Competition and Executive Compensation: Evidence from Pharmaceutical Breakthrough Designations

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Abstract

We examine the effect of competitive shocks on executive compensation and innovation in the pharmaceutical sector. The pharmaceutical sector is ideal for testing the joint theories of Arrow (1962) and Manso (2011) because innovation is paramount and periodic shocks to the competition space are common. Breakthrough therapy designations (BTDs), which expedite the approval of promising therapies, represent significant competitive shocks that are exogenous to rival firms' compensation structures. We find that when a pharmaceutical firm receives a BTD, rival firms respond by increasing risk-incentive pay via option grants in the subsequent year. This effect is robust to various econometric specifications and various ways of identifying rival firms. Furthermore, the observed effect is most pronounced for the most afflicted rivals (i.e., the rivals that exhibit the worst stock price reaction to the BTD) and for CEOs relative to other executives. We also examine if rival firms respond to the increase in executive stock options by shifting resources to riskier innovation. The evidence suggests that afflicted rivals escalate the developments of new drugs, initiate more drug projects using new technologies, and are more inclined to take on projects with lengthy development times. Overall, our results corroborate theoretical models wherein (i) firms facing competitive pressures optimally intensify innovation, and (ii) stock options encourage executives to undertake such innovation.

1. Introduction

In the face of enhanced competition, firms must adapt their strategies to preserve value. Arrow (1962) shows that innovation is more value-enhancing for firms under competitive pressure than under monopolistic conditions, suggesting that firms should increase innovation when competition intensifies. The model of Aghion, Bloom, Blundell, Griffith, and Howitt (2005) agrees, with the caveat that innovation declines when competition is sufficiently fierce due to meager rent availability.

However, risk-averse executives may withhold efforts to boost innovation because "innovation is intrinsically risky and progress more erratic than with standard investments" (Holmstrom, 1989, p. 311). Holmstrom (1989) argues that even risk-neutral executives are averse to risky projects and deviate from the standard net present value rules, because they are "carrying (by design) some undiversified risk" (p. 311). Man so (2011) confronts this concern and studies how incentives should be structured when the principal needs to motivate the agent to increase innovation. He shows that the optimal contract tolerates early failures and rewards long-term success. Unlike standard pay-for-performance schemes, executive stock options meet both criteria. Thus, Manso (2011) concludes that the optimal contract that motivates innovation includes stock options, whereas standard pay-for-performance schemes could adversely affect innovation. The conclusion falls in line with an extensive literature that proposes that options encourage managerial risk-taking, including Jensen and Meckling (1976), Haugen and Senbet (1981), Smith and Stulz (1985), and Guay (1999).

Complementing the theory, several empirical studies examine how competition shocks affect executive compensation. One strand of literature, including Hubbard and Palia (1995), Crawford, Ezzell, and Miles (1995), and Cuñat and Guadalupe (2009a), utilizes banking

deregulation as competition shocks. The collective evidence suggests that banks respond through increases in total pay as well as pay-performance sensitivity, while showing modest increases in stock options. Another strand of literature, including Cuñat and Guadalupe (2009b), Bakke, Feng, Mahmudi, and Zhu (2020), and Lie and Yang (2022), examines competition shocks in an international setting using tariff cuts, exchange rate changes, or economic reform in China. Based on changes in tariffs and exchange rates, Cuñat and Guadalupe (2009b) report that competition increases pay-performance sensitivity. Using tariff cuts, Bakke et al. (2020) report that competition *reduces* risk-incentive pay from stock option grants. Lastly, Lie and Yang (2022) find that instrumented import competition from China decreases stock grants but does not affect stock option grants among US manufacturing firms.

In sum, past studies suggest that competition prompts more performance-based pay, but the effect on risk-incentive pay from stock option grants is mixed. Thus, there is unconvincing evidence that competition spurs the use of options to augment innovation, as jointly implied by Arrow (1962) and Manso (2011). We assert that there are a couple of plausible explanations for the disconnect between theory and past empirical results. First, the empirical studies capture more than causal effects. For example, Cuñat and Guadalupe (2009a) study a period of secular shifts in the banking industry as well as the broad economy, either of which are likely culprits to explain compensation policy changes. Also, Lie and Yang (2022) report evidence that changes in tariffs and exchange rates are highly endogenous. Second, past studies focus on the banking and manufacturing sectors, where innovation is a secondary strategic tool. Thus, they are inadvertently rigged against finding changes in risk-incentive pay meant to spur innovation.

We reexamine how competition affects risk-incentive pay using the pharmaceutical sector which is ideal for testing the joint theories of Arrow (1962) and Manso (2011). In the

pharmaceutical sector, innovation is a primary strategic tool, because pharmaceutical firms continuously aim to develop products that meet unresolved or emerging medical needs, and successful innovations enjoy strong patent protection for many years. Furthermore, periodic shocks to competition are common in the pharmaceutical sector, as firms successfully develop and launch products that steal market share from rivals. The last decade offers a unique way to identify these shocks.

In 2012, the Food and Drug Administration (FDA) introduced an expedited pathway program commonly referred to as the breakthrough therapy designation (BTD) program. It is designed to facilitate and expedite the approval of therapies that have demonstrated substantial improvements over available treatments in a therapeutic area. BTD events at focal firms represent significant competitive shocks to *rival* firms, defined here as other firms that are working in the same therapeutic areas as the focal firm that received the BTD (Garfinkel and Hammoudeh, 2022). We further argue that the shocks are exogenous to rival compensation structures. Armed with a series of BTD shocks scattered across time and therapeutic areas, we examine their impact on the structure of executive compensation at rival firms.

Naturally, there is substantial heterogeneity in rivals' exposure to BTD shocks. For example, rival firms that are diversified across therapeutic markets are less exposed than rivals with narrow drug project portfolios. Thus, we identify sub-groups of *afflicted* rivals, defined to be rivals that experience the most negative stock price response to BTD shocks. We expect stronger results for these afflicted rivals than for non-afflicted rivals.

We begin by establishing that rival firms and control firms (defined later) exhibit similar ex-ante levels and trends in the primary compensation measures, including the value of option grants and the percentage of total compensation that stems from option grants. Thus, any difference in

the risk-incentive compensation measures across rival and control firms *after* a BTD shock is unlikely to be the result of a prolonged trend.

Next, we examine the effect of BTD shocks on compensation. Our difference-in-differences estimates show a post-shock divergence in the primary compensation measures. That is, both the level of option grant value and its fraction of total compensation increase for rival firms relative to control firms in the year after the BTDs. The effect is, if anything, stronger for the most afflicted rivals and for CEOs (compared to other executives). Conversely, other compensation variables, including salaries, bonuses, and stock grants, remain similar for rival firms compared to control firms after the BTDs. We conclude that BTD shocks prompt afflicted rivals to boost risk-inventive pay.

The most obvious reason for the boost in risk-incentive pay is to encourage innovation. As such, our evidence provides joint support for Arrow (1962), who shows that competition increases the rents from innovation, and Manso (2011), who shows that executive stock options embolden executives to undertake the necessary innovation. We extend our analysis to explore the latter, i.e., whether rival firms, fortified with new stock options in the executive rank, shift resources toward riskier innovation.

Consistent with Manso's (2011) prediction, we find that afflicted rivals are more likely to initiate new drug projects. Moreover, many of the new projects require new technology or prolonged development and are, therefore, particularly gutsy. While we cannot establish clear causality between the increase in options and the risky development activities, we are inclined to attribute part of these activities to the options and conclude that the options have the desired effect.

Overall, we report that competitive pressures on pharmaceutical firms trigger enhanced risk-taking incentives in the form of increased stock options granted to upper management, along with

riskier drug development projects. Our results dovetail with Arrow's (1962) implication that firms should raise innovation in response to competitive pressure and Manso's (2011) contention that stock options contain the requisite structure to motivate innovative activities. However, our results differ notably from those in other empirical studies of how competition affects compensation structure. We argue that our use of BTDs is a more powerful instrument for establishing a causal effect of competition on compensation than past studies, because BTDs vary in both the time-series and cross section and are exogenous to executive compensation structure of rivals. Furthermore, we submit that our pharmaceutical setting, in which innovation is a first-order strategic activity, is particularly suited to test the combined predictions of Arrow (1962) and Manso (2011). Thus, we contribute to the literature by shedding a skeptical light on prior empirical results and by corroborating past theory.

We also contribute to the literature on the empirical effect of competition on innovation, although this is not our primary focus. Among the recent and influential studies in this literature, Bloom, Draca, and Van Reenen (2016) report that import competition leads to higher R&D expenditures in a sample of European firms, whereas Hombert and Matray (2018) and Autor, Dorn, Hanson, Pisano, and Shu (2020) report that import competition leads to lower R&D expenditures among US manufacturing firms. Our study differs in two major ways. First, we focus on firms that rely on innovation as their primary competitive response. Second, we examine measures beyond R&D expenditures to capture innovation and risk-taking, which turns out to be important. While we find little evidence that the BTD shocks affect overall R&D activities among afflicted rivals, we do find evidence that the R&D is shifted toward higher-risk areas, including new drug development with new technologies. We should also note that Garfinkel and Hammoudeh (2022)

find that BTDs discourage rivals from continuing developments in the shocked therapeutic area, complementing our results that resources are shifted to new arenas.

2. The pharmaceutical setting and data description

2.1 Institutional background

The biopharmaceutical industry is well suited for investigating the effect of competition on risk-incentive pay and innovation based on the theoretical framework of Arrow (1962), Aghion et al. (2005), and Manso (2011). First, long-term innovation is crucial to the survival of pharmaceutical firms. Before a firm can market and sell a drug, it must obtain FDA approval. The drug-approval process entails costly and rigorous clinical development to demonstrate both safety and efficacy of a drug. It can take between 5 and 20 years to obtain FDA approval to market a drug (Brown et al., 2021). In addition, drug development is associated with high uncertainty. Of every 100 drug projects in the preclinical stage (i.e., early in development and focusing on animal testing), roughly one project advances and eventually obtains FDA approval (Wouters et al., 2020).[1] As another indicator of high uncertainty and risk, most firms are precommercial without any FDA-approved products, i.e., they only have drug projects under development.[2,3] Finally, after obtaining drug-approval, firms are granted strong patent protection for numerous years. Overall, the pharmaceutical industry rewards long-term successes and has a high incidence of early failures, matching the conditions of Manso (2011).

[1] Furthermore, Hay et al., (2014) estimate that only 10.4% of drugs that reach *human* trials are eventually approved.
[2] Technically, there is a distinction between the terms "drug" and "drug project." A drug can be developed to target several medical conditions, while each drug-medical condition pairing is a drug project. Notably, the FDA approves a drug for a specific medical condition if the drug's human clinical testing results demonstrate its safety and efficacy in treating that medical condition.
[3] In our final sample, 80% of firms were precommercial status at one point in time.

Second, the market for pharmaceutical drugs is highly competitive. New products are continually developed and successfully launched, causing rival firms to lose market share and perhaps abandon drug development (e.g., Krieger (2021)). Put another way, there is entry/exit across the many therapeutic markets available to pharmaceutical firms. Because of continuous progression and discoveries from development activities, rivals must often confront new threats; they may retreat, transition to a new therapeutic area, or retaliate.

Third, breakthrough therapy designations (BTDs) allow us to identify transformational product introductions (i.e., the greatest competitive shocks) at an early stage. The BTD program was established in 2012, allowing the FDA to designate drugs that are "intended to treat a serious condition and that preliminary clinical evidence indicates may demonstrate substantial improvement over available therapies" (Sherman et al., 2013). While the BTD program is the fourth addition to the FDA's expedited approval pathway programs, it tops the ranking of how FDA resources are prioritized (Senior, 2013). Drugs with BTDs benefit from the organizational commitment of FDA senior managers, intensive guidance on efficient drug development programs, and higher likelihood of, and quicker, FDA-approval.[4] Upon approval, BTD drugs are perceived as superior (Krishnamurti et al., 2015; Kesselheim et al., 2016), and anecdotal evidence suggests that they are likely to dominate their therapeutic markets.[5]

Finally, the strict regulatory reporting requirements in the pharmaceutical industry provide detailed descriptions of products and projects, including the target therapeutic market, the target actions/technology of drugs, and the progress of projects. This granular description allows us to

[4] Hwang et al., (2018) find that for a sample of cancer drugs, the median time from Investigational New Drug (IND) application (marking the initiation of human trials) to first FDA approval was 5.2 years for breakthrough-designated drugs, compared to 7.1 years for non-breakthrough-designated drugs.

[5] For example, a report published by Vantage in 2018 highlights the growing dominance of Merck's Keytruda in the non-small cell lung cancer therapeutic market. The report states that Keytruda's competitors, "the boat has sailed, and Keytruda has left them fighting over what is at best a vanishingly small slice of the pie."

identify (i) the rival firms in a narrowly defined therapeutic area, which is imperative to our identification strategy, and (ii) how rival firms respond at the project level to a product market shock. In short, we can examine the real effects of competition shocks (BTDs) on rival firms and analyze the transfer of resources to riskier projects.

2.2 Drug development, therapeutic markets, target actions, and BTD data

2.2.1 Drug development data

Our drug development data come from Cortellis Competitive Intelligence and include pharmaceutical innovation obtained from company records, conferences, and other public sources. The data has been used in recent studies (e.g., Krieger (2021), Krieger, Li, and Papanikolaou (2021), and Garfinkel and Hammoudeh (2022)). As of the end of 2019, the full sample includes comprehensive development histories and ownership data on over 30,000 drug projects developed by over 5,000 firms targeting about 500 medical conditions.

Our sample construction begins in 2010 with approximately three years of data before the first awarded BTD in December, 2012. The sample ends in 2019 due to availability of our drug development data. We only keep drug-indications developed for US markets. We drop drug projects with missing key development dates and "zombie" projects.[6] One challenge with identifying the correct owner of a drug in a certain point in time is that drugs are often acquired or out-licensed. Furthermore, a drug may be developed by a subsidiary of another firm. Therefore, we follow the process from Garfinkel and Hammoudeh (2022) to match each drug project to its

[6] Firms are often reluctant to report project suspensions. Consistent with Li, Liu, and Taylor (2023), we assume that "zombie" projects are suspended three years after a "no development reported" designation in the Cortellis data.

correct owner in each year of the sample period.[7] The resulting sample includes 29,672 drug projects developed by 4,392 firms.

2.2.2 Therapeutic markets and target actions (technology)

A therapeutic area is the medical condition that a drug is meant to treat. A single drug may be developed for several indications.[8] Cortellis reports all indications a drug is intended to treat, e.g., "Metastatic Breast Cancer." In some cases, two or more indications refer to the same condition, e.g., the indication "liver disease" is likely the same indication as "liver cirrhosis" (Krieger, 2021).[9] To identify potentially competing products within a therapeutic area, we map Cortellis indications to the 9th revision of the International Statistical Classification of Diseases and Related Health Problems classifications (herein ICD-9).[10] We define a market by grouping drugs with the same ICD-9 code. This process results in 475 unique ICD-9 therapeutic markets.

The target action of a drug is anything in the body on which the drug binds to elicit its effect. The target action of a drug is the process in which the drug binds to anything in the body to elicit its effect. Herein, we refer to this as the *technology* of a drug. For example, mRNA vaccines work by inducing the muscle cells near the injection cite to produce spike proteins similar to those found on the surface of the SARS-CoV-2 virus. This causes the immune system to produce specific antibodies that bind to the spike proteins of the virus and neutralize it. A single drug compound may also have multiple target actions. We identify 44,488 unique target actions in our sample.

[7] Garfinkel and Hammoudeh (2022) conduct an extensive search to identify the correct owner of drugs in the Cortellis data. They use exact and fuzzy matching methods to match firms in Cortellis to firms in the SDC platinum database using firm names. They identify subsidiaries using the detailed drug development history descriptions in Cortellis.
[8] We use the terms "medical condition," "indication," "ICD-9 code," "market" and "therapeutic market" interchangeably when referring to the medical condition that is targeted by a drug project.
[9] Approximately 35% of drugs in our data are developed for more than one indication.
[10] We thank Manuel Hermosilla for sharing the mapping data between Cortellis indications and ICD-9 codes.

2.2.3 Breakthrough therapy designations

We follow Garfinkel and Hammoudeh (2022) to identify BTD events and grant dates. Specifically, we collect information on breakthrough designations from the Friends of Cancer Research (FOCR) website.[11] FOCR identifies each BTD drug name, the announcement date, the sponsoring firm, and the indications for which the BTD was granted. We manually match the FOCR data to our drug development data using drug names. If a BTD is granted to more than one drug or more than one firm, we treat each as a separate BTD event.[12] That field also indicates whether a BTD was granted but does not identify the grant date or the drug-indication. We validate announcement dates via firm financial statements, FDA disclosures, and business media articles. We also crosscheck our dates with the 143 BTDs in the online supplementary appendix for Hoffmann et al. (2019). Finally, we drop five BTDs that were rescinded. Our final sample of BTD awards include 253 unique BTDs awarded to 107 firms in 93 ICD-9 markets from December 2012 through December 2019.

2.3 Executive compensation details

Executive compensation details are obtained from a variety of sources. We first collect data from ExecuComp and Institutional Shareholder Services (ISS) for large firms in our sample. For all remaining firms in Cortellis not covered by each of these datasets (mostly smaller, precommercial firms), we manually collect data from the Summary Compensation Table in firms' annual proxy statements (and, if necessary, annual reports). We collect compensation details for the CEO and the other named executive officers (NEOs) that are the most highly compensated (five or three) individual officers of the firm. We record the form of compensation (salary, bonus, stock, options, etc.) and the disclosed titles of each listed executive as of the end of the fiscal year

[11] https://www.focr.org/breakthrough-therapies
[12] We crosscheck our BTD labels on drugs using the "Regulatory Designation" field in Cortellis.

to identify CEOs, CFOs, and other NEOs. We define an indicator, *CEO* (*CFO*), equal to one if the executive was listed as the CEO (CFO) at the end of the firm-year and zero otherwise.

The objective of this paper is to study the effect of competition shocks on the risk-incentive pay of management. Therefore, we restrict our focus to stock options, stocks, salary, and total compensation. We calculate the natural log of each compensation variable winsorized at the 1st and 99th level. We also calculate the percent of total (winsorized) compensation that is comprised of each component (stock options, stock, and salary).

2.4 Rival risk-taking measures

To empirically examine the predictions of Arrow (1962) and how rival firms respond to BTD events, we create three risk-taking measures. As noted above, the pharmaceutical industry contains detailed reporting of drug products and projects. This allows us to construct granular measures of drug-project innovations including new initiations, introduction of a new technology not previously used, and development of a drug with lengthy gestation time for a particular therapeutic market. Given these innovation project-level indicators, we can aggregate up to the firm level.

We begin with the most basic version of drug innovation (to the firm) and identify the years in which a firm begins development of a new project. *Drug Initiation* is an indicator variable that takes the value of one if the firm initiates (begins developing for the first time) a new project in the given year. Second, we identify whether a new drug project utilizes a new technology (i.e., target action) that was not previously used by the firm before now, on any of their existing drug projects. The firm's lack of experience with the new technology increases the uncertainty associated with the development success. *New Technology* is an indicator variable equal to one if the firm starts developing a new drug project with a new technology in the year.

Our final risk-taking measure is based on the length of time a drug project is expected to be under development. Drug development is inherently risky due to its high cost, lengthy development times, and low success rates.[13] When the time under development is longer than average, perhaps due to the complexity of treatments in that therapeutic area, the risk is heightened. Why do firms choose to develop projects in markets with lengthy development times? We find that such markets have significantly fewer competing drug projects, and more importantly, fewer approved-for-sale products.[14] This suggests that firms may develop projects in these markets in the hopes of obtaining economic rents upon success. We calculate a therapeutic market's average development time as the number of years to complete each clinical trial (i.e., Phase-I, Phase-II or Phase-III) for each drug project within a market, and then compute a grand average across all these projects. *Lengthy Development Time* is an indicator variable equal to one if the firm begins developing a new drug project in a market with an average development time above the median in the Cortellis sample in year *t*.

It is worth noting that each of these variables are comprised of drug-level data only available due to the detailed reporting requirements of the industry. While we aggregate drugs and project-level variables to the firm-level, each measure is more granular than typical firm-level proxies for firm risk-taking (e.g., R&D expense in Compustat) and should theoretically better reflect changes made by rivals following BTD events. For example, if a firm responds to a competitor receiving a BTD by reallocating scarce resources from an existing project to a new project using a new technology (target action) with an above median development time, all three of our risk-taking

[13] Only 12% of drugs in clinical testing eventually receive FDA approval (see Hay et al. 2014).
[14] In untabulated results, we use a sample with observations at the market-level, and run two regressions with number of drug projects (number of approved products) as the dependent variable in the first (second) regression. In both regressions, the main independent variable is the average development time (in quarters) of a market. We find a negative and statistically significant relationship between both dependent variables and development time.

measures would reflect this reallocation. Conversely, a measure like R&D expenses may not capture this reallocation.[15]

2.5 Construction of the firm-level and executive-level samples

We study the overlap of firms covered by Cortellis with available executive compensation details during 2010–2019. To avoid potential confounding effects of BTD awards on recipient firms' compensation decisions, we exclude observations of BTD firms following the BTD event. Our data requirements yield an initial sample of 3,053 firm-year observations across 535 unique firms with both drug development and executive pay details. Among these firms, we identify 4,549 executives (955 CEOs) and base our main analysis on this sample at the executive-firm-year level.

2.6 Identifying afflicted rivals

To assess the effect of the BTD on competitors, we first identify all rival firms. Rivals are defined as firms that were developing a drug project in the same therapeutic area that experienced the BTD. Importantly, rival firms are not receiving the BTD; rival firms are considered shocked as their competitive position is likely weakened.

We look at five years surrounding the BTD event (*T–*, *T–1*, *T*, *T+1*, and *T+2*) and consider each rival to be shocked in the three years before the BTD award year (indexed as year T) through the end of the second year after the BTD award year (years *T*, *T+1*, and *T+2*). Naturally, not all rivals are equally affected by BTD events. For example, rivals that are highly exposed to a shocked market — those with a significant portion of their drug portfolio in that market — are likely more afflicted by the shock than larger rivals that compete in several diversified markets. Since the objective of our study is to examine the responses of rivals that are most sensitive to the shock

[15] Unlike our drug-based measures for risk-taking, we find no significant effect of BTD shocks on R&D expenses.

(those whose competitive position is weakened most), we focus our attention on what we define to be severely afflicted rivals.[16]

We identify severely afflicted rivals via event study reactions to the BTD events. Specifically, we examine all rivals' three-day cumulative abnormal stock returns centered around each BTD announcement date (labeled CARs).[17] For our 253 BTD events, we have about 5,300 rival reactions to potentially explore. However, each compensation variable we seek to explain is annual. Therefore, our selection of afflicted rivals must also consider the annual cadence of compensation decisions at firms.

We proceed as follows: first, we recognize that firms often set executive pay of year *T+1* at the fiscal year end of year *T* (e.g., firms with fiscal year ends in December may set executive pay for 2016 in December of 2015). Given that 95% of firms in our sample have a December fiscal year end, we consider any rival firms that experience BTD shocks in November or December of year *T*, as shocked in year *T+1*. BTD announcements that occur in January through October of year *T* are considered to be shocks to rivals in the same year *T*.[18]

Next, in the event that a rival firm experiences two BTD shocks during the year, we retain the event that resulted in the lowest CAR value. In other words, we allow each rival to have exactly one BTD shock each year they are shocked. We then sort the CAR values of these unique rival-

[16] It is possible that even large, diversified firms may recognize BTD events as significant game changers and alter their executive compensation practices. However, we expect this to bias against our results and make it more difficult to discern a statistical difference between the "afflicted rivals" and the control firms.

[17] We use a market model with parameters estimated over [−271, −21], relative to the BTD announcement date, and calculate CARs over the three-trading day window [−1, +1], where 0 is the announcement date.

[18] We assume firms need two months to incorporate the information relayed by a year *t* BTD shock in their executive compensation decisions for year *T+1*. We therefore assume that shocks occurring in November or December of year *t* are only reflected in a firm's year *T+2* pay. Nevertheless, we find similar results if we do not make this modification, or if we consider shocks occurring in October through December of year *t* as shocks to the firm in year *T+1*.

year observations into four, three, or two quantiles regardless of the shock year.[19] We label rivals as *afflicted* rivals in year *T* if their lowest CAR during year *T* was in the lowest quantile of all rival CARs across all years. Finally, for each afflicted rival, we define 5 event-year indicators, *Rival Shock (T–, T–1, T, T+1, T+2)*, for each of the 5 years centered around the afflicted BTD event year.[20, 21]

The final sample includes two types of firms. Afflicted rivals, defined as rival firms within the lowest quantile, and control firms. Control firms, therefore, include firms that did not experience a BTD event in the five-year window or rivals that were not *afflicted* (bottom quantile CAR).

2.7 Sample Descriptive Statistics

Variables in the executive-level pay data are described in Table 1. Panel A shows the average values of the BTD rival indicators. About 6.5% (9%, 13.5%) of observations correspond to a year in which a rival experienced an afflicting shock when using quartile (tercile, median) sorts.[22] The narrower the definition for afflicted rivals, the more afflicted they are. Our prior is that the more stringent the definition used to define afflicted rivals, the more pronounced the firm's response.

In Panel B of Table 1, both the executive compensation level and component percentage variables are summarized. The summary statistics indicate that CEOs receive higher compensation packages relative to non-CEO executives, with mean CEO total compensation of about $4,000,000 and average non-CEO total compensation of about $2,000,000. Irrespective of using the level or

[19] We sort CARs into quantiles regardless of the shock year because we wish to identify the most afflicted rivals over the entire sample period. This is particularly important because the distribution of afflicted rivals is not even across years, e.g., more rivals experienced afflicting events in 2015 than in 2013.

[20] If a rival experiences multiple afflicting BTD events in consecutive years, then more than one rival-year indicator may equal one. For example, if a rival experiences two afflicting BTD events in 2014 and 2015, then for that rival's year 2013 observations a value of one is assigned to both indicators *Rival Shock (T–1)* (referencing the 2014 event) and *Rival Shock (T–2)* (referencing the 2015 event).

[21] *Rival Year* indicators are defined for each quantile (quartile, tercile or median) sort.

percentage variables, stock options constitute the largest component of compensation for executives in our sample. This finding is consistent with those reported in business media outlets.[23] Furthermore, the finding that about 38% (an average of about $1,700,000 in stock options) of CEO pay is in the form of stock options is also consistent with previous findings.[24] They also receive an average of 13% of their total compensation in the form of stocks (about $900,000 in stocks, on average), and 30% in the form of salary compensation (about $1,500,000 in cash, on average). Panel B suggests that relative to non-CEO executives, the compensation packages of CEOs have higher proportions of performance-based compensation and lower proportions of cash compensation. This result motivates our focus on subsamples partitioned by executive type, and we expect to see a stronger response to CEOs' compensation structures following a BTD shock.

3. Empirical Design and Results

In this section, we discuss the empirical design used in our analysis. Then we present the results from these tests. We finish the section with a description of tests used in the rival risk-taking analysis and a discussion of those findings.

3.1 Executive compensation around BTD events

We examine the effect of BTD shocks on the structure of executive compensation at rival firms using a difference-in-differences (DiD) analysis. This analysis compares afflicted rivals to

[23] For example, an article published by the biopharmaceutical research institute, WTW, states that the percentage of stock options in the biopharma sector is more than double that of the next sector. Source: https://www.wtwco.com/en-US/Insights/2021/01/biopharma-industry-still-relies-on-stock-options.

[24] For example, in the article referenced in the footnote above, stock options constitute 46% of CEO pay. We note that our finding of 38% includes both established "big pharma" and precommercial biotech, whereas their sample focuses solely on smaller biotech.

control firms before and after the BTD events. We use OLS regressions to estimate the following model:

$$Compensation_{e,f,t} = \sum_{n=-2}^{n=2} \beta_n Rival\ Year\ (T+n)_{f,t,s} + X_{f,t} + \emptyset_f + \gamma_t + \delta_s + \varepsilon_{e,f,t} \quad (1)$$

where *e* indexes executive, *f* indexes firm, *t* indexes calendar year, and *s* indexes BTD shock vintage year. The dependent variable, *Compensation,* is either a compensation level variable or a compensation percentage variable. The level is always calculated as the natural log of the compensation component for executive *e* in year *t*. The component percentage variable is calculated as the percentage of executive *e*'s total compensation that is in a given component in year *t*. *Rival Year* is the main independent variable of interest. We examine compensation changes centered around the afflicting BTD event by including indicator variables centered around the afflicting BTD event (*T–*, *T–1*, *T*, *T+1*, *T+2*).

$X_{f,t}$ represent firm-level controls. *Precommercial* is an indicator variable equal to one for firms with no approved projects and proxies for firm maturity and competitive position. *Firm total projects* measures the number of current projects the firm has approved or is currently working on and proxies for firm size. $\emptyset_f$ are firm fixed effects, γ_t are year fixed effects, and δ_s are BTD shock vintage year fixed effects. We cluster standard errors at the firm level.

Before drawing any causal inferences, DiD estimations require that the parallel trends assumption be satisfied. That is, the average outcome in treated and comparison populations would have followed "parallel trends" in the absence of treatment. In our context, executive pay should not appear significantly different between afflicted firms and control firms *before* the BTD shock. Thus, we do not expect to see any noticeable differences between afflicted and control firms, if any, until after the shock occurs. The regression model in equation (1) is effectively a test of this parallel trends assumption. The Rival Year indicators capture the differential effect of BTD shocks

on executive pay in the years before and after the shock year. We investigate the validity of this assumption by running OLS regressions using equation (1). Table 2 and Table 3 report the results when using compensation levels and compensation component percentages, respectively.

Table 2 reports the results from regressing compensation levels on the shock year indicators separately for a sample of only CEOs and for a sample using all named executive officers. Panels A, B, C, and D use the (natural log) of stock options, stock, salary, and total compensation as the dependent variable. In all panels, the results support the parallel trends assumption, i.e., the coefficients of the indicators in the two years before the shock are not statistically different from zero. Statistically significant differences in executive pay levels between afflicted rivals and control firms begin to appear only after the BTD events.

Turning to rival responses to BTD shocks, Panel A (where the dependent variable is the natural log of stock options) suggest that afflicted rivals respond by significantly increasing the risk-incentive pay of executives in the first year immediately after the shock. Furthermore, as we define afflicted rivals more stringently, we observe larger coefficients and observed adjustments in risk-incentive pay.

The adjustment in risk-incentive pay is evident in both the CEO sample and the full executive sample. However, the coefficient magnitudes suggest that this effect is more economically pronounced for CEOs. In Panels B, C, and D, we find little consistent evidence that that afflicted rivals alter their executive stock, salary, or total compensation levels following BTD events relative to the set of control firms.

Table 3 reports the results from OLS regressions when replacing the dependent level variable with compensation *component percentages*. The results are strikingly similar to those reported in Table 2. That is, in the first year after a BTD shock, afflicted rivals increase the percentage of

executive stock option pay relative to control firms. Furthermore, the coefficients on *Rival Shock (T+1)* again increase as tighten the definition of afflicted rivals (i.e., quartile sorts relative to median sorts). We observe a slight reduction in the percentage of pay tied to stocks and salary in the first year after the shock, although the statistical significance is weak in several specifications.

The evidence suggests that afflicted rivals view higher levels of risk-taking as an appropriate response to competitive shocks and adjust executive compensation accordingly. In the next section we investigate the risk-taking activities of rivals following BTD shocks and the subsequent increase in pay tied to stock options.

3.2 Rival risk-taking around BTD events

We estimate the effect of BTD shocks on rivals' risk taking using a difference-in-differences (DiD) analysis. We use OLS regressions to estimate the following model:

$$Risk_{f,t} = \sum_{n=-2}^{n=2} \beta_n Rival\ Year\ (T+n)_{f,t,s} + \emptyset_f + \gamma_t + \delta_s + \varepsilon_{f,t} \quad (2)$$

where f indexes firm, t indexes calendar year, and s indexes BTD shock vintage year. The dependent variable, *Risk*, is one of the three indicators that proxy for risk-taking (described in section 1.3). *Rival Year* is the main independent variable of interest and includes five indicators, one for each of the five years centered around the afflicting BTD shock that occurred in year *s* relative to year *t*. $\emptyset_f$ are firm fixed effects, γ_t are calendar year fixed effects, and δ_s are BTD shock vintage year fixed effects. Standard errors are clustered at the firm level.

Once again, the regression model in Equation 2 effectively serves as a test for the parallel trend assumption. If this assumption is to hold, then we would expect the coefficients on the rival year indicators to be insignificant in the two years *before* the shock year; any difference should only appear after the shock.

Table 4 presents summary statistics on the rival year indicators and the risk-taking measures. The results in Panel A suggest that the distribution of rival year indicators in the firm-level sample is comparable to that of the executive-level sample described in Panel A of Table 1.

Panel B of Table 4 displays descriptive statistics for the risk-taking variables. Drug initiations are very common with at least one drug initiation in about half the firm-year observations. Initiations of drugs using a new technology that was not previously used by the firm appear less common. Finally, drug initiations in markets with lengthy development times appear somewhat common.

Table 5 reports the results from OLS regressions of firm risk-taking on rival year indicators. Panel A reports these results using the *Drug Initiation* indicator as the dependent variable. The results suggest that afflicted rivals are significantly more likely to initiate a new drug project in the first year after the shock. Furthermore, rivals that were more afflicted by the shock (defined on quartile sorts) are more likely to initiate a drug project relative to less afflicted rivals (defined on median sorts).

Panel B of Table 5 reports the results from OLS regressions using *New Technology* initiations as the dependent variable. We again observe that afflicted rivals, especially those highly afflicted by the shock, are significantly more likely to initiate drug projects that use new technology, in the first year after being shocked. There is not a statistical difference for less afflicted rivals in the first model.

Panel C of Table 5 reports results when using the *Lengthy Development Time* indicator as the dependent variable. Again, we observe a higher propensity for more afflicted rivals to initiate projects in markets with lengthy development times. In summary, the results in this section provide

evidence in favor of increased risk-taking by afflicted rivals, and the effect is proportional to the extent of affliction.

A natural question arises as to why rivals' risk-taking response occurs in the first year after a BTD shock, when the risk-incentive pay of executives is also increased in the same year. An alternative sequencing of events, however, would predict the risk-taking activities of rivals to intensify in the year after executive risk-incentive pay was increased, i.e., firms respond to competitive shocks by increasing risk-incentive pay in the first year after, and executives respond to this increase in risk-incentive pay by increasing their risk taking in the second year after the shock (the first year after the change in pay). We conjecture that rivals increase their risk-taking activities in the first year after the shock because executives anticipate the increases in the risk-incentive component of their compensation. Furthermore, drug development normally requires several years before completion and FDA-approval. This fact, along with our findings in Table 5, suggest that executives accelerate the execution of risky drug development in order to set the innovation process in motion without further delays. Finally, executives at afflicted firms now face, through the BTD-awarded project, a credible threat to their future cashflows and their firm's survival and must respond swiftly to save their firm from failing.

4. Robustness

In this section, we examine the robustness of our findings. We rerun our main executive compensation and risk-taking tests using an alternative definition for afflicted rivals. In our main tests above, an afflicted rival may experience multiple afflicting BTD shocks. Panel A of Table 6 reports the distribution of the number of afflicting events to which a rival is exposed. About 60% of afflicted rivals are shocked exactly once (using quartile sorts). Of the 40% of rivals shocked

twice or more, 85% are shocked in close proximity (i.e., within two consecutive years). This raises several concerns.

One, first-time shocked rivals' responses may systematically differ from those of rivals shocked for a second or third time. For example, our results may be driven by rivals' responses to subsequent shocks if these rivals do not alter executive pay and risk-taking following the first shock.[25] Second, rival year indicators defined for rivals shocked at least twice in consecutive years may pose an econometric issue since several of the rival year indicators for these rivals may have a value of one. This could lead to the overweighting of estimates for a group of afflicted rivals that had adjusted executive pay and risk-taking for unrelated reasons and could spuriously affect our results. Third, rivals shocked multiple times may be systematically different from those shocked only once because they likely have larger portfolios in more markets, which is why they were shocked multiple times. Our results may be driven by these larger rivals, and not by competitive shocks.

We mitigate the concerns above by redefining afflicted rivals and restrict our focus to the first time a rival is shocked. That is, we retain the first shock and disregard all subsequent shocks. In doing so, we ensure that any observed effect of BTD shocks on executive pay and risk-taking is due to the shock and not to rivals learning about the shock or to the overweighting of estimates.

We rerun the same regression models in Tables 2, 3 and 5 using the alternative definition for afflicted rivals. We report the results in Tables 7, 8 and 9, respectively. In all robustness tables, the results are similar to those in the main tests in direction, magnitude, and in most cases, statistical

[25] This could happen if rivals learn about the threat posed by the BTD several years after being shocked for the first time. These rivals would then have a more informed and calculated response if they are shocked a second time.

significance. These results support our findings and help mitigate any concerns that our findings are driven by a group of firms or by factors related to econometric design.

5. Conclusion

We study firms' responses to competitive shocks through their compensation. Theory suggests that the optimal firm response to heightened competition is to increase innovation and that this may be incentivized through option compensation. Empirical work in the compensation literature fails to support this prediction. We offer a new approach and new results.

Our analysis is of the pharmaceutical industry. This focus carries several advantages, including (i) the nature of corporate investment, which is highly innovation oriented, (ii) the industry's detailed granular investment activity data, and (iii) a set of time-varying cross-sectional shocks to firms' competitive positions.

Our shocks are Breakthrough Therapy Designations (BTDs) on drugs. The FDA assigns BTDs on the basis of strong (safety and) efficacy of drug treatment effects on significant diseases. Firms that currently have a drug project in that disease space but do not receive the BTD are logically thought to find themselves at a sudden competitive disadvantage. We study the firms' responses through both executive compensation and eventual investment behavior.

We identify a set of significantly afflicted BTD-shocked rivals. We show that these firms increase risk-incentive pay after the shock. Moreover, those firms exhibit investment behavior that is more risk-oriented after the shock. We conclude that theoretical predictions of firm optimal behavior in the face of competition are empirically followed.

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Table 1: Summary Statistics on the Afflicted Rival-Year Indicators and the Executive Compensation Variables

This table reports the average values of the BTD rival indicators (Panel A) and the executive compensation variables (Panel B). The analysis sample consists of compensation records for 4,253 executives at 535 publicly listed firms from 2010 through 2019. These records correspond to 12,304 unique executive-firm-year observations. The sample excludes the observations of firms that receive a BTD award (i.e., BTD-awarded firms) from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. Afflicted rivals are firms that had significantly negative stock returns (more details below) around the announcement of a BTD award to a competitor in a therapeutic market where the rival was active. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year.

Panel A reports the average values of the afflicted rival-shock indicators. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. The subscript *T* indexes the afflicting BTD event year, where *T–2* identifies the second year before the BTD event, *T+2* identifies the second year after the event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals one in year *(T±N)* relative to the year the rival experienced the afflicting BTD event. If a rival experiences multiple afflicting BTD events in consecutive years, then more than one rival-year indicator may equal one. For example, if a rival experiences two afflicting BTD events in 2014 and 2015, then for that rival's year 2013 observations a value of one is assigned to both indicators *Rival Shock (T–1)* (referencing the 2014 event) and *Rival Shock (T–2)* (referencing the 2015 event).

Panel B reports the average values of the executive compensation variables. Statistics are reported for the sample of CEOs in columns (1) and (2), and for the sample of all executives in columns (3) and (4). Columns titled "Level" summarize the natural log of the compensation component, whereas columns titled "Fraction" summarize the fraction of a component in the total compensation. All compensation variables are first winsorized at the 1% and 99% levels before calculating the natural log or the fractions.

Panel A: Afflicted Rival-Shock Indicators

	Median	Tercile	Quartile
	(1)	(2)	(3)
Rival Shock (T–2)	0.123	0.080	0.059
Rival Shock (T–1)	0.136	0.089	0.066
Rival Shock (T)	0.135	0.089	0.065
Rival Shock (T+1)	0.129	0.084	0.061
Rival Shock (T+2)	0.095	0.063	0.046

Panel B: Executive Compensation Variables

	CEO		All Executives	
	Level	Fraction	Level	Fraction
	(1)	(2)	(3)	(4)
Options	13.508	0.384	12.776	0.344
Stocks	5.241	0.129	5.293	0.125
Salary	13.028	0.302	12.738	0.343
Total Compensation	14.544		14.073	

Table 2: Executive Compensation and Afflicting BTD Events: Compensation Levels

The tests in this table examine the effect of afflicting BTD events on rival executive compensation levels, relative to those of control firms. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are indicated in the title of each panel, and are computed for each executive-year as the natural log of each compensation component. The analysis sample, summarized in Table 1, consists of compensation records for 4,253 executives at 535 publicly listed firms from 2010 through 2019. These records correspond to 12,304 unique executive-firm-year observations. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year, closes (if they do not experience another BTD event). The subscript *T* indexes the afflicting BTD event year, where *T–2* identifies the second year before the BTD event, *T+2* identifies the second year after the event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals one in year *(T±N)* relative to the year the rival experienced the afflicting BTD event. Results in the first (last) three columns are reported from tests that use the sample of CEOs (all executives). t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel A: Natural Log of Stock Options			
Rival Shock (T–2)	–0.247	–0.432	–0.505	–0.192	–0.292	–0.443
	(–0.712)	(–1.107)	(–1.153)	(–0.771)	(–0.993)	(–1.303)
Rival Shock (T–1)	0.423	0.349	0.185	0.292	0.133	0.056
	(1.231)	(0.954)	(0.453)	(1.167)	(0.496)	(0.178)
Rival Shock (T)	–0.014	0.080	0.201	–0.170	–0.107	0.038
	(–0.040)	(0.196)	(0.456)	(–0.631)	(–0.343)	(0.107)
Rival Shock (T+1)	0.984**	1.203***	1.318***	0.899***	1.207***	1.221***
	(2.306)	(2.655)	(2.702)	(2.795)	(3.621)	(3.307)
Rival Shock (T+2)	0.985*	0.618	0.791	0.759*	0.607	0.853*
	(1.779)	(1.025)	(1.268)	(1.753)	(1.276)	(1.828)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.405	0.405	0.405	0.349	0.349	0.349
			Panel B: Natural Log of Stocks			
Rival Shock (T–2)	0.037	0.033	–0.199	0.117	0.112	0.188
	(0.101)	(0.078)	(–0.417)	(0.397)	(0.330)	(0.486)
Rival Shock (T–1)	–0.329	–0.173	0.249	–0.555**	–0.248	0.154
	(–0.940)	(–0.420)	(0.549)	(–1.961)	(–0.750)	(0.413)
Rival Shock (T)	–0.701*	–0.538	–0.469	–0.689**	–0.470	–0.227
	(–1.938)	(–1.273)	(–1.029)	(–2.373)	(–1.401)	(–0.604)
Rival Shock (T+1)	–0.175	–0.118	0.046	–0.203	–0.020	0.165
	(–0.382)	(–0.231)	(0.085)	(–0.561)	(–0.050)	(0.382)
Rival Shock (T+2)	–0.007	0.914	0.891	0.145	0.563	0.610
	(–0.012)	(1.395)	(1.223)	(0.297)	(1.089)	(1.073)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.573	0.573	0.572	0.529	0.529	0.528

Table 2 continued

	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel C: Natural Log of Salary			
Rival Shock (T–2)	–0.025	–0.009	–0.008	0.006	0.003	0.006
	(–0.749)	(–0.246)	(–0.181)	(0.292)	(0.142)	(0.274)
Rival Shock (T–1)	–0.011	–0.037	–0.035	0.000	–0.005	–0.019
	(–0.355)	(–0.999)	(–0.834)	(0.013)	(–0.252)	(–0.782)
Rival Shock (T)	–0.042	–0.040	–0.029	0.020	0.029	0.008
	(–1.342)	(–0.998)	(–0.625)	(1.019)	(1.338)	(0.332)
Rival Shock (T+1)	0.038	0.079*	0.069	0.009	0.041	0.019
	(0.945)	(1.900)	(1.502)	(0.409)	(1.633)	(0.679)
Rival Shock (T+2)	–0.007	0.098**	0.103*	–0.011	0.034	0.051
	(–0.129)	(1.994)	(1.794)	(–0.370)	(1.072)	(1.501)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.621	0.622	0.622	0.334	0.334	0.334
			Panel D: Natural Log of Total Compensation			
Rival Shock (T–2)	–0.047	–0.051	–0.060	–0.048	–0.046	–0.048
	(–0.977)	(–0.946)	(–1.002)	(–1.593)	(–1.369)	(–1.267)
Rival Shock (T–1)	0.059	0.060	0.038	0.061**	0.074**	0.060
	(1.294)	(1.172)	(0.690)	(2.007)	(2.185)	(1.618)
Rival Shock (T)	–0.034	–0.024	–0.043	–0.020	–0.011	0.004
	(–0.718)	(–0.457)	(–0.780)	(–0.653)	(–0.311)	(0.112)
Rival Shock (T+1)	0.080	0.084	0.066	0.032	0.064*	0.034
	(1.512)	(1.453)	(1.028)	(0.898)	(1.697)	(0.818)
Rival Shock (T+2)	–0.062	–0.043	–0.051	–0.017	–0.043	–0.051
	(–0.916)	(–0.607)	(–0.645)	(–0.370)	(–0.884)	(–0.970)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.685	0.685	0.685	0.556	0.557	0.556

Table 3: Executive Compensation and Afflicting BTD Events: Compensation Component Percentages

The tests in this table examine the effect of afflicting BTD events on rival executive compensation percentages, relative to those of control firms. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are indicated in the title of each panel, and are calculated for each executive-year as the dollar amount of a compensation component divided by total compensation. The analysis sample, summarized in Table 1, consists of compensation records for 4,253 executives at 535 publicly listed firms from 2010 through 2019. These records correspond to 12,304 unique executive-firm-year observations. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years.. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year, closes (if they do not experience another BTD event). The subscript *T* indexes the afflicting BTD event year, where *T–2* identifies the second year before the BTD event, *T+2* identifies the second year after the event. *Rival Shock (T±N)* is an indicator defined at the firm–level and equals one in year *(T±N)* relative to the afflicting BTD year. Results in the first (last) three columns are reported from tests that use the sample of CEOs (all executives). t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Percentage of Stock Options					
Rival Shock (T–2)	–0.021	–0.017	–0.022	–0.020*	–0.015	–0.020
	(–1.211)	(–0.869)	(–0.994)	(–1.740)	(–1.132)	(–1.281)
Rival Shock (T–1)	0.033**	0.023	0.011	0.021*	0.014	0.005
	(1.966)	(1.246)	(0.544)	(1.801)	(1.069)	(0.361)
Rival Shock (T)	0.012	0.020	0.010	0.008	0.013	0.013
	(0.702)	(0.992)	(0.453)	(0.623)	(0.913)	(0.828)
Rival Shock (T+1)	0.053**	0.064***	0.066***	0.040***	0.050***	0.052***
	(2.525)	(2.777)	(2.634)	(2.736)	(3.236)	(2.903)
Rival Shock (T+2)	0.034	0.012	0.012	0.017	0.006	0.018
	(1.291)	(0.436)	(0.405)	(0.850)	(0.269)	(0.782)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.417	0.417	0.416	0.374	0.374	0.374

Table 3 continued

	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: Percentage of Stocks						
Rival Shock (T–2)	–0.012	–0.009	–0.014	–0.008	–0.006	–0.008
	(–1.047)	(–0.651)	(–0.922)	(–0.990)	(–0.607)	(–0.661)
Rival Shock (T–1)	–0.011	–0.007	0.004	–0.010	–0.005	0.007
	(–1.024)	(–0.578)	(0.257)	(–1.169)	(–0.503)	(0.629)
Rival Shock (T)	–0.017	–0.009	–0.009	–0.019**	–0.016*	–0.006
	(–1.518)	(–0.706)	(–0.628)	(–2.336)	(–1.702)	(–0.605)
Rival Shock (T+1)	–0.019	–0.016	–0.017	–0.025**	–0.018*	–0.016
	(–1.463)	(–1.135)	(–1.087)	(–2.437)	(–1.651)	(–1.397)
Rival Shock (T+2)	–0.005	0.013	0.005	–0.005	0.004	–0.005
	(–0.297)	(0.736)	(0.231)	(–0.379)	(0.318)	(–0.348)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.544	0.543	0.543	0.480	0.479	0.479
Panel C: Percentage of Salary						
Rival Shock (T–2)	0.028**	0.030**	0.025	0.028***	0.025**	0.023*
	(2.156)	(1.978)	(1.510)	(3.127)	(2.383)	(1.958)
Rival Shock (T–1)	–0.018	–0.022*	–0.014	–0.012	–0.020**	–0.019*
	(–1.517)	(–1.704)	(–0.921)	(–1.313)	(–2.099)	(–1.780)
Rival Shock (T)	0.007	–0.002	0.006	0.012	0.008	0.000
	(0.531)	(–0.123)	(0.421)	(1.332)	(0.820)	(0.026)
Rival Shock (T+1)	–0.023	–0.027*	–0.024	–0.015	–0.022**	–0.019
	(–1.616)	(–1.803)	(–1.451)	(–1.416)	(–2.040)	(–1.538)
Rival Shock (T+2)	–0.014	–0.005	–0.003	–0.013	–0.003	0.007
	(–0.830)	(–0.257)	(–0.156)	(–1.004)	(–0.205)	(0.449)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.476	0.476	0.475	0.412	0.411	0.411

Table 4: Summary Statistics on the Rival Risk-Taking Sample

This table reports summary statistics on the BTD rival indicators (Panel A) and the firm risk-taking variables (Panel B). The analysis sample consists of 535 firms that were publicly listed and reported executive compensation in at least one year from 2010 through 2019. The observation level of the sample is firm-year, and the final panel includes 3,090 observations. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. Afflicted rivals are firms that had significantly negative stock returns (more details below) around the announcement of a BTD award to a competitor in a therapeutic market where the rival was active. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year, closes (if they do not experience another BTD event).

Panel A reports the average values of the afflicted rival-year indicators. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. The subscript *T* indexes the afflicting BTD event year, where *T–2* identifies the second year before the BTD event, *T+2* identifies the second year after the event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals one in year *(T±N)* relative to the year the rival experienced the afflicting BTD event. If a rival experiences multiple afflicting BTD events in consecutive years, then more than one rival-year indicator may equal one. For example, if a rival experiences two afflicting BTD events in 2014 and 2015, then for that rival's year 2013 observations a value of one is assigned to both indicators *Rival Shock (T–1)* (referencing the 2014 event) and *Rival Shock (T–2)* (referencing the 2015 event).

Panel B reports the averages, medians, and standard deviations of the risk-taking indicators. These variables are first constructed using the drug-level records in the Cortellis database, then aggregated to the firm-level. *Drug Initiation* is an indicator calculated each firm-year, and it is equal to one in the years when a firm starts developing a drug project for the first time. *New Technology Initiation* is an indicator that is equal to one in the years when a firm starts developing a drug project for the first time, and that new project uses a technology (i.e., target-based action) that the firm has not used before. *Lengthy Development Initiation* is an indicator equal to one in the years that a firm starts developing a new project for the first time, and that new project targets a therapeutic market that has an average development time above the median level in the Cortellis database. Development time is the average time spent by drug projects in a therapeutic market to complete clinical trials and receive FDA approval.

Panel A: Afflicted Rival-Year Indicators

	Lower Half	Lowest Tercile	Lowest Quartile
	(1)	(2)	(3)
Rival Shock (T–2)	0.143	0.095	0.071
Rival Shock (T–1)	0.158	0.105	0.079
Rival Shock (T)	0.153	0.102	0.075
Rival Shock (T+1)	0.108	0.072	0.054
Rival Shock (T+2)	0.074	0.047	0.034

Panel B: Risk-Taking Variables

	Mean	Median	Standard Deviation
	(1)	(2)	(3)
Drug Initiation	0.549	1.000	0.498
New Technology Initiation	0.296	0.000	0.456
Lengthy Development Initiation	0.382	0.000	0.486

Table 5: Firm Risk-Taking Activities and Afflicting BTD Events

The tests in this table examine the effect of afflicting BTD events on the risk-taking activities of rivals, relative to those of control firms. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are defined below. The analysis sample, summarized in Table 4, consists of 535 firms that were publicly listed and reported executive compensation in at least one year from 2010 through 2019. The observation level of the sample is firm-year, and the final panel includes 3,090 observations. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years.. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year, closes (if they do not experience another BTD event). The subscript *T* indexes the afflicting BTD event year, where *T–2* identifies the second year before the BTD event, *T+2* identifies the second year after the event, and so on. *Rival Shock (T±N*) is an indicator defined at the firm-level and equals one in year *(T±N*) relative to the year the rival experienced the afflicting BTD event. t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

In Panel A, the dependent variable, *Drug Initiation*, is an indicator calculated each firm-year, and is equal to one in the years when a firm starts developing a drug project for the first time.

The dependent variable in Panel B, *New Technology Initiation*, is an indicator that is equal to one in the years when a firm starts developing a drug project for the first time, and that new project uses a technology (i.e., target-based action) that the firm has not used before.

In Panel C, the dependent variable, *Lengthy Development Initiation*, is an indicator equal to one in the years that a firm starts developing a new project for the first time, and that new project targets a therapeutic market that has an average development time above the median level in the Cortellis database. Development time is the average time spent by drug projects in a therapeutic market to complete clinical trials and receive FDA approval.

	Median	Tercile	Quartile
	(1)	(2)	(3)
Panel A: Drug Initiations			
Rival Shock (T–2)	0.060*	0.060	0.050
	(1.836)	(1.639)	(1.258)
Rival Shock (T–1)	0.041	0.001	–0.024
	(1.242)	(0.017)	(–0.625)
Rival Shock (T)	0.028	0.030	0.064
	(0.737)	(0.743)	(1.466)
Rival Shock (T+1)	0.080**	0.078**	0.109**
	(2.202)	(2.014)	(2.438)
Rival Shock (T+2)	–0.023	0.008	0.021
	(–0.480)	(0.146)	(0.395)
Observations	3,090	3,090	3,090
R-squared	0.371	0.370	0.370

Table 5 continued

	Median (1)	Tercile (2)	Quartile (3)
Panel B: Drug Initiations using New Technology			
Rival Shock (T–2)	0.022	0.014	–0.028
	(0.680)	(0.383)	(–0.699)
Rival Shock (T–1)	0.018	–0.010	–0.031
	(0.536)	(–0.279)	(–0.830)
Rival Shock (T)	–0.027	0.010	0.012
	(–0.679)	(0.243)	(0.243)
Rival Shock (T+1)	0.010	0.103**	0.127***
	(0.276)	(2.437)	(2.622)
Rival Shock (T+2)	0.032	0.066	0.060
	(0.622)	(1.128)	(1.004)
Observations	3,090	3,090	3,090
R-squared	0.357	0.359	0.360
Panel C: Drug Initiations in Therapeutic Markets with Lengthy Development Times			
Rival Shock (T–2)	0.059*	0.022	0.007
	(1.773)	(0.566)	(0.168)
Rival Shock (T–1)	0.031	0.013	0.019
	(0.954)	(0.365)	(0.483)
Rival Shock (T)	–0.031	–0.032	–0.020
	(–0.826)	(–0.764)	(–0.420)
Rival Shock (T+1)	0.066*	0.103**	0.108**
	(1.744)	(2.547)	(2.223)
Rival Shock (T+2)	–0.039	–0.005	–0.006
	(–0.726)	(–0.080)	(–0.100)
Observations	3,090	3,090	3,090
R-squared	0.368	0.367	0.367

Table 6: Summary Statistics on BTD Rival Indicators using only the First BTD Event

This table reports summary statistics on the distribution of BTD shock events across firms (Panel A) and the alternative BTD rival indicators defined using only the first afflicting BTD shock event (Panel B), which is used in the robustness tests of Tables 7 through 9. The analysis sample consists of 535 firms that were publicly listed and reported executive compensation in at least one year from 2010 through 2019. The observation level of the sample is firm-year. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year.

Panel A reports the distribution of BTD shock events across firms in the sample. *% Never Shocked (Control) Firms* display the percentage of firms that had never experienced an afflicting BTD event, defined on the respective quantile, at any time during the sample period. *% Shocked Exactly Once (Exactly Twice, Three or More Times*) displays the percentage of firms that have experienced exactly one (two, three or more) afflicting BTD events in the full sample, which was described in Table 1.

Panel B reports the average values of the alternative Afflicted Rival-Year Indicators that were defined using only the first afflicting BTD shock, i.e., a firm can only experience one afflicting BTD event, which is the very first one. The subscript *T* indexes the first afflicting BTD event year, where *T–2* identifies the second year before the first afflicting BTD event, *T+2* identifies the second year after the first BTD shock event, and so on. *Rival Shock (T±N*) is an indicator defined at the firm-level and equals one in year *(T±N*) relative to the first year the rival experienced the first afflicting BTD event.

	Median	Tercile	Quartile
	(1)	(2)	(3)
Panel A: Distribution of Sample Firms by Exposure to BTD Events			
% Never Shocked (Control) Firms	59.43	67.85	73.27
% Shocked Exactly Once	17.57	17.38	15.70
% Shocked Exactly Twice	10.84	8.22	7.66
% Shocked Three or More Times	12.15	6.54	3.36
Panel B: Afflicted Rival-Year Indicators using only the First BTD Event			
Rival Shock (T–2)	0.052	0.042	0.035
Rival Shock (T–1)	0.062	0.049	0.042
Rival Shock (T)	0.061	0.048	0.040
Rival Shock (T+1)	0.056	0.045	0.037
Rival Shock (T+2)	0.046	0.037	0.030

Table 7: Compensation Levels Robustness Tests using only the First BTD Event

The tests in this replicate those reported in Table 2 only using the alternative Afflicting BTD Rival-Year indicators that are defined using only the first afflicting BTD event. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are indicated in the title of each panel, and are computed for each executive-year as the natural log of each compensation component. The analysis sample is similar to that used in Table 2. These records correspond to 12,304 unique executive-firm-year observations. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year. The subscript *T* indexes the first afflicting BTD event year, where *T–2* identifies the second year before the first afflicting BTD event, *T+2* identifies the second year after the first BTD event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals one in year *(T±N)* relative to the year the rival experienced the first afflicting BTD event. Results in the first (last) three columns are reported from tests that use the sample of CEOs (all executives). The compensation (rival-year indicator) variables are described in Table 1 (Table 6). t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Natural Log of Stock Options					
Rival Shock (T–2)	–0.294	–0.712*	–0.794*	–0.170	–0.485*	–0.618*
	(–0.870)	(–1.840)	(–1.827)	(–0.694)	(–1.656)	(–1.842)
Rival Shock (T–1)	0.447	0.170	–0.025	0.369	0.060	–0.045
	(1.304)	(0.486)	(–0.063)	(1.439)	(0.228)	(–0.143)
Rival Shock (T)	–0.379	–0.395	–0.026	–0.409	–0.419	–0.160
	(–1.072)	(–0.996)	(–0.060)	(–1.550)	(–1.344)	(–0.448)
Rival Shock (T+1)	0.352	0.925**	1.173**	0.399	0.941***	1.136***
	(0.825)	(2.105)	(2.438)	(1.268)	(2.883)	(3.038)
Rival Shock (T+2)	0.911*	0.290	0.896	0.852*	0.339	1.029**
	(1.645)	(0.478)	(1.388)	(1.911)	(0.685)	(2.064)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.404	0.404	0.405	0.348	0.348	0.349
	Panel B: Natural Log of Stocks					
Rival Shock (T–2)	–0.089	0.007	–0.276	0.032	0.159	0.183
	(–0.251)	(0.016)	(–0.604)	(0.114)	(0.495)	(0.496)
Rival Shock (T–1)	–0.151	–0.099	0.291	–0.348	–0.155	0.241
	(–0.439)	(–0.252)	(0.665)	(–1.252)	(–0.491)	(0.663)
Rival Shock (T)	–0.666*	–0.533	–0.440	–0.569**	–0.321	–0.114
	(–1.824)	(–1.323)	(–1.001)	(–1.968)	(–0.996)	(–0.313)
Rival Shock (T+1)	–0.302	–0.389	–0.133	–0.241	–0.088	0.073
	(–0.632)	(–0.769)	(–0.252)	(–0.658)	(–0.219)	(0.174)
Rival Shock (T+2)	–0.193	0.483	0.617	0.227	0.349	0.470
	(–0.290)	(0.686)	(0.783)	(0.452)	(0.631)	(0.770)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.572	0.572	0.572	0.529	0.528	0.528

Table 7 continued

Rival Defined on	CEO Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
			Panel C: Natural Log of Salary			
Rival Shock (T–2)	–0.021	–0.013	–0.009	0.003	–0.001	0.008
	(–0.624)	(–0.371)	(–0.221)	(0.129)	(–0.029)	(0.360)
Rival Shock (T–1)	0.003	–0.044	–0.040	–0.014	–0.009	–0.017
	(0.095)	(–1.139)	(–0.983)	(–0.681)	(–0.413)	(–0.717)
Rival Shock (T)	–0.041	–0.055	–0.038	0.026	0.020	0.013
	(–1.149)	(–1.263)	(–0.830)	(1.389)	(0.940)	(0.583)
Rival Shock (T+1)	0.040	0.070	0.062	0.021	0.048*	0.026
	(0.878)	(1.525)	(1.211)	(0.845)	(1.896)	(0.900)
Rival Shock (T+2)	0.024	0.103*	0.116*	0.023	0.031	0.053
	(0.370)	(1.745)	(1.739)	(0.764)	(0.939)	(1.481)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.621	0.622	0.622	0.334	0.334	0.334
			Panel D: Natural Log of Total Compensation			
Rival Shock (T–2)	–0.056	–0.063	–0.076	–0.048*	–0.046	–0.053
	(–1.217)	(–1.194)	(–1.313)	(–1.652)	(–1.398)	(–1.404)
Rival Shock (T–1)	0.083*	0.066	0.035	0.077**	0.093***	0.071*
	(1.805)	(1.339)	(0.665)	(2.417)	(2.728)	(1.889)
Rival Shock (T)	–0.052	–0.057	–0.066	–0.028	–0.015	–0.002
	(–1.089)	(–1.126)	(–1.223)	(–0.904)	(–0.464)	(–0.052)
Rival Shock (T+1)	0.047	0.116**	0.091	–0.004	0.086**	0.052
	(0.885)	(2.064)	(1.454)	(–0.118)	(2.313)	(1.245)
Rival Shock (T+2)	0.005	–0.012	–0.013	0.058	–0.018	–0.003
	(0.069)	(–0.162)	(–0.154)	(1.242)	(–0.373)	(–0.058)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.685	0.685	0.685	0.556	0.557	0.556

Table 8: Component Percentages Robustness Tests using only the First BTD Event

The tests in this table replicate those of Table 3 only using the alternative Afflicted Rival-Year indicators that are defined using only the first afflicting BTD event. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are indicated in the title of each panel, and are calculated for each executive-year as the dollar amount of a compensation component divided by total compensation. The analysis sample is similar to that used in Table 3. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year. The subscript *T* indexes the first afflicting BTD event year, where *T–2* identifies the second year before the first afflicting BTD event, *T+2* identifies the second year after the first BTD event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals one in year *(T±N)* relative to the year the rival experienced the first afflicting BTD event. Results in the first (last) three columns are reported from tests that use the sample of CEOs (all executives). The compensation (rival-year indicator) variables are described in Table 1 (Table 6). t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

	CEO Sample			All Executives Sample		
Rival Defined on	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
	Panel A: Percentage of Stock Options					
Rival Shock (T–2)	–0.022	–0.025	–0.030	–0.016	–0.018	–0.024
	(–1.262)	(–1.289)	(–1.367)	(–1.371)	(–1.392)	(–1.589)
Rival Shock (T–1)	0.031*	0.017	0.006	0.024**	0.013	0.002
	(1.825)	(0.942)	(0.283)	(2.063)	(1.002)	(0.163)
Rival Shock (T)	–0.001	0.003	–0.006	–0.002	0.001	–0.002
	(–0.036)	(0.149)	(–0.295)	(–0.192)	(0.081)	(–0.108)
Rival Shock (T+1)	0.033	0.059**	0.068***	0.021	0.041**	0.051***
	(1.514)	(2.518)	(2.640)	(1.421)	(2.492)	(2.779)
Rival Shock (T+2)	0.039	0.020	0.028	0.030	0.015	0.035
	(1.375)	(0.674)	(0.879)	(1.406)	(0.634)	(1.406)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.417	0.416	0.417	0.374	0.374	0.374

Table 8 continued

Rival Defined on	CEOs Sample			All Executives Sample		
	Median	Tercile	Quartile	Median	Tercile	Quartile
	(1)	(2)	(3)	(4)	(5)	(6)
Panel B: Percentage of Stocks						
Rival Shock (T–2)	–0.012	–0.008	–0.014	–0.009	–0.003	–0.006
	(–1.148)	(–0.592)	(–0.948)	(–1.141)	(–0.334)	(–0.538)
Rival Shock (T–1)	–0.006	–0.005	0.007	–0.005	–0.000	0.012
	(–0.596)	(–0.403)	(0.514)	(–0.556)	(–0.008)	(1.058)
Rival Shock (T)	–0.017	–0.010	–0.007	–0.015*	–0.009	–0.001
	(–1.544)	(–0.799)	(–0.517)	(–1.825)	(–0.933)	(–0.090)
Rival Shock (T+1)	–0.015	–0.020	–0.017	–0.020**	–0.015	–0.014
	(–1.107)	(–1.448)	(–1.098)	(–2.014)	(–1.381)	(–1.232)
Rival Shock (T+2)	–0.007	0.008	0.005	0.006	0.008	0.004
	(–0.381)	(0.377)	(0.248)	(0.384)	(0.503)	(0.263)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.544	0.543	0.543	0.480	0.479	0.479
Panel C: Percentage of Salary						
Rival Shock (T–2)	0.030**	0.034**	0.032*	0.028***	0.025**	0.026**
	(2.380)	(2.288)	(1.913)	(3.117)	(2.459)	(2.155)
Rival Shock (T–1)	–0.020*	–0.021*	–0.011	–0.017*	–0.022**	–0.021**
	(–1.675)	(–1.661)	(–0.768)	(–1.859)	(–2.387)	(–1.969)
Rival Shock (T)	0.016	0.011	0.016	0.017*	0.012	0.004
	(1.249)	(0.837)	(1.051)	(1.816)	(1.224)	(0.409)
Rival Shock (T+1)	–0.010	–0.024	–0.020	–0.001	–0.019*	–0.015
	(–0.627)	(–1.569)	(–1.138)	(–0.069)	(–1.730)	(–1.182)
Rival Shock (T+2)	–0.015	0.004	0.003	–0.024*	–0.003	–0.002
	(–0.779)	(0.216)	(0.133)	(–1.665)	(–0.213)	(–0.091)
Observations	2,990	2,990	2,990	12,304	12,304	12,304
R-squared	0.476	0.476	0.475	0.412	0.411	0.411

Table 9: Firm Risk-Taking Activities and BTD Events: Robustness Tests using only the First BTD Event

The tests in this table replicate those of Table 5 only using the alternative afflicted rival-year indicators that are defined using only the first afflicting BTD event. The table presents coefficients from OLS regressions that include firm-, calendar year-, and BTD event vintage year fixed effects, and cluster standard errors by firm. The dependent variables are defined below. The analysis sample is similar to that used in Table 5. The sample excludes the observations of BTD-awarded firms from the first award year to the end of the sample period. The sample includes two types of firms: afflicted rivals and control firms. The column headings indicate whether an afflicted rival has an announcement return around a BTD event that is in either the lower half ("Median"), lowest tercile ("Tercile"), or lowest quartile "(Quartile") of all rival announcement returns around all BTD events in all years. Control firms are either firms that have never experienced a BTD event in any of their markets, or firms that eventually experience a BTD event, but before or after the five-year window centered on the BTD event year. The subscript *T* indexes the first afflicting BTD event year, where *T–2* identifies the second year before the first afflicting BTD event, *T+2* identifies the second year after the first BTD event, and so on. *Rival Shock (T±N)* is an indicator defined at the firm-level and equals in year *(T±N)* relative to the year the rival experienced the first afflicting BTD event. The risk-taking (rival-year indicator) variables are described in Table 4 (Table 6). t-statistics are reported in parenthesis. asterisks indicate statistical significance as follows: *** p<0.01, ** p<0.05, * p<0.1.

In Panel A, the dependent variable, *Drug Initiation*, is an indicator calculated each firm-year, and is equal to one in the years when a firm starts developing a drug project for the first time.

The dependent variable in Panel B, *New Technology Initiation*, is an indicator that is equal to one in the years when a firm starts developing a drug project for the first time, and that new project uses a technology (i.e., target-based action) that the firm has not used before.

In Panel C, the dependent variable, *Lengthy Development Initiation*, is an indicator equal to one in the years that a firm starts developing a new project for the first time, and that new project targets a therapeutic market that has an average development time above the median level in the Cortellis database. Development time is the average time spent by drug projects in a therapeutic market to complete clinical trials and receive FDA approval.

	Median	Tercile	Quartile
	(1)	(2)	(3)
Panel A: Drug Initiations			
Rival Shock (T–2)	–0.003	0.017	0.010
	(–0.062)	(0.356)	(0.199)
Rival Shock (T–1)	0.062	0.020	–0.021
	(1.386)	(0.436)	(–0.434)
Rival Shock (T)	0.052	0.056	0.091*
	(1.018)	(1.073)	(1.730)
Rival Shock (T+1)	0.098**	0.101**	0.126**
	(1.981)	(2.024)	(2.398)
Rival Shock (T+2)	–0.038	0.014	0.072
	(–0.685)	(0.242)	(1.174)
Observations	3,090	3,090	3,090
R-squared	0.373	0.372	0.373

Table 9 continued

	Median	Tercile	Quartile
	(1)	(2)	(3)
Panel B: Drug Initiations using New Technology			
Rival Shock (T–2)	–0.032	–0.033	–0.046
	(–0.708)	(–0.717)	(–0.988)
Rival Shock (T–1)	0.069	0.010	–0.013
	(1.586)	(0.221)	(–0.286)
Rival Shock (T)	–0.002	0.047	0.054
	(–0.033)	(0.921)	(0.962)
Rival Shock (T+1)	0.043	0.161***	0.165***
	(0.892)	(3.166)	(3.054)
Rival Shock (T+2)	0.039	0.098*	0.108*
	(0.732)	(1.681)	(1.692)
Observations	3,090	3,090	3,090
R-squared	0.365	0.367	0.368
Panel C: Drug Initiations in Therapeutic Markets with Lengthy Development Time			
Rival Shock (T–2)	–0.000	–0.016	–0.001
	(–0.004)	(–0.325)	(–0.014)
Rival Shock (T–1)	0.045	0.017	0.020
	(0.987)	(0.360)	(0.409)
Rival Shock (T)	–0.010	0.012	0.031
	(–0.199)	(0.236)	(0.585)
Rival Shock (T+1)	0.061	0.091*	0.091*
	(1.226)	(1.793)	(1.675)
Rival Shock (T+2)	–0.060	–0.006	–0.003
	(–1.065)	(–0.088)	(–0.046)
Observations	3,090	3,090	3,090
R-squared	0.371	0.370	0.370