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The impact of pay dispersion on executive behavior: Evidence from innovation

Mario Daniele Amore
Department of Management and Technology
Bocconi University and CRIOS
Via Roentgen, 1
20136 Milan – Italy
mario.amore@unibocconi.it

Virgilio Failla
School of Management
University of Bath
Bath BA2 7AY, United Kingdom
V.Failla@bath.ac.uk

Abstract

Compensation packages are widely used to motivate top executives. Dispersion in pay levels among a firm's executives can trigger two antithetic effects, social comparison and individual motivation, with unclear implications for firm performance. We focus on innovation activities, one important channel through which pay dispersion affects firm performance. We find that executive pay dispersion acts as a double-edged sword: on the one hand, dispersion in *variable pay* significantly increases innovation; on the other hand, dispersion in *fixed pay* depresses innovation. Results are robust to a number of tests, including considering cash pay only, and restricting the analysis to executives with direct responsibility for innovation projects.

Keywords: executive pay; pay dispersion; executive behavior; innovation

1. Introduction

Monetary incentives have long been considered the cornerstone instrument to motivate top executives (Bonner and Sprinkle, 2002). Indeed, the provision of monetary incentives via compensation schemes can be tailored to increase executives' commitment towards long-term projects (Balkin et al., 2000; Lerner and Wulf, 2007; Manso, 2013) and better align managers' and shareholders' interests (Coughlan and Schmidt, 1985). However, the literature has provided mixed evidence on the nexus between monetary incentives and task performance; results have been shown to vary depending on the nature of the task, context characteristics and compensation schemes (Bonner and Sprinkle, 2002).

Building on the view that top executives often operate as teams rather than isolated individuals, a growing literature focuses on the dispersion of pay within a firm's top executive team (Bushman et al. 2016). Pay dispersion is crucial for executives' decision-making because it creates reference points for each executive to assess his/her own compensation package. Unfortunately, there is limited and contradictory evidence on the corporate implications of executive pay dispersion: some scholars have shown negative effects on firm performance (Bloom, 1999; Jaskiewicz et al., 2016; Siegel and Hambrick, 2005; Carpenter and Sanders, 2004) while others have found that it may beneficial for companies (Kale et al., 2009; Lee et al., 2008). From an empirical standpoint, while several studies have explored executive pay dispersion on accounting and stock market returns, the specific mechanisms through which pay inequality influences firm performance are still largely unknown.

One such mechanism, increasingly under scrutiny in the accounting literature (e.g., Koh and Reeb, 2015; Plumlee et al., 2015; Lin and Wang, 2017), is a firm's innovation policy. Successful technological innovations are typically the result of interconnected work at the apex of companies (Siegel and Hambrick, 2005), and are thus particularly sensitive to mechanisms that alter the individuals' propensity to share knowledge and cooperate for a common organizational goal. However, until now, it is not clear how pay dispersion can affect the incentives to engage in innovation activities. We fill this research gap by investigating the relationship between the configuration of pay dispersion within the top executive team and the firm's innovation activities.

We consider both the configuration of pay elements (Trevor et al., 2012) and their degree of legitimization or normative acceptance (Shaw et al., 2002). Accordingly, we posit that the distribution of executive rewards through pay dispersion is likely to affect innovation by means of two antithetic forces: i) incentives to organizational commitment and effort provision, when pay dispersion is likely to be perceived as legitimate and accepted; and ii) obstacles to cooperation and knowledge sharing, increment in conflicts and thus harmful consequences for activities requiring coordinated work effort, in a contingence of weak legitimization of the pay dispersion. Borrowing from further observations that pay contingencies influence individuals' task performance (Pazy and Ganzach, 2009), we take into consideration whether or not pay is tied to individual effort by differentiating between *fixed* and *variable* pay elements. To our knowledge, this is the first attempt to integrate the conflicting views of pay disparity and its impact on innovation by separately analyzing the fixed and variable components of executive pay dispersion. Building on existing studies about executive pay dispersion and its impact on firm outcomes (Bonner and Sprinkle, 2002; Rankin and Sayre, 2011; Bushman et al., 2016), we posit that a larger dispersion in variable pay (i.e. pay more closely tied to individual effort) is relatively more likely to be perceived as justified, and would thus positively impact on the innovation activities conducted by the executive team. By contrast, high dispersion in fixed pay is relatively more likely to trigger the negative effects of social comparisons and ultimately hurt innovation outcomes: being less dependent from individual contributions, high fixed pay dispersion is likely to be perceived as less equitable and less legitimate or normatively accepted, and may thus be harmful for effort provision and motivation, interpersonal cooperation and knowledge sharing.

We conduct the empirical analysis on a panel of US listed firms for the period 1992-2006. Following a consolidated approach in the literature (e.g. Griliches, 1990; Hall et al., 2001, 2005), we measure innovation activities using patent metrics. Consistent with our hypotheses, we find that fixed and variable executive pay dispersions have statistically significant effects of *opposite* sign: higher dispersion in fixed executive pay leads to worse innovation outcomes (i.e. fewer granted patents and less forward citations), whereas higher dispersion in variable executive pay leads to more innovation.

We address potential concerns about confounding mechanisms with additional analyses focusing on executives directly in charge of innovation: computing our pay dispersion measures based on these executives reinforces our confidence about the channels through which pay dispersion influences innovation. Also, to validate that investment in innovation inputs is a key mechanism behind our results, we show that fixed pay dispersion is associated with lower R&D expenditures, whereas variable pay dispersion is associated with greater R&D expenditures. Finally, we document that our finding on variable pay is mainly driven by dispersion in pay items such as cash bonuses that are mostly attributable to individual task performance rather than firm performance at large.

Our paper contributes to various streams of research. First, we extend recent insights on the role of corporate governance and executive compensation schemes in innovative firms (e.g. Bebchuk et al., 2011; Bhojraj et al., 2017; Manso, 2013; Kale et al., 2009). For instance, Ederer and Manso (2013) find that to promote innovation an ideal compensation package should provide a combination of tolerance for early failure and reward for long-term success. We contribute to this debate by expanding the research that goes beyond the analysis of compensation for given executives considered in isolation (e.g. Carpenter and Sanders, 2002), and thus provide one of the first investigations on the nexus between corporate innovation and configurations of executive pay dispersion. As such, our work also complements recent studies (e.g. Lim, 2015) that emphasize the importance of relative CEO compensation from a temporal perspective (i.e., negative or positive deviations from past compensation) for a firm's innovation expenditures.

Second, our study contributes to the debate (Bushman et al., 2016; Ridge et al., 2015; Shaw et al. 2002; Trevor et al. 2012) seeking to reconcile the literature on the "bright side" of pay dispersion, arguing that it may be a powerful device to motivate managers via tournament incentives (Kale et al., 2009), with the literature on the "dark side" of pay dispersion, which delineates negative corporate consequences due to social comparisons (Carpenter and Sanders, 2004; Fredrickson et al., 2010; Pepper and Gore, 2015) and poor corporate governance (Bebchuk et al., 2011). Our contribution here is to demonstrate that these positive and negative effects may well co-exist within the context of firm innovation depending on the *type* of pay dispersion. By considering the variable and fixed components of pay inequality and isolating the effects of these components on firm innovation, we significantly extend Yanadori and Cui (2013), who explore the innovation implications of pay dispersion among R&D workers, as well as Sharma (2011) and Jia et al. (2016), who focus on top executives but do not disentangle the antithetic innovation effects of dispersion in variable and fixed pay items.

2. Theory and hypotheses

2.1. Executive pay dispersion: Incentivizing device or trigger of social comparisons?

While there is a consensus that executive pay dispersion can shape executive actions (e.g. Bushman et al., 2016; Carpenter and Sanders, 2002), the theoretical and empirical views on the direction of such impact are conflicting. On the one hand, existing studies have explained how pay dispersion can be leveraged to serve as an effective incentivizing device. This perspective builds on the notion of tournament systems, i.e. compensation configurations that by entailing some degree of pay inequality increase the motivation of managers and workers (Lazear, 1988). The incentives arising from tournaments can have positive repercussions for a broad set of corporate activities such as R&D investment (Kini and Williams, 2012) and ultimately firm performance (Kale et al., 2009).

Other streams of research highlight incentive problems in tournaments (e.g. Sayre et al., 1998; Rankin and Sayre, 2011), and show that tournament performance depends on such conditions as the size of the "winner proportion", prize structures and group identity (e.g. Newman and Tafkov, 2014; Kelly and Presslee, 2017). Adopting an agency perspective, Bebchuk et al. (2011) illustrate a negative relationship between the share of total executive pay captured by the CEO (her/his "pay slice") and firm performance, likely as a result of managerial entrenchment. It has also been emphasized that behavioral aspects play a key role in shaping the outcome of pay dispersion (Pepper and Gore, 2015). Dating back to Festinger (1954), social comparison theory has suggested that individuals evaluate their own characteristics with reference to peers with whom they share similar traits, occupations etc. (Newman and Tafkov, 2014, Nickerson and Zenger, 2008). Recent studies (e.g. Carpenter and Sanders, 2004; Ridge et al., 2017) adopt this framework to understand how executive pay dispersion can affect work relationships among firm executives. Evidence from this research suggests that receiving a much lower pay than given peers can trigger negative feelings of inequity, which in turn dampen effort provision and motivation, reduce organizational commitment (Fredrickson et al., 2010; Trevor and Wazeter, 2006) and create obstacles to cooperation and knowledge sharing (Pfeffer and Langton, 1993; Siegel and Hambrick, 2005). In combination, these effects will undermine the whole effectiveness of decision-making processes in firms (Cohn et al., 2014).

As Trevor et al. (2012) point out, the conflicting evidence on the positive or negative effects of pay dispersion can be ascribed to one particular shortcoming in the main theoretical frameworks adopted, i.e. the implicit connection between unequal pay allocation and its perceived inequity. Indeed, unequal pay allocation does not necessarily imply inequity, and may even be perceived as equitable if the pay is tied to productive contributions of useful inputs (Shaw et al., 2002). Building on these considerations, we argue that the two competing effects related to pay dispersion can be disentangled by considering the multi-faceted nature of executive pay. Accordingly, we jointly examine the combination of the *level* of pay dispersion (i.e. the ratio of compensation for the highest and the lowest paid executive) and the *forms* of executive pay (i.e. the fixed and variable components). This approach makes it possible to pinpoint the two antithetic effects that pay dispersion exerts on innovation activities: i) incentivizing device; ii) determinant of social comparison.

Building on Shaw et al. (2002), we consider *variable* pay as the set of pay items that links the compensation of executives to their work contributions and productivity (after accounting for firm-specific factors). In contrast, we consider *fixed* pay as those items less explicitly tied to individuals' current productivity, which, as such, and may to some extent be attributed to factors such as favoritism, politics, or even randomness. It follows, that social comparisons would primarily exert a negative effect due to large *fixed* pay dispersion. In a similar context, lower-paid executives may be more prone to perceive a high CEO fixed pay as unfair and undeserved, legitimized by political power and status rather than individual effort (Finkelstein, 1992; Shaw et al., 2002; Trevor et al. 2012). Indeed, failure to reward executives based on their productivity-related inputs may entail a sense of inequity, and the legitimization of such pay schemes is likely to be low (Trevor et al., 2012; Shaw et al., 2002). On the contrary, high pay variability justified by differences in subjective contributions to broader organizational goals would not have *per se* negative consequences for innovation given its higher degree of legitimization and acceptance.

2.2. Executive pay dispersion, inequity, and firm innovation

The decision processes related to firm innovation can be viewed as a combination and synthesis of different paradoxical cognitions (Smith and Tushman, 2005). Without such cognitive conflicts – i.e. conflicts among different viewpoints – the quality of these processes suffers (Amason, 1996). Cognitive conflict is therefore a key element for effective executives' decision-making. Under the circumstance of high dispersion in fixed pay, we expect the conflict to be more likely of the form of *affective conflict*, which is "emotional and focused on personal incompatibilities and disputes" (Amason, 1996 p:129) and therefore dysfunctional to the quality of decisions, including those directly concerning innovation. Affective conflict is likely to negatively impact on complex decisions such innovation activities, which are characterized by high task interdependence and strong coordination. Further, higher fixed pay dispersion is likely to obstacle a fluid flow of information within the top executives (West and Anderson, 1996; Henderson and Frederickson 2001), a contingency particularly negative for innovation which crucially hinges on information sharing (Siegel and Hambrick, 2005). The right understanding of complex projects such as those regarding innovation is key to generate successful outcomes. Ultimately, investments in R&D – which need a high degree of information exchange and coordination – are hampered where affective conflict is prevalent and where information does not flow freely. If the discussion of such complex projects occurs on the basis of affective conflicts and limited information sharing, the possibility of investing at the margin into better R&D is lower.

In sum, we expect high dispersion in fixed pay to weaken motivation and effort provision. Lower-paid executives cannot directly fill the pay gap relative to the higher-paid peers by working harder (since fixed pay is not directly related to current effort). They are less likely to engage in tasks requiring coordination and to share resources and knowledge. Affective conflicts and obstacles to information sharing will be more likely to occur, thereby significantly impacting the process of R&D investments and thus innovation outcomes, with an overall detrimental effect for the firm.

Hypothesis 1. *Greater dispersion in fixed executive pay is negatively associated with innovation*.

Due to its greater contingency upon individual task performance (particularly in the case of individual bonuses), dispersion in variable pay is less likely to be perceived as inequitable or non-legitimate, and instead tends to be justified by differences in individual work effort or objective success (Cohn et al., 2014). Contrary to fixed pay dispersion, a lower level of affective conflict is expected to arise when differences in executive compensation occur in the form of variable pay. This, in turn, improves innovation-related decision-making, which requires the integration of top executives' views and expertise. Also, dispersion in variable pay may induce stronger incentives to exert effort. Observing that peers receive higher compensation in terms of variable pay would induce lower-paid executives' to increase commitment and effort provision (Newman and Tafkov, 2014) in order to secure similar compensation packages and rewards (and thus fill the pay gap with higher-paid colleagues). In other words, dispersion in monetary compensation tied to individual inputs would incentivize greater effort, since agents do not perceive that their effort will remain unrewarded (Sheppard, 1993 and references therein). This is expected to be particularly beneficial for innovation, since higher executive effort is likely to be increase engagement with R&D projects and development of new products and services. The beneficial effect of better coordination and information sharing are also likely to be reflected in the increased quality and complexity of R&D investments.

In connection to innovation-related activities and the decisions regarding R&D, i.e. under circumstances characterized by higher profit uncertainty, learning by doing enables a virtuous circle between profitability-uncertainty and incentives: "greater effort, induced by high-powered incentives, leads to more informative signals about uncertain project profitability, improving the firm's future investment decisions" (He et al., 2014). Higher levels of effort are thus likely to have a positive impact on a firm's innovative output, which consists of projects whose profitability is uncertain a priory. Compensation packages with important components of variable pay also motivate managers to focus on growth (Jaskiewitz et al., 2016), which can be achieved organically through higher innovation efforts and the introduction of new products and services.

Perceived justice is another characteristic function of the pay configuration likely to impact firm innovation. Perceived justice (i.e. equitable distribution but not necessarily equal) of the pay structure has a strong impact on the dynamics of team interactions. Breugst et al. (2014) show that when the members of a team perceive high distributional justice, they are likely to experience the feeling of belonging to a strong entity, and the dynamics associated to the dissolution of teams would decrease substantially. High gaps in variable pay are expected to be perceived as accepted and just, and thus decrease the emergence of affective conflict while improving the quality of top managers' decisions, including those related to R&D projects. Further, team cohesion improves the flow of information and ultimately results in better evaluation of decisions on innovation.

Investment decisions regarding complex R&D projects are expected to be more effective if the incentive system promotes the prevalence of cognitive conflict, effort provision, information sharing and learning, team cohesion among top executives. Overall, we expect that the incentivizing effects of variable pay dispersion will promote managerial effort and thereby high quality learning, and desirable team dynamics, which would ultimately result in greater innovation output.

Hypothesis 2. *Greater dispersion in variable executive pay is positively associated with innovation.*

3. Data and variables

3.1. Sample

Our sample comes from three different reliable data sources widely used in previous empirical research. We gather patent data from the National Bureau of Economic Research (NBER) patent dataset. The NBER patent dataset is a comprehensive source of information for all patents granted by the US Patent and Trademark Office (USPTO) and all citations made to these patents starting from 1976 and up to 2006 (Hall et al., 2001). Executive compensation data come from the Standard&Poors' Execucomp database, which contains information on the top executives of a large set of US listed companies. Specifically, Execucomp provides, for all the 5-top executives of a given firm (though a few firms report data for more than 5), data on the various items forming executive pay packages as well as a few demographic characteristics such as executive age and tenure in the company. This approach is consistent with many existing works (e.g., Fredrickson et al., 2010), which have studied the importance of social comparisons among members of the CEO's top team. Finally, firm-level accounting data come from the Compustat dataset, which we merge with the NBER patent dataset following the procedure described in Bessen (2009). We select a time-period spanning from 1992 (i.e. the first year available in the Execucomp dataset) through 2006 (i.e. the last year for which we have citation data from the NBER patent dataset).

3.2. Dependent variables

Due to the high uncertainty between executives' action and firm performance in dynamic environments, financial incentives for high-technology firms top executives tend to be loosely linked to observed firm performance, but are significantly intertwined to measurable innovation efforts (e.g. Balkin et al., 2000): for this reason, we focus on patent metrics to assess such effort.

Consistent with the innovation literature, we construct two measures of innovation that will be used as dependent variables. The first, *patent counts*, is the raw number of patents granted to a firm in a given year. Given the typical average lag between application and granting years, we follow the literature (e.g., Hall et al., 2005) and date patent counts at the time of the patent application, which better reflects the actual time of innovation. While this variable measures the raw output of a firm's innovation effort, it is well known that patents vary greatly in their economic and technological importance. To better account for these differences, we again follow the existing literature (e.g. Hall et al., 2005) and adopt the number of forward citations received by a firm's patents (*citation counts*), which offer a precise and reliable proxy for the economic and technological importance of patents (Jaffe et al., 2000; Hall et al., 2005). Consistent with the literature, we mitigate the usual problem of truncation (i.e. that patents filed at a later stage have less time to be cited) by adjusting citations using the weights provided by the NBER.

3.3. Independent variables

We proceed by constructing the key measures of executive compensation dispersion. To this end, in accordance with existing works (e.g. Connelly et al., 2016), we start by collecting data on the various items of executive compensation packages, such as base salary, cash bonuses, restricted stock granted, the Black-Scholes value of stock options granted, and other long-term incentive payouts.

We then distinguish between fixed and variable pay items. As measure of fixed compensation we use the base fixed salary (Cohen et al., 2012), which is usually specified in the employment contract and remains constant over a period of time. In order to quantify the variable amount of executive pay, we take the sum of cash bonuses (typically representing a variable compensation on an annual basis), restricted stock granted and Black-Scholes value of stock options granted (reflecting the long-run component of variable pay). Both of these measures are in line with the literature on CEO incentives (e.g. Bergstresser and Philippon, 2006; Cohen et al., 2012). One concern of including stock options in the variable pay is that, contrary to our theory, stock options might not necessarily relate to past effort and individual performance but could be intended instead as motivational tools to engage executives to perform well in the future, being driven by company results rather than individual-level performance. To avoid this potential concern, we conduct additional analyses where variable pay is only measured with cash-based bonuses, a pay component more directly linked to *current* and *individual-level* task performance.

Next, we measure the dispersion in fixed and variable pay. Extant empirical research is fragmented and no clear consensus exists on how to measure pay dispersion. We operationalize pay dispersion by means of a ratio, which is consistent with prior works. For instance, Connelly et al. (2016), who adopt the ratio of TMT pay to average worker pay in their study of pay dispersion and firm performance, suggest that ratios are useful to measure “multidimensional constructs in which variations in one variable are theoretically meaningful with reference to variations in the other” and that “pay dispersion is operationalized as theoretically prescribed ratio” (pg. 10-11).

Following these indications, we take the ratio between the compensation of the executive with the highest pay and the compensation of the executive with the lowest pay as reported in Execucomp (notice that we do not use the Gini index to avoid potential biases arising from the limited number of executives; Deltas, 2003). In order to separate out the effect of dispersion in fixed and variable pay components, we then compute three versions of this ratio, i.e. based on (1) total compensation (*total compensation gap*); (2) fixed compensation only (*fixed compensation gap*); and (3) variable compensation only (*variable compensation gap*). Given the presence of a few extreme values, possibly outliers due to e.g. temporary executive appointments, we trim observations in the bottom/top 0.5% of the distribution of each ratio. Finally, please notice that to improve table readability the pay gaps have been divided by 100.

Our measure has several appealing features. First, it accounts for the structure of the whole executive team (not just the CEO or CFO) thereby mirroring also the pay strategies applicable to R&D managers (Balkin et al., 2000). Second, data on the composition of pay packages allow us to directly and precisely account for the different structure of incentives in place. Third, our ratio draws on accurate and reliable data, it does not need any arbitrary algebraic transformation, and it has an intuitive interpretation: it takes value of 1 if the highest and the lowest executive pay are the same, whereas values above 1 indicate the degree to which the compensation of the most paid executive exceeds the one of the executive with lowest pay. Fourth, our measure is constructed using information on the pay of key decision-makers with crucial influence on the business (and thus on innovation policies).

To be more precise on this point, we fine-tune the computation of the ratio exploiting the information on the job title of each executive. To this end, we conduct a textual analysis of each reported job title and for each firm identify the executive manager explicitly and formally responsible for innovation activities. Specifically, we identify executives explicitly involved in innovation activities by searching within each job title the following words: *Innovation*, *Innovative*, *Knowledge*, *Laboratory*, *Product*, *R&D*, *Research*, *Science*, *Scientist*, *Scientific*, *Technology*, and *Technological*. Then, in an additional test we employ the ratio between the pay of the highest paid executive and the pay of the executive in charge of innovation activities. This is to ensure that we capture unambiguously the effect of pay dispersion on firm innovation. Moreover, this ratio explicitly incorporates the effort of the executive responsible for innovation activities, which we argue to be shaped by pay dispersion configurations. After dropping observations with missing data in the key dependent and explanatory variables, we obtain a sample of 1,137 unique firms for 6,176 firm-year observations.

3.4. Control variables

We construct a number of variables that will be included as controls in the regression models. Consistent with the literature on patents (e.g. Galasso and Simcoe, 2011), we start with taking the logarithm of firm revenues (*Ln Sales*), and the logarithm of the capital to labor ratio (*Capital to labor*), computed as property, plants and equipment divided by employees. We also construct the logarithm of firm age (*Ln Firm age*), proxied by the number of years a firm has been in Compustat, to control for differences in the stage of development across firms. As written above, Execucomp covers the 5 highest-paid executives, but a few firms report compensation for a few more executives. We are aware that the number of executives for which the company reports compensation data can affect the values of the dispersion ratio. For instance, the ratio could take a lower value for a firm that reports compensation only for the CEO and the CFO (usually the executives with the highest pay), as compared to a firm that reports compensation for several more executives (thus including the low-end of the pay distribution). In the empirical analysis, we explicitly account for this potential problem by controlling for the number of executives used to compute the dispersion ratios (*Ln number executives*). Finally, we construct two variables at the CEO level that may correlate with both compensation structures and innovation, and thus confound our results. These are the logarithm of CEO age (*Ln CEO age)* and the logarithm of the years the CEO has worked in the firm (*Ln CEO experience*). Summary statistics are presented in the bottom part of Table 1.

4. Results

4.1. Summary statistics

The correlation table is reported in Table 1, while summary statistics are presented in Table 2, which includes the dispersion ratio in terms of total pay, as well as separately for fixed and variable items.

[[INSERT Table 1 about Here]]

[[INSERT Table 2 about Here]]

From Table 1, it can be noted the positive correlation between the total compensation gap and its specific components, but also a positive correlation between fixed and variable compensation gaps. However – being relatively low – this correlation does not raise concerns of multicollinearity.

4.2. Empirical model

Our goal is to estimate the effect of executive compensation dispersion on a firm's innovation activities. To this end, we follow the literature (e.g. Hausman et al., 1984) and assume that the expected number of patents is an exponential function of the explanatory variables X_{it}. More specifically, we estimate a Poisson model with conditional mean:

$$E[Y_{it} \mid \mathbf{X}_{it}] = \exp(\delta + \beta \text{Compensation gap}_{it} + \gamma'\mathbf{Z}_{it} + \alpha_i + \alpha_t)$$

in which the dependent variable is, alternatively, the raw patent count or the count of truncation-adjusted patent cites for a firm *i* at times *t*. Consistent with existing works that have documented a relatively short lag between innovative investments and patenting (e.g. Hall et al., 1986), we use current values (i.e. dated at time *t*) of both dependent and explanatory variables. However, we will show that our results hold using lagged rather than current explanatory variables.

The key explanatory variables included in the $\mathbf{X}_{it}$ vector are the compensation gaps of firm *i* at times *t*. Here we include the fixed and variable compensation gaps in the same model. In robustness checks, we verify that our findings hold if the two variables are separately included. The vector $\mathbf{X}_{it}$ further includes a host of controls to mitigate the concern of omitted factor bias, as well as α_i and α_t that represent, respectively, firm fixed effects, used to absorb firm-specific and time-invariant heterogeneity, and year dummies, which absorb overall trends in innovation.

Following existing works based on innovation counts (e.g. Amore et al., 2013; Czarnitzki et al., 2011; Simcoe et al., 2009), we estimate the model using the Quasi-Maximum-Likelihood (QMLE) method, which has the advantage of providing consistent estimates as long as the conditional mean is correctly specified even if the true underlying distribution is not Poisson. Standard errors are clustered at the firm level, which is deemed appropriate since it accounts for heteroskedasticity and serial autocorrelation (common with panel data); yet, in untabulated checks we have validated our results using industry or state-level clustering, as well as estimating the model with a negative binomial regression.

4.3. Main results

Our theory suggests that the dispersion measured by using total compensation masks the two opposite effects coming from its variable and fixed components, ultimately resulting in this lack of significance. We tease out the two opposite effects in Table 3, Columns 1 and 2, which include the fixed and variable pay dispersion ratios as separate explanatory variables. As expected, the two coefficients in Column (1) are statistically significant and display opposite signs: a greater dispersion in fixed compensation has a negative effect on patent counts (-0.043; p=0.012), whereas a greater dispersion in variable compensation has a positive effect (0.0003; p=0.007). These findings hold true even considering patent cites instead of patent counts as dependent variable (Column 2). Hypotheses 1a and 1b are thus fully confirmed.

[[INSERT Table 3 about Here]]

To validate that the proposed relationship between pay dispersion, with its fixed or variable components, and innovative output hinge on the mechanisms described theoretically in Section 2, we compute additional pay dispersion measures by only using the executives formally involved in innovation activities. This approach increases the consistency with our theoretical framework since it restricts the analysis to lower-paid executives that undertake activities directly related to the dependent variable of interest (i.e. patent counts and citation counts). To this end, we compute the ratio of the highest executive pay to the pay of executive specifically involved in the innovation activities (see Section 3.3. for details). Results, reported in Columns (1) and (2) of Table 4, show significant effects fully consistent with our previous arguments. Interestingly, the coefficients are economically larger, possibly owing to the fact that the restriction to innovation executives magnifies the effect of pay dispersions on innovation.

We further validate our findings by excluding stock options from the computation of the variable dispersion ratio. The rationale behind this exclusion is that stock option value may be contaminated by stock price fluctuations and thus only indirectly reflect individual executives' effort provision. Results, reported in Columns (3) and (4) display again coefficients strongly in line with our main hypotheses.

[[INSERT Table 4 about Here]]

In the Appendix, we confirm our main result with an extensive set of robustness checks. For instance, we show that our results are largely unaffected by outliers, that they hold controlling for a broader set of explanatory variables, that they are not influenced by sample composition concerns, and that simultaneity concerns do not bias significantly our results.

Before conclusion, we establish that our results are driven by changes in the provision of innovative inputs. This is important to further validate our argument that the effects on patenting documented so far are indeed driven by changes in innovative effort. Following existing approaches, we construct a measure of R&D intensity by taking the ratio of a firm's R&D expenditures to revenues; to account for the presence of missing R&D items, we replace missing observations with the average R&D by 3-digit SIC code and year and further include as explanatory variable a dummy equal to one for missing R&D and zero for non-missings. We then estimate a OLS model employing the same set of controls of the previous analyses, together with an interaction between our key pay dispersion ratios and a dummy identifying high-R&D industries (i.e. equal to one if the annual average ratio of R&D to sales of a given 3-digit SIC code is above the sample median, and equal to zero otherwise).

[[INSERT Table 5 about Here]]

Results reported in Table 5 indicate a negative interaction between high-R&D industry and fixed pay dispersion; by contrast, the interaction with variable pay dispersion turns positive and significant. Although the statistical significance of the interaction terms is lower than that of our previous results, the sign and magnitude of these coefficients provide a useful validation of our theoretical arguments.

5. Discussion and conclusion

Following recent calls to better understand the relationship between intra-firm pay dispersion and firm results (Trevor et al., 2012; Connelly et al., 2016; Ridge et al., 2017) and the role of alternative tournament reward structures (Kelly and Presslee, 2017), we investigate the nexus between corporate innovation and dispersion in fixed or variable executive pay. We concentrate on a firm's innovation activities as outcome of interest, given its high sensitivity to executives' coordination and effort provision as well as its importance for firm performance.

We contend that executive pay dispersion can act as a double-edged sword for innovation activities: on the one hand, it can promote effort provision, coordination and good team dynamics among top executives involved in innovation processes (e.g. Kale et al., 2009); on the other hand, it can trigger affective conflicts and make executives unwilling to exert effort, share knowledge and cooperate (e.g. Carpenter and Sanders, 2004; Fredrickson et al., 2010). While the literature has long argued that social comparison and tournament theory can be important theoretical frameworks to explain the implications of executive compensation (O'Reilly III et al., 1988), scholars have only recently begun to integrate these theories (Shaw et al., 2002; Trevor et al., 2012; Ridge et al., 2017). Drawing on recent works on the importance of pay contingencies (Pazy and

Ganzach, 2009), we posit that whether the negatives or the positives of executive pay dispersion on innovation prevail would depend on the type of pay dispersion, i.e. *fixed* or *variable* pay dispersion. We build on the idea that dispersion in variable pay – being largely designed to respond to individual effort (Shaw et al., 2002; Suchman, 1995) – is more likely to be perceived as equitable (Trevor et al., 2012). As such, variable pay dispersion can spur work effort provision and organizational commitment, coordination and learning as lower-paid executives can try to directly fill the pay gap with higher-paid peers; this, in turn, will result in higher innovative outcomes. By contrast, a pronounced dispersion in fixed pay may foster the negative effects of social comparisons because increased effort does not directly affect fixed pay, which would in turn imply executives' unwillingness to coordinate and share knowledge with each other; in combination, these effects will harm a firm's innovative performance.

Consistent with the hypotheses we set forth, our empirical investigation of US firms' patenting activities confirms that executive pay dispersion does lead to antithetic effects on firm innovation: high dispersion in fixed compensation is associated with fewer patents and of lower quality (as measured by forward citations), whereas high dispersion in variable compensation is associated with higher number of patents and of better quality.

Documenting these associations helps reconcile the opposite existing views on executive compensation dispersion and business outcomes. Our study connects the two main research streams on pay dispersion and documents their simultaneous validity in the context of corporate innovation. Our contribution is thus twofold. First, we study the effects of pay dispersion on corporate innovation outcomes, an important channel behind the dispersion-performance relationship documented in previous studies. Second, we operationalize the distinction between fixed and variable pay in connection with pay at the executive level, and show that interdependent innovation work does not necessarily suffer from high pay dispersion. We also go beyond the analysis of executives generically considered and show that our results are magnified when the consistency between job titles and corporate outcomes is greater.

Our study has important implications for the growing academic and practitioner debates on the importance of pay inequality at the apex of firms (e.g. Bebchuck et al., 2011) and the role of tournaments as incentive devices (e.g. Newman and Tafkov, 2014; Rankin and Sayre, 2011). To the extent that our findings are driven by a firm's optimal compensation choices, they suggest that large fixed pay dispersion can be applied in low-tech contexts, whereas large variable pay dispersion is best suited for innovative firms. Moreover, our results suggest that executive compensation schemes and corporate outcomes should be examined by considering the importance of *relative* and not just *absolute* compensation levels (e.g. Carpenter and Sanders, 2002, 2004). Going beyond the analysis of CEO pay in isolation, we highlight the importance of relative pay across the entire structure of executive teams, and propose that relative pay effects are especially important given that innovation activities require cooperation and knowledge sharing between a firm's key decision makers (especially those directly involved in the innovation process). Finally, this paper suggests that it is crucial to pay special attention to the specific forms of remuneration, again not just in isolation but also in relative terms, towards the difficult task of motivating executives and spur corporate innovation activities.

Our study is not without limitations, which we acknowledge before concluding. The first has to do with the fact that, despite having carried out a comprehensive host of robustness tests and produced evidence consistent with a causal interpretation, we cannot rule out that some unobserved factor could bias our results. The second limitation, which is also a promising avenue for future research, relates to the fact that we have not considered how executive pay dispersion interacts with internal and external corporate governance mechanisms in shaping innovative outcomes. Future studies could introduce corporate governance or institutional moderators. Finally, we acknowledge that our study adopts patent data, which have a number of well-known advantages over accounting-based items such as R&D expenses, but are certainly imperfect measures of innovation. We did offer some validation tests using R&D expenditures using R&D information from archival sources, but future studies could further explore this aspect by adopting finer-level data measuring effort provision and decision-making at the individual level.

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Table 1.
Correlations

	1	2	3	4	5	6	7	8	9	10
1. Patent counts										
2. Citation counts	0.91***									
3. Ln (Sale)	0.25***	0.21***								
4. Capital to labor	0.06***	0.05***	0.19***							
5. Ln (Firm age)	0.13***	0.09***	0.53***	0.17***						
6. Ln (CEO age)	0.04***	0.02	0.26***	0.12***	0.25***					
7. Ln (CEO experience)	0.01	-0.01	0.24***	0.13***	0.32***	0.35***				
8. Ln (number executives)	0.01	0.01	0.16***	0.05***	0.09***	-0.04***	0.05***			
9. Total compensation gap	0.02	0.01	-0.01	-0.01	-0.07***	-0.15***	-0.07***	0.15***		
10. Fixed compensation gap	-0.01	-0.01	0.05***	0.01	0.03	-0.05***	0.03	0.20***	0.35***	
11. Variable compensation gap	-0.01	-0.01	-0.08***	-0.04***	-0.07***	-0.09***	-0.07***	0.08***	0.41***	0.17***

*** indicates significance level at the 1% level.

Table 2.
Summary statistics

	Average	s.d.	Median
Patent counts	35.523	174.165	1
Citation counts	592.181	3568.829	0
Ln (Sale)	7.278	1.729	7.276
Capital to labor	3.922	1.150	3.723
Ln (Firm age)	3.081	0.736	3.178
Ln (CEO age)	4.007	0.132	4.025
Ln (CEO experience)	2.531	0.922	2.708
Ln (number executives)	1.647	0.162	1.609
Total compensation gap	5.785	6.874	3.975
Fixed compensation gap	2.929	1.870	2.544
Variable compensation gap	20.479	94.622	5.197

Table 3.
Innovation, fixed and variable compensation gaps

Dependent variable:	Patent counts	Citation counts
	(1)	(2)
Fixed compensation gap	-4.32*	-7.28**
	(1.72)	(2.67)
Variable compensation gap	0.03**	0.05**
	(0.01)	(0.02)
Ln (Sales)	0.51***	0.53***
	(0.10)	(0.08)
Capital to labor	0.04	0.13
	(0.09)	(0.09)
Ln (Firm age)	0.64*	0.47
	(0.30)	(0.26)
Ln (CEO age)	0.07	0.09
	(0.04)	(0.04)
Ln (CEO tenure)	0.63	0.47
	(0.44)	(0.49)
Ln (executives number)	-0.28*	-0.31*
	(0.14)	(0.15)
Year fixed effects	Yes	Yes
Firm fixed effects	Yes	Yes
Observations	4502	4162

Firm-clustered standard errors are reported in parentheses.
* corresponds to *p*-value<0.1
** corresponds to *p*-value<0.05
*** corresponds to *p*-value<0.01

Table 4.
Robustness tests

Dependent variable:	Patent counts	Citation counts	Patent counts	Citation counts
	Executives involved in innovation		Variable compensation gap as cash bonus	
	(1)	(2)	(3)	(4)
Fixed compensation gap	-32.15*	-26.51	-4.00	-5.60*
	(14.54)	(15.69)	(2.23)	(2.64)
Variable compensation gap	0.06**	0.10***	0.99***	1.01***
	(0.02)	(0.03)	(0.28)	(0.24)
Ln (Sales)	-0.27	-0.13	0.53***	0.61***
	(0.15)	(0.20)	(0.10)	(0.09)
Capital to labor	-0.17	0.02	0.03	0.13
	(0.22)	(0.21)	(0.10)	(0.10)
Ln (Firm age)	0.70	-1.73	0.53	0.39
	(0.95)	(0.97)	(0.30)	(0.26)
Ln (CEO age)	0.64**	1.98*	0.09	0.12*
	(0.22)	(0.78)	(0.06)	(0.05)
Ln (CEO tenure)	-2.66***	-5.30	0.60	0.40
	(0.72)	(2.74)	(0.47)	(0.44)
Ln (executives number)	-0.08	0.01	-0.44*	-0.45**
	(0.67)	(0.64)	(0.17)	(0.17)
Year fixed effects	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Observations	356	299	3251	3023

Firm-clustered standard errors are reported in parentheses.
* corresponds to *p*-value<0.1
** corresponds to *p*-value<0.05
*** corresponds to *p*-value<0.01

Table 5.

Effect on R&D intensity in innovative and non-innovative contexts

Dependent variable: R&D intensity	
	(1)
Fixed compensation gap	0.01
	(0.35)
Fixed compensation gap×High-R&D industries	-1.57*
	(0.87)
Variable compensation gap	-0.01
	(0.01)
Variable compensation gap×High-R&D industries	0.03*
	(0.02)
Table-4 controls	Yes
Year fixed effects	Yes
Firm fixed effects	Yes
Observations	4,703

Firm-clustered standard errors are reported in parentheses.
* corresponds to *p*-value<0.1
** corresponds to *p*-value<0.05
*** corresponds to *p*-value<0.01

Appendix

In this section, we confirm our results using a variety of robustness checks. Results, which replicate the specification of Table 3, are reported in Table A1. As shown, all of our results remain economically and statistically significant.

In Column 1, we augment our specification with the Herfindahl-Hirschman index, computed using the distribution of firm revenues at the 3-digit Standard Industrial Classification (SIC) level, and its squared term in order to take into account the effect of competition on innovation. While our specification absorbs overall trends in innovation by the inclusion of year dummies, it does not control for industry-specific trends in innovation. To control for this additional factor, in Column 2, we augment our specification with the average of the dependent variable computed at the year and 3-digit SIC level, after excluding the focal firm. In Column 3 we control for geographic trends including the average of the dependent variable computed by year and State of headquarter, and, in Column 4, we include together industry and state trend variables.

Next, we deal with sample composition concerns. We start, in Column 5, by excluding the last sample years (i.e. 2005 and 2006), which can be problematic due to severe truncation problems in citations and patent applications. We move on by trimming, in Column 6, 1% of observations on the right tails of the patent count distribution to mitigate concerns of influential observations. Similarly, in Column 7 we trim a further 1% of observations (in addition to the 0.5% already trimmed in the variable construction) to the left and right tail of the dispersion ratios. To further reduce the concern that of extreme values due to e.g. extremely short tenures, in untabulated regressions we check our results using firms in which the CEO has been present in the firm for at least one year. This test does not materially affect our main findings.

In Columns 8 and 9, we check that our results are not driven solely by the smallest firms, which can be exhibit intensive innovative activity post-IPO due to intense equity issuances, or by the largest firms, typically endowed with a large stock of innovative knowledge; to this end, we remove firms in the bottom or top 2.5% of the sales distribution. In Column 10, we limit our analysis primarily to the manufacturing sectors (SIC up to 4000).

In conclusion, we verify the robustness to controlling for additional firm-specific variables that may confound our baseline evidence. In Column 11 we control for R&D spending by including the logarithm of R&D expenditures. In Column 12 we control for the return on assets (ROA), computed as the ratio of earnings before interest, taxes, depreciation and amortization to total assets, in order to control for differences in profitability across firms. In Column 13, we augment the model with firms' market performance by including the market to book ratio, computed using the market value of equity divided by the book value of equity. In Column 14, we attempt to improve the causal interpretation of our results by using 1-year lagged dispersion ratios rather than contemporaneous ones; lagged values help ruling out the concern that it is firm patenting that affects the compensation dispersion rather than the other way around.

[[INSERT Table A1 about Here]]

Table A1.
Robustness checks

Dependent variable: Patent counts

	Controlling for competition	Controlling for SIC trends	Controlling for State trends	Controlling for State and SIC trends	Excluding late years	Excluding patent outliers	Excluding pay outliers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Variable compensation gap	0.03***	0.03***	0.03***	0.03***	0.03***	0.03**	0.02***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.00)
Fixed compensation gap	-3.60**	-4.23**	-4.53***	-4.36**	-4.54***	-3.63**	-6.45***
	(1.61)	(1.75)	(1.71)	(1.73)	(1.72)	(1.56)	(0.7)
Table-4 controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,507	4,507	4,507	4,507	3,867	4,487	4,318
	Excluding smallest firms	Excluding largest firms	Only manuf-acturing firms	Controlling for R&D spending	Controlling for ROA	Controlling for market-book ratio	Lagged pay variables
	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Variable compensation gap	0.03***	0.03***	0.03***	0.03**	0.03*	0.03***	0.03*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
Fixed compensation gap	-4.21**	-5.03***	-5.02***	-3.31**	-2.90**	-4.21**	-2.90**
	(1.67)	(1.88)	(1.82)	(1.57)	(1.43)	(1.20)	(1.43)
Table-4 controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	4,390	4,358	3,584	3,407	4,487	4,505	3,657

Firm-clustered standard errors are reported in parentheses. * corresponds to *p*-value<0.1; ** corresponds to *p*-value<0.05; *** corresponds to *p*-value<0.01.