P-value	<.001	<.001	<.001	<.001	<.001									
(7) ΔOptions							1							
Pearson's r	-0.053	0.569***	0.545***	0.473***	0.855***	0.703***								
P-value	0.157	<.001	<.001	<.001	<.001	<.001								
(8) ΔLTIP								1						
Pearson's r	0.006	0.636***	0.618***	0.499***	0.861***	0.753***	0.796***							
P-value	0.872	<.001	<.001	<.001	<.001	<.001	<.001							
(9) MV									1					
Pearson's r	-0.088*	-0.102**	-0.117**	0.104**	0.042	0.213***	0.142***	0.078*						
P-value	0.019	0.006	0.002	0.005	0.256	<.001	<.001	0.039						
(10) Leverage										1				
Pearson's r	-0.128***	-0.099**	-0.116**	0.164***	0.055	0.130***	0.137***	0.064	0.671***					
P-value	<.001	0.008	0.002	<.001	0.137	<.001	<.001	0.089	<.001					
(11) R&D											1			
Pearson's r	0.676***	-0.031	0.042	0.055	-0.031	0.092*	0.058	0.009	0.045	-0.075*				
P-value	<.001	0.405	0.256	0.137	0.405	0.013	0.121	0.804	0.231	0.043				
(12) Firm Size												1		
Pearson's r	-0.135***	-0.111**	-0.134***	0.142***	0.045	0.165***	0.135***	0.070	0.724***	0.880***	0.786***			
P-value	<.001	0.003	<.001	<.001	0.231	<.001	<.001	0.062	<.001	<.001	<.001			
(13) Firm age													1	
Pearson's r	-0.020	-0.108**	-0.094*	0.139***	-0.075*	-0.061	-0.021	0.002	0.121***	0.221***	0.177***	0.171***		
P-value	0.585	0.004	0.012	<.001	0.043	0.100	0.572	0.959	0.001	<.001	<.001	<.001		
(14) CEO age														1
Pearson's r	-0.006	-0.080	-0.088	0.010	-0.064	-0.015	-0.096**	-0.046	0.076*	0.169***	0.130***	0.195***	0.261***	
P-value	0.876	0.031	0.017	0.788	0.083	0.693	0.010	0.222	0.040	<.001	<.001	<.001	<.001	

Panel B: Pearson and P-value Correlations for the Variables Used in the Firm Performance Model – Level1.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) NGPs	1								
(2) ΔROE		1							
Pearson's r	-0.142***								
P-value	<.001								
(3) ΔROA			1						
Pearson's r	-0.100**	0.013							
P-value	0.007	0.725							
(4) ΔROI				1					
Pearson's r	0.020	-0.720***	-0.028						
P-value	0.596	0.007	0.451						
(5) MV					1				
Pearson's r	-0.088*	0.749***	-0.029	-0.607***					
P-value	0.019	<.001	0.436	<.001					
(6) Leverage						1			
Pearson's r	-0.097**	0.814***	0.066	-0.657***	0.675***				
P-value	0.009	<.001	0.075	<.001	<.001				
(7) Firm age							1		
Pearson's r	-0.020	0.156***	-0.004	-0.231***	0.121**	0.190***			
P-value	0.585	<.001	0.910	<.001	0.001	<.001			
(8) CEO age								1	
Pearson's r	-0.006	0.177***	0.055	-0.086*	0.076*	0.168***	0.261***		
P-value	0.876	<.001	0.143	0.021	0.040	<.001	<.001		
(9) ROI									1
Pearson's r	0.045	-0.761***	-0.043	0.945***	-0.645***	-0.706***	-0.235***	-0.105**	
P-value	0.230	<.001	0.244	<.001	<.001	<.001	<.001	0.005	

Panel C: Pearson and P-value Correlations for the Variables Used in the CEO Departure Model – Level1.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
(1) NGPs	1									
(2) Binary		1								
Pearson's r	0.068									
P-value	0.068									
(3) MV			1							
Pearson's r	-0.088*	-0.011								
P-value	0.019	0.761								
(4) Leverage										
Pearson's r	-0.128***	-0.052	0.671***	1						
P-value	<.001	0.164	<.001							
(5) Firm size										
Pearson's r	-0.135***	-0.078*	0.724***	-0.880***	1					
P-value	<.001	0.036	<.001	<.001						
(6) R&D										
Pearson's r	-0.151***	-0.698**	-0.135***	0.771***	0.786***	1				
P-value	<.001	<.001	<.001	<.001	<.001					
(7) Firm age							1			
Pearson's r	-0.020***	-0.080*	-0.121**	0.221***	0.171***	0.177***				
P-value	0.585	0.031	0.001	<.001	<.001	<.001				
(8) CEO age								1		
Pearson's r	0.006	-0.153***	0.076*	0.169***	0.195***	0.130***	0.261***			
P-value	0.876	<.001	0.040	<.001	<.001	<.001	<.001			
(9) ROE									1	
Pearson's r	0.134***	0.067	-0.761***	-0.775***	-0.795***	-0.695***	-0.148***	-0.088*		
P-value	<.001	0.070	<.001	<.001	<.001	<.001	<.001	0.017		
(10) ROA										1
Pearson's r	0.012	0.014	0.060	0.082*	-0.070	0.059	0.001	0.025	-0.062	
P-value	0.743	0.699	0.109	0.028	0.061	0.110	0.970	0.496	0.097	

Panel D: Pearson and P-value Correlations for the Variables Used in the R&D Investments Model – Level1.

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
(1) NGPs	1								
(2) ΔR&D		1							
Pearson's r	-0.146***								
P-value	<.001								
(3) MV			1						
Pearson's r	-0.088*	0.638***							
P-value	0.019	<.001							
(4) Leverage				1					
Pearson's r	-0.097**	0.722***	0.675***						
P-value	0.009	<.001	<.001						
(5) Firm age					1				
Pearson's r	-0.020	0.178***	0.121**	0.190***					
P-value	0.585	<.001	0.001	<.001					
(6) CEO age						1			
Pearson's r	-0.006	0.130***	0.076*	0.168***	0.261***				
P-value	0.876	<.001	0.040	<.001	<.001				
(7) ROI							1		
Pearson's r	0.045	-0.678***	-0.645***	-0.706***	-0.235***	-0.105**			
P-value	0.230	<.001	<.001	<.001	<.001	0.005			
(8) CashComp								1	
Pearson's r	-0.010***	-0.097**	0.087*	-0.043	-0.058	-0.082*	0.083*		
P-value	0.794	0.009	0.019	0.246	0.117	0.028	0.025		
(9) TotAtRisk									1
Pearson's r	-0.068	-0.037	0.049	0.023	-0.077*	-0.060	-0.021	0.599***	
P-value	0.067	0.318	0.189	0.533	0.037	0.108	0.577	<.001	

Note. All these variables are defined with more details in Table 3.

2.6.2 Pooled Regressions (Level 1):

2.6.2.1 The Impact of Failure in Innovation on CEO Compensation Package

Table 6 displays the results from estimating Equations 1–3 using the OLS regression. In the first column, we show the findings from estimating the model of change in CEO cash compensation, the dependent variable after the NGPs occurred, and control variables. The coefficient of -0.023 (with *p value* of 0.010) on *ΔCash.Comp* demonstrates that the change in CEO cash compensation is significantly higher after the firm receives unsuccessful patents than the year prior to NGPs, as expected in *H1*. We find that R&D is negatively and significantly associated with the change in the log of cash compensation (*p* 0.002). We also find that firm age is negatively associated with the change in the cash compensation (*p* 0.032). We find no significance in the coefficients for other control variables. Such strong negative result of NGPs on ΔCash.Comp in the presence of other variables shows that the change in CEO cash compensation could be driven by the effect of NGPs. The model has an adjusted R^2 of 0.038, with 723 firm-year observations. Finally, prior research often applied granted patents in a similar model and showed inconsistent outcomes with the change in CEO cash compensation. We, however, use NGPs to document these intriguing results.

We conduct separate tests of the two components of the cash compensation (salary and bonus) to determine which variable is more impacted by NGPs. To do so, we run the same model for both variables separately. The second column of Table 6 indicates the results from the modified version of Equation 1, regarding the change in salary. The coefficient of -0.029 (with a p value of <.001) on *Δsalary* demonstrates that the subsequent reduction in CEO salary is significantly higher in the following year NGP, as predicted in *H2*. We also find that R&D is negatively and significantly associated with the change in the CEO salary (*p* 0.007). The model has an adjusted R^2 of 0.044. The other control variables—MV, leverage, firm age, and CEO age—have insignificant coefficients.

The third column of Table 6 reports the results of regressing the change in bonus following the NGPs. The results display a coefficient of -0.336 (with a p value of <.001) on *Δbonus*, which is significantly higher than salary. This finding is consistent with the most results in the literature that the CEO's compensation will face a reduction in the subsequent bonus when they show poor performance. Since the bonus is based on performance, generating NGP may motivate firms to reduce their CEOs' bonuses. We also find that firm age is positively associated with the change in the bonus (with a *p* value of 0.002). This result, which is as we expected in *H3*, reveals that old firms have more experience dealing with CEO bonuses when they show unexpected outcomes. The model has an adjusted R^2 of 0.042. Overall, the evidence supports the argument that the reduction in subsequent CEO short-term incentives is linked to prior performance. Our contribution to these arguments, however, is that NGP is a significant factor that may "exclusively" drive such an influence on the CEO's short-term incentives.

Table 2.6 Regression Analyses of Changes in the CEO's Short-Term Compensation (Total Cash Comp, Salary, and Bonus) in the year following NGPs: Hypotheses 1, 2, 3 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**	
	Δ Cash.Com		**Δ Salary**		**Δ Bonus**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-0.023	0.010	-0.029	< .001	-0.336	< .001
MV	-0.018	0.498	-0.017	0.525	-0.007	0.820
Leverage	0.046	0.342	0.043	0.371	0.082	0.139
Firm Age	-0.155	0.032	-0.119	0.098	0.257	0.002
CEO Age	-0.011	0.197	-0.013	0.132	-0.011	0.256
R&D	-0.120	0.002	-0.103	0.007	0.027	0.550
Size	0.010	0.837	0.049	0.765	-0.006	0.917
Observations	723 FY		723 FY		723 FY	
Year Indicators	Yes		Yes		Yes	
Adjusted R^2	0.038		0.044		0.042	
Constant	-1.288		-1.459		-2.156	

Note: * p < .05, ** p < .01, *** p < .001

Table 7 shows the results from estimating Equations 4–7 using the modified version of the first equation. We explore the possibility of a negative relationship between NGPs at time *t* and potential changes in the CEO's long-term incentives (i.e., *ΔToAtRisk*). The first column of Table 7 indicates the coefficients on *ΔToAtRisk*, which measures the changes in the total long-term incentives. The model has an adjusted R^2 of 0.025, with 723 firm-year observations. The result is negative but not statistically significant with a coefficient of -0.158 (*p* 0.053). For the rest of the controls, we find that R&D and leverage are both negatively and significantly associated with the change in the *ΔToAtRisk* (*p* 0.046 and <.001).

The second column of Table 7 shows the best results (i.e., *ΔStock-based compensation*). The model has an adjusted R^2 of 0.063, and the results indicate a coefficient of -0.530 (with a *p* value of <.001) on *Δstock*, which is significantly lower than the stock-based incentives in the year before. This finding is based on the fact that stock-based compensation is more sensitive to risk (failures in our study) than other long-term incentive components. This result is consistent with *H5*. We also find that firm age is negatively and significantly associated with the change in the *Δstock* (*p* 0.037), while market value indicates a positive and significant result (*p* <.001).

The other two dependent variables in columns three and four of Table 7 (i.e., *ΔOptions* and *ΔLTIP*) show insignificant association with NGPs. Thus, we reject *H6* and *H7* because they are not in line with our expectations. Overall, the evidence on how innovation failures could negatively impact the CEO's long-term incentives remains surprisingly scant in the corporate finance literature. Although we find mixed results, we emphasize that NGPs have a significant impact on, at least, one component of the CEO's long-term compensation (i.e., stock-based compensation).

Table 2.7 Regression Analyses of Changes in the CEO's long-Term Compensation (Total at Risk, Stock, Option, and LTIP) in the year following NGPs: Hypotheses 4, 5, 6, 7 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**		**(3)**	
	ΔToAtRisk		**Δ Stock**		**Δ Options**		**Δ LTIP**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-0.158	0.053	-0.530	< .001	-0.142	0.157	0.016	0.872
MV	0.009	0.720	0.182	< .001	0.046	0.129	0.032	0.306
Leverage	0.092	0.046	-0.041	0.628	0.090	0.108	0.026	0.646
Firm Age	-0.131	0.060	-0.267	0.037	-0.041	0.626	0.014	0.869
CEO Age	-0.013	0.060	-0.006	0.664	-0.031	0.002	-0.016	0.113
R&D	-0.127	<.001	-0.131	0.055	-0.126	0.005	-0.097	0.030
Size	0.037	0.439	0.144	0.103	0.078	0.178	0.073	0.221
Observations	723 FY		723 FY		723 FY		705 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R^2	0.025		0.063		0.040		0.007	
Constant	-0.349		-10.905		-1.229		-1.310	

Note: * p < .05, ** p < .01, *** p < .001

To investigate whether the change in firm performance is associated with the firm's innovation failure, we run the second model, allowing the coefficients on performance to vary in the presence of the firm's NGP and other controls at time *t*. We measure the changes in the firm's performance by *ΔROA*, *ΔROE*, and *ΔROI*. The three columns of Table 8 report the results from Model 2. The model has an adjusted R^2 of 0.019, 0.777, and 0.588, respectively. The first column of Table 8 reports that the coefficient on *ΔROA*, which measures the change in a firm's return on assets, is negative and significant (-1.102 with a *p* value of 0.007). We also find that market value is negatively and significantly associated with the change in the *ΔROA* (*p* 0.004), while leverage indicates a positive and significant result (*p* 0.040).

In the second column of Table 8, we also find that the coefficient on *ΔROE*, which measures the change in a firm's return on equities, is strong negatively and significantly (-.558 with a *p* value of <.001). For the remaining control variables, the results show that market value, leverage, and CEO age have a positive and significant result with a *p* value of <.001. The firm age and ROI reveal a negative and significant result, with a *p* value of 0.020 and <.001, respectively. The third column of Table 8 indicates that the change in *ΔROI*, however, shows an insignificant coefficient in the year following NGPs. When we combine *ΔROI* with the other set of variables, the regression shows a significant negative result with a coefficient of -0.171 (and a *p*-value <.001).

All together, we find strong evidence supporting two of the three hypotheses—as we expected—which suggest that changes in firm performance, particularly *ΔROA* and *ΔROE*, are in response to firms' failure to innovate. As we previously stated, this is also consistent with the first model in the sense that a reduction in the CEO’s compensation in the post-NGP year negatively impacts the subsequent performance. The literature on firm performance frequently uses R&D output (i.e., granted patents) to evaluate the firm's performance. We focus on the missing factor in the literature, NGPs, to explore its potential effects on the subsequent performance. In sum, all these results are consistent with our hypotheses *H8*, *H9*, and *H10*.

2.6.2.2 The Impact of Failure in Innovative on Firm Performance

Table 2.8 Regression Analyses of Changes in Firm Performance (ROE, ROA, and ROI) in the year following NGPs: Hypotheses 8, 9, 10 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**	
	ΔROA		**ΔROE**		**Δ ROI**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-1.102	0.007	-0.558	< .001	0.042	0.596
MV	-0.363	0.004	0.231	< .001	-0.171	0.324
Leverage	0.316	0.040	0.388	< .001	-0.123	< .001
Firm Age	-0.328	0.351	-0.139	0.020	-0.195	< .001
CEO Age	0.052	0.202	0.025	< .001	0.007	0.182
ROI	-0.243	0.295	-0.434	< .001	0.263	<.001
Observations	723 FY		723 FY		723 FY	
Year Indicators	Yes		Yes		Yes	
Adjusted R^2	0.019		0.777		0.588	
Constant	1.263		-3.200		8.659	

Note: * p < .05, ** p < .01, *** p < .001

2.6.2.3 The Impact of Failure in Innovative on CEO Renewal Position

Table 2.9 Logistic Regression Analysis of the Relationship Between NGPs and CEO Departure: Hypothesis 11 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

CEO Departures - Binary

Model	**Deviance**	**AIC**	**BIC**	**df**	**X^2**	**p**	**McFadden R^2**	**Nagelkerke R^2**	**Tjur R^2**	**Cox & Snell R^2**
H_0	558.761	562.761	571.928	721						
H_1	530.102	550.248	596.082	713	28.513	< .001	0.051	0.072	0.046	0.039

Note. Null model contains nuisance parameters: l-NGP

An intriguing observation in our data prompts us to conduct additional tests. Using a logistic model, we begin by examining the relationship between CEO departures and our main independent variable, NGPs. We apply a binary variable, set to 1 if CEOs maintain their position in the post-NGP year and 0 otherwise. In short, the model summary above in Table 9 indicates that H_1 has an AIC (550.248) lower than H_0 (562.761) and the *p-value* less than .001, suggesting a significant relationship between the dependent (CEO leaving) and some independent variables, NGPs and controls.

Table 2.10 The relationship between the departure of the CEO and the NGPs Over 2001-2020.

Coefficients

					Wald Test		
	Estimate	Standard Error	Odds Ratio	z	Wald Statistic	df	p
(Intercept)	5.441	1.380	230.740	3.944	15.554	1	< .001
NGP	0.242	0.174	1.274	1.387	1.924	1	0.165
MV	0.062	0.041	1.064	1.539	2.370	1	0.124
Leverage	0.135	0.092	1.144	1.462	2.138	1	0.144
Size	-0.064	0.099	0.938	-0.641	0.411	1	0.522
R&D	-0.128	0.068	0.880	-1.890	3.571	1	0.059
Firm age	-0.143	0.131	0.867	-1.095	1.198	1	0.274
CEO age	-0.054	0.015	0.948	-3.568	12.732	1	< .001
ROE	0.063	0.057	1.065	1.091	1.190	1	0.275
ROA	0.007	0.014	1.007	0.504	0.254	1	0.615

Note. Binary level '1' coded as class 1.

The coefficient in Table 10 displays the interaction between CEO departure and NGPs, as well as a set of control variables. The p-value for R&D is not significant, indicating that the firm's investments have no impact on the CEO's departure. However, the CEO age variable shows a significant negative result with a p-value <.001, which can be interpreted as a motivation for CEOs to leave their positions. We previously stated that almost 24% of all firms' CEOs (i.e., 95 out of 401) left their positions the year following NGPs in our data set. Additionally, we noted that retirement accounted for 27% of CEO departures in the year following NGPs (i.e., 26/95), while resignation accounted for 70% (i.e., 67/95). The result of the CEO age reveals that even though resigning, which we interpreted as firing, was the primary reason for CEOs departures, it could be linked to their age, as the average age of all CEOs in our data set is 53, suggesting that these CEOs may opt for early retirement. Therefore, we reject the hypothesis (H11) that NGP has a negative impact on CEO departure. In short, we conclude that while innovation failure could be a contributing factor—especially given the long tenure of these CEOs and their high number of NGPs—it is obviously not the main reason innovation firms replace their CEOs. Or put it differently, failures in innovation may indirectly push CEOs to leave their positions as they show poor innovative performance over the long term (i.e., with a contract of at least three years). Thus, if more innovation firms, particularly those with a high number of NGPs, tend to replace their CEOs in the year following NGPs, our hypothesis of CEO departure could potentially be accepted.

Another test we conduct is whether the potential change in the firm's R&D has a negative relationship with NGPs. The fourth model we run allows the coefficients on R&D to vary in the presence of the firm's NGP and other controls at time *t*. The column below of Table 11 reports the results from Model 4. The model has an adjusted R^2 of 0.060. We find that the coefficient on *ΔR&D*, which measures the change in a firm's research and investments, is negative and significant (-0.543 with a p value of <.001). We also find that both market value and leverage are positively and significantly associated with the change in the *ΔR&D,* with a p <.001, while ROI indicates a negative and significant result (p <.001). Overall, these findings support the literature that the firm reduces its subsequent R&D following the negative outcomes in the past year. More specifically, the main result in this model suggests that a CEO who has engaged in innovation activities that ended in failure is likely to be discouraged from involving future investments in R&D.

2.6.2.4 The Impact of Failure in Innovative on R&D Investments

Table 2.11 Regression Analyses of Changes in R&D Investment in the year following NGPs: Hypothesis 12 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

	Δ R&D	
	Coefficient	*p-value*
NGPs	-0.543	< .001
MV	0.152	< .001
Leverage	0.346	< .001
Firm Age	0.016	0.828
CEO Age	0.006	0.525
ROI	-0.385	< .001
Cash.Comp	-0.002	0.968
TotEqtAtRisk	-0.110	0.029
Observations 723 FY		
Year indicators Yes		
Constant 4.184		
Adjusted R^2 0.60		

Note: * p < .05, ** p < .01, *** p < .001

Table 12 summarizes all the main results we show from our four different models. We present Pearson's results that clearly state a strong negative significant relationship between NGP and the changes in short-term CEO compensation, stock-based compensation, and firm performance (as measured by ROA and ROE), as well as R&D investment.

Table 2.12 Summarizes the Hypotheses' Testing Outcomes for all models in Level 1.

Hypothesis	Relationships	Pearson's r	Supported
H1	NGPs - Δ l-Salary	-0.123***	Yes
H2	NGPs - Δ l-Bonus	-0.126***	Yes
H3	NGPs - Δ l-Cash.Comp	-0.096*	Yes
H4	NGPs - Δ l-Stock	-0.128***	Yes
H5	NGPs - Δ l-Option	-0.053	No
H6	NGPs - Δ LTIPs	0.006	No
H7	NGPs - Δ l-TotAtRisk	-0.072	No
H8	NGPs - Δ l-r-ROA	-0.100**	Yes
H9	NGPs - Δ l-r-ROE	-0.142***	Yes
H10	NGPs - Δ l-r-ROI	0.020	No
H11	NGPs - CEO REN-POS	0.068	No
H12	NGPs - Δ l-R&D	-0.146***	Yes

2.6.3 Robustness – Level 2

At this stage, we use level two as a robustness for all our main results. Thus far, we have found in the first model that the changes in the CEO's short-term incentives have, jointly or separately, negative associations with NGPs. We use our entire database to run the models. In level 2, however, we exclude CEOs who left their position post-NGP year and only test three models (i.e., CEO compensation, firm performance, and R&D), as we are unable to analyze the relationship between NGPs and the departure of the CEOs, as we demonstrated in the first stage. This is due to the constraints in our dataset at this level, which solely comprises CEOs who held their positions one year prior to, during, and following the NGPs. These CEOs represent 87% of our total data on CEOs. Moreover, we argue that reappointed CEOs are fully accountable for the firm's patent applications from the moment they begin the filing process until the firm receives the USPTO examiner's final decision. In specific, because these CEOs remain in their positions for at least three years and show failure in innovation, such a result could have a strong negative effect on their short- and long-term incentives in the subsequent year. As a result, there may be a reduction in the firm's performance and R&D investment, an observable characteristic of firm innovation. The effect on the latter variable is particularly significant because it is the only input into the innovation process that is "entirely under managerial control." In other words, if CEO compensation packages decrease due to innovation failure, their motivation to invest in R&D is most likely to decrease.

Comparing the two summary tables for levels 1 and 2 (Table 12 and Table 17), we confirm the robustness of our main findings, and we show a strong result on short-term incentives from the first level to the second, with Pearson's -0.110** at level 2 compared to the Pearson's -0.096* at level 1. Even when we separately test salary and bonus, the results remain strong, with a Pearson's -0.138*** and -0.131*** at level 2 compared to the Pearson's -0.123*** and -0.126*** at level 1, respectively. For the long-term incentives, we demonstrate that stock-based incentives at level 2 indicate a statistically significant negative result, as indicated by Pearson's -0.121**. While the results at level 1, -0.128***, indicate a more favorable outcome, the model produces a robust result at level 2.

Then, we run the same model of firm performance, measured by RO, ROE, and ROI. Considering the results from the two summary tables for levels 1 and 2 (Table 12 and Table 17), we assert that our findings on ROA and ROE at level 1 are robust. In particular, ROA and ROE have Pearson's -0.109** and -0.128**, respectively, at level 2, compared to Pearson's -0.100** and -0.142*** at level 1. With regards to the R&D model, we also confirm the robustness of our findings at level 1, with a Pearson's -0.132*** at level 2 compared to the Pearson's -0.146*** at level 1. These results emphasize our expectations of a decline in the firm's R&D subsequent to the prior negative innovative outcomes.

2.6.3.1 The Impact of Failure in Innovative on CEO Compensation Package

Table 2.13 Regression Analyses of Changes in CEO Short-Term Compensation (Total Cash Comp, Salary, and Bonus) in the year following NGPs: Hypotheses 1, 2, 3 using the Sample of 628 Year-Observations with 1,823 Cases of NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**	
	Δ Cash.Com		**Δ Salary**		**Δ Bonus**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-0.025	0.006	-0.032	< .001	-0.352	< .001
MV	-0.018	0.498	-0.011	0.721	0.006	0.872
Leverage	0.046	0.342	0.053	0.327	0.102	0.101
Firm Age	-0.155	0.032	-0.126	0.113	0.252	0.006
CEO Age	-0.011	0.197	-0.011	0.230	-0.008	0.443
R&D	-0.120	0.002	-0.110	0.009	-0.006	0.894
Size	0.010	0.837	-0.012	0.833	-0.008	0.905
Observations	628 FY		628 FY		628 FY	
Year Indicators	Yes		Yes		Yes	
Adjusted R^2	0.034		0.041		0.042	
Constant	-1.219		-1.397		-2.148	

Note: * p < .05, ** p < .01, *** p < .001

Table 2.14 Regression Analyses of Changes in CEO long-Term Compensation (Total at Risk, Stock, Option, and LTIP) in the year following NGPs: Hypotheses 4, 5, 6, 7 using the Full Sample of 628 Year-Observations with 1,823 Cases of NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**		**(3)**	
	ΔToAtRisk		**Δ Stock**		**Δ Options**		**Δ LTIP**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-0.158	0.081	-0.513	0.002	-0.112	0.301	0.053	0.611
MV	0.033	0.669	0.230	< .001	0.046	0.203	0.035	0.327
Leverage	0.109	0.040	-0.069	0.473	0.121	0.055	0.057	0.382
Firm Age	-0.147	0.059	-0.313	0.028	-0.089	0.337	-0.037	0.692
CEO Age	-0.013	0.173	-0.002	0.904	-0.031	0.005	-0.016	0.150
R&D	-0.131	0.002	-0.128	0.089	-0.148	0.003	-0.105	0.030
Size	0.034	0.538	0.146	0.151	0.068	0.302	0.063	0.352
Observations	628 FY		628 FY		628 FY		611 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R^2	0.024		0.072		0.042		0.011	
Constant	-0.320		-10.851		-1.236		-1.300	

Note: * p < .05, ** p < .01, *** p < .001

2.6.3.2 The Impact of Failure in Innovative on Firm Performance

Table 2.15 Regression Analyses of Changes in Firm Performance (ROE, ROA, and ROI) in the year following NGPs: Hypotheses 8, 9, 10 using the Full Sample of 628 Year-Observations with 1,823 Cases of Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**	
	Δ ROA		**Δ ROE**		**Δ ROI**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-1.188	0.006	-0.495	< .001	0.016	0.847
MV	-0.492	< .001	0.276	< .001	-0.023	0.266
Leverage	0.451	0.006	0.377	< .001	-0.129	< .001
Firm Age	-0.272	0.469	-0.143	0.024	-0.199	< .001
CEO Age	0.048	0.271	0.030	< .001	0.005	0.363
ROI	-0.399	0.119	-0.378	< .001	0.759	<.001
Observations	628 FY		628 FY		628 FY	
Year Indicators	Yes		Yes		Yes	
Adjusted R^2	0.033		0.781		0.887	
Constant	1.406		-3.299		8.695	

Note: * p < .05, ** p < .01, *** p < .001

2.6.3.3 The Impact of Failure in Innovative on R&D Investments

Table 2.16 Regression Analyses of Changes in R&D Investments in the year following NGPs: Hypothesis 11 using the Full Sample of 628 Year-Observations with 1,823 Cases of NGPs Over 2001-2020.

	Δ R&D	
	Coefficient	*p-value*
NGPs	-0.486	< .001
MV	0.198	< .001
Leverage	0.349	< .001
Firm Age	0.015	0.853
CEO Age	0.011	0.223
ROI	-0.315	< .001
Cash.Comp	-0.001	0.979
TotEqtAtRisk	-0.086	0.100
Observations 628 FY		
Year indicators Yes		
Constant 4.057		
Adjusted R^2 0.60		

Note: * p < .05, ** p < .01, *** p < .001

Table 2.17 Summarizes the Hypotheses' Testing Outcomes for all models in Level 2.

Hypothesis	Relationships	Pearson's r	Supported
H1	NGPs - Δ l-Salary	-0.138***	Yes
H2	NGPs - Δ l-Bonus	-0.131***	Yes
H3	NGPs - Δ l-Cash.Comp	-0.110**	Yes
H4	NGPs - Δ l-Stock	-0.121**	Yes
H5	NGPs - Δ l-Option	-0.041	No
H6	NGPs - Δ LTIPs	0.021	No
H7	NGPs - Δ l-TotAtRisk	-0.070	No
H8	NGPs - Δ l-r-ROA	-0.109**	Yes
H9	NGPs - Δ l-r-ROE	-0.128**	Yes
H10	NGPs - Δ l-r-ROI	0.008	No
H11	NGPs - Δ l-R&D	-0.132***	Yes

2.7 Conclusion:

This paper sheds light on the relationship between failure in innovation, as measured by NGPs, CEO compensation packages, firm performance, and other additional tests. Compensation packages serve as an instrument to motivate CEOs to achieve high performance. On the one hand, CEOs may engage in a reckless shopping spree to build an empire without penalty for poor performance. On the other hand, if the penalty is severe, CEOs will be reluctant to extend the firm's investment in innovation, which is long-term, unpredictable, idiosyncratic, and involves a high probability of failure. To strike a balance between investing in innovation projects and risk aversion, our study suggests that firms might need to design optimal incentive packages that are more tolerant to CEOs who experience failures in innovation.

Using a USPTO sample, we, first, find that there is a significant reduction post-NGPs year in CEO's short-term incentives (jointly and separately) and stock-based compensation. Such reduction results in a negative and significant correlation with NGPs. We do not, however, find a decline in the other components of the CEO's long-term incentives (i.e., options and LTIP) response to non-granted patents, which suggests that firms only tolerate some long-term components for CEOs—with the expectation that it may enhance their performance in the long run to be more innovative—but not the short-term components. Second, we find that the changes in subsequent firm performance, as measured by ΔROA and ΔROE, have a significant negative correlation with the NGPs. We also use the firm’s return on investments (ΔROI) to measure the firm’s changes in ROI, but we do not observe any correlation between NGPs and ΔROI.

Furthermore, we set up two additional empirical models to investigate (1) the relationship between CEO departure and (2) R&D investments with innovation failure. The results indicate that the changes in R&D (ΔR&D) are negatively and statistically significant in response to NGPs. This finding indicates that CEOs tend to sharply reduce the firm’s subsequent investment in R&D, particularly when they face failures in obtaining patents. Although we observe that almost 24% of CEOs in our entire sample left their positions in the following year of NGPs, the CEO departure model does not reflect any significant correlation with NGPs, suggesting that failure in innovation is not the main cause of the CEO departure. We argue that if more innovation firms, particularly those with a high number of NGPs, tend to replace their CEOs in the year following NGPs, our hypothesis of CEO departure could potentially be accepted.

All in all, these findings reveal that CEO compensation and firm performance are significantly linked when the firm faces failure in innovation. These results are asserted in both levels 1 and 2. We contribute to the stream of literature on CEO compensation and corporate innovation activity, especially on the role of ‘‘failures in innovation’’. We also contribute to the stream of literature that examines the relationship between corporate innovation and firm performance.

2.8 Endnotes:

[1] See 35 USC 102 "Conditions for patentability; Novelty; Prior Art https://www.uspto.gov/web/offices/pac/mpep/s2152.html https://www.uspto.gov/patents/laws/american-inventors-protection-act-1999/helpful-hints-regarding

[2] Strictly speaking, the USPTO never officially rejects patent applications; rather, they are abandoned by applicants who still have the option to appeal them (see the discussion in Lemley and Sampat 2008). These scholars have collected 2,724 rejected patents. For the sake of clarity, we follow (Sampat et al., 2019; Farre-Mensa et al., 2020) and refer to such abandoned applications as rejected. We provide more information in section 4.

[3] Although we include a comprehensive set of control variables, the result of the logistic model remains unchanged. We emphasize that the possibility does not exist that NGPs affect the CEOs departure in our current sample data.

[4] In this figure, we show the potential impact of our major independent variable, NGPs, on three groups of dependent variables (short- and-long-term incentives and firm performance, as well as other additional variables, R&D and CEO departure).

2.9 Appendix A:

Table 1: Variable Definitions

Variables	Description
Dependent Variables	
Δ Cash.Comp	natural logarithm for the sum of CEO's salary and bonus.
Δ Salary	natural logarithm for the CEO's salary
Δ Bonus	natural logarithm for CEO's *bonus*
Δ TotAtRisk	natural logarithm of the CEO's total compensation at risk (i.e., the sum of stock, option, and LTIP).
Δ Stock	natural logarithm of the CEO's stock-based compensation
Δ Option	natural logarithm of the CEO's option-based compensation
Δ LTIPs	natural logarithm of the CEO's long-term incentive payment (i.e., restricted stocks + unvested option).
Δ TST&TOP	natural logarithm of the total stock and options
Δ LT&ST	natural logarithm of the total long-term incentive (i.e., LTIP) + short-term incentive (i.e., bonus).
Δ Others	natural logarithm of the other compensation of CEO's as a fraction of the CEO's total remuneration
Δ CEO Total.Rem	natural logarithm of the CEO's total remuneration (i.e., the sum of Cash.Comp + TotAtRisk)
Δ ROA	natural logarithm of the return on assets divided by total assets
Δ ROE	natural logarithm of the return on equities divided by total equities
Δ ROI	natural logarithm of the return on investments divided by total invested capital x 100.
Δ ROS	natural logarithm of the return on assets scaled by total assets
Δ R&D	natural logarithm of the change in research and development
Independent Variables	
NGPs	Patent applications that are submitted to the USPTO and ultimately rejected by USPTO examiners
CEO age	the age of the CEO of a firm
CEO tenure (years)	the number of years the CEOs have been in the chief executive position at the current firm
CEO gender (%)	male or female sex scaled by percentage.
Leverage	natural logarithm of the total debt to total assets.
Size	natural logarithm of a firm's book total assets.
Firm Age	natural logarithm of the number of years since the IPO date
MV	the annual close price x the total number of outstanding shares.
R&D	natural logarithm in research and development at time *t*.

2.10 Appendix B. Additional Analyses - Level 1

Descriptive Statistics – Level 1. This table displays summary statistics for the key variables for a sample of all 256 US firms from 2000 to 2020 consist of 723 firm-year observations. For each variable, the mean, median, standard deviation, and number of year-observations are also displayed in the table. The CEO compensation-related variables are reported in US dollars (000s).

Variables	Number	Mean	Median	Standard Deviation
***Panel A:* Failure in Innovative**				
NGPs	723 Y-Obs	0.445	1.000	0.778
***Panel B:* CEO Compensation Package**				
Sohrt-Term Components: **($ thousands)**				
Δ Cash.Comp	723 Y-Obs	-1.351	-1.252	1.790
Δ Salary	723 Y-Obs	-1.540	-1.456	1.792
Δ Bonus	723 Y-Obs	-2.306	-2.853	2.081
Long-Term Components: **($ thousands)**				
Δ TotAtRisk	723 Y-Obs	-0.420	-0.360	1.711
Δ Stock	723 Y-Obs	-11.141	-11.453	3.216
Δ Option	723 Y-Obs	-1.292	-1.336	2.094
Δ LTIPs	705 Y-Obs	-1.303	-1.357	2.027
Δ TST&TOP	723 Y-Obs	9.569	9.692	2.017
Δ LT&ST	713 Y-Obs	9.830	9.783	1.688
Δ Others	642 Y-Obs	7.996	8.748	2.885
Δ CEO Total.Rem	723 Y-Obs	10.857	10.983	2.109
***Panel C:* Firm Performance**				
Δ ROA	723 Y-Obs	0.773	0.013	8.605
Δ ROE	723 Y-Obs	-3.449	-3.279	3.055
Δ ROI	723 Y-Obs	8.678	9.435	1.659
Δ ROS	723 Y-Obs	10.300	10.259	3.274
***Panel D:* CEO Characteristics**				
CEO age	723 Y-Obs	52.733	53.000	8.203
CEO tenure (years)	723 Y-Obs	2.869	3.000	0.338
CEO gender (%)	723 Y-Obs	0.100	0.100	0.000
CEO stays one year after NGPs – binary	723 Y-Obs	0.869	1.000	0.338
***Panel E:* Firm Characteristics**				
Δ R&D	723 Y-Obs	3.942	4.205	2.889
Leverage	723 Y-Obs	- 4.338	- 4.258	3.034
Size	723 Y-Obs	6.324	6.369	3.193
Firm Age	723 Y-Obs	2.533	2.708	0.959
MV	723 Y-Obs	13.347	13.726	3.667
R&D	723 Y-Obs	3.916	4.130	2.869

Note: Variable Definitions: *NGPs* = patent applications that are submitted to the USPTO and ultimately rejected by USPTO examiners. *Cash.Comp$* = natural logarithm for the sum of CEO's salary and bonus. *Salary$*= natural logarithm for the CEO's salary. *Bonus* = natural logarithm for CEO's *bonus$*. *TotAtRisk$* = natural logarithm of the CEO's total compensation at risk (i.e., the sum of stock, option, and LTIP). *Stock$* = natural logarithm of the CEO's stock-based compensation. *Option$* = natural logarithm of the CEO's option-based compensation. *LTIPs$* = natural logarithm of the CEO's long-term incentive payment (i.e., restricted stocks + unvested option). *TST&TOP$* = natural logarithm of the total stock and options. *LT&ST$* = natural logarithm of the total long-term incentive (i.e., LTIP) + short-term incentive (i.e., bonus). *Others$* = natural logarithm of the other compensation of CEO's as a fraction of the CEO's total remuneration. *CEO Total.Rem$* = natural logarithm of the CEO's total remuneration (i.e., the sum of Cash.Comp + TotAtRisk). *ROA* = natural logarithm of the return on assets divided by total assets. *ROE* = natural logarithm of the return on equities divided by total equities. *ROI* = natural logarithm of the return on investments divided by total invested capital x 100. *ROS* = natural logarithm of the return on assets scaled by total assets. *CEO age* = the age of the CEO of a firm. *CEO tenure* = the number of years the CEOs have been in the chief executive position at the current firm. *CEO gender* = male or female sex scaled by percentage. *R&D* = natural logarithm of the change in research and development. *Leverage* = natural logarithm of the total debt to total assets. *Size* = natural logarithm of a firm's book total assets. Firm age = natural logarithm of the number of years since the IPO date. *MV* = the annual close price x the total number of outstanding shares. R&D = natural logarithm in research and development at time *t*. Results using total stock and option, long-and-short-term incentives, other payments, and total CEO remuneration as dependent variables indicate a positive or insignificant correlation with NGPs. These results are not reported for brevity. We also separately computed total stock and option (TST+TOP), long and short incentives (LT+ST), and other CEO's compensations as dependent variables. NGPs, however, have insignificant effects on each of these variables.

The Impact of Failure in Innovative on CEO Compensation Package - Level 1

Further Hypotheses and Models:

Hypotheses:

Δ l-TST&TOP:

H13: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total stocks and options at time (t+1)*

Δ l-LT&ST:

H14: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total long-term and short-term incentives at time (t+1)*

Δ l-Other Comp:

H15: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO's other incentives at time (t+1)*

Δ l-CEO TotRem:

H16: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total remuneration at time (t+1)*

Models:

Δ l-TST&TOP:

$\Delta\log\text{- TST\&TOP}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t}$

Δ l-LT&ST:

$\Delta\log\text{- LT\&ST}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t}$

Δ l-Other.Comp:

$\Delta\log\text{- Other.Comp}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t}$

Δ l-CEO. TotRem:

$\Delta\log\text{- CEO.TotRem}_{i,\,t+1} = \beta_0 + \beta_1\, \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\, \textit{F-Size}_{i,\,t} + \beta_3\, \textit{R\&D}_{i,\,t} + \beta_4\, \textit{F-Age}_{i,\,t} + \beta_5\, \textit{Leverage}_{i,\,t} + \beta_6\, \textit{CEO-age}_{i,\,t} + \beta_7\, \textit{MV}_{i,\,t} + \varepsilon_{i,\,t}$

Regression Analyses of Changes in CEO Compensations (Stock & Option, Long-and-Short-Term Comp, Others, and Total CEO Remuneration) in the year following NGPs: Hypotheses 13, 14, 15, and 16 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

IND-V	(1) ΔTST&TOP		(2) Δ LT&ST		(3) Δ Other		(3) Δ Tot.Rem	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	0.233	0.016	0.391	< .001	-0.024	0.092	0.384	< .001
MV	-0.091	0.002	-0.141	< .001	-0.140	0.001	-0.143	< .001
Leverage	0.142	0.008	0.042	0.351	0.104	0.211	0.056	0.308
Firm Age	0.170	0.037	0.212	0.001	-0.450	< .001	0.227	0.006
CEO Age	-0.032	<.001	-0.018	0.019	0.003	0.854	-0.003	0.741
R&D	-0.029	0.499	-0.024	0.496	-0.052	0.457	0.103	0.019
Size	-0.059	0.287	0.026	0.587	-0.183	0.046	-0.136	0.017
Observations	723 FY		713 FY		642 FY		723 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R^2	0.041		0.101		0.124		0.095	
Constant	9.466		9.654		8.066		10.686	

Note: * p < .05, ** p < .01, *** p < .001

We noted that when we combine the third variable, other compensation, with the other set of controls, the regression shows a significant negative result, with a *coefficient* of -0.028 and a *p-value* of 0.037.

The Impact of Failure in Innovative on Firm Performance

Hypothesis:

ROS:

H17: *The firm's number of NGPs at time (t) is negatively related to the change that occurred in the firm's performance, represented by return on sale ROS, at time (t+1)*

Model:

$\Delta\text{log-ROS}_{i,\,t+1} = \beta_0 + \beta_1\ \textit{Innovation Failures}_{i,\,t}\{\textit{NGPs}_{(i,\,t-3)}\} + \beta_2\ \textit{ROI}_{i,\,t} + \beta_3 \textit{F-Age}_{i,\,t} + \beta_4\ \textit{Leverage}_{i,\,t} + \beta_5\ \textit{CEO-age}_{i,\,t} + \beta_6\ \textit{MV}_{i,\,t} + \varepsilon_{i,\,t}$

Regression Analyses of Changes in Firm Performance (ROE, ROA, ROI, ROS) in the year following NGPs: Hypotheses 8, 9, 10, 17 using the Full Sample of 723 Year-Observations with 2,003 NGPs Over 2001-2020.

IND-V	**(1)**		**(2)**		**(3)**		(4)	
	Δ ROA		**ΔROE**		**Δ ROI**		**Δ ROS**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-1.102	0.007	-0.558	< .001	0.042	0.596	0.430	0.006
MV	-0.363	0.004	0.231	< .001	-0.171	0.324	-0.093	< .001
Leverage	0.316	0.040	0.388	< .001	-0.123	< .001	-0.335	< .001
Firm Age	-0.328	0.351	-0.139	0.020	-0.195	< .001	0.124	0.080
CEO Age	0.052	0.202	0.025	< .001	0.007	0.182	-0.054	< .001
ROI	-0.243	0.295	-0.434	< .001	0.263	<.001	0.763	<.001
Observations	723 FY		723 FY		723 FY		723 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R^2	0.019		0.777		0.588		0.727	
Constant	1.263		-3.200		8.659		10.108	

Note: * p < .05, ** p < .01, *** p < .001

Table 18 **Summarizes the Hypotheses' Testing Outcomes in Level 1.**

Hypothesis	Relationships	Pearson's r	Supported
H13	NGPs - Δ l-LT&ST	0.181***	No
H14	NGPs - Δ l-TST&TOP	0.090*	No
H15	NGPs - Δ l-Other Comp	-0.066	No
H16	NGPs - Δ l-CEO TotRem	0.142***	No
H17	NGPs - Δ l-ROS	0.102**	No

2.11 Appendix B. Additional Analyses - Level 2

Descriptive Statistics – Level 2. This table displays summary statistics for the key variables for a sample of all 256 US firms from 2000 to 2020 consist of 628 firm-year observations. For each variable, the mean, median, standard deviation, and number of year-observations are also displayed in the table. The CEO compensation-related variables are reported in US dollars (000s). The description of all variables is given in Appendix A. We also consider subsample data of level 2 in Appendix B-Level 2. Data source: Own calculation based on BoardEx database.

Variables	Number	Mean	Median	Standard Deviation
***Panel A:* Failure in Innovative**				
NGPs	628 Y-Obs	0.466	0.000	0.796
***Panel B:* CEO Compensation Package**				
Sohrt-Term Components: **($ thousands)**	628 Y-Obs			
Δ Cash.Comp		-1.293	-1.226	1.850
Δ Salary	628 Y-Obs	-1.490	-1.444	1.854
Δ Bonus	628 Y-Obs	-2.312	-2.895	2.135
Long-Term Components: **($ thousands)**				
Δ Total equity at risk	628 Y-Obs	-0.394	-0.363	1.803
Δ Stocks	628 Y-Obs	-11.091	-11.387	3.368
Δ Option	628 Y-Obs	-1.289	-1.355	2.167
Δ LTIPs	611 Y-Obs	-1.275	-1.337	2.080
Δ TST&TOP	628 Y-Obs	9.543	9.676	2.038
Δ Long and Short Incentives	619 Y-Obs	9.827	9.717	1.676
Δ Others	559 Y-Obs	7.982	8.724	2.931
Δ Total CEO compensations	628 Y-Obs	10.827	10.880	2.155
***Panel C:* Firm Performance**				
Δ ROA	628 Y-Obs	0.852	0.013	8.675
Δ ROE	628 Y-Obs	-3.530	-3.500	3.084
Δ ROI	628 Y-Obs	8.702	9.472	1.675
Δ ROS	628 Y-Obs	10.414	10.407	3.307
CEO Characteristics				
CEO age	628 Y-Obs	52.247	53.000	8.178
CEO tenure (years)	628 Y-Obs	3.000	3.000	0.000
CEO male (%)	628 Y-Obs	0.100	0.100	0.000
CEO stays one year after NGPs – binary	628 Y-Obs	0.100	0.100	0.000
Firm Characteristics				
Δ R&D	628 Y-Obs	3.831	4.064	2.931
Leverage	628 Y-Obs	-4.399	-4.505	3.050
Size	628 Y-Obs	6.227	6.072	3.198
Firm Age	628 Y-Obs	2.503	2.708	0.969
MV	628 Y-Obs	13.331	13.622	3.623
R&D	628 Y-Obs	3.802	3.928	2.910

Note: Variable Definitions: *NGPs* = patent applications that are submitted to the USPTO and ultimately rejected by USPTO examiners. *Cash.Comp$* = natural logarithm for the sum of CEO's salary and bonus. *Salary$*= natural logarithm for the CEO's salary. *Bonus* = natural logarithm for CEO's *bonus$*. *TotAtRisk$* = natural logarithm of the CEO's total compensation at risk (i.e., the sum of stock, option, and LTIP). *Stock$* = natural logarithm of the CEO's stock-based compensation. *Option$* = natural logarithm of the CEO's option-based compensation. *LTIPs$* = natural logarithm of the CEO's long-term incentive payment (i.e., restricted stocks + unvested option). *TST&TOP$* = natural logarithm of the total stock and options. *LT&ST$* = natural logarithm of the total long-term incentive (i.e., LTIP) + short-term incentive (i.e., bonus). *Others$* = natural logarithm of the other compensation of CEO's as a fraction of the CEO's total remuneration. *CEO Total.Rem$* = natural logarithm of the CEO's total remuneration (i.e., the sum of Cash.Comp + TotAtRisk). *ROA* = natural logarithm of the return on assets divided by total assets. *ROE* = natural logarithm of the return on equities divided by total equities. *ROI* = natural logarithm of the return on investments divided by total invested capital x 100. *ROS* = natural logarithm of the return on assets scaled by total assets. *CEO age* = the age of the CEO of a firm. *CEO tenure* = the number of years the CEOs have been in the chief executive position at the current firm. *CEO gender* = male or female sex scaled by percentage. *R&D* = natural logarithm of the change in research and development. *Leverage* = natural logarithm of the total debt to total assets. *Size* = natural logarithm of a firm's book total assets. Firm age = natural logarithm of the number of years since the IPO date. *MV* = the annual close price x the total number of outstanding shares. R&D = natural logarithm in research and development at time *t*. Results using total stock and option, long-and-short-term incentives, other payments, and total CEO remuneration as dependent variables indicate a positive or insignificant correlation with NGPs. These results are not reported for brevity. We also separately computed total stock and option (TST+TOP), long and short incentives (LT+ST), and other CEO's compensations as dependent variables. NGPs, however, have insignificant effects on each of these variables.

The Impact of Failure in Innovative on CEO Compensation Package - Level 2

Further Hypotheses and Models:

Hypotheses:

Δ l-LT&ST:

H13: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total long-term and short-term incentives at time (t+1)*

Δ l-TST&TOP:

H14: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total stocks and options at time (t+1)*

Δ l-Other Comp:

H15*: The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO's other incentives at time (t+1)*

Δ l-CEO TotRem:

H16: *The firm's number of non-granted patents at time (t) is negatively related to the change that occurred in the CEO total remuneration at time (t+1)*

Models:

Δ l-LT&ST:

Δlog- LT&ST$_{i,\,t+1}$ $= \beta_0 + \beta_1$ *Innovation Failures*$_{i,\,t}$ $\{NGPs_{(i,\,t-3)}\}$ $+ \beta_2$ *F-Size*$_{i,\,t}$ $+ \beta_3$ *R&D*$_{i,\,t}$ $+ \beta_4$ *F-Age*$_{i,\,t}$ $+ \beta_5$ *Leverage*$_{i,\,t}$ $+ \beta_6$ *CEO-age*$_{i,\,t}$ $+ \beta_7$ *MV*$_{i,\,t}$ $+ \varepsilon_{i,\,t}$

Δ l-TST&TOP:

Δlog- TST&TOP$_{i,\,t+1}$ $= \beta_0 + \beta_1$ *Innovation Failures*$_{i,\,t}$ $\{NGPs_{(i,\,t-3)}\}$ $+ \beta_2$ *F-Size*$_{i,\,t}$ $+ \beta_3$ *R&D*$_{i,\,t}$ $+ \beta_4$ *F-Age*$_{i,\,t}$ $+ \beta_5$ *Leverage*$_{i,\,t}$ $+ \beta_6$ *CEO-age*$_{i,\,t}$ $+ \beta_7$ *MV*$_{i,\,t}$ $+ \varepsilon_{i,\,t}$

Δ l-Other.Comp:

Δlog- Other.Comp$_{i,\,t+1}$ $= \beta_0 + \beta_1$ *Innovation Failures*$_{i,\,t}$ $\{NGPs_{(i,\,t-3)}\}$ $+ \beta_2$ *F-Size*$_{i,\,t}$ $+ \beta_3$ *R&D*$_{i,\,t}$ $+ \beta_4$ *F-Age*$_{i,\,t}$ $+ \beta_5$ *Leverage*$_{i,\,t}$ $+ \beta_6$ *CEO-age*$_{i,\,t}$ $+ \beta_7$ *MV*$_{i,\,t}$ $+ \varepsilon_{i,\,t}$

Δ l-CEO. TotRem:

Δlog- CEO.TotRem$_{i,\,t+1}$ $= \beta_0 + \beta_1$ *Innovation Failures*$_{i,\,t}$ $\{NGPs_{(i,\,t-3)}\}$ $+ \beta_2$ *F-Size*$_{i,\,t}$ $+ \beta_3$ *R&D*$_{i,\,t}$ $+ \beta_4$ *F-Age*$_{i,\,t}$ $+ \beta_5$ *Leverage*$_{i,\,t}$ $+ \beta_6$ *CEO-age*$_{i,\,t}$ $+ \beta_7$ *MV*$_{i,\,t}$ $+ \varepsilon_{i,\,t}$

Regression Analyses of Changes in CEO Compensations (Total CEO Rem, Stock & Option, Long-and-Short-Term Comp, Others) in the year following NGPs: Hypotheses 13, 14, 15, and 16 the Full Sample of 628 Year-Observations with 1,823 Cases of Over 2001-2020.

IND-V	(1)		(2)		(3)		(3)	
	ΔTST&TOP		**Δ LT&ST**		**Δ Other**		**Δ Tot.Rem**	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	0.234	0.022	0.397	< .001	-0.025	0.082	0.357	< .001
MV	-0.129	< .001	-0.150	< .001	-0.227	< .001	-0.184	< .001
Leverage	0.205	< .001	0.092	0.058	0.095	0.308	0.087	0.151
Firm Age	0.156	0.070	0.208	0.003	-0.370	0.003	0.263	0.003
CEO Age	-0.035	<.001	-0.023	0.005	-0.013	0.386	-0.003	0.785
R&D	-0.061	0.183	-0.041	0.267	-0.014	0.846	0.095	0.043
Size	-0.078	0.206	-0.006	0.900	-0.153	0.139	-0.142	0.025
Observations	628 FY		619 FY		559 FY		628 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R²	0.068		0.121		0.155		0.119	
Constant	9.433		9.640		8.059		10.661	

Note: * p < .05, ** p < .01, *** p < .001

The Impact of Failure in Innovative on Firm Performance

Hypothesis:

ROS:

H15: *The firm's number of NGPs at time (t) is negatively related to the change that occurred in the firm's performance, represented by return on sale ROS, at time (t+1)*

Model:

$\Delta \text{log-ROS}_{i,\,t+1} = \beta_0 + \beta_1\ \textit{Innovation Failures}_{i,\,t}\,\{NGPs_{(i,\,t-3)}\} + \beta_2\ ROI_{i,\,t} + \beta_3 \textit{F-Age}_{i,\,t} + \beta_4\ \textit{Leverage}_{i,\,t} + \beta_5\ \textit{CEO-age}_{i,\,t} + \beta_6\, MV_{i,\,t} + \varepsilon_{i,\,t}$

Regression Analyses of Changes in Firm Performance (ROE, ROA, ROI, and ROS) in the year following NGPs: Hypotheses 8, 9, 10, 17 using the Full Sample of 628 Year-Observations with 1,823 Cases of Over 2001-2020.

IND-V	(1) Δ ROA		(2) ΔROE		(3) Δ ROI		(4) Δ ROS	
	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*	Coefficient	*P-value*
NGP	-1.188	0.006	-0.495	< .001	0.016	0.847	0.374	0.024
MV	-0.492	< .001	0.276	< .001	-0.023	0.266	-0.127	< .001
Leverage	0.451	0.006	0.377	< .001	-0.129	< .001	-0.346	< .001
Firm Age	-0.272	0.469	-0.143	0.024	-0.199	< .001	0.135	0.071
CEO Age	0.048	0.271	0.030	< .001	0.005	0.363	-0.061	< .001
ROI	-0.399	0.119	-0.378	< .001	0.759	<.001	0.704	<.001
Observations	628 FY		628 FY		628 FY		628 FY	
Year Indicators	Yes		Yes		Yes		Yes	
Adjusted R^2	0.033		0.781		0.887		0.736	
Constant	1.406		-3.299		8.695		10.240	

Note: * p < .05, ** p < .01, *** p < .001

Table 18 Summarizes the Hypotheses' Testing Outcomes in Level 2.

Hypothesis	Relationships	Pearson's r	Supported
H13	NGPs - Δ l-CEO TotRem	0.132***	No
H14	NGPs - Δ l-LT&ST	0.189***	No
H15	NGPs - Δ l-TST&TOP	0.092*	No
H16	NGPs - Δ l-Other Comp	-0.074	No
H17	NGPs - Δ l-ROS	0.090*	No

CHAPTER 3

CORPORATE INNOVATION, MACROECONOMIC RISK, AND STOCK RETURNS

3.1 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. Firms that have a low exposure to short-run macroeconomic risk invest intensively in R&D activities because there is a low probability of losing a large proportion of their investments in the near future; this makes future profit highly positively correlated to long-run macroeconomic risk and, so have higher returns. We further develop portfolios by ranking firms by their level of innovation and find a positive and weak relationship between patents awarded and stock returns. Yet, when sorted on both R&D and patents, we obtain that the positive relationship between R&D and returns is concentrated among firms that produce more patents. To understand the mechanisms behind this latter result, we determined the level of exposure of each portfolio to the two sources of risk and found that these returns' patterns strongly correlated with exposure to long-run macroeconomic risk.

Keywords: Corporate Innovation Investment, Patenting Activities, R&D, Risk Cycle, Risk Exposure, Long Run Risks, Short Run Risks, Risk Premium, Stock Returns, U.S

3.2 Introduction

Do firms that innovate have higher returns? Do firms that innovate have higher exposure to Long-Run Risk?

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 should be the main driver of equity risk premium". However, recent studies suggest that long run systematic risk are capturing most of the equity risk premium (Bansal, at al., 2004). Long-run risk represents, on average, 81.6% of equity risk premium in periods of economic downturns (Dorion et. al., 2020). 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 long-run as well as short-run risk. In particular, we examine whether some firms are more exposed to long-run risk than others are; if so, what are the firm-level characteristics that explain exposure differences. We argue that some firms persistently exhibit greater exposure to long-run risk, while others present greater exposure to short-run risk.

Innovation inputs (e.g., R&D projects) are risky because they could fail, particularly with the presence of strong rivals that could win the innovation race (Gu, L. 2016). However, when innovation activities lead to innovation output (e.g., patents), the risk of the firm is shifted to non-innovator rivals in the industry (Chun et al., 2008), and thus, innovation output leads 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 will be persistent (low or high) as they continuously (frequently) engage in successful innovation activities. Hence, the risk of non-innovators (or infrequent innovators) should be high, while the risk of frequent innovators should be low. More specifically, continuous innovators should exhibit greater exposure to LRR while non-innovators (or infrequent innovators) should have greater exposure to SRR. Furthermore, the premium on innovators LRR should be low while the premium on non-innovators LRR should be high (because future uncertainties are high). Premiums on innovators SRR could be high or low, but those on non-innovators SRR will be high.

In this paper, we extend the literature by investigating the relationship between the firm's innovation inputs (i.e., R&D investments), the firm's innovation outputs (i.e., patents granted), and stock returns. To understand this relationship, we first apply two important factors that are missing in the literature: consumption growth-short-run risk (SRR) and expected economic conditions-long-run risk (LRR). We first examine the relationship between R&D expenditures and 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. Using four datasets, including the USPTO, over the period 2000-2019, we find that the R&D is strongly negatively correlated to short-run risk (economic growth), but positively correlated to long-run risk (expected economic conditions). Then, we examine the correlation between R&D investment and risk premium, as R&D spending shows a strong positive correlation with the firm's exposure to expected economic conditions (LRR). The results reveal that firms with higher size-adjusted R&D investment also exhibit higher stock returns or risk premiums. Next, we investigate the relationship between the firm's innovation outputs (i.e., patents granted) and exposures to economic shocks, expected economic growth, and expected macroeconomic uncertainty. Contrary to R&D expenditures, 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). 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.

In addition, we explore the relationship between patents, R&D spending, risk exposures, and returns. We develop strategies that double-sort firms into two dimensions by considering R&D spending and patents granted. First, we examine the risk exposures of firms with similar R&D spending levels and show that the risk exposures decrease in each group category as the number of patents rises. 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 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 patent 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 short, the main contribution of the paper is to demonstrate that expected returns can be determined based on the firm's level of R&D investments, risk exposure—consumption growth (SRR) and expected economic conditions (LRR)—as well as granted patents per year.

The remainder of the paper is organized as follows: Section 2 briefly summarizes the necessary literature. Section 3 introduces the data. The empirical results are presented in Section 4, and the final section concludes.

3.3 Literature review

We aim at examining the relationship between innovation, risk exposure, and equity risk premium. We specifically explore two innovation measures: R&D expenditures and patents.

3.3.1 Granted Patents:

Patenting has been frequently used as an alternative proxy to capture corporate innovation (He J.J et al, 2018). Several studies in the field of finance and patenting literature have examined patents due to mergers and acquisitions (Bena et al., 2014), banking deregulation (Hombert et al., 2017), going public (Bernstein, 2015), and stock volatility (Bartram et al., 2012). Others have examined the impact of litigation (Choi et al., 20107), unions (Bradley et al., 2017), and other factors on firms' innovation. In all of these studies, researchers use granted patents as a main variable to measure corporate innovation at the firm level because such patents have value to the firms that obtain them. For instance, (Agarwal et al., 2010) estimate the patent premium using an empirical approach and suggest that the presence of granted patents increases the returns to an invention by around 40 to 50 percent on average. (Brander et al., 2017) investigate the correlation between employee relations (ER) and innovation, as measured by granted patents and patent citations. They use the NBER Patent Data File over the period 1991 to 2010 and find that patents granted have a positive relationship with both real R&D and the number of employees. In contrast, (e.g., Hall et al., 2010) show a negative relationship between patents granted and innovation activities. Whether the patents granted reflect true innovation or not, it is still of interest to assess the factors that contribute to successful patenting.

3.3.2 R&D Expenditures

R&D investment is one of the main sources of innovation (Hall et al., 2010) that drives a firm's long-term viability (Yu et al., 2016) and provides a significant contribution to a firm's innovation (Dodgson et al 2008). Prior studies that examine the relationship between R&D and granted patents, for instance, show a strong correlation. For example, (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. Accordingly, R&D appears to always have a positive effect on a firm's patents, since it is the most significant factor of innovation. However, not all innovations are eventually patented, as no one can guarantee that a firm's investments in R&D will automatically result in successful innovation. This suggests that some of firm's R&D could turn to sunk costs.

Overall, these two innovation activities are complementary—firms that conduct a lot of R&D tend to patent more. And ordinarily, reducing the investment in R&D will hinder more patents.

3.3.3 Risk-Uncertainty

Special attention has been paid to risk as a key factor impacting innovative activity. Risk—the lack of certainty in outcomes—assumes a unique, known distribution of future outcomes. For example, (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 listed over the period 2002–2012, they show that both policy and market uncertainties can negatively affect the firm's R&D. The uncertainties associated with potential changes of government policy have significant implications for corporate investment. (Czarnitzki, at al., 2007) explore the impact of product market uncertainty and government R&D on firm-level R&D investment. They show that product market uncertainty reduces R&D investment and government R&D subsidies increase R&D investment. Recently, (Coiculescu, et al., 2023) show that the influence of risk on R&D is positive and significant, but the corresponding effect on patents and citations is negative and significant.

3.4 Empirical strategy and data

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

3.4.1 Data sources and Sample Selection

The datasets used in this research come from four main 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. We then collect Research and Development spendings (R&D) and Market Equity Values (ME) from COMPUSTAT. Asset Prices 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. The sample ranges from 2000 to 2019.

3.4.2 Hypotheses and Empirical Models

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

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.[1] 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.

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 spending declines linearly by 20% (Chan, et al., 2001) the total amount of R&D each year is a combination of previous and current R&D spendings. Therefore, the following approximation is used.

$$RD\ spending_{it} = RD_{it} + 0.8 \times RD_{it-1} + 0.6 \times RD_{it-2} + 0.4 \times RD_{it-3} + 0.2 \times RD_{it-4}$$

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

$$RD\ spending_{it}/ME_{it} = a_{it} + b \times \beta_{it}^{\Delta c} + c \times \beta_{it}^{GF} + d \times \beta_{it}^{GD} + \varepsilon_{it}$$

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 rolling windows) $\beta_{it}^{\Delta c}, \beta_{it}^{GF}$, and β_{it}^{GF}.

$$StockRet_{it} = a_{it} + \beta_{it}^{\Delta c} \times \Delta c_t + \varepsilon_{it},$$

$$StockRet_{it} = a_{it} + \beta_{it}^{GF} \times GF_t + \varepsilon_{it},$$

$$StockRet_{it} = a_{it} + \beta_{it}^{GD} \times GD_t + \varepsilon_{it},$$

Contemporaneous consumption growth, Δc, represents the SRR factor, while both economic growth forecasts (GF) and the forecast dispersion are the two LRR factors. The results presented in Table 1 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).

[1] 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.

H2 *Firms that invest more in R&D are more exposed to long-term macroeconomic risks, so have higher returns.*

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). 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.

To illustrate this, 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.

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.

H3 *There exists a positive but weak relationship between the number of patents awarded and stock 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):

$$Patents_{it} = \varepsilon_{it} + \beta \times Risk_{it} + Controls_i{}^{2}$$

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 3 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 4, 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.

[2] Do the test with alternative innovation measures such as citations, innovation quality (innovative, marginal, etc.).

H4 *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.*

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.

3.5 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 3.1 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 3.2 Correlation for all variables

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

3.5.1 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). 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 3.3).

Table 3.3 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 (SLL)	-.074***			-.066***
	(.007)			(.007)
B-Forecasts (LRR)		.165***		.146***
		(.017)		(.017)
B-Volat (LRR)			-.012***	0.00
			(.003)	(.003)
Cons	.144***	.146***	.147***	.142***
	(0.001)	(0.001)	(0.001)	(0.001)
Observations	101524	107346	107346	101524
Fixed effects	Y	Y	Y	Y

3.5.2 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 3.4. 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 3.4 The table presents the link between R&D and risk premium

	1	2	3	4	5
Ranked by R&D/size	**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 3.5.1. 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.

3.5.3 Patents, Risk Exposure, and Stock Returns

Table 3.5 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 3.5). 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 learn from its failures, gain more experience with the patent system, and become more innovative. Investors see firms that obtain more patents as being more capable of live through future uncertainty than other companies.

Table 3.5 reports the regressions of innovation outputs (i.e., patent granted) on exposures economic shocks, expected economic growth, and expected macroeconomic uncertainty

	(1)	(2)	(3)	(7)
	Patents	Patents	Patents	Patents
B-Cons Groth	13.708***			12.091***
	(1.612)			(1.652)
B-Forecasts		.962		4.934
		(3.465)		(3.634)
B-Volat			3.939***	3.752***
			(.55)	(.596)
Cons	22.011***	21.433***	21.39***	21.901***
	(.102)	(.103)	(.098)	(.108)
Observations	102,740	108,664	108,664	102,740
Fixed effects	Y	Y	Y	Y

In Table 3.6, 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 3.6, 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 3.6 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

3.5.4 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 3.5.1. 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 3.4. This attenuating effect varies between 25 to 75%. See Table 3.7.

Table 3.7 displays risk exposures for firms with similar level of R&D spending and similar number of patents granted per year

Panel A: Beta of consumption growth

	Paten number/year			
RD/ME	1	2	3	4
1	0.004	0.007	0.003	0.001
2	0.004	0.006	0.010	0.001
3	0.006	0.009	0.001	0.001
4	0.007	0.007	-0.002	-0.001
4-1	0.003	0.001	-0.005	-0.002
tstat	2.220	0.402	-2.711	-1.888
p_val	0.027	0.688	0.007	0.060

Panel B: Beta of forecast

	Patent number/year			
RD/ME	1	2	3	4
1	0.002	0.003	0.003	0.002
2	0.003	0.004	0.004	0.003
3	0.008	0.006	0.004	0.002
4	0.008	0.006	0.005	0.006
4-1	0.006	0.003	0.002	0.004
tstat	6.526	1.762	2.001	6.810
p_val	0.000	0.079	0.046	0.000

Panel C: Beta of volatility

	Paten number/year			
RD/ME	1	2	3	4
1	-0.011	-0.003	-0.012	0.005
2	-0.010	-0.013	-0.002	0.002
3	-0.010	-0.017	-0.018	0.005
4	-0.021	0.005	-0.012	-0.002
4-1	-0.010	0.009	0.000	-0.007
tstat	-2.395	1.681	0.036	-2.524
p_val	0.017	0.094	0.971	0.012

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 3.8 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 3.8 displays stock returns for firms with different level of R&D spending and similar number of patents granted per year

Panel A: Returns (annualized) with double sorting.

R&D/Size	1	2	3
1	0.154	0.161	0.167
2	0.123	0.178	0.127
3	0.154	0.147	0.147
4	0.139	0.130	0.184
5	0.112	0.178	0.159
Average	0.136	0.159	0.157

Panel B: Beta of expected economic growth

R&D/Size	1	2	3
1	0.144	0.146	0.175
2	0.135	0.130	0.151
3	0.139	0.143	0.171
4	0.146	0.122	0.163
5	0.154	0.168	0.135

Panel C: Beta of expected economic condition volatility

R&D/Size	1	2	3
1	0.140	0.119	0.140
2	0.110	0.099	0.100
3	0.152	0.137	0.102
4	0.143	0.132	0.133
5	0.149	0.136	0.137

3.6 Concluding Remarks

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).

Finally, 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.

CHAPTER 4

CONCLUSION

The thesis consists of two empirical studies on corporate innovation. Particularly, this thesis examines the impact of innovation activity, CEO compensation packages, firm performance, and macroeconomic risk. In this chapter, I conclude each empirical study and some limitations and implications for the second chapter.

4.1 Empirical Chapter 2

In the first study, the results show that there is a significant reduction post-NGPs year in CEOs' short-term incentives (jointly and separately). In particular, when we look at the relationship between NGPs and the changes in salary and bonus separately, we find a negative and significant correlation between these factors and NGPs, with more impact on bonus than salary. When we join these two components of CEO compensations, we discover a negative and significant correlation between a CEO's cash compensation (the sum of both) and NGPs. When we examine the relationship between NGPs and a CEO's long-term incentives, we find a negative and significant correlation between the subsequent CEO's stock-based compensation and firms' NGPs. However, we did not observe any significant correlation between NGPs and the changes in other components the CEO's long-term compensation, such as option-based compensation. We also find that the changes in subsequent firm performance, as measured by ΔROA and ΔROE, have a significant negative correlation with the NGPs. In addition, we set up two additional empirical models, and the results indicate that NGPs have no direct impact on CEO departure following the failure in innovation. Finally, we find that the change in R&D is negatively and statistically significant in following the NGPs year.

4.2 Empirical Chapter 3

In the second research, we find that R&D strongly negatively correlated to short-run risk (economic growth), but positively correlated to long-run risk (expected economic conditions). We also find that firms with higher size-adjusted R&D investment show higher stock returns or risk premiums. When we investigate the relationship between the firm's patents granted and exposures to economic shocks, expected economic growth, and expected macroeconomic uncertainty, we find a positive association between patents and short-term shocks and a negative connection between patents and expected economic conditions. We also discover that firms with more patents have lower exposures to future macroeconomic uncertainty but have higher returns. Lastly, we explore the relationship between patents, R&D spending, risk exposures, and returns. We show that the risk exposures decrease in each group category as the number of patents rises. 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 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 patent 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.

4.3 Limitations:

It is worth noting that this study has some important limitations. First, previous research on failures in innovation using USPTO data has been limited, which leaves a lack of knowledge that requires further exploration. The prior studies note the difficulties associated with gathering patent applications that have not been granted from the USPTO database, due to the access issues, differences in definitions of such patents, and variations in their types. We, for example, spent over two years on the effort of collecting and purifying our data and related details to ensure their validity and reliability for our research investigation. Yet, our sample collection and analysis of the USPTO database is limited to 2,003 patent applications for 256 firms, due to almost the same obstacles and limitations in earlier research. Even though we present robust evidence of the consequences of NGPs, future research may shed new light on the USPTO database and gather more observations of unsuccessful patent applications.

Second, our sample is also limited to a particular type of USPTO data, that is, utility patents, which contain approximately 90% of USPTO patent applications in recent years (for more details see https://www.uspto.gov/web/offices/ac/ido/oeip/taf/patdesc.htm). Third, we do not include pending patent into this study because they have not yet been refused and may be awarded in the future, potentially creating value for the firm, neither do we consider granted patents because our research does not track innovation success. Rather, we limit our research exclusively to patent applications that were rejected by the USPTO examiners, as we specifically study failures in corporate innovation.

Fourth, another important limitation in this study is that the research period ends in 2020 due to the average time lag of USPTO patent applications. We track nonprovisional utility patents of firms that receive a "final decision" from the USPTO examiners, typically within a period of approximately five years. This time lag includes the examiner's first office action, which is typically three years. In other words, it might take a USPTO examiner until the year 2025 to issue a final decision on a patent application filed in 2020. We acknowledge, however, that future research on unsuccessful patents with a longer period of time is necessary, even though we cover a longer period of time than previous research (e.g., Farre-Mensa et al., 2020; Kline et al., 2019; Sampat et al., 2019; Balsmeier, B et al., 2017; He, J.et al., 2013; Lemley et al., 2008), which together cover the period of 2001–2013. We finally confirm that our sample, analysis, and findings are still reliable and valid despite all these limitations.

4.4 Implications:

This paper has explored the dark and unexpected side of US innovative firms by indicating the negative effects of failure in innovative applications on different firms' activities that firms may have to tackle when obtaining such failures. Two important implications for US firms and CEOs are discussed below.

First, we demonstrate that USPTO-NGP applications indeed matter to corporate innovation. In particular, we employ an empirical approach and find that NGPs significantly negatively impact the CEO short-term incentives (salary, bonus, and total cash compensation) at both levels of analysis. We also find that, among all CEO long-term components, stock-based incentives are significantly and strongly negatively impacted by NGPs in the following year. This empirical evidence, however, speaks against the existing results in the literature, since our study is the first to use USPTO data to link the unsuccess of innovation to CEO compensation packages. Prior work addresses the success of innovation, as measured by patents granted and citations, and shows a positive association between CEO compensations and patents granted in the short and long run. Taken together with the previous literature, our evidence suggests that firms might need to design *optimal incentive packages that are more tolerant of the CEOs who experience failures in innovation*. This is because any decrease in a CEO's incentive package due to innovation failures—as a novel factor, among others, that reduces a CEO compensations—appears to significantly negative on a CEO's motivation to innovate. Our suggestion is in line with earlier research (Manso et al., 2011), which demonstrates that in order to motivate exploration, the optimal incentive contract should provide protection from failure in the short term and reward success in the long term. In other words, CEOs may reduce investments in profitable but risky projects in the year following NGPs due to the decrease in their compensation packages. Consequently, this will lead to more failures innovation. Our results are also consistent with this direct linkage effect.

Second, we also indicate that NGPs have a significant negative impact on the firm's performance in the following year, as measured by ROA and, as a robustness, ROE and ROI. The latter variable is particularly important as it reflects the result of innovative inputs, R&D expenditure, which is entirely under CEOs control. Specifically, while we find a decline in several components of CEOs compensation, we also find that CEOs' responses to show good firm performance significantly declined in the following year. Accordingly, the poor performance of a firm in the year following NGPs is not only the result of reductions the CEO's compensation package or R&D investment but could also be the result of failure in innovation in the past year. The findings of the current study strongly support such a direct effect of NGPs on US firms' performance in the subsequent year. We reiterate our argument that the existing literature on corporate innovation does not recognize the dark and unexpected side of patents that have not been granted and whether such patents influence firms' activities in the short and long run. Finally, we suggest that *such impacts on our sample of US firms are apparent through direct (NGPs) and indirect (compensation and R&D linkages) consequences.*

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