UNINTENDED CONSEQUENCES OF OUTCOME BASED COMPENSATION – HOW CEO BONUSES, STOCKS AND STOCK OPTIONS AFFECT THEIR FIRMS' PATENT LITIGATION

ABSTRACT

Enforcing a firm's patents is crucial for defending its competitive advantage. CEOs are central for making these strategic decisions but we know little about how their individual incentives shape their decision-making. We integrate theory from outcome-based CEO compensation designs into models explaining firms' decisions to become plaintiffs in patent litigation. Based on how compensation shapes time horizons and risk-taking of CEOs, we predict that CEO compensation tied to stock increases the firm's likelihood to enforce patents, while bonuses and stock options reduce it. Further, we reason that the tenacity of patent disputes in an industry creates a boundary condition for the effects of CEO compensation because they curtail the degree of agency that CEOs have for incorporating their personal incentives when making litigation decisions for the firm. We test these hypotheses for 2,302 US firms with 4,420 different CEOs and 3,451 patent litigation cases between 1997 and 2015 and find support for all hypotheses with the exception of the boundary condition for stocks as CEO compensation. These findings advance existing theory on firms' decision-making on patent litigation by explicating how firm and CEO incentives can diverge with direct consequences for the likelihood of litigation to occur.

Keywords: patent enforcement, patent litigation, compensation, stock options

1 Introduction

The competitive advantages of many firms depend increasingly on their patented technologies (Somaya, 2012). This makes decisions to enforce patents against competitors strategic (Kafouros, Aliyev and Krammer, 2021; Trigeorgis, Baldi and Makadok, 2022). The extant theory explains the decision to sue for patent litigation largely based on conditions such as the nature of the patented technology (Rudy and Black, 2018), reputational considerations (Agarwal, Ganco and Ziedonis, 2009) or the efficiency of the legal system (Beukel and Zhao, 2018; Papageorgiadis and Sofka, 2020). The incentives for CEOs to enter the lengthy and costly court proceedings with uncertain outcomes (Diestre, Lumineau and Durand, 2023; Lemley and Shapiro, 2005) rarely enter the theoretical reasoning. Given the complexity of patent litigation decisions, CEOs have substantial leeway to avoid it and devote attention instead to other firm strategies that promote their own career goals (Bessen and Meurer, 2012; Monk, 2009). When CEOs have such leeway, most firms put compensation packages in place to affect the time horizon and riskiness of CEO decision making (Devers, McNamara, Wiseman and Arrfelt, 2008; Graffin, Hubbard, Christensen and Lee, 2020; Sanders and Hambrick, 2007). Hence, the type of CEO compensation can affect CEO decision making on their firm's patent litigation but these effects are hardly understood. In the absence of such theory, we may systematically over- or underestimate when CEOs commit their firms to the costly and consequential decision of becoming a plaintiff in patent litigation.

In this study, we integrate theoretical mechanisms from CEO compensation designs (Coles, Daniel and Naveen, 2006; Devers et al., 2008) into models explaining how firms make decisions about becoming plaintiffs in patent litigations (Rudy and Black, 2018; Somaya, 2003, 2012). More precisely, we focus on the three dominant forms of outcome-based compensation, i.e. bonuses, stocks and stock options, because they are put in place by many firms to align the risk preferences and time horizons of firm shareholders with those of CEOs (Eisenhardt, 1989; Graffin et al., 2020). Based on the distinct incentive mechanisms for each compensation type we hypothesize that the short-term focus induced by bonus criteria for CEOs reduces their firms' likelihood to file for lengthy patent litigation while tying CEO compensation to firm stocks has the opposite effect. Further, we predict that the degree to which CEO compensation depends on

stock options, the compensation aspect rewarding maximum risk-taking (Sanders and Hambrick, 2007), reduces the firm's propensity to become a plaintiff in patent litigation because CEOs with stock options may want to focus their attention on initiatives with higher risk-return relationships, such as investing into completely new technologies. Finally, we explore explicit conditions under which the CEO compensation mechanisms apply within the wider literature on patent enforcement. We reason that the tenacity of patent disputes in an industry constitutes an important boundary condition for the effects of CEO compensation designs because shareholders and financial analysts focus on patent litigation in industries in which patent disputes are highly tenacious, thereby limiting CEOs' agency to follow their personal incentives.

Our theorizing rests on two largely disconnected bodies of research. On the one hand, patent strategy literature emphasizes that the decision to file for patent litigation is complex and information-intensive. Firms need to assess the odds of success, i.e. the technological and legal conditions (Beukel and Zhao, 2018; Rudy and Black, 2018), relate them to the costs which can range in the millions of US dollars per case (Kafouros et al., 2021) and consider how the litigation affects its broader reputation (Agarwal *et al.*, 2009). This stream of research acknowledges the importance of CEOs for the decision making on patent litigation but their influence remains anecdotal (Somaya, 2003, 2012). On the other hand, principal-agent literature is rich in demonstrating how differences in CEO compensation packages alter their firms' decision making (Devers et al., 2008; Lin, Liu and Manso, 2021). In this stream of research, the dominant reason for putting outcome-based compensation designs in place originates from the need to alleviate agency and risk-taking problems between CEOs and the shareholders of their firms (Eisenhardt, 1989). Sanders and Hambrick (2007) show that the compensation effects extend to the decision making of firms on their innovation but they study it merely for new R&D investments, arguably a very different decision context than enforcing existing patents. In sum, the goal of our research is to integrate both streams of research.

We test our theoretical reasoning using a unique sample of all 2,302 US based firms in the Standard and Poor's Execucomp database and 4,420 different CEOs between 1997 and 2015. The information of these firms is merged with firm level data on patent infringement cases from the USPTO patent litigation dataset which identifies 3,451 patent infringement litigation cases. We rely on instrument variable probit

models for the statistical analysis considering that CEO compensation packages are not exogenously or randomly determined. The results of our empirical study confirm all hypotheses. A firm's propensity to become a plaintiff in patent litigation increases with the degree to which their CEO's compensation depends on stocks, while CEO bonuses and stock options reduce the firm's likelihood to file for patent litigation. Moreover, the tenacity of patent disputes in an industry creates boundary conditions for the effects of CEO bonuses and stock option incentives, while the same is not true for stocks.

We advance existing theory in two important ways. First, we make the first step towards a theory explaining patent litigation which integrates incentive mechanisms at the individual level of CEOs. While there is substantial evidence that CEOs consider their personal incentives when applying for patents (Ahuja, Coff and Lee, 2005), the arguably more strategic act of enforcing them is hardly understood. Extant research ignoring the effects of CEO compensation is likely to suffer from biased results. At the same time, CEO compensation designs are not the only way in which CEO-level mechanisms enter firm's patent strategy. Future research may extend our theory and explore the microfoundational effects, e.g. by incorporating mechanisms such as CEO personality traits.

Second, we overcome the narrow focus of compensation design literature on investment decisions by theorizing the consequences for patent litigation decisions. The existing literature on compensation designs focuses on investment decisions of CEOs, such as firm acquisitions and investing in new R&D projects (Sanders and Hambrick, 2007; Wright, Kroll, Krug and Pettus, 2007; Wright, Kroll, Lado and van Ness, 2002). Our theoretical reasoning introduces the enforcement aspect of existing firm assets, i.e. patent litigation. This extension provides a new perspective on the full extent of the influence of CEO compensation designs on strategic decisions of firms. Future research may, for example, build on our angle of CEO compensation design and incorporate other competitive actions such as recruiting key employees from industry rivals.

2 Theory and Hypotheses

Our theoretical reasoning incorporates CEO compensation mechanisms into models explaining the likelihood of firms to become plaintiffs in patent litigation. For this purpose, we review research describing

the emergence of outcome-based compensation as a response to agency problems and its effects on CEO decision making in general. Subsequently, we integrate these effects into the specific decision-making on patent litigation and develop hypotheses based on the three dominant elements of outcome-based compensation packages, i.e. bonuses, stocks and stock options. Finally, we explore boundary conditions based on the tenacity of patent disputes in the firm's industry.

2.1 CEO compensation designs as a response to principal-agent problems

CEOs are pivotal in their firm's strategic decisions for how to generate economic rents and achieve a sustainable competitive advantage (Castanias and Helfat, 1991; Shi, Connelly, Mackey and Gupta, 2019). A CEO's role requires utilizing managerial judgement to evaluate the strategic options available to the firm, deciding on the most appropriate ones and leading their implementation. Common strategic growth options include investments in R&D, mergers and acquisitions or entering new markets (DesJardine and Shi, 2021; Shi et al., 2019). Typically, CEOs deal with complex decisions with varying degrees of risks, time horizons (long term/short term) and resource commitments (Hambrick, Cho and Chen, 1996; Shi et al., 2019).

The nature of CEO decisions gives rise to a principal-agent problem where the goals and preferred actions of the agent (CEO) are not aligned with those of the principal (shareholders) (Eisenhardt, 1989). Agency theory identifies two problems that occur in agency relationships, the agency and risk sharing problems (Eisenhardt, 1989). Agency problems between co-operative partners are prevalent when the self-interest and goals of the agent are misaligned with the ones of the principals. This misalignment becomes salient when it is difficult for the principal to evaluate and confirm if the agent's decisions and actions are appropriate and aligned with the principal's goals (Eisenhardt, 1989). Monitoring and evaluating the appropriateness of an agent's decision making can be particularly difficult when the expected outcomes of specific managerial actions are uncertain and difficult to predict.

Risk sharing problems occur when the agent and the principal have different perspectives and preferences in relation to risk taking and risk management (Graffin et al., 2020). The two problems are often intertwined. CEOs may prefer to avoid risk taking activities because these can endanger their personal wealth which is tied to a firm's current performance, whereas shareholders (who often have diversified their

risk exposure through a portfolio of investments in different firms) expect that the CEOs will engage in risk taking activates so that they can increase the future value creation opportunities of the firm (Devers et al., 2008; Lin et al., 2021).

Firms put compensation packages in place to deal with the principal-agent problem in a firm (Devers et al., 2008; Eisenhardt, 1989; Graffin et al., 2020). There are two main types of compensation designs, behavior-based and outcome-based compensations (Eisenhardt, 1989). Behavior based compensation predominantly rewards agents with a pre-determined salary. Such compensation packages are often awarded to agents who carry out tasks that have a high degree of programmability and when it is feasible for the principals to monitor the agent's activities (Eisenhardt, 1989). However, this type of compensation is also prone to increase the agency and risk sharing problems in firms. The self-interest and goals of CEOs, i.e. the agents, favor low risk firm strategies that are sufficient to fulfil the criteria that shareholders, i.e. the principal, can monitor. Taking riskier decisions with significant potential to increase firm returns and value in the future, would be in the interest of shareholders but CEOs may neglect them (Devers et al., 2008; Heron and Lieb, 2017).

Outcome based types of compensation reward agents with bonus incentives and/or the sharing of current and future firm equity (Graffin et al., 2020). Such compensation designs are expected to align the self-interest and goals of the agent with the ones of the principal, since meeting the agreed outcomes is mutually rewarding for both. A broad stream of research shows that these CEO incentives are effective and change the investment behavior of their firms (Sanders and Hambrick, 2007; Wright et al., 2007; Wright et al., 2002). R&D investments are particularly sensitive to the nature of CEO compensation since resulting new technologies and products can create important revenue potentials for the firm in the future but CEOs can neglect R&D activities because their success is uncertain (Sanders and Hambrick, 2007). Hence, outcome-based compensation shifts CEO attention to a firms' innovation processes. However, R&D investments are merely the starting point of innovation projects. We reason that CEO compensation has distinct effects on the end of an innovation project when firms have patented technologies and can enforce them against competitors through patent litigation.

2.2 The nature of firm decisions to file for patent litigation

Patent litigation typically involves a patent owning firm (plaintiff) suing another firm (defendant) for manufacturing, importing, using, or selling an invention that is infringing the plaintiff's patented technology without receiving prior authorization or license (Rudy and Black, 2018). Patents provide their owners with the rights to keep others from using a technology but enforcing these rights in court is a separate decision (Rudy and Black, 2018). The context of a firm's decision to file for patent litigation is complex and information intensive. It involves considering the expected benefits and projected outcomes of engaging in litigation with the associated monetary and non-monetary costs of the litigation (Kiebzak, Rafert and Tucker, 2016; Somaya, 2016). These considerations emerge from multiple domains.

First, the odds of success in the legal system depend on the nature of a technology (Rudy and Black, 2018), the efficiency of the jurisdiction (Papageorgiadis and Sofka, 2020) as well as the experience of specific courts (Somaya and McDaniel, 2012). Second, plaintiffs need to assess the degree to which patent litigation will be consequential for the defendant and provoke them to settle the case, e.g. because it disrupts their operations or forces them to lose access to key markets (Bessen and Meurer, 2012; Tan, 2016). Third, litigation will also shape the reputation of the plaintiff for other transactions. Litigation cases can convey a reputation for toughness regarding a plaintiff's willingness and ability to enforce patents which can discourage competitive action from rivals, e.g. for hiring away key personnel (Agarwal et al., 2009; Ganco, Ziedonis and Agarwal, 2015; Lanjouw and Schankerman, 2001; Somaya, 2012).

Apart from the strategic potentials of patent litigations, firms need to consider the adverse consequences of patent litigation on their own firm. First, plaintiffs need to estimate the legal costs as these can often be high and reach millions of dollars per case (Somaya, 2003). Second, firms need to consider the downside risks from losing the litigation case, since this could diminish the value of their patent portfolio and even have their patent revoked due to litigation retaliation from a defendant (Monk, 2009; Theeke and Lee, 2017). Third, plaintiffs can waste precious managerial time and attention for patent litigation which will not be available for other strategic activities (Bessen and Meurer, 2012; Monk, 2009). Fourth, the

possibility of a defendant's retaliation and countersuing needs to be considered and its consequences, e.g. in terms of time, costs and reputational outcomes (Theeke and Lee, 2017).

Overall, a firm's decision to engage in litigation is not a simple decision based on the existence of patent violations. Instead, the decision to file a patent lawsuit depends on the collection and evaluation of complex information from multiple domains. Dedicated patent lawyers and consultants can help with assembling and preparing necessary information but decision making requires management attention and judgement. Accordingly, CEO and top management decision making are central for patent litigation to occur (Somaya, 2003, 2012). At the same time, the individual incentives for CEOs to file a patent lawsuit on behalf of the firm can deviate from firm-level considerations because CEOs can apply their own judgement about the risk-return-relationship of patent litigation for their individual benefit. We acknowledge that decisions on patent litigation are likely to be the result of discussions by the management team, e.g. involving Chief Technology Officers (CTOs) or legal counsels. Within our theorizing, we assume explicitly that CEOs, as the most powerful decision makers in their firms (Blagoeva, Mom, Jansen and George, 2020; Hambrick, 2007), create a distinct principal-agent problem in the decision making of firms on patent litigation and translate this theoretical assumption into fitting control variables in the empirical study which can hold the effects of CTOs or legal counsels constant (details below).

A principal-agent problem is likely to occur because it is difficult for shareholders (i.e. the principal) or their representatives to observe incidents of patent infringement, assess their magnitude and judge whether patent litigation can be the preferred way of action (Somaya, 2003). Assessing these conditions would require a type of specialized technological, legal and business expertise of a firm's patent portfolio that would be extremely costly to develop for shareholders or financial analysts in the average industry (we explore distinct industry conditions as a boundary condition in a dedicated section after the main hypotheses). At the same time, considering patent litigation filing comes with important opportunity costs for CEOs individually since it takes away attention from other strategic decisions, such as developing new products or markets, which are potentially more beneficial for their future careers. Therefore, the incentives of CEOs and their firms can be misaligned so that the firm might benefit more from litigation than from

investment into R&D. In the presence of these agency problems, CEO compensation designs are likely to affect a firms' likelihood to become plaintiffs in patent litigations even when the effect is inadvertent and not designed to affect patent litigation directly.

2.3 Types of outcome-based CEO compensation and their effects on patent litigation

Literature distinguishes between three dominant forms of outcome-based compensations, i.e. bonuses, stocks and stock options (Devers, Cannella, Reilly and Yoder, 2007; Jensen and Murphy, 1990). We explore the distinct mechanism from each incentive type and relate it to a firm's likelihood to become a plaintiff in patent litigation. The reference point for our theorizing are the incentives of a CEO who would receive exclusively a cash salary without outcome-based components.

We start by considering bonuses. Bonuses reward agents with additional payments on top of a base salary when certain predefined conditions are met, e.g. sales growth (Devers *et al*., 2008). Bonuses are frequently part of CEO compensation packages (Alessandri, Tong and Reuer, 2012; Larraza-Kintana, Wiseman, Gomez-Mejia and Welbourne, 2007; Wright et al., 2007). The bonus payments are contingent upon the year on year performance of a firm and are agreed upon ex-ante. Hence, the predetermined bonus criteria reward predictable, stable and certain returns (Alessandri et al., 2012; Larraza-Kintana et al., 2007). By design, bonuses incentivize CEOs to focus on the time frame by which the bonus criteria are assessed, i.e. they shift attention to the short term. Short-term compensation designs incentivize CEOs to favor less risky decisions on strategic options that have sufficient potential to guarantee meeting the objectives tied to their bonus compensation. CEOs are likely to overlook or bypass longer-term investment opportunities that could potentially maximize the returns for the shareholders and favor strategic options that can bring a faster and more certain pay back (Alessandri et al., 2012; Hoskisson, Hitt and Hill, 1993). Long-term strategic options may increase the uncertainty and volatility in the performance of their firms during the required implementation period and jeopardize a CEOs potential to succeed in meeting the bonus related objectives.

The short-term focus induced by bonuses makes patent litigation comparatively unattractive for CEOs. Patent litigation cases take typically many years to be decided by courts (Ziedonis, 2003), typically between

three to five years (Thomson Reuters, 2022). For example, the average patent litigation case in US courts between 1997 and 2015 took 486.71 days before it could be closed with substantial differences between cases (SD = 558.14). 22% of cases take longer than two years with 13% of cases reaching the trial stage. Even successful cases can go through lengthy appeal or counter-litigation stages. Hence, the odds that bonus relevant outcomes emerge in the short term, e.g. from licensing fees, are low. In a best case, defendants would like to settle a case quickly but the likelihood for such an outcome is hard to predict ex-ante (Somaya, 2003). Hence, the patent litigation outcomes that could be relevant for CEO bonuses are hard to predict (Bessen and Meurer, 2005). At the same time, patent litigation would consume scarce CEO attention that is then not available for other strategic decisions (Bessen and Meurer, 2012; Monk, 2009). If CEOs can avoid becoming plaintiffs in patent litigation, they can devote more attention to strategic decisions that will deliver results in the short term and secure the bonus payment (Devers *et al*., 2008). We, therefore, expect that:

Hypothesis 1: The likelihood of firms to file for patent litigation decreases with the proportion of bonuses of their CEO's cash payment.

The second major element of output-based compensation is rewarding CEOs with company stocks. Stocks reduce the agency costs that shareholders face when the availability of information and monitoring of CEO performance is difficult or hard to obtain for the owners of the firm (Godfrey and Hill, 1995). CEOs with vested interest in the stock of a company have a strong incentive against acting opportunistically and shirking responsibilities (Eisenhardt, 1989). Since CEOs themselves become shareholders, their strategic actions are not only in line with the interests of the shareholders (principals), but also with their self-interest through increasing the value of their stock (Denis, Denis and Sarin, 1997). CEOs are more likely to behave appropriately and consider the longer-term impact of their decision making and not hesitate in taking difficult but important decisions that preserve and grow the value of the firm (Eisenhardt, 1989).

The long-term orientation of CEOs is important in decisions about patent litigations for their firm in direct and indirect ways. The direct effect emerges from the length of the focal litigation itself. The litigation process can take multiple years (Ziedonis, 2003) before the firm will experience positive performance

effects from a settlement or favorable court verdict. In indirect terms, patent litigation can have wider performance effects when firms establish a reputation for defending their intellectual property vigorously as a deterrence for competitors (Agarwal et al., 2009) or attracting licensees when the value of the firm's patent portfolio is confirmed as enforceable (Somaya, 2012). Compensating CEOs with stocks incentivizes CEOs to consider the long-term consequences and engage in more patent litigation activity whenever there is an opportunity to increase the firm's stock market price in the long run by doing so (Hu, Yoshioka-Kobayashi and Watanabe, 2017). Short-term focused CEOs owning stock of their firm face opportunity costs when they avoid investing the time and attention into potentially promising patent litigations since they forego a higher personal income from an increase in the firm's stock market price in the future. We therefore predict:

Hypothesis 2: The likelihood of firms to file for patent litigation increases with the degree to which the compensation of their CEOs depends on the firm's stock market price.

Finally, we focus on the effects of stock options as CEO compensation. Stock options are distinct from stocks within CEO compensation packages because they affect the risk-taking in their decision making (Graffin et al., 2020). The value of (call) options is often times associated with the options pricing model of Black and Scholes (1973) and Merton (1973). Within these models, the price (or value) of an option depends on price of the underlying asset (typically the stock price), the strike price of the option, the time until expiration of the option[1], the risk-free interest rate and the volatility of the underlying asset (Black and Scholes, 1973; Merton, 1973). The volatility component is particularly salient when stock options are used in compensation designs because they create convex incentive schemes for CEOs receiving stock options (Coles et al., 2006) i.e. they reward CEOs making risky decisions that will ultimately increase the volatility of the stock price and therefore the value of the options. CEOs would personally profit from exercising their stock option through the difference between the agreed stock option purchase price and the actual price of the stock (Sanders, 2001). If the future price of the stock is lower than the agreed purchase price, CEOs can

[1] The maturity or expiration date does not imply that the stock options cannot be exercised earlier.

simply not exercise their right to purchase the stock (Sanders, 2001). There is therefore limited risk for the CEO individually while making risky decisions with high upside potentials for the firm's value would pay off for CEOs personally (Devers et al., 2008). By using stock options as part of CEO compensation designs, firms can address the divergence in optimal risk taking between CEOs, whose financial and human capital is typically highly concentrated in the firm that they work for, and shareholders who can diversify their risk (Heron and Lieb, 2017). Stock options incentivize CEOs to make substantial investments in firm activities that have the maximum potential to achieve positive outcomes for the firms and its stock market price even when they are risky (Sanders and Hambrick, 2007; Wright et al., 2007; Wright et al., 2002).

For the purpose of our reasoning, it is important to understand whether patent litigation would fall in the category of firm decisions that create the highest risk-return relationships and would therefore benefit from the risk-taking incentives created by stock options within a CEO's compensation package. Extant research has mostly focused on types of management decisions that "…place relatively large bets in uncertain investment categories, such as R&D, capital expenditures, and acquisitions…" (Sanders and Hambrick, 2007, p. 1056). We reason that the decision to become plaintiffs in patent litigation is unlikely to be among the choices with the highest risk-return relationships for the average firm. While some firms create substantial revenue from licensing their patents and litigating against infringers, this is often times the second-best option for innovative firms when they lack the resources for turning new technologies into their own product innovations (Arora and Gambardella, 2010). In contrast, CEOs with stock options have been found to increase their firm's investments in R&D which can result in new technologies and business opportunities (Sanders and Hambrick, 2007). These investments have the potential to create substantially new performance potentials for their firms. Conversely, the revenue potential from enforcing existing patents is comparatively limited while still requiring substantial CEO time and attention (Kafouros et al., 2021).

The case of electric vehicle producer Tesla provides an illustrative example for the trade-offs that CEOs consider when they are compensated with stock options. Elon Musk, the CEO of Tesla Inc, was granted a new compensation package that entirely consisted of future stock option awards to acquire 5% of

Tesla's total issued and outstanding shares at a price of US$31.17 per share in August 2012 (Tesla, 2013). Musk steered Tesla into making large investments in R&D by, for example, quintupling its R&D expenditures from US$231m in 2013 to US$1.37 billion in 2017 (Statista, 2022) to complete the development, validation, and testing of the new car Model X and accelerate design and engineering work on Model 3 (Tesla, 2015). Tesla also invested in building four (to date) "gigafactories" costing an estimated amount of US$4-5 billion each (Tesla, 2015) and increased vehicle production from 32,000 cars in 2014 to 500,000 in 2020 and 1.3m in 2022 (Shvartsman, 2023). Overall, Tesla's market capitalization over the time period 2012-2017 increased 1,243%, from US$3.2 billion in 2012 to US$52.4 billion in 2017, resulting in Musk receiving the equivalent of US$2.28 billion, by creating shareholder value of approximately US$40 billion (Tesla, 2018, 2021).

During the same time period, Musk publicly declared that Tesla would shift its attention away from filing patent litigations against competitors, stating: "Tesla will not initiate patent lawsuits against anyone who, in good faith, wants to use our technology" (Musk, 2014). Musk also further exemplified his point by indicating that the benefits of patent litigation are relatively small compared to these of innovating to boost a firm's market position, by stating "…technology leadership is not defined by patents, which history has repeatedly shown to be small protection indeed against a determined competitor, but rather by the ability of a company to attract and motivate the world's most talented engineers. We believe that applying the open source philosophy to our patents will strengthen rather than diminish Tesla's position in this regard..." (Musk, 2014).[2]

[2] The purpose of this example is primarily for illustration. We recognize that in addition to Elon Musk's compensation design, other extraneous factors could have influenced Tesla's patent litigation strategy such as the potentially positive network effects that may have arisen from making their patented technology available for "fair use". We would like to thank an anonymous reviewer for this comment.

While Tesla might constitute a specific, well publicized case, we predict more generally that stock options shift CEO attention away from patent litigation towards strategic decisions with higher risk-return relationships for the firm. We predict:

Hypothesis 3: The likelihood of firms to file for patent litigation decreases with the degree to which the compensation of their CEOs depends on stock options.

2.4 Tenacity of patent disputes in an industry as a boundary condition for the effects of CEO compensation

An important assumption within our theoretical reasoning is that CEO compensation affects patent litigation because the monitoring of desirable CEO actions by shareholders is unlikely (Eisenhardt, 1989). However, this assumption may hold to varying degrees in different industry settings and may constitute an important boundary condition to our theorizing. More specifically, we focus on the degree of tenacity that patent disputes in an industry typically reach as an indicator for the level of agency that CEOs have vis-à-vis their shareholders. Within our logic, tenacity in patent disputes can be defined as the amount of time and resources that plaintiffs and defendants are willing to invest before closing a patent litigation case. Such closures do not necessarily require a court verdict but can occur much more quickly when plaintiffs and defendants reach settlements (Lanjouw and Lerner, 1998). If these settlements occur quickly, the tenacity of patent disputes is low. Conversely, tenacity is high when the parties proceed through all stages of the legal procedure ranging for example from exchanges of opinions through discovery all the way to a court trial (Heath and Petit (2005) provide an overview for various countries).

The likelihood of reaching these settlements depends on two broad factors (Somaya, 2003). First, settlements emerge more quickly and frequently when all parties have sufficient and reliable information which allows them to form expectations about the outcome of the legal procedure (Meurer, 1989; Priest and Klein, 1984). Second, the strategic stakes of plaintiffs and defendants depend to varying degrees on the patented technology in question, e.g. co-specialized fixed capital investments in production. Settlements are more likely to occur when plaintiffs and defendants can find licensing terms that are superior to the plaintiff controlling the patented technology exclusively (Bessen and Meurer, 2005; Somaya, 2003). If these

conditions do not hold, patent disputes are more likely to become tenacious by consuming more time and resources because reaching settlements becomes a lengthy process or cases might eventually be decided through court verdicts. The underlying factors can be extrapolated to the industry level since many technological and strategic conditions are determined by industry conditions, such as the nature of technologies or competition.

We reason that the tenacity of patent disputes in an industry determines the degree to which shareholders take them into account when monitoring CEOs. In highly tenacious industries, lengthy patent disputes are a major cost factor, the outcomes are consequential for the competitive advantages of firms and the likelihood increases that media coverage may hurt the reputation of firms (Tan, 2016). Under these conditions, shareholders and/or financial analysts are more likely to collect and analyze patent litigation information when evaluating a firm and its management. As a result, CEOs have limited agency to make litigation decisions based on their own personal incentives. Conversely, in less tenacious industries, patent litigation is quickly settled between parties and is less likely to reach the level of strategic importance that would warrant costly information collection by investors or financial analysts. Accordingly, CEO monitoring is comparatively less effective and makes the effects of CEOs' personal incentives based on compensation designs salient.

In conclusion, the tenacity of patent disputes in an industry creates a boundary condition for the mechanisms laid out in the reasoning for Hypotheses 1, 2 and 3. When patent disputes are highly tenacious in an industry, patent litigation is increasingly salient for shareholders and financial analysts. When they are able to monitor CEO action with regard to patent litigation decisions thoroughly, the effects of compensation designs affecting the personal incentives of CEOs should be limited. Consequently, we predict that all compensation effects should be dampened with increasing tenacity of patent disputes in an industry.

Hypothesis 4a: The likelihood of firms to file for patent litigation decreases with the proportion of bonuses of their CEO's cash payment, and this effect is diminished by the tenacity of patent disputes in the firm's industry.

Hypothesis 4b: The likelihood of firms to file for patent litigation increases with the degree to which the compensation of their CEOs depends on the firm's stock market price, and this effect is diminished by the tenacity of patent disputes in the firm's industry.

Hypothesis 4c: The likelihood of firms to file for patent litigation decreases with the degree to which the compensation of their CEOs depends on stock options, and this effect is diminished by the tenacity of patent disputes in the firm's industry.

3 Data and Methods

3.1 Data and Sample

We test our theoretical reasoning by creating a unique sample based on 36,616 firm-year observations that belong to US-based firms included in Standard and Poor's ExecuComp database over the period 1997 to 2015. We follow previous research and eliminate 1,834 firm-year observations that belong to firms in the utility industry (SIC 4900-4999) because of these firms' idiosyncratic nature (Liu, 2014). Subsequently, we merge the information on CEO characteristics from ExecuComp with the financial information from Standard and Poor's Compustat annual database. We then eliminate 475 firm-year observations due to missing values. Next, we combine information on granted patents from four sources: 1) Duke Innovation & Scientific Enterprises Research Network (DISCERN) (Arora, Belenzon and Sheer, 2021); 2) Dataset created by Stoffman, Woeppel and Yavuz (2022); 3) KPSS Database (Kogan, Papanikolaou, Seru and Stoffman, 2017); and 4) US patents by WRDS. We, also, combine information on patent characteristics such as Cooperative Patent Classification (CPC) class and citations from PatentsView. Furthermore, we exclude 5,696 firm-year observations that have had no patents granted in the last 20 years because they have no grounds to file for patent litigation. Additionally, we eliminate 2,619 firm-year observations because we require the CEO to remain in position during the period t-1 to t, since we model the probability of filling patent litigation based on the available information at time t-1.

In the last step, we complement the data with information on patent litigation cases involving patent infringement for all firms in the sample. For this purpose, we obtain access to the USPTO patent litigation

database (USPTO, 2022). The database was compiled by the Office of the Chief Economist (OCE) at the USPTO, in collaboration with the US National Technical Information Service, providing the most reliable, comprehensive, and publicly accessible US patent litigation data available (Marco, Tesfayesus and Toole, 2007). The database is a dominant source of information for legal professionals, policymakers and academics and contains data on all patent litigation cases filed in US district courts during the period 1963 to 2016. To merge the data, we first collect information on the historical names of firms in the sample, from the Center for Research in Security Prices (CRSP) database. We then employ fuzzy text matching to match the plaintiff names from the USPTO data. We require the fuzzy text algorithm to provide an exact matching score, i.e. all words of a firm's name are matched (except common words, e.g. "corporation", "company", etc.). We manually check the cases where the algorithm did not provide an exact matching score to ensure the correct matching of the names. Finally, we eliminate 2,690 firm-year observations that belong to industries that had not filed patent litigation in our sample period. This is necessary because it allows us to include of 2-digit SIC industry-fixed effects in the estimation models and holds the industry context constant. After this last step of the data preparation, the final sample with complete information consists of 23,302 firm-year observations. This sample represents 2,302 firms, 4,420 different CEOs and 3,451 patent litigation cases.

3.2 Measures

3.2.1 Dependent Variable

Patent Litigation. An indicator that takes the value of one if the firm has become the plaintiff in at least one patent litigation case in fiscal year t. This specification reflects the hypothesized relationships predicting the likelihood of a firm becoming a plaintiff in patent litigation. At the same, time it is also in line with the distribution of the data, implying that firms use patent litigation rather selectively. Nevertheless, we also experiment with the number of patent litigation cases brought by a plaintiff firm in a given year as dependent variable. These additional estimations yield consistent findings which we discuss as consistency check estimations.

Moreover, patent litigation cases can also occur in response to litigation that is initially brought by another firm. Naturally, these counter-litigation cases may follow different considerations since they are typically much more reactive in nature. Hence, we exclude counter-plaintiff cases for the main models testing the hypotheses. However, we conduct additional robustness check estimations including counter-plaintiff cases and find consistent results which are discussed in the dedicated section below.

3.2.2 Main Independent Variables

Bonus Ratio. Hypothesis 1 focuses on the effect of CEO bonuses on the likelihood of their firms becoming plaintiffs in patent litigation. For our purposes, it is important that these bonuses are paid in cash and not tied to the firm's stock price. At the same time, CEOs are likely to receive multiple types of compensation within a compensation package. We take this into account and calculate the ratio of a CEO's bonus relative to the value of the CEO's total annual compensation (that includes salary, bonus, stock grants, the value of option grants, long-term incentive pay-outs, as well as other annual compensations) (Brockman, Lee and Salas, 2016).

Stock Ratio. Hypothesis 2 predicts that the degree to which CEOs receive stocks as compensation increases the likelihood of their firms becoming plaintiffs in patent litigation. We calculate the stock ratio as the dollar value of annual grants of restricted stock scaled by the total compensation of the CEO, consistent with the scaling of the bonus ratio described above.

Stock options Ratio. Hypothesis 3 proposes that the degree to which a CEO's compensation depends on stock options decreases the likelihood of their firms becoming plaintiffs in patent litigation. We calculate the stock options ratio as the dollar value of annual stock option grants scaled by the total compensation of the CEO. Note that for the period before 2006, we use ExecuComp's computed Black-Scholes value of option grants because firms were not required to report options grants characteristics such as grant date value before 2006.

3.2.3 Moderator Variable

Average case duration. We capture the tenacity of patent disputes in the firm's industry by the average patent litigation case duration, i.e., the lengthier the patent litigation the higher the tenacity of patent

disputes in the given industry. For this purpose, we collect all patent litigation cases in the US and measure the time duration between the filing of a litigation case and the closing of a case. Cases can be closed because plaintiffs and defendants have settled out of court, let filing periods expire or courts arrive at a verdict. Time duration is a useful measure of tenacity since the length of procedures determines the costs for filing legal documents from specialized lawyers and the public exposure through channels such as media coverage. In contrast, tenacity is low in industries in which plaintiffs and defendants can quickly settle cases. We calculate the average duration, in days, of patent litigation cases in a 2-digit SIC industry in a 5-year window.

3.2.4 Control Variables

We include controls for an array of factors that could directly or indirectly influence the decision of filing patent litigation at the CEO, firm and industry levels. All independent variables are lagged by one year to take potential simultaneity into account. To the best of our knowledge, CEO characteristics have not been used in prior research to explain patent litigation decisions and we cannot build on established empirical models. Instead, we adopt suitable control variables that have been used in prior compensation studies to explain other firm decisions.

First, we control for the base salary of a CEO, i.e. the amount that does not depend on outcome-based metrics, as the logarithmic value of the CEO's salary. Additionally, we control for CEO characteristics that have been found to influence CEO decision-making, i.e. CEO duality (a proxy of CEO power) (Krause, Semadeni and Cannella, 2014), tenure (Hambrick, Geletkanycz and Fredrickson, 1993) and age (Serfling, 2014). CEO duality is a binary variable that takes the value of one if the CEO is also the chairman of the board and zero otherwise. CEO tenure is the number of years that a CEO is in the office with the current firm and CEO age is controlled for separately. The latter could be important for tracking both overall CEO experience as well as closeness to retirement age which can affect the horizon of decision-making (Aktas, Boone, Croci and Signori, 2021; Cho and Kim, 2017).

Second, we control for the compensation structure of executives that are related to the firm's innovation or legal activities because they can directly or indirectly influence the decision to file for patent

litigation. Specifically, we calculate the yearly averages of the ratio of compensation components (bonus, stock grants, stock option grants and salary) to total compensation for the following executives: Chief Technology Officer (CTO), Chief Scientist, Chief Legal Officer (CLO), Chief Compliance Office (CCO), and General/Chief Counsel. If such information is not available we set these variables to zero and we control for the existence of such executives in a given firm by including a dummy variable that takes the value of one if the information on compensation for any of these executives' data is reported from ExecuComp for the particular firm-year; and zero otherwise.

Third, we include control variables related to firm characteristics that may influence the decision to file for patent litigation. In particular, we control for the number of valid patents granted to the firm in the last 20 years as a precondition for pursuing patent litigation as a plaintiff (Kafouros et al., 2021; Rudy and Black, 2018). Additionally, we control for patents' quality, value and the firm's innovation diversification (Arora, Cohen, Lee and Sebastian, 2023; Trappey, Trappey, Wu and Lin, 2012). Similar to Arora et al. (2023), we measure firm's patents quality as the average of patents forward citations in the first 5 years after being granted normalized by the corresponding average forward citations in 3-digit Cooperative Patent Classification (CPC). We measure firm's patents as the average value of patents held as given by Stoffman et al. (2022). To calculate the firm's innovation diversification, we first construct a measure that is the product of the number of distinct 3-digit CPC classes that the firm patents in and reverse the concentration measure (1-HHI$CPC3$), where HHI$CPC3$ is the Herfindahl–Hirschman Index across the CPC classes that the firm patents in. The final measure is a binary variable that takes the value of one if the firm is above the median of this measure, and zero otherwise (Arora et al., 2023). Moreover, we control for the firm's R&D expenditures as a share of sales since it determines the firm's investment in the development of new technologies.

Further, some firms may have more experience with patent court cases than others. Hence, we include the cumulated number of plaintiff cases that the firm is involved either as a plaintiff or defendant. Additionally, we control for other firm characteristics reflecting a firm's resource availability as an important condition for patent ligation, i.e., total firm return, firm return on assets (ROA), firm size, market-

to-book ratio, cash position, leverage and advertising expenses to sales (Audia and Greve, 2006; Kafouros et al., 2021). The firm return is defined as the total shareholders' return at fiscal year-end minus the median stock returns of the 2-digit SIC industry (excluding the focal firm). The firm's ROA is defined as the ratio of earnings before interest and tax to total assets at fiscal year-end, minus the median return on assets of the industry. Firm size is defined as the natural logarithm of total assets at fiscal year-end. Market-to-book ratio is the ratio of the market value of assets to the book value of assets. Firm cash position is the ratio of cash and short-term investments to total assets. Leverage is the ratio of long-term and current debt to total assets. Advertising is the ratio of advertising expenses to sales.

Fourth, industries differ in the nature of competition and the importance of patenting (Peng, Sun, Pinkham and Chen, 2009). Hence, we control for industry characteristics such as the number of firms in a specific 2-digit SIC industry, industry median ROA and stock return. Additionally, to capture the litigation propensity in the industry we control for the ratio of the number of plaintiff cases in the industry to the number of firms in the industry, and to capture the patent effectiveness in an industry we control for the 5-year average percentage of patent litigation cases that are decided in trials in the industry. Finally, it is worth noting that all industry-level variables are time-variant and industry-fixed effects can be included.

3.3 Estimation Approach

To test our hypotheses, we use probit regression models since our dependent variable is a binary one. We apply two approaches to eliminate potential biases. First, we include the three-year pre-sample mean of the dependent variable for capturing any unobserved factors as a firm-specific dynamic fixed effect (Blundell and Dias, 2009; Blundell, Griffith and Windmeijer, 2002) which could also affect the propensity of the firm to file for patent litigation (Greene, 2012). We use the dynamic fixed effect approach, in line with previous research (Lach and Schankerman, 2008; Salomon and Jin, 2008; Wang and Hagedoorn, 2014), because they can account for dynamic components of unobserved factors which are likely in our case, i.e. patent litigation in the past is likely to affect current litigation decisions. Separately, we estimate linear regression models with firm fixed effects and the number of cases as dependent variable (instead of the likelihood) as consistency checks and find consistent results which are described in detail in the dedicated section below.

Second, CEO compensation designs might not be fully exogeneous. In particular, both the decision to file for patent litigation and the CEO's compensation design are directly or indirectly influenced by the risk-taking behavior of the CEO which is not easily measurable. Hence, we apply instrumental variable (IV) regressions (Bascle, 2008). Specifically, we rely on extended probit regression with endogenous treatment, which implements a maximum likelihood estimator following Wooldridge (2010) and allows for interactions of endogenous with exogenous variables (Liu and Maula, 2021; Stata, 2021). We derive the instruments from prior literature and use the marginal tax rate (Armstrong and Vashishtha, 2012) and indicator variables that are related to industry median values of CEO bonus ratio, stock ratio and stock options ratio. These instruments fulfil the relevancy conditions, i.e. they have explanatory power for CEO compensation components and they are uncorrelated to the dependent variable, i.e. patent litigation.

Specifically, following Armstrong and Vashishtha (2012), our first instrument is expected to be negatively related to equity-based compensation because such compensation design is likely to be less costly for firms with lower marginal tax rates. There is no apparent economic reason for a direct link between a firm's marginal tax rate and the filling of patent litigation. Like Armstrong and Vashishtha (2012), we rely on an indicator variable (Tax Loss) that takes the value of one if a firm has a tax-loss carry-forward in any of the past three years and zero otherwise as a proxy of the marginal tax rate (Armstrong and Vashishtha, 2012; Core and Guay, 1999). Moreover, similar to Benson, Chen, James and Park (2020) and Kini and Williams (2012), we adopt the notion that firms set the standards for the compensation structure based on the compensation designs of similar firms within the industry. These standards are unlikely to directly influence the decision to file for patent litigation (especially after controlling for industry and year fixed effects). Additionally, Hentschel and Kothari (2001) state that a relatively naive measure of an endogenous variable is suitable to be employed as instrument because it is expected to capture the level of the variable but it is unlikely to capture endogenously determined variations around those levels. Therefore, we construct the three indicator IVs that correspond to CEO bonus ratio, stock ratio and stock options ratio variables. Precisely, each indicator takes the value of one, if the corresponding variable is

equal or above the median value, excluding the firm in question, of that variable, for firms in the same industry and in the same size quartile as the firm in question.

To simplify the interpretation of the coefficient estimates of the probit regression we standardize all continuous variables. Finally, robust standard errors (clustered at the firm level) are used in all models.

4 Results

Table 1 displays the number of patent litigations filed across industries based on 2-digit SIC industries. As indicated in the table, litigation occurs from plaintiffs in many different industries. Nevertheless, almost 70% of the patent litigation in the sample originate from four industries (with 'Chemicals and Allied Products' being the dominant industry with 35% of the patent litigation cases, in line with expectations for how important patenting and patent enforcement is for competition in these industries). This first insight provides further confidence that the inclusion of industry-level control variables as well as fixed effects in all estimations is warranted. Furthermore, Table 1 displays the average percentage of patent litigation cases that are decided in trials in each industry for the whole sample. This is an indication for how costly patent litigation is in the industry and, as shown in the table, this (on average) varies considerably by industry. Finally, the last column of Table 1 displays the average duration (in days) of the patent litigation cases in each industry for the duration of the whole sample period, which is a proxy for the tenacity of patent disputes. Again, in line with our expectations, this varies considerably across industries.

Insert Table 1 here

Table 2 displays the descriptive statistics and pairwise correlations of our variables. About 7% of the firm-year observations in the sample take the value of one for firms becoming plaintiffs in patent litigation. This indicates that patent litigation is a meaningful strategic decision for firms in our sample but not one that is taken indiscriminately. Moreover, compensation incentives appear to be nontrivial for the CEOs in the sample. Specifically, on average, CEO bonuses account for about 12% of the annual CEO total compensation. Moreover, stock-based compensation represents about 19% of the annual compensation

while stock options-based compensation accounts for about 28% of the annual compensation of the CEO. Additionally, the values of the standard deviation of the main independent variables (0.160, 0.239 and 0.276 for Bonus ratio, Stock ratio and Stock options ratio respectively) indicate that there is a significant variation in the compensation components among the CEOs in the sample. Furthermore, most variables correlate with the patent litigation indicator variable and exhibit the expected sign.

To test the impact of multicollinearity on the estimation process, we calculate the variance inflation factors (VIFs) values and the condition indices (Hair, 2009) among our independent variables in the second stage of our regression models. None of these measures supports the existence of multicollinearity among the independent variables. Specifically, the highest VIF score is 2.82, which is well below the critical value of 10 (Menard, 2008). The highest value of the condition index is 3.79, which is well below the typically applied critical values (Belsley, Kuh and Welsch, 1980).

Insert Table 2 here

Table 3 shows the results of the two-stage IV probit models. Models 1 to 3 present the first-stage regressions, which show that all the instrument variables are statistically significant indicating, that they have explanatory power over the three variables that are considered to be exogenous. Model 4 shows the second stage of the IV probit model. Moreover, the Wald tests of exogeneity and the correlations of error terms of the second stage equation and the first stage ones, reported at the bottom of Table 3, support our theoretical arguments on the existence of endogeneity in our model. In support of our Hypothesis 1, the coefficient associated with the CEO bonus ratio is negative and significant ($b=-0.175$, $z=-3.65$, $p<0.001$). Specifically, the marginal effect analysis indicates that one standard deviation increase from the mean value of CEO bonus ratio leads to an average decrease of 41.95% ($z=-2.83$, $p=0.005$) in the probability to file for patent litigation. Whereas, one standard deviation decrease from the mean value of the CEO bonus ratio leads to an average increase of 65.55% ($z=2.23$, $p=0.026$) of the probability to file patent litigation.

In support of Hypothesis 2, the coefficient associated with the CEO stock ratio is positive and significant (b=0.121, z=1.99, p =0.047). Consistent with our expectations, this suggests that firms with CEOs that have a high percentage of stocks as part of their total compensation are more likely to file for patent litigation. Particularly, the marginal effect analysis indicates that one standard deviation increase from the mean value of the CEO stock ratio leads to an average increase 42.87% (z=1.96, p=0.05) in the probability to file for patent litigation. Also, one standard deviation decrease from the mean value of the CEO stock ratio leads to an average decrease of 31.34% (z=-2.06, p =0.039) in the probability to file patent litigation.

In support of Hypothesis 3, the coefficient associated with the CEO stock options ratio is negative and significant (b=-0.093, z=-2.48, p=0.013). Specifically, the marginal effect analysis indicates that one standard deviation increase from the mean value of CEO stock options ratio leads to an average decrease of 24.63% (z=-2.00, p=0.045) in the probability to file for patent litigation. One standard deviation decrease from the mean value of CEO stock options ratio leads to an average increase of 31.22% (z=1.97, p=0.048) in the probability to file patent litigation.

Insert Table 3 here

To test Hypotheses 4a to 4c we include in the models the 2-way interaction terms of the corresponding ratio of the compensation component and the average case duration in the industry (tenacity of patent disputes). Model 5 of Table 3 includes the 2-way interaction term of the CEO bonus ratio and the average case duration. In support of Hypothesis 4a, the coefficient of the interaction term is positive and statistically significant (b= 0.036, z= 2.27, p=0.023). For ease of interpretation, we plot the findings in Figure 1 and we perform the corresponding marginal effects analysis. Figure 1 shows the moderating effect of average case duration on the relationship between the CEO bonus ratio and the probability to file patent litigation. Both the plot and the marginal effects analysis indicated that this moderating effect is considerable. Specifically, as the CEO bonus ratio increases, the average rate of change of the probability to file patent litigation is

1.45 times higher when the average case duration is low (b= -0.019, z= -3.74, p < 0.001) compared with when the average case duration is high (b= -0.013, z =-2.58, p= 0.01).

Insert Figure 1 here

Model 6 of Table 3 includes the 2-way interaction term of CEO stock ratio and the average case duration in the industry. While the coefficient of the interaction term is as expected negative, it is not statistically significant (b= -0.001, z F= -0.07, p =0.94), therefore the results provide no support for Hypothesis 4b. Apparently, the incentive effect for CEOs receiving stock is not dependent on the tenacity of patent disputes in their industry. The increased monitoring by stakeholders (or analysts) in industries in which patent disputes are highly tenacious might be less relevant when CEOs are shareholders based on their compensation in stocks and interest are aligned.

Finally, Model 7 of Table 3 includes the 2-way interaction term of CEO stock options ratio and the average case duration. In support of Hypothesis 4c, the coefficient of the interaction term is positive and statistically significant (b= 0.031, z= 1.86, p=0.062). Figure 2 shows the moderating effect of average case duration on the relationship between the CEO stock options ratio and the probability to file for patent litigation. The analysis of marginal effects indicates that, as the CEO stock options ratio increases, the average rate of change of the probability to file patent litigation is 1.85 times higher when the average case duration is low (b= -0.011, z= -2.88, p = 0.004) compared with when the average case duration is high (b= -0.006, z =-1.52, p= 0.129). Model 8 of Table 3, includes all interaction terms and confirms the above results. Overall, our empirical findings indicate the boundary conditions from the tenacity of patent disputes in a firm's industry are particularly relevant when CEOs might neglect filing for patent litigation because bonuses or stock options affect their individual time horizons and risk preferences so that they diverge from the ones of shareholders and industry conditions affect the likelihood of monitoring by the latter.

Insert Figure 2 here

Apart from the coefficients testing our hypotheses, we also summarize the significant estimation results for the control variables. They are largely in line with expectations. We have not developed a-priori hypotheses for the direction of these relationships and can only explore the findings. At the CEO level, CEOs with longer tenure and higher levels of base salary are more likely to file for patent litigation which may indicate that CEOs need to feel comfortable in their roles for making litigation decisions. Intriguingly, for other executives who may be involved in the decision to file for patent litigation only the degree to which their compensation depends on stock options seems to influence the decision and it is in the opposite direction to the CEO's corresponding one. At the firm level, we find that both the patent stock as well as previous experience as defendant in patent litigation increase the odds of becoming a plaintiff in patent litigation. Interestingly, R&D intensity has no significant effect. Further, there is some indication that firms with more resources are more likely to file for patent litigation, i.e. a positive return on asset and cash, while firm size per se has a negative effect. Finally, at the industry level, lower return-on-asset ratios in the industries increase the likelihood for patent litigation. The findings can imply that patent litigation is more likely to occur in sectors in which competitive pressures from lower firm performance are high.

4.1 Robustness Checks

We conduct a range of consistency check estimations to probe the stability of results. All estimation results tables that are not explicitly referenced are available from the authors upon request. Our consistency checks fall into four broad categories. First, we test the sensitivity of results to alternative measurements. Most importantly, patent litigation could be more broadly defined. Therefore, as a robustness check, we include counter litigations in the calculation of the dependent variable. While these litigation cases may be a part of a defensive strategy, they are still authorized by the CEO. The inclusion of these additional cases results in the increase of the mean of the dependent variable to 0.15. We rerun the main analysis, as it is shown in Model 1 of Table 4, and the results are fully consistent with the ones presented in Table 3.

Insert Table 4 here

Second, we assess the effect of our methodological choices. Due to the firm-specific nature of patent litigation, it is important to account for time invariant firm characteristics. However, introducing firm fixed-effects to the IV probit models may result in a sample selection bias because firms with the same response in the sample period (either they do not file for patent litigation at all or file for patent litigation at least once a year) will be excluded from the analysis. Therefore, we use the logarithmic number of the patent litigations that a firm files in a year, plus one (1) as the dependent variable and employ a linear instrumental variable panel regression with firm fixed-effects and robust standard errors clustered by firm. Within this specification, the outcome in question is not the likelihood of patent litigation as a plaintiff by a firm but the number thereof. Additionally, the approach provides statistics indicating the relevance and exogeneity of our selected instrument variables. Specifically, in support of the choice of instruments, the first-stage Sanderson-Windmeijer (SW) F-tests are statistically significant for all the models (F-value =1348.83, $p < 0.001$; F-value =1291.87, $p < 0.001$; F-value =1512.10, $p < 0.001$ for Bonus ratio, Stock ratio and Stock options ratio models respectively) showing that the instruments adequately correlate with the independent variables. Additionally, the Sargan-Hansen test indicates that the instruments are uncorrelated with the error terms in each model (i.e., exogenous) ($\chi 2$ =2.137, $p = 0.144$). As shown in Model 2 of Table 4 the second stage results of the IV panel regression model are fully consistent to the ones presented in Table 3.

Third, we explore the likelihood of alternative explanations driving the significant findings. It is possible that firms that belong to industries that have high R&D expenditures may design their CEOs' compensation packages differently than the others. At the same time, these firms may also have a higher probability to file for patent litigation. Thus, our results could be an artefact of these relationships. To rule out such explanations we re-run the main analysis on industry sample splits, i.e. industries that have high R&D expenditures (above the yearly average) vs the rest. As shown in Models 3 and 4 of Table 4, which present the above analysis, the expected relationships are found in both models ruling out this alternative

explanation. Finally, given that large US patent assertion entities may be included in the sample, the results may be driven by such entities. To dismiss such explanation, we follow Kiebzak et al. (2016) to identify "frequent litigators" as the ones that file twenty or more patent litigations, and exclude those from the sample. As shown in Model 5 of Table 4, the results are fully consistent to the ones presented in Table 3.

Finally, we explore potential interacting "team" effect between CEO compensation packages and the compensation packages of their CTOs or counsels. None of the compensation components of the other executives (CTO, counsel) produces significant moderation effects with the respective compensation component of the CEO. Moreover, we test whether the education of CEOs with a law or engineering degree affects the results since it may affect the degree to which they rely on advice from others. However, we find no significant interaction effects. Overall, the consistency check estimations support the notion that CEOs play an outsized role in the decision making of their firms and their individual incentives as affected by the compensation design alters their firms' decision to file for patent litigation.

5 Discussion

We conduct this study to provide a more complete understanding of how firms decide to enforce their patents through litigation. Within our reasoning, patent litigation is not merely determined by technological, legal or resource conditions (Kafouros et al., 2021; Rudy and Black, 2018; Zhao, 2006) but depends on the individual incentives of CEOs as final decision-makers. CEOs have substantial agency to avoid or force patent litigation because the decision-making context is so complex and information-intensive that it is hard to monitor by the firm's shareholders. We reason, therefore, that CEOs' compensation designs will influence their firms' propensity to engage in patent litigation. We develop an integrated theoretical model that uses mechanisms from research on the incentive effects of CEO compensation (Coles et al., 2006; Devers et al., 2008) and integrate it into theory explaining firm decisions to become plaintiffs in patent litigation (Rudy and Black, 2018; Somaya, 2003, 2012). Based on this model, we hypothesize that bonus payments and stock options for CEOs affect the time horizons and risk preferences of their decision making in a way that reduces their firms' likelihood to file for patent litigation. Conversely, we predict that CEO compensation in firm stock aligns the longer-term time horizon of CEOs with those of their firms'

shareholders and results in more frequent patent litigation. Additionally, we identify the tenacity of patent disputes in an industry as an explicit condition limiting the effects of CEO compensation mechanisms because it curtails the agency that CEOs have for following their individual incentives when shareholders and financial analysts are used to analyzing patent disputes. Our empirical study supports all of these hypotheses but the boundary condition does not apply to stocks within CEO compensation.

These results have consequences for academic research in two primary ways. First, patent litigation is central to the theory of firms' value capture from intellectual property (Kafouros et al., 2021; Somaya, 2012). However, the usefulness of the theory is limited if it rests on the strong assumption that CEOs are homogeneous in the degree to which they analyze information about patent infringement and act on it. We focus on the mechanisms that shape CEO incentives in virtually every firm, i.e. bonuses, stocks and stock options as part of compensation packages. Our model comes closer to the reality of patent litigation decisions in firms with CEOs as heterogeneous decision-makers considering the time horizons and riskiness of their decision making in light of its consequences for their own economic wellbeing. These incentive mechanisms are well understood in theory on compensation design (Coles et al., 2006; Devers et al., 2008) but have not entered theory on patent strategy before. Our integrated theory has wider consequences for theory on patent strategy because CEO incentives are likely to affect a variety of other firm decisions related to its intellectual property such as the likelihood to settle cases (Somaya, 2003) or bargain aggressively for licensing fees (Arora and Ceccagnoli, 2006).

Second, compensation design literature details how shareholders devise CEO compensation packages to affect the investment decisions of their CEOs (Sanders and Hambrick, 2007; Wright et al., 2007; Wright et al., 2002). However, generating CEO incentives through bonuses, stocks or stock options is much broader in their effects. They are not limited to investment decisions but are likely to affect CEO considerations in many unintended ways. We focus on one of these unintended consequences, i.e. patent litigation. Hence, we move towards a more complete theory of CEO compensation affecting firm innovation activities in which firms increase their R&D spending in response to their CEOs receiving stock options (Sanders and Hambrick, 2007) but at the same time forego opportunities to enforce their firm's existing patents through

litigation. We suspect that more of these unintended consequences exist, especially in settings in which CEO investment decisions are not easily observed by shareholders or financial analysts but the enforcement of existing property rights is easily neglected by CEOs because they go unnoticed. Hence, our theoretical reasoning expands the usefulness of theory on the incentive effects of CEO compensation designs to many strategic firm decisions that are not investments.

Finally, our findings have also immediate importance for management practice in two ways. First, the threat from patent litigation is a major impediment for firms that lack resources for engaging in lengthy legal confrontations (Cremers and Schliessler, 2015). Hence, the assessment of a firm's exposure to costly patent litigation is crucial for the comprehensive management of the intellectual property. Our findings indicate that these assessments should not be limited to legal and technological considerations. Instead, the financial incentives of rival CEOs should be considered. Their compensation packages can reveal whether it is in their own best interest to pursue patent litigation aggressively or whether bonuses or stock options make them comparatively more cautious.

What is more, aligning CEO and shareholder incentives is a major task for shareholders and their representatives. Our results indicate that many outcome-based compensation designs for CEOs can have unintended consequences. This is particularly salient for firms with large stocks of existing patents that could be enforced against rivals. Shareholders have to be aware that CEOs with compensations relying heavily on bonuses and stock options while lacking stock are increasingly unlikely to realize the firm's opportunities for patent enforcement.

6 Limitations and future research

While conducting this research project, we discover several issues which limit its generalizability or require dedicated studies. These limitations exist along five dimensions.

First, we infer firm decision on patent litigation from patent filings in court. Realistically, the potential scope of aggressive patent enforcement is much broader and starts, for example, with cease and desist letters. Dedicated studies might be able to capture the increasing intensity of patent enforcement and how such intensity is affected by CEO incentives.

Second, our results are consistent with the theoretical predictions for how CEO bonuses, stocks and stock options affect their firms patent litigations. We rely on an instrument variable approach to identify effects. Ideally, we would like to observe the decision-making processes and the related considerations of CEOs directly. Future studies might benefit from experimental designs that can capture the decision making directly.

Third, CEOs are the final decision makers on patent litigation of their firms. However, they rely on specialists inside, e.g. patent management, and outside the firm, e.g. patent lawyers, who prepare their decision making. There might be an interesting interplay in which the firm's organization of patent decision-making enables or constrains their CEO's freedom for considering individual incentives from compensation designs. We suspect that studies uncovering these effects would require qualitative designs to capture the richness of interactions.

Fourth, we test our hypothesis for US firms. This has the advantage that data on compensation designs and patent litigation is available for many firms over long time periods. However, certain aspects of the US setting might not apply in other countries such as the reliance on stocks and stock options for compensating CEOs and the strength of the patent system. We encourage comparative studies which could not just substantiate our empirical findings but introduce country level mechanisms, e.g. institutional or cultural differences, into the theoretical logic.

Fifth, while we strive to ensure that endogeneity does not affect our findings by relying on instrumental variables approaches and fixed-effects estimators, concerns about causal identification may still exist. This is because these approaches try to separate the sources of variation in the independent variables as originating from particular causal mechanisms versus alternatives (Shaver, 2020). However, it is possible that other causal mechanisms still exist. Thus, future research can employ additional and complementary approaches such as natural experiments (Shaver, 2020) and/or qualitative methods to reinforce the causal identification.

7 Conclusion

In this study, we present a theoretical model that incorporates CEOs' financial incentives into their firms' decision to file for patent litigation. CEO bonuses, stocks and stock options have diverging effects on this important firm decision. Our integrated model makes these costly and consequential decisions for both plaintiffs and defendants more reliably predictable and thereby overcomes the limitations of existing theory which is largely focused on firm-level characteristics.

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Tables

Table 1 – Patent litigations filed by industry

Industry	Number of patent litigations	Percentage of patent litigations	Average ratio of trial to patent litigations (%)	Average duration of patent litigations
Mining and Quarrying of Nonmetallic Minerals, Except Fuels	6	0.174	16.667	912.500
Heavy Construction, Except Building Construction, Contractor	9	0.261	33.333	428.889
Food and Kindred Products	12	0.348	0.000	487.333
Textile Mill Products	25	0.724	20.000	374.760
Lumber and Wood Products, Except Furniture	5	0.145	0.000	233.000
Furniture and Fixtures	14	0.406	14.286	632.429
Paper and Allied Products	95	2.753	21.053	457.926
Printing, Publishing and Allied Industries	11	0.319	0.000	148.909
Chemicals and Allied Products	1205	34.917	14.606	556.110
Petroleum Refining and Related Industries	10	0.290	20.000	372.700
Rubber and Miscellaneous Plastic Products	41	1.188	7.317	325.610
Leather and Leather Products	46	1.333	0.000	322.457
Primary Metal Industries	19	0.551	21.053	443.632
Fabricated Metal Products	25	0.724	12.000	647.520
Industrial and Commercial Machinery and Computer Equipment	404	11.707	11.139	509.114
Electronic & Other Electrical Equipment & Components	521	15.097	10.749	460.702
Transportation Equipment	98	2.840	15.306	579.653
Measuring, Photographic, Medical, & Optical Goods, & Clocks	285	8.258	17.544	593.733
Miscellaneous Manufacturing Industries	81	2.347	8.642	366.580
Communications	50	1.449	10.000	533.800
Wholesale Trade - Durable Goods	21	0.609	19.048	451.667
Wholesale Trade - Nondurable Goods	12	0.348	16.667	547.750
Building Materials, Hardware, Garden Supplies & Mobile Homes	10	0.290	0.000	187.200
General Merchandise Stores	9	0.261	11.111	707.222
Apparel and Accessory Stores	11	0.319	9.091	546.000
Home Furniture, Furnishings and Equipment Stores	5	0.145	0.000	658.800
Eating and Drinking Places	9	0.261	11.111	283.222
Miscellaneous Retail	20	0.580	25.000	517.300
Depository Institutions	9	0.261	11.111	471.333
Holding and Other Investment Offices	38	1.101	21.053	555.737
Business Services	283	8.201	9.894	483.519
Amusement and Recreation Services	5	0.145	0.000	236.400
Health Services	26	0.753	15.385	1,100.310
Engineering, Accounting, Research, and Management Services	13	0.377	7.692	652.615
Other	18	0.522	33.333	699.889
Total	3,451	100	13.300	519.858

Table 2 – Descriptive statistics and pairwise correlation matrix

		mean	median	sd	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.
1.	Plaintiff indicator	0.070	0.000	0.255	1													
2.	Bonus ratio	0.116	0.019	0.160	-0.01	1												
3.	Stock ratio	0.185	0.025	0.239	-0.02**	-0.32***	1											
4.	Stock options ratio	0.282	0.228	0.276	0.07***	-0.14***	-0.35***	1										
5.	Average case duration	721.213	724.155	172.084	0.02**	-0.07***	0.00	0.01	1									
6.	Pre-sample mean dep. var.	0.130	0.000	0.336	0.25***	0.02***	-0.03***	0.09***	-0.00	1								
7.	CEO duality	0.530	1.000	0.499	0.00	0.09***	-0.06***	0.02***	0.00	0.08***	1							
8.	CEO tenure	7.551	5.331	7.010	0.01	0.03***	-0.07***	-0.09***	-0.03***	-0.05***	0.22***	1						
9.	CEO age	55.273	55.000	7.136	-0.02***	0.04***	0.01	-0.13***	-0.03***	0.02***	0.25***	0.40***	1					
10.	CEO non-equity comp.	6.816	6.801	0.722	0.03***	0.46***	0.06***	0.01**	-0.05***	0.15***	0.23***	-0.01	0.16***	1				
11.	CTO/counsel present	0.346	0.000	0.476	0.00	-0.14***	0.18***	-0.08***	0.06***	-0.01	-0.02***	-0.09***	-0.03***	0.02***	1			
12.	CTO/counsel - Bonus ratio	0.029	0.000	0.086	-0.00	0.28***	-0.07***	-0.03***	0.02***	-0.00	0.05***	-0.03***	-0.01	0.20***	0.47***	1		
13.	CTO/counsel - Stocks ratio	0.070	0.000	0.156	-0.00	-0.20***	0.47***	-0.20***	0.03***	-0.02***	-0.05***	-0.06***	-0.02***	0.01*	0.61***	0.08***	1	
14.	CTO/counsel - Stock options ratio	0.072	0.000	0.162	0.05***	-0.07***	-0.08***	0.27***	0.05***	0.04***	0.02***	-0.05***	-0.04***	0.05***	0.61***	0.28***	0.14***	1
15.	CTO/counsel - Salary ratio	0.124	0.000	0.205	-0.02***	-0.11***	0.09***	-0.12***	0.04***	-0.04***	-0.04***	-0.05***	-0.02**	-0.09***	0.83***	0.38***	0.39***	0.38***
16.	Patent litigation experience	4.189	0.000	9.584	0.34***	-0.11***	0.15***	0.01*	-0.01*	0.45***	-0.01	-0.02***	-0.00	0.11***	0.07***	-0.01*	0.11***	0.07***
17.	Stock of patents	2.870	2.485	2.491	0.28***	-0.09***	0.08***	0.11***	0.01**	0.46***	0.04***	-0.08***	0.02***	0.14***	0.11***	0.02**	0.10***	0.13***
18.	Patents quality	1.465	1.174	1.369	0.29***	-0.11***	0.05***	0.16***	0.03***	0.42***	-0.00	-0.06***	-0.03***	0.07***	0.10***	0.01	0.09***	0.14***
19.	Patents value	1.672	1.585	1.364	0.16***	-0.10***	0.13***	0.16***	0.03***	0.24***	0.08***	-0.10***	-0.02***	0.26***	0.10***	0.03***	0.12***	0.13***
20.	Patents classes diversification	0.500	0.500	0.500	0.18***	-0.07***	0.05***	0.07***	-0.01	0.31***	0.04***	-0.07***	0.04***	0.09***	0.09***	0.01**	0.07***	0.09***
21.	Firm return	0.090	0.080	0.389	0.02**	0.11***	-0.05***	0.01	-0.02***	0.01	-0.01**	0.01	-0.03***	0.04***	-0.03***	0.02***	-0.03***	-0.03***
22.	Firm ROA	0.068	0.043	0.119	0.11***	0.04***	-0.03***	0.07***	0.05***	0.10***	0.01	0.02**	0.01	0.07***	0.00	0.01	-0.01	0.05***
23.	Firm size	7.596	7.441	1.792	0.04***	-0.01**	0.26***	-0.02***	0.03***	0.14***	0.22***	-0.09***	0.12***	0.56***	0.06***	0.05***	0.15***	0.03***
24.	Market to book ratio	2.028	1.559	1.385	0.09***	0.01**	-0.12***	0.21***	-0.00	0.06***	-0.05***	0.04***	-0.11***	-0.11***	-0.06***	-0.03***	-0.06***	0.05***
25.	Firm cash position	0.159	0.088	0.177	0.09***	-0.08***	-0.07***	0.16***	0.03***	-0.01	-0.16***	0.05***	-0.14***	-0.26***	0.00	-0.03***	-0.03***	0.07***
26.	Leverage	0.218	0.198	0.186	-0.04***	0.03***	0.08***	-0.05***	0.00	0.01	0.08***	-0.06***	0.05***	0.20***	0.07***	0.06***	0.07***	-0.00
27.	R&D expenses to sales	0.051	0.000	0.119	0.12***	-0.10***	-0.08***	0.21***	0.07***	0.07***	-0.13***	0.01**	-0.11***	-0.20***	0.02***	-0.04***	-0.02***	0.12***
28.	Advertising to sales	0.011	0.000	0.025	0.04***	-0.01*	-0.02***	0.03***	-0.00	0.01	-0.00	-0.00	-0.07***	0.05***	-0.01	-0.01*	-0.00	-0.00
29.	Industry trials to litigations ratio	0.152	0.154	0.083	0.04***	0.14***	-0.24***	0.18***	0.12***	0.09***	0.06***	-0.03***	-0.03***	0.01*	-0.09***	0.05***	-0.15***	0.03***
30.	Industry litigations ratio	0.009	0.004	0.016	0.04***	-0.09***	0.08***	-0.07***	-0.06***	0.04***	-0.04***	-0.01	0.04***	0.01	0.00	-0.03***	0.01	-0.01**
31.	Industry number of firms	81.271	77.000	58.672	0.10***	-0.10***	-0.02***	0.11***	0.16***	0.06***	-0.07***	0.00	-0.10***	-0.20***	0.05***	-0.01	0.03***	0.07***
32.	Industry return	-0.008	0.031	0.268	-0.03***	0.07***	0.04***	-0.08***	-0.10***	-0.03***	0.00	0.00	0.04***	0.09***	0.02***	0.03***	0.04***	-0.03***
33.	Industry ROA	0.059	0.080	0.089	-0.10***	0.07***	0.01**	-0.10***	-0.13***	-0.05***	0.02***	-0.00	0.00	0.04***	-0.08***	-0.02***	-0.02***	-0.11***

Table 2 – Continued

	15.	16.	17.	18.	19.	20.	21.	22.	23.	24.	25.	26.	27.	28.	29.	30.	31.	32.
15. CTO/counsel - Salary ratio	1																	
16. Patent litigation experience	-0.01	1																
17. Stock of patents	0.03***	0.47***	1															
18. Patents quality	0.02**	0.46***	0.90***	1														
19. Patents value	-0.02***	0.33***	0.60***	0.60***	1													
20. Patents classes diversification	0.03***	0.29***	0.80***	0.63***	0.49***	1												
21. Firm return	-0.05***	-0.00	0.01	0.02**	0.01	0.00	1											
22. Firm ROA	-0.05***	0.11***	0.14***	0.13***	0.11***	0.08***	0.21***	1										
23. Firm size	-0.08***	0.26***	0.18***	0.12***	0.45***	0.09***	-0.07***	-0.06***	1									
24. Market to book ratio	-0.08***	0.05***	0.08***	0.17***	0.15***	0.03***	0.33***	0.40***	-0.26***	1								
25. Firm cash position	0.02***	0.07***	0.12***	0.25***	0.08***	0.05***	0.07***	0.04***	-0.37***	0.41***	1							
26. Leverage	0.04***	-0.03***	-0.02***	-0.08***	0.05***	-0.00	-0.08***	-0.10***	0.30***	-0.22***	-0.38***	1						
27. R&D expenses to sales	0.02**	0.09***	0.26***	0.38***	0.14***	0.17***	-0.00	-0.09***	-0.28***	0.29***	0.57***	-0.16***	1					
28. Advertising to sales	-0.01*	0.10***	0.00	0.00	0.08***	-0.03***	-0.00	0.06***	-0.01	0.13***	0.08***	-0.02***	-0.02***	1				
29. Industry trials to litigations ratio	-0.07***	-0.05***	0.07***	0.08***	0.03***	0.05***	0.03***	0.10***	-0.10***	0.09***	0.02***	-0.03***	0.10***	0.00	1			
30. Industry litigations ratio	0.01**	0.22***	0.03***	0.00	0.00	0.05***	-0.02***	-0.00	0.00	-0.01	-0.01	-0.01	-0.06***	0.12***	-0.06***	1		
31. Industry number of firms	0.06***	0.07***	0.19***	0.29***	0.14***	0.09***	0.06***	0.20***	-0.14***	0.18***	0.35***	-0.21***	0.37***	-0.05***	0.15***	-0.27***	1	
32. Industry return	0.03***	0.01*	-0.04***	-0.06***	-0.02***	-0.02***	-0.12***	-0.11***	0.08***	0.03***	-0.04***	0.01**	-0.08***	-0.00	-0.04***	0.04***	-0.12***	1
33. Industry ROA	-0.06***	-0.07***	-0.17***	-0.20***	-0.10***	-0.09***	-0.08***	-0.56***	0.04***	-0.14***	-0.21***	0.05***	-0.34***	0.02***	-0.11***	0.10***	-0.42***	0.16***

N = 23,302

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ (two-tailed tests)

Table 3 – Instrumental variable (IV) probit regression of the probability of filing for patent litigation

	First Stage			Second Stage				
Dependent variable	Bonus ratio	Stocks ratio	Stock options ratio	Plaintiff in patent litigation				
	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7	Model 8
Bonus ratio				-0.175***	-0.174***	-0.175***	-0.178***	-0.175***
				(0.048)	(0.048)	(0.048)	(0.048)	(0.048)
Stocks ratio				0.122**	0.122**	0.122**	0.122**	0.122**
				(0.061)	(0.061)	(0.061)	(0.061)	(0.061)
Stock options ratio				-0.093**	-0.092**	-0.093**	-0.095**	-0.096**
				(0.037)	(0.037)	(0.037)	(0.037)	(0.037)
Bonus ratio **x** Average case duration					0.036**			0.055***
					(0.016)			(0.020)
Stocks ratio **x** Average case duration						-0.001		0.023
						(0.016)		(0.019)
Stock options ratio **x** Average case duration							0.031*	0.049**
							(0.017)	(0.020)
Average trial duration	-0.010	0.009	-0.011	0.032	0.020	0.032	0.023	-0.006
	(0.007)	(0.007)	(0.007)	(0.029)	(0.030)	(0.029)	(0.029)	(0.032)
Pre-sample mean dep. var.	0.032	-0.072**	-0.011	0.200***	0.199***	0.200***	0.201***	0.201***
	(0.026)	(0.036)	(0.028)	(0.058)	(0.058)	(0.058)	(0.058)	(0.058)
CEO duality	-0.061***	0.015	-0.013	-0.035	-0.036	-0.035	-0.035	-0.036
	(0.014)	(0.016)	(0.015)	(0.040)	(0.041)	(0.040)	(0.041)	(0.041)
CEO tenure	0.022**	-0.061***	-0.027***	0.075***	0.075***	0.075***	0.074***	0.074***
	(0.010)	(0.010)	(0.009)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
CEO age	-0.023***	0.000	-0.028***	-0.066***	-0.065***	-0.066***	-0.066***	-0.065***
	(0.008)	(0.009)	(0.008)	(0.021)	(0.021)	(0.021)	(0.021)	(0.021)
CEO non-equity comp.	0.432***	0.038***	0.019	0.129***	0.128***	0.129***	0.131***	0.129***
	(0.018)	(0.012)	(0.013)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
CTO/counsel present	-0.363***	-0.402***	-0.183***	-0.137	-0.133	-0.138	-0.135	-0.122
	(0.034)	(0.050)	(0.039)	(0.139)	(0.139)	(0.139)	(0.139)	(0.139)
CTO/counsel - Bonus ratio	0.169***	0.018**	-0.027***	0.042	0.039	0.042	0.043*	0.038
	(0.011)	(0.008)	(0.007)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
CTO/counsel - Stocks ratio	0.024***	0.278***	-0.027***	-0.009	-0.009	-0.009	-0.009	-0.011
	(0.008)	(0.012)	(0.009)	(0.035)	(0.035)	(0.035)	(0.035)	(0.035)
CTO/counsel - Stock options ratio	0.007	0.010	0.171***	0.072***	0.073***	0.072***	0.071***	0.071***
	(0.007)	(0.010)	(0.010)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
CTO/counsel - Salary ratio	0.061***	0.028*	-0.003	0.031	0.029	0.031	0.031	0.028
	(0.011)	(0.015)	(0.012)	(0.035)	(0.035)	(0.035)	(0.036)	(0.036)

	First Stage			Second Stage				
Dependent variable	Bonus ratio	Stocks ratio	Stock options ratio	Plaintiff in patent litigation				
Patent litigation experience	0.041***	0.055***	-0.008	0.283***	0.283***	0.283***	0.283***	0.283***
	(0.010)	(0.017)	(0.009)	(0.020)	(0.020)	(0.020)	(0.020)	(0.020)
Stock of patents	-0.066***	0.029	-0.034	0.053	0.054	0.053	0.053	0.056
	(0.024)	(0.029)	(0.025)	(0.069)	(0.069)	(0.069)	(0.069)	(0.069)
Patents quality	0.035**	0.039*	0.048**	0.151***	0.151***	0.151***	0.151***	0.151***
	(0.018)	(0.022)	(0.021)	(0.049)	(0.049)	(0.049)	(0.049)	(0.049)
Patents value	-0.024**	-0.026**	0.026**	0.038	0.038	0.038	0.037	0.038
	(0.011)	(0.013)	(0.010)	(0.034)	(0.034)	(0.034)	(0.034)	(0.034)
Patents classes diversification	-0.013	-0.019	-0.040	0.017	0.015	0.017	0.017	0.014
	(0.025)	(0.031)	(0.027)	(0.070)	(0.070)	(0.070)	(0.070)	(0.070)
Firm return	0.026***	-0.004	-0.021***	0.014	0.014	0.014	0.014	0.015
	(0.005)	(0.006)	(0.006)	(0.015)	(0.015)	(0.015)	(0.015)	(0.015)
Firm ROA	0.032***	0.026**	-0.004	0.087***	0.088***	0.087***	0.086***	0.087***
	(0.012)	(0.012)	(0.011)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Firm size	-0.234***	0.134***	0.124***	-0.096**	-0.096**	-0.096**	-0.098**	-0.099**
	(0.017)	(0.017)	(0.015)	(0.043)	(0.043)	(0.043)	(0.043)	(0.043)
Market to book ratio	-0.022**	-0.001	0.081***	0.004	0.003	0.004	0.004	0.003
	(0.010)	(0.010)	(0.011)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
Firm cash position	0.024**	-0.024**	0.043***	0.050**	0.050**	0.050**	0.049**	0.049**
	(0.012)	(0.011)	(0.011)	(0.024)	(0.024)	(0.024)	(0.024)	(0.024)
Leverage	-0.017**	0.028***	0.005	0.014	0.014	0.014	0.014	0.013
	(0.009)	(0.009)	(0.008)	(0.023)	(0.023)	(0.023)	(0.023)	(0.023)
R&D expenses to sales	-0.012	0.011	0.031***	0.035	0.036	0.035	0.034	0.035
	(0.010)	(0.011)	(0.012)	(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Advertising to sales	-0.011	-0.019**	0.004	0.067***	0.066***	0.067***	0.066***	0.066***
	(0.009)	(0.009)	(0.008)	(0.019)	(0.019)	(0.019)	(0.019)	(0.019)
Industry trials to litigations ratio	-0.015**	0.007	0.005	-0.029	-0.030	-0.029	-0.030	-0.031
	(0.006)	(0.007)	(0.006)	(0.030)	(0.030)	(0.030)	(0.030)	(0.030)
Industry litigations ratio	0.003	-0.014	0.012	0.028	0.026	0.028	0.027	0.025
	(0.008)	(0.011)	(0.009)	(0.028)	(0.028)	(0.028)	(0.028)	(0.028)
Industry number of firms	0.074**	-0.199***	-0.047	0.122	0.132	0.122	0.126	0.138
	(0.034)	(0.042)	(0.039)	(0.111)	(0.112)	(0.111)	(0.111)	(0.111)
Industry return	0.036***	-0.012	0.004	0.023	0.025	0.023	0.023	0.024
	(0.008)	(0.008)	(0.009)	(0.033)	(0.033)	(0.033)	(0.033)	(0.033)
Industry ROA	0.052***	0.053***	-0.095***	-0.084*	-0.082*	-0.084*	-0.088**	-0.085*
	(0.016)	(0.018)	(0.018)	(0.044)	(0.044)	(0.044)	(0.044)	(0.044)
Tax loss	-0.029**	0.030*	0.037**					

	First Stage			Second Stage				
Dependent variable	Bonus ratio	Stocks ratio	Stock options ratio	Plaintiff in patent litigation				
	(0.014)	(0.016)	(0.014)					
Industry bonus indicator	-0.194***	-0.250***	1.190***					
	(0.013)	(0.015)	(0.018)					
Industry stocks ratio indicator	-0.120***	0.842***	-0.093***					
	(0.015)	(0.024)	(0.015)					
Industry stock options ratio indicator	0.942***	-0.181***	-0.241***					
	(0.019)	(0.016)	(0.017)					
Constant	0.697***	-1.247***	-0.537***	-2.610***	-2.593***	-2.609***	-2.603***	-2.575***
	(0.093)	(0.354)	(0.129)	(0.579)	(0.569)	(0.578)	(0.584)	(0.578)
Wald test of exogeneity				317.74***	314.16***	317.07***	318.54***	314.60***
corr ($\epsilon_{Plaintiff\ indicator}, \epsilon_{Bonus\ ratio}$)				0.351***	0.350***	0.351***	0.351***	0.349***
				(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
corr ($\epsilon_{Plaintiff\ indicator}, \epsilon_{Stock\ ratio}$)				0.207***	0.208***	0.207***	0.207***	0.207***
				(0.042)	(0.042)	(0.042)	(0.042)	(0.042)
corr($\epsilon_{Plaintiff\ indicator}, \epsilon_{Stock\ option\ ratio}$)				0.299***	0.298***	0.299***	0.298***	0.297***
				(0.025)	(0.025)	(0.025)	(0.025)	(0.025)
Log likelihood				-77,309.420	-77307.397	-77309.417	-77307.782	-77303.864
Walt X^2				2,3,55.055***	2,347.776***	2,355.039***	2,355.899***	2,348.891***

Note: N =23,302; Industry and year fixed effects are included in all models; robust standard errors are reported in parenthesis.

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ (two-tailed tests)

Table 4 – Robustness check

Methodology	IV Probit	IV panel regression	IV Probit		
Dependent variable	Likl. plaintiff (including counter cases)	Natural logarithm of yearly number of plaintiff cases	Likl. plaintiff in patent litigation	Likl. plaintiff in patent litigation	Likl. plaintiff in patent litigation
			Low R&D industries	High R&D industries	Excluding "frequent litigators"
	Model 1	Model 2	Model 3	Model4	Model 5
Bonus ratio	-0.111**	-0.015***	-0.267**	-0.171***	-0.200***
	(0.050)	(0.005)	(0.121)	(0.055)	(0.047)
Stock ratio	0.100**	0.008**	0.339***	0.165**	0.121**
	(0.040)	(0.004)	(0.124)	(0.078)	(0.060)
Stock options ratio	-0.071**	-0.008**	-0.203**	-0.103**	-0.109***
	(0.036)	(0.003)	(0.093)	(0.041)	(0.037)
Average case duration	0.048**	0.004***	-0.000	-0.026	0.038
	(0.021)	(0.001)	(0.033)	(0.039)	(0.029)
Pre-sample mean dep. var.	0.169***		0.224	0.139**	0.209***
	(0.050)		(0.137)	(0.064)	(0.058)
CEO duality	-0.065**	-0.002	-0.004	-0.047	-0.031
	(0.031)	(0.004)	(0.098)	(0.048)	(0.041)
CEO tenure	0.028	0.003	0.059	0.085***	0.071***
	(0.017)	(0.003)	(0.038)	(0.028)	(0.023)
CEO age	-0.067***	0.001	-0.004	-0.080***	-0.071***
	(0.018)	(0.003)	(0.045)	(0.025)	(0.021)
CEO non-equity comp.	0.022	0.012***	0.250***	0.108***	0.149***
	(0.033)	(0.004)	(0.076)	(0.037)	(0.034)
CTO/counsel present	-0.110	0.011	-0.165	-0.154	-0.126
	(0.103)	(0.011)	(0.273)	(0.180)	(0.140)
CTO/counsel - Bonus ratio	0.023	0.000	0.013	0.034	0.045*
	(0.019)	(0.002)	(0.049)	(0.027)	(0.026)
CTO/counsel - Stocks ratio	-0.026	-0.002	-0.125*	-0.027	-0.011
	(0.025)	(0.003)	(0.065)	(0.046)	(0.036)
CTO/counsel - Stock options ratio	0.051*	0.001	0.068	0.085**	0.072***
	(0.028)	(0.003)	(0.068)	(0.033)	(0.027)
CTO/counsel - Salary ratio	0.029	-0.004	0.107	0.034	0.021
	(0.023)	(0.003)	(0.071)	(0.045)	(0.036)
Patent litigation experience	0.473***	-0.027***	0.174***	0.352***	0.291***
	(0.025)	(0.009)	(0.046)	(0.022)	(0.024)
Stock of patents	-0.059	0.008	-0.193	0.202**	0.054
	(0.054)	(0.010)	(0.173)	(0.083)	(0.069)
Patents quality	0.078*	0.020**	0.433***	0.059	0.151***
	(0.041)	(0.008)	(0.117)	(0.057)	(0.049)
Patents value	0.057**	-0.004	-0.103	0.147***	0.031
	(0.024)	(0.003)	(0.071)	(0.042)	(0.034)
Patents classes diversification	0.052	-0.019	0.441*	0.016	0.010
	(0.055)	(0.011)	(0.225)	(0.081)	(0.070)
Firm return	-0.022*	0.000	0.107***	0.009	0.012
	(0.013)	(0.001)	(0.041)	(0.017)	(0.015)
Firm ROA	0.056**	0.008**	-0.029	0.088***	0.074***
	(0.024)	(0.004)	(0.059)	(0.031)	(0.027)
Firm size	0.201***	0.020***	-0.194**	-0.218***	-0.113***
	(0.031)	(0.007)	(0.078)	(0.048)	(0.042)
Market to book ratio	0.077***	-0.004	-0.009	-0.012	0.008

Methodology	IV Probit	IV panel regression	IV Probit		
Dependent variable	Likl. plaintiff (including counter cases)	Natural logarithm of yearly number of plaintiff cases	Likl. plaintiff in patent litigation	Likl. plaintiff in patent litigation	Likl. plaintiff in patent litigation
			Low R&D industries	High R&D industries	Excluding "frequent litigators"
	(0.018)	(0.003)	(0.060)	(0.026)	(0.023)
Firm cash position	0.049**	-0.002	0.263***	0.036	0.048**
	(0.020)	(0.004)	(0.055)	(0.027)	(0.024)
Leverage	-0.024	0.001	0.049	0.006	0.008
	(0.018)	(0.003)	(0.045)	(0.026)	(0.023)
R&D expenses to sales	0.031	-0.009	0.107	0.021	0.031
	(0.023)	(0.007)	(0.082)	(0.026)	(0.025)
Advertising to sales	0.093***	0.002	0.040	0.039*	0.068***
	(0.016)	(0.004)	(0.032)	(0.021)	(0.020)
Industry trials to litigations ratio	0.014	-0.001	0.056*	-0.140***	-0.021
	(0.018)	(0.001)	(0.033)	(0.048)	(0.030)
Industry litigations ratio	0.072***	0.005**	0.060*	0.060**	0.023
	(0.020)	(0.002)	(0.032)	(0.027)	(0.029)
Industry number of firms	0.065	-0.002	-0.214*	0.032	0.057
	(0.101)	(0.007)	(0.120)	(0.032)	(0.114)
Industry return	-0.058**	0.001	0.004	0.027	0.022
	(0.024)	(0.002)	(0.065)	(0.039)	(0.033)
Industry ROA	0.021	-0.000	0.048	-0.049	-0.103**
	(0.041)	(0.006)	(0.087)	(0.035)	(0.045)
Constant	-3.854***	0.077***	-1.809***	-0.959***	-1.913***
	(0.960)	(0.010)	(0.269)	(0.124)	(0.411)
Industry fixed effects	Yes	No	No	No	Yes
Firm fixed effects	No	Yes	No	No	No
Number of observations	23,302	23,302	10,925	12,377	23,023
Walt X^2	3,046.04	1,000.738***	276.34***	1,647.18***	1,954.09***

Notes: Year fixed effects are included in all models; robust standard errors are reported in parenthesis.
* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$ (two-tailed tests)

Figure 1 – Plot of the interaction effect of CEO bonus ratio with the average case duration on the probability to file patent litigation

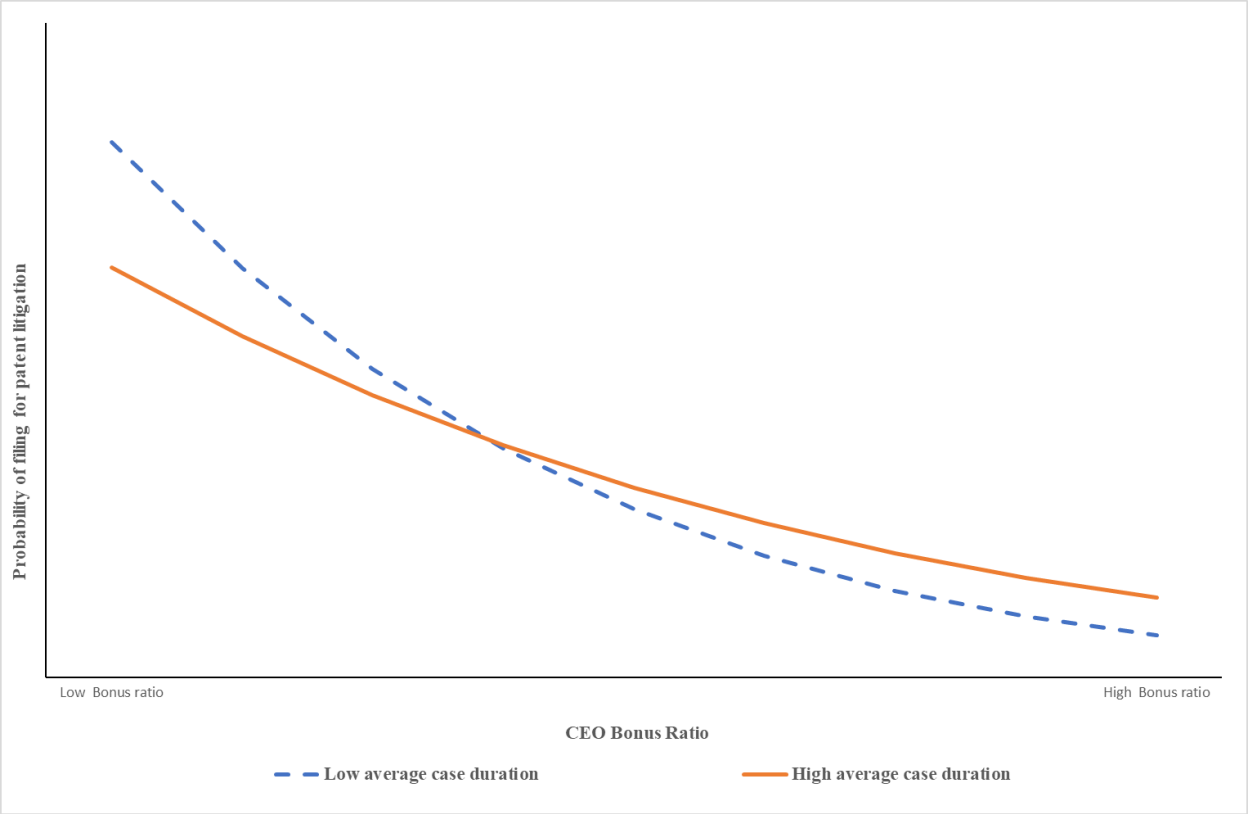

Figure 2 – Plot of the interaction effect of CEO stock options ratio with the average case duration on the probability to file patent litigation