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Essays on Financial Disclosure and Innovation

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Upon completing my PhD at EUR, I reflect on the past five years and recognize that I had initially underestimated the challenges of pursuing a PhD, particularly in Accounting. However, with the tremendous support of those around me, I have successfully reached this milestone.

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Any errors or shortcomings in this work are solely my responsibility.

Abstract

The corporate sector wields significant influence over industries and societies through its innovation activities. However, the financing of corporate innovation is hindered by information asymmetry, resulting in underinvestment in corporate R&D. A comprehensive understanding of firms' incentives or disincentives to engage in R&D activities and disclose R&D information is crucial for governments and regulatory bodies to make informed decisions regarding the implementation of policies that promote R&D investment. This dissertation investigates firms' incentives for R&D disclosure and investment, presenting empirical and analytical evidence in three areas.

In Chapter 2, I analyse firms' strategic concerns regarding R&D disclosure in financial reporting within the context of an R&D race. The study identifies varying equilibrium disclosure strategies based on investment and disclosure costs. An asymmetric disclosure mandate is proposed as a resolution to selection issues in the asymmetric equilibrium on determining the disclosing and the nondisclosing firm, despite the potential negative spillover effects.

Chapter 3 focuses on a newly established Chinese stock market with a disclosure mandate regarding R&D information, where firms reduce voluntary R&D disclosure when their peers are subject to the mandate. This reduction is primarily driven by cost-saving incentives. Remarkably, the diminished disclosure does not adversely affect stock liquidity.

Chapter 4 examines the impact of a firm's political connections on innovation. By utilizing US special elections as a quasi-natural experiment, the study reveals a negative influence of political connections on firm innovation, indicating a shift from long-term to short-term activities due to managerial short-termism. However, this effect is constrained by various disciplining forces in place. Overall, the findings contribute to our understanding of firms' decision-making processes and outcomes in innovation and aid policymakers and researchers in shaping effective strategies to promote innovation and address information asymmetry in corporate R&D.

Contents

1   Introduction

This dissertation delves into three important aspects of corporate innovation: the disclosure of R&D information, interplay between firms' innovation strategies and other operations, and the impact of political connections on innovation. Understanding these dynamics is crucial for policymakers, investors, and corporate decision-makers in today's dynamic business environment. The corporate sector, being a key driver of economic growth and innovation, holds significant influence over industries and societies (Aghion and Howitt, 1992). Among various business activities, research and development (R&D) activities are particularly vital for firms seeking a competitive edge, introducing groundbreaking products and services, and ensuring long-term sustainability. However, the success of R&D initiatives relies not only on internal capabilities but also on effective information management and strategic decision-making.

Despite the recognized importance of R&D, the voluntary disclosure of substantial R&D information remains relatively rare in corporate reporting. This scarcity of R&D disclosures stems from factors such as the proprietary nature of R&D investments and the associated costs and risks of information revelation. Firms face a delicate balance between sharing enough

information to signal their innovative potential and safeguarding proprietary knowledge from competitors (Botosan, 1997; Verrecchia, 2001). Consequently, financing corporate innovation faces significant information asymmetry, leading to documented underinvestment in R&D in the corporate sector (Roychowdhury et al., 2019).

Encouraging firms to engage in R&D activities and disclose related information requires a deeper understanding of the incentives and mechanisms that shape their decisions. Governments and regulatory bodies worldwide have implemented various policy tools, such as tax credits, grants, and intellectual property protection, to incentivize corporate R&D (Howell, 2017; Dechezleprêtre et al., 2016; Mansfield, 1986). While these initiatives play a crucial role in fostering innovation, whether proper disclosure frameworks still have additional values remains unclear.

China's Shanghai Stock Exchange (SSE) STAR market stands as a notable exception to the scarcity of R&D disclosure mandates. Firms listed on the STAR market are required to disclose detailed information about their R&D activities, aiming to promote technological advancement by alleviating the financial stress of funding innovation. However, the effects of this disclosure mandate on firms' investment levels remain unclear due to the various

incentives involved in firms' decision-making processes. Previous studies have examined incentives and dis-incentives of voluntary disclosure, but the investment and disclosure decisions in the context of an R&D race still lack clarity. Therefore, it is worth exploring whether the disclosure mandate has unintended consequences.

Chapter 2 of this thesis, joint work with Jeroen Suijs, analyses voluntary R&D disclosures within the context of a two-period R&D race and applies the analysis to a partial disclosure regulation similar to the one from STAR market. This chapter aims to investigate analytically how firms strategically disclose information about their R&D progress, shedding light on the determinants and consequences of disclosure choices in the pursuit of innovation. Understanding the factors that drive firms towards full, partial, or non-disclosure equilibria is instrumental in designing policies and frameworks that promote transparency, market efficiency, and technological advancement. Our model takes into account the fixed timing of disclosure and the R&D race lasting multiple reporting periods, which more closely aligns with firms' financial reporting timeline in practice.

In the area of corporate R&D disclosure, patent filings have been studied extensively in recent empirical literature for its relevance to capital markets

(e.g., Tseng, 2022; Martens, 2023) and patent disclosure contains all the technical details that are necessary for competitors to catch up technically. In contrast, R&D disclosure in financial reports are usually narrative in nature (e.g., Merkley, 2014; Jones, 2007) and do not reveal sufficient technical details. In Chapter 2, we model the R&D process in a way that is more closely linked to firms' financial report. Two primary features that reflect the close linkage are the fixed timing of disclosure and the R&D race lasting for multiple reporting periods.

We obtain full disclosure, asymmetric disclosure and non-disclosure in equilibrium and identify two regions regarding the second period investment cost. In one region, only one single equilibrium can obtain at a time while in the other region, multiple equilibria can co-exist. Regarding the relation between disclosure cost and disclosure equilibrium, we find that a small disclosure cost is sufficient for disclosure equilibrium to obtain while a non-disclosure equilibrium does not necessarily need a large disclosure cost.

Our results of the asymmetric equilibrium, i.e., one and only one firm makes a disclosure, suggest that an asymmetric disclosure mandate could resolve the selection issue by determining which firm is the disclosing and which firm is the non-disclosing firm. In other words, in an equilibrium where there

can only be one disclosing firm, when the regulation requires the previously non-disclosing firm to make a disclosure, the previously disclosing firm ceases to disclose. Therefore, this study also helps to explain the negative spillover effect of the R&D disclosure mandate which I document in Chapter 3.

Additionally, our results of the comparative statics indicate the disclosure mandate's different effect on firms' investment level. We show that the effect depends on whether or not the unregulated firm discloses voluntarily prior to the regulation. Specifically, when the unregulated firm does not disclose absent of the regulation, the disclosure regulation increases the investment of the regulated firm while it decreases the investment of the unregulated firm. When the unregulated firm already discloses voluntarily absent of the regulation, the disclosure regulation switches the disclosing firm with the non-disclosing firm and again increases the investment of the regulated firm while it reduces the investment of the unregulated firm. Collectively, the disclosure regulation increases the investment of the regulated firm and/or decreases the investment of the unregulated firm.

In Chapter 3 of the dissertation, I investigate empirically the effect of mandatory R&D disclosure on peer firms' voluntary disclosure, shedding

light on the spillover effects and strategic interactions among firms operating in the same market. This research explores how extensive R&D disclosure requirements, such as those implemented on the STAR Market, influence the disclosure behaviour of non-STAR peer firms. The findings provide valuable insights into the dynamics of information spillover, competitive strategies, and the trade-offs firms face in disclosing R&D information.

Given potentially different trade-offs firms make when it concerns R&D disclosure against other types of disclosure, it is unclear ex ante how peers will react and which disclosure incentive prevails. In Chapter 3, I use STAR IPO applicants' mention of comparable peers in their prospectus to identify the treated firms of the study. Using two measures of voluntary R&D disclosure, i.e., the number of R&D sentences and the discussion of specific R&D information items as mandated for STAR firms, I document a negative spillover effect: treated firms/peers of the STAR applicants appear to reduce their voluntary R&D disclosure relative to the control group – firms that do not have any peers applying for the STAR market.

A key component of Chapter 3 is to examine disclosure incentives derived from prior theoretical work (e.g., Foster, 1980; Dye, 1985; Verrecchia, 1983). The negative spillover narrows the possible incentives into two, i.e.,

free riding and proprietary cost. The former suggests that the STAR firms' disclosure serves as substitute of the treated firms' disclosure so that once a STAR firm starts disclosure, the peer firm does not have to do that anymore to save costs related to its own disclosure. The latter argument suggests that STAR firms are better able to expropriate non-STAR firms' disclosure such that non-STAR firms reduce voluntary disclosure due to higher marginal proprietary costs. The empirical evidence is consistent with the freeriding argument but inconsistent with the proprietary cost argument. On the one hand, the spillover effect is stronger for firms in weaker information environment suggesting that these firms have greater incentives to freeride due to higher costs of producing information. Stock liquidity is not affected by the reduction of R&D disclosure. These two pieces of evidence support the freeriding argument. In addition, the reduced disclosure is primarily non-proprietary information, and the spillover effect does not vary along industry competition, both of which do not provide supporting evidence for the proprietary argument.

Meanwhile, part of the results from Chapter 2 also help explain the negative spillover effect of Chapter 3 in the sense that the asymmetric disclosure mandate resolves the selection issue in the asymmetric disclosure

equilibrium. In other words, in an asymmetric disclosure equilibrium where only one firm of the two competitors for the same innovation discloses, the disclosure regulation decides which firm is the disclosing and which firm is the non-disclosing firm. When the competitor is required to disclose, the focal firm ceases to disclose rendering a negative association of a firm's own disclosure and the peer disclosure. The mechanism provided by Chapter 2 in explaining the negative spillover is that the benefit of disclosing is only sufficient to sustain one firm's disclosure strategy which is different from the arguments in prior literature discussed in Chapter 3. The analysis in Chapter 2 shows that the marginal benefit of own disclosure decreases after the other firm discloses, which is also consistent with the attenuated spillover effects for firms in better information environment in Chapter 3.

Chapter 4 of the dissertation, joint work with Wenjiao Cao and Zhiyan Wu, takes a broader perspective and examines the influence of political connections on firms' innovation strategies. By exploring the effects of a firm-supported politician winning or losing a close election on subsequent innovation activities by this firm, this research uncovers the intricate relationship between political outcomes and corporate innovation. Our results indicate there is a negative effect of political connections on firms'

innovation. We find that short-termism helps explain the effect, since short-term oriented managers tend to shift their strategic focus towards quicker solutions in order to more quickly realise the political benefits that they have gained through the connection. Understanding how firms respond to political events and navigate the trade-offs between short-term political gains and long-term innovation pursuits provides valuable insights into the nexus of politics, business, and societal impact.

In this study we use election outcomes of US closely contested special elections as an exogeneous shock to firms' political connections. Using patent filings as a proxy for firms' innovation activities, we find that politically connected firms tend to reduce their innovation effort relative to the non-connected donating firms. Previous studies almost exclusively employed correlational analyses with potential confounders such as market position (Rikap, 2022) and corporate competence. The identification strategy of using the closed contested special elections as a Regression Discontinuity Design helps provide evidence for a causal impact of political connection on innovation.

Regarding the mechanism, we find evidence consistent with short-termism. While the politically connected firms reduce their patenting activities, they

appear to acquire more patents through mergers and acquisitions. This suggests firms seek quicker solutions after having obtained political benefits. These firms prefer to shift their focus towards more short-term oriented measures to realize the political benefits they have gained. This argument is supported by the evidence that the negative effect is clustered for firms with CEO's that tend to have short-term preferences and for firms that face situational pressures. Meanwhile, having disciplining forces from the board, ownership and co-developers in place curbs managerial short-termism and weakens the negative effects.

Collectively, these three chapters provide a comprehensive exploration of firm behaviour, encompassing voluntary R&D disclosures, inter-firm information spillover, and the impact of political connections on innovation strategies. By connecting these areas of research, this thesis offers a holistic understanding of the complex dynamics influencing firms' decision-making processes and subsequent outcomes. The findings contribute to the literature on strategic disclosures, inter-firm dynamics, and the intersection of politics and business.

Declaration of contributions

In this section, I declare my contribution to the different chapters of this dissertation and also acknowledge the contribution of the co-authors and the supervisors.

Chapter 2: I developed the idea for the model together with my co-author. I conducted the equilibrium analysis and implemented feedback from my co-author. I wrote the first draft of the chapter and implemented the feedback of my co-author. My co-author and I enhanced the initial draft by incorporating new ideas that evolved over the course of our regular discussions.

Chapter 3: I am the sole author of this chapter. The idea, analyses and write-up were conducted independently by me. During the process, I received and implemented feedback from my supervisors.

Chapter 4: I developed the idea for this chapter together with my co-authors, based on my exploratory work with the PATSTAT data we use in this chapter. I conducted the data collection and initial analysis together with one of the co-authors and added cross-sectional analyses based on suggestions from my supervisors. I wrote the first draft of the data description and result interpretation sections, and my co-authors wrote the first version of the

introduction and conclusion sections. Together all three authors of this chapter revised the chapter to incorporate my supervisors' feedback on the write-up.

2 Voluntary R&D disclosures in financial reporting in a two-period R&D race

2.1 Introduction

Information about firms' R&D activities is highly relevant to capital markets as R&D is an important driver of firms' future profitability. R&D information may be revealed through various channels like patent filings, the annual financial report, and/or press releases. Patent filings have been studied in recent empirical literature for its relevance to capital markets (e.g., Tseng 2022, Martens 2023) and require the patent applicant to disclose all relevant technical details. These patent disclosures can impose proprietary costs for the disclosing firm (Kim and Valentine 2021) but they can also be used strategically to deter product market competition (Glaeser and Landsman 2021). In contrast, R&D disclosures in annual financial reports are usually narrative in nature (e.g. Merkley 2014, Jones 2007) and do not reveal sufficient technical details. These annual report disclosures may still be relevant for stakeholders as they hint at the progress that has been made in the R&D race and the likelihood of the firm winning the R&D race. It

provides timely information to stakeholders without revealing all the technical details that enable competitors to catch-up technologically in the R&D race. Unlike the patent disclosure which is mandatory, in most countries, the regulation of R&D-related disclosure in financial reports remains *de facto* voluntary, and even for the countries where R&D disclosure is considered mandatory there is a lack of specificity of what information should be disclosed.[2] In this paper, we analyse firms' incentives to disclose R&D information without technological spillovers and its effect on firms' investment levels in R&D.

We model the R&D process in a two-period game with 2 firms: for the first period each firm decides on how much to invest in R&D. When the first period ends, each firm decides whether to voluntarily disclose in a periodic (financial) report the progress that has been made in the first period of the R&D race. We assume that such voluntary disclosure comes with a fixed cost *k*. After observing the disclosure decision of the other firm, the second period starts and each firm again decides on how much to invest in R&D. After the

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[2] For a brief summary of the regulatory regime on R&D disclosure of western Europe, see La Rosa and Liberatore (2014) . An exception is the China's SSE STAR market which was launched in 2019 and requires firms listed on the new market to disclose detailed R&D information. This creates a situation where the disclosure mandate only regulates some firms but not the other that compete for the same innovation.

second period ends, the outcome of the R&D investment becomes known and the payoffs realize. The focus of this research is on whether firms are willing to disclose voluntarily about their R&D process in its periodic (financial) report and how the disclosure decisions and investment decisions interact with each other. In practice, an R&D project of a listed firm can spread over multiple reporting periods and on each reporting date one firm has achieved interim progress which affects its own final success rate and once the progress information is disclosed to the competitors it may affect competitors' subsequent investment level. The way we model the two periods of the R&D race mimics the above mentioned R&D process with regard to financial reporting and is an additive structure, meaning that more progress in the first period (i.e., advanced stage) increases the firm's eventual chance to find the innovation but less progress in the first period (i.e., premature stage) still enables the firm to be successful in the second period and find the innovation.

First of all, we find that different disclosure strategies can be supported in equilibrium. Full disclosure can arise where both firms disclose the advanced stage when they have obtained it. Asymmetric disclosure can arise where one firm remains silent about its stage in the R&D process and the other firm

discloses the advanced stage when it has been obtained. And a non-disclosure equilibrium can arise where both firms remain silent about their stage in the R&D process. We have identified two regions regarding the second period investment cost, in one of which these three types of equilibria are mutually exclusive whereas in the other these three types of equilibria can exist simultaneously.

Furthermore, our results for the relation between disclosure and second period investment are relatively more robust due to simpler cost-benefit structure. Specifically, we find that disclosure typically but not always results in lower expected level of investment.

Moreover, we find that disclosure and first period investment are linked in the following way. First period investment by firm i comes with two benefits and two costs. The first benefit of high first period investment is that it increases the probability of the focal firm of obtaining the innovation in a direct way. The second benefit arises from disclosure: when firm i discloses its advanced stage, it may deter firm j from making the high investment in the second period, which in turn increases the probability that firm i is the only firm that obtains the innovation. The first cost is the investment cost c_1 and the second cost is the increase in expected disclosure cost. When a

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disclosing firm makes the high first period investment, it is more likely to obtain the advanced stage, in which case it discloses and incurs the disclosure cost k. In short, disclosure affects first period investment because a high first period investment increases the expected cost of disclosure. This cost would not arise when the firm knows that it will not disclose at the intermediate date.

Our findings imply that higher disclosure cost makes first period investment less attractive. The model does not explicitly specify what drives the disclosure cost. Besides the cost of collecting and disseminating information, it can also include proprietary cost that are not explicitly captured in the model (i.e., the response by the competing firm in the R&D race) or legal liability cost when the disclosure includes soft information or forward looking information. Consequently, to incentivize first period investment, a regulator may introduce policy or regulations that reduce the disclosure cost.

Our findings also show that when multiple equilibria exist, the difference in first period investment levels between the full disclosure and non-disclosure equilibrium critically depends on the first investment cost and disclosure cost. When the first period investment cost is relatively high and the disclosure cost is relatively low, first period investment is higher in the full

disclosure equilibrium. In such cases, mandatory disclosure regulation may be desirable as it eliminates the equilibrium selection problem and mandates firms to play the equilibrium with the higher first period investment levels. However, the opposite holds when the first period investment cost is relatively low and the disclosure cost is relatively high. In that case, the non-disclosure equilibrium results in higher first period investment and mandatory disclosure regulation may not be desirable.

Lastly, a specific application of the model is to analyse the effect of the asymmetric disclosure mandate on firms' investment decisions similar to the STAR market regulation. Our results from the asymmetric equilibrium help explain a negative spillover effect of an asymmetric disclosure mandate in the sense that the mandate resolves the disclosure selection issue which can lead to a switch of the disclosing and the non-disclosing firm. As a result of the switch, the regulated firm increases its investment in the first period while the unregulated firm reduces its investment in the first period. The comparative statics between the non-disclosure equilibrium and the asymmetric equilibrium indicates the effect of an asymmetric disclosure mandate on firms' investment level. Specifically, the mandate increases the

investment of the regulated firm and/or decreases the investment of the unregulated firm.

Overall, this paper aims to provide a baseline model and framework to analyse the interaction between firms' R&D disclosure decisions in financial reporting and their R&D investment decisions. We have demonstrated one application of this model on the effect of an asymmetric disclosure mandate.[3] We find that when the benefit of disclosure is only sufficient to sustain one firm's disclosure strategy, a disclosure mandate that requires the previously non-disclosing firm to make a disclosure switches the disclosing and the non-disclosing firm at equilibrium making the unregulated firm to cease disclosing and investing. When the disclosure cost is relatively high, an asymmetric disclosure mandate that requires only one of the non-disclosing firms to make a disclosure increases the investment of the regulated firm and/or decreases the investment of the unregulated firm.

We differ from prior studies in the way how we model the R&D process and disclosure. Specifically, the R&D process in our model is more closely related to periodic financial reporting reflected primarily in two aspects.

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[3] The asymmetric disclosure mandate is a setting like the STAR market which will be described in more details in Chapter 3.

First, our model does not assume a technological spillover, i.e., disclosing the R&D information does not create a catch-up of the competitor. Second, the source of uncertainty mainly comes from the interim progress while the overall payoff structure is publicly known to both competitors. The first aspect stems from the narrative nature of the R&D disclosure in firms' financial report which, unlike the patent disclosure, normally does not reveal technical details. The second aspect serves to simulate the R&D process in a sense that firms from the same industry compete for a project and the payoff and cost of the project is common knowledge within the industry.

Our model is different from models in the theoretical literature on R&D races/contests and disclosure, which usually distinguishes between learning and feedback. Learning is more consistent with revealing technological information whereas feedback refers to information on a firm's progress in R&D that does not affect another firm's investment technology. Models on learning find that learning can arise either due to signals including the passage of time (Malueg and Tsutsui, 1997) or the exit of a competitor (Moscarini and Squintani, 2010), or due to the disclosure by a competitor on its interim success (Choi, 1991) or investment costs (Jansen, 2010). Several studies analyse disclosure strategies made by innovation leaders in a leader-

follower setting in which disclosure serves to deter the rival from entering into the competition or making higher investment (Anton and Yao, 2004; Hughes and Pae, 2015; Gill, 2008).

In the field of R&D disclosure, learning is most relevant to patent disclosure, while feedback is mainly used in a contest setting where multiple agents compete for a set prize and the principal has information advantage over the agents. Studies on the optimal design of R&D races/contests have different assumptions on the source of uncertainty and different objectives.. Halac et al. (2017) analyses on the optimal disclosure and prize rule when there is uncertainty about the existence of the innovation, Bimpikis et al. (2019) analyses optimal disclosure when there is uncertainty about the discovery rate, and Mihm and Schlapp (2019), Aoyagi (2010) analyse optimal feedback rules when there is uncertainty about the value of the project. In this regard, our model is a contest without a principal who can design the rules of the R&D race; each agent is equally informed about the project's fundamentals and the only private information is the rival's own interim progress.

A closely related study is Yildirim (2005) that models an R&D race between two firms over two periods where firms can disclose their interim progress (i.e., feedback). It differs from our paper in that the likelihood of winning the

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R&D race only depends on the aggregate investment level over the two periods in Yildirim (2005). When firms are symmetric, disclosure about first period investment levels serves no purpose because only the aggregate investment level is relevant and, in equilibrium, both firms can perfectly anticipate the aggregate investment level. This, however, is different when firms are asymmetric, when both firms strictly prefer disclosure. Our paper shows for symmetric firms that, when first period investment does affect the likelihood of winning the R&D race, (non)disclosure affects first and/or second period investment levels and firms are no longer indifferent.

The remainder of the paper is organized as follows. Section 2.2 describes the model specification. Section 2.3 presents the equilibrium analysis. Section 2.4 discusses the results and analyses the relation between disclosure, disclosure cost, and investment levels. Section 2.5 analyses the investment decision for the first period. Finally, Section 2.6 concludes.

2.2   Model description

The model considers an R&D race over 2 periods with 2 homogeneous firms competing for the same innovation with the final payoffs depending on the number of successful firms. The model is a simplified version of the R&D process in practice and we have included a graphical representation of the

modelled R&D process in Figure 1. At the beginning of Period 1, firm $i = 1,2$ makes the first period investment $x_{1i} \in \{0,1\}$. For tractability reasons, we assume that the investment decision is binary where $x_{1i} = 0$ represents a low investment level and $x_{1i} = 1$ represents a high investment level. Investment is costly and the cost of the high investment level is $C_1 > 0$ while the cost of the low investment level is normalized to 0. First period investment decisions are made simultaneously.

At the end of Period 1, each firm learns how much progress it has made in finding the innovation. The progress s_i of firm i is again binary, i.e., $s_i \in \{A,P\}$, where $s_i = A$ means that the R&D process is currently at an advanced stage and $s_i = P$ means that it is still at a premature stage. The probability of obtaining the advanced stage is a linear function of a base success rate p, firm i's first investment level x_{1i} and a marginal benefit of investment q, i.e., $p_{1i} = Pr(s_i = A | x_{1i}) = p + x_{1i}q$ where $p,q > 0$ and $p+q < 1$. Hence, the high investment level makes it more likely to achieve the advanced stage, but comes with the additional investment cost $C_1 > 0$.

At the end of period 1, firms also disclose a periodic financial report. Each firm decides whether or not to voluntarily disclose the progress s_i in the periodic report. Disclosure decisions are made simultaneously and the

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disclosure decision d_i is binary and conditional on its own progress s_i, i.e., d_i = $(d_i(A), d_i(P)) \in (\{A, ND\}, \{P, ND\})$, where $d_i(s_i) = s_i$ means firm i discloses its progress s_i and $d_i(s_i) = ND$ means firm i does not disclose its progress s_i. Firm j's disclosure decision $d_j(s_j)$ affects firm i's belief on firm j's progress. We assume that disclosure is truthful, e.g., because the periodic report is audited by an external party or because untruthful disclosure leads to exclusively high reputation or legal costs. Furthermore, we assume that disclosure is costly and we denote the fixed disclosure cost for firm i by $k > 0$. Note that the disclosure cost k stands for all relevant costs of disclosure except for the R&D race-related proprietary cost, which is endogenous in our model.

At the beginning of Period 2, each firm observes the disclosure outcome of the other firm. Let $b_{ij}(d_j(s_j))$ denote the belief of firm i about the probability that firm j is at the advanced stage $s_j = A$ given the voluntary disclosure $d_j(s_j)$ by firm j. Because disclosure is truthful we have $b_{ij}(A) = 1$, $b_{ij}(P) = 0$ and $b_{ij}(ND) \in [0,1]$. In the remainder of this paper, we write b_{ij} instead of $b_{ij}(d_j)$ whenever the argument adds no relevant information.

After having observed the financial reports, both firms make the Period 2 investment decision x_{2i}. Similar to the investment decision for Period 1, the

investment decision x_{2i} is also assumed to be binary, i.e., $x_{2i} \in \{0,1\}$. The high investment $x_{2i} = 1$ bears an incremental cost $C_2 > 0$ compared to the low investment cost which is normalized to $x_{2i} = 0$. Note that the Period 2 investment decision of each firm i is conditional on its own first period progress s_i and its belief b_{ij} about the first period progress s_j of firm j. Second period investment decisions are made simultaneously.

Finally, at the end of Period 2, the final outcome z_i of the R&D investments realizes. The final outcome $z_i \in \{S,F\}$ is binary, i.e., $z_i = S$ means that firm i has succeeded in achieving the innovation and $z_i = F$ means that firm i has failed in achieving the innovation. The probability p_{2i} of obtaining the innovation $z_i = S$ for firm i is a function of its own progress s_i in Period 1 and the second investment decision x_{2i}, i.e., $p_{2i} = Pr(z_i = S | x_{2i}, s_i) = p + r(s_i) + x_{2i}q$, where $r(P) = 0$ and $r(A) = r > 0$ is the additional advantage when firm i achieves the advanced stage at the end of Period 1. We assume that $p + q + r < 1$ so that even in the best scenario a firm is not guaranteed to be successful in obtaining the innovation. When a firm obtains the innovation at the end of Period 2, it receives a benefit v_n which is decreasing in the number of successful innovators n, i.e., $v_1 > v_2 \geq 0$.

We make the following assumptions regarding the benefit v_n and incremental investment cost C_t:

(i)   To simplify notation, $C_t = c_t q$ where $c_t > 0$, $t = 1, 2$.

(ii)   For Period 2, the high investment is profitable in case one firm finds the innovation, i.e., $v_1 > c_2$, for otherwise both firms would never make the high investment.

(iii)   For Period 2, the high investment is unprofitable in case two firms find the innovation, i.e., $v_2 < c_2$, for otherwise both firms would always make the high investment.

2.3   Equilibrium analysis

The strategy of firm i consists of the triple $x_i = (x_{1i}, d_i, x_{2i})$ specifying the investment of firm i for Period 1 and 2 and the disclosure decision for the Period 1 progress s_i. Together with firm i's belief b_{ij} about firm j's progress, and given the strategy of firm j, it yields the following expected payoff of firm i

$$V_{1i}(x_i, x_j, b_{ij}) = p_{2i}\left((1 - \hat{p}_{2j})v_1 + \hat{p}_{2j}v_2\right) - c_1 q x_{1i} - c_2 q x_{2i} - k|(d_i = s_i),$$

$$(1)$$

where p_{2i} denotes the expected probability that firm i obtains the innovation, i.e., $p_{2i} = p + (p + x_{1i}q)r + x_{2i}q$, and $\hat{p}_{2j}$ is the perception of firm i on firm j's probability of obtaining the innovation, i.e., $\hat{p}_{2j} = p + b_{ij}r + x_{2j}q$. To decompose the payoff function: $p_{2i}(1 - \hat{p}_{2j})$ is the probability that firm i is the only firm that finds the innovation in which case the benefit for firm i equals v_1. Conversely, $p_{2i}\hat{p}_{2j}$ is the probability that both firms find the innovation in which case the benefit for firm i equals v_2. When firm i does not find the innovation, there is no benefit for firm i. Note that the perceived success probability $\hat{p}_{2j}$ is a function of firm i's belief b_{ij} that is affected by firm j's disclosure decision.

In equilibrium, the strategies $x_i^* = (x_{1i}^*, d_i^*, x_{2i}^*)$, $x_j^* = (x_{1j}^*, d_j^*, x_{2j}^*)$ and beliefs b_{ij}^* and b_{ji}^* are such that the decisions of each firm are optimal given this firm's beliefs and the strategy and beliefs of the other firm, and the beliefs of each firm are rational with respect to the strategy of the other firm:

   (i)   For each firm, the strategy x_i^* maximizes the expected payoff given the strategy of the other firm and the beliefs about the other firm's state, i.e.,

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$$x_i^* = \arg\max_{x_i} V_{1i}(x_i, x_j^*, b_{ij}^*)$$

(ii)　　For each firm, the beliefs b_{ij}^* are rational, i.e., they satisfy Bayes rule whenever possible, that is, $b_{ij}^* = \Pr(s_j = A|d_j)$.

We analyse the equilibrium using backward induction.

Investment decision for Period 2

At the beginning of Period 2, both firms have observed the other firm's disclosure d_i and d_j resulting in the beliefs $b_{ji}(d_i)$ and $b_{ij}(d_j)$, where $b_{ij}(d_j) \in [0,1]$ denotes the belief of firm i that firm j is in stage $s_j = A$. Since disclosure is truthful by assumption, the beliefs are certain when the other firm discloses its progress, i.e., if firm j discloses that $s_j = A$, then $b_{ij}(A) = 1$; if firm j discloses that $s_j = P$, then $b_{ij}(P) = 0$. The only uncertainty arises when the other firm does not disclose. In that case $b_{ij}(ND) = p + \hat{x}_{1j}q$ where $\hat{x}_{1j}$ is firm i's conjecture about firm j's investment level x_{1j} in Period 1.

Let $\hat{x}_{2j} \in \{0,1\}$ denote firm i's conjecture of firm j's second period investment decision x_{2j}. Given $\hat{x}_{2j}$, firm i's state s_i and beliefs b_{ij}, we can write the expected payoff of firm i at the beginning of Period 2 as

$$V_{i3}(x_{2i}, \hat{x}_{2j}, b_{ij}, s_i) =$$

$$(p + r_i + x_{2i}q)(v_1 - (p + b_{ij}r + \hat{x}_{2j}q)(v_1 - v_2)) - c_2qx_{2i}, \qquad (2)$$

where r_i is shorthand notation for $r(s_i)$. The expected payoff consists of three components: the first component $(p + r_i + x_{2i}q)$ is the probability that firm i obtains the innovation and this probability is known to firm i. Observe that this probability depends on a firm's own first investment through r_i, i.e., $r_i = r$ if and only if firm i has achieved the advanced stage $s_i = A$ after Period 1. The second component $(v_1 - (p + b_{ij}r + x_{2j}q)(v_1 - v_2))$ is the expected benefit of obtaining the innovation. This benefit is decreasing in the probability $p + b_{ij}r + x_{2j}q$ that firm j also obtains the innovation as in that case the benefit of firm i decreases by $v_1 - v_2$. Note that this probability depends on firm i's beliefs b_{ij} that firm j is at the advanced stage.

Finally, the third component is the incremental cost c_2qx_{2i} of the high investment level.

Firm i makes the high investment level $x_{2i} = 1$ if and only if $V_{i3}(1, \hat{x}_{2j}, b_{ij}, s_i)$ $\geqslant V_{i3}(0, \hat{x}_{2j}, b_{ij}, s_i)$, i.e.,

$(p+r_i+q)(v_1-(p+b_{ij}r+\hat{x}_{2j}q)(v_1-v_2))-c_2q \geqslant (p+r_i)(v_1-(p+b_{ij}r+\hat{x}_{2j}q)(v_1-v_2))$.

Rearranging terms gives

$$(1-(p+b_{ij}r+\hat{x}_{2j}q))(v_1-c_2)-(p+b_{ij}r+\hat{x}_{2j}q)(c_2-v_2) \leqslant 0.$$

Conditional on firm i obtaining the innovation, making the high investment results in a benefit v_1-c_2 for firm i when firm i is the only firm obtaining the innovation and it results in a loss c_2-v_2 for firm i when both firms obtain the innovation. The first term in this inequality represents the expected benefit of making the high investment and the second term represents the expected cost. The benefits exceed the cost when the probability of firm j obtaining the innovation is sufficiently low, i.e., firm i makes the high second period investment if and only if

$$p+b_{ij}r+\hat{x}_{2j}q \leq \frac{v_1-c_2}{v_1-v_2} \qquad (3)$$

Inequality (3) implies that firm i is more likely to make the high investment when firm j is less likely to be at the advanced stage (i.e., lower value of b_{ij}) or firm j is less likely to make the high second period investment (i.e., lower value of $\hat{x}_{2j}$), since a higher success rate of firm j reduces the expected

benefit for firm i. The disclosure decision of firm j determines b_{ij} and thus affects firm i's investment decision x_{2i} in the second period.[4]

Observe that firm i's decision to make the high investment does not directly depend on its own stage s_i. The reason for this is the assumed additive structure of the success rate $p_{2i} = p + r_i + x_{2i}q$, i.e., the first stage s_i only affects r_i but not the marginal effect of the second period investment x_{2i}.

Furthermore, observe that $\frac{v_1 - c_2}{v_1 - v_2}$ can be written as $\frac{v_1 - c_2}{(v_1 - c_2) + (c_2 - v_2)}$, implying that $\frac{v_1 - c_2}{v_1 - v_2}$ is increasing in the benefit $v_1 - c_2$ and decreasing in the cost $c_2 - v_2$.

Finally, observe that if $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2}$, then firm i always makes the high investment irrespective of what investment firm j makes in the second period. This case arise when the cost c_2 is relatively low and/or the probability of firm j finding the innovation is relatively low so that the benefit of the high investment outweighs the cost. If $p + b_{ij}r < \frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$, firm i only makes the high investment when firm i conjectures that firm j will not make the high investment for Period 2. If firm i conjectures that firm j will make the high investment for Period 2, it is optimal for firm i to make the

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[4] Recall for $b_{ij}(d_j)$ that $b_{ij}(A) = 1$, $b_{ij}(P) = 0$, and $b_{ij}(ND) \in [0,1]$.

low investment. In this case, the cost c_2 is at an intermediate level so that the high investment is optimal only if the probability of firm j finding the innovation is relatively low, i.e., when firm j makes the low investment. Consequently, the firms' second period investments are substitutes to each other. If $\frac{v_1-c_2}{v_1-v_2} < p + b_{ij}r$, firm i always makes the low investment irrespective of which investment level firm j chooses. In this case, the cost c_2 is relatively high and/or the probability of firm j finding the innovation is so high that the cost of the high investment outweighs the benefit.

In equilibrium, the investment decisions x_{2i} and x_{2j} satisfy equation (3) and the conjectures $\hat{x}_{2i}$ and $\hat{x}_{2j}$ are correct:

$$x_{2i} = 1 \ \ if \ and \ only \ if \ p + b_{ij}r + \hat{x}_{2j}q \leq \frac{v_1-c_2}{v_1-v_2} \qquad (4)$$
$$x_{2j} = 1 \ \ if \ and \ only \ if \ p + b_{ji}r + \hat{x}_{2i}q \leq \frac{v_1-c_2}{v_1-v_2} \qquad (5)$$
$$x_{2i} = \hat{x}_{2i} \qquad (6)$$
$$x_{2j} = \hat{x}_{2j} \qquad (7)$$

For example, when both firms disclose to be at an advanced stage (i.e., $b_{ji} = b_{ij} = 1$), high investment by both firms (i.e., $x_{2i} = x_{2j} = 1$) arises when $\frac{v_1-c_2}{v_1-v_2} \geq p + r + q$. Similarly, high investment by firm i (i.e., $x_{2i} = 1$) and low investment by firm j (i.e., $x_{2j} = 0$) cannot occur when both firms are at an

advanced stage as high investment by firm i requires $\frac{v_1-c_2}{v_1-v_2} \geq p + r + q$ whereas low investment by firm j requires $\frac{v_1-c_2}{v_1-v_2} < p + r + q$. More generally, an asymmetric equilibrium in which the two firms make different decisions cannot occur when they have made or are expected to have made the same progress in Period 1.

The equilibrium conditions (4)-(7) yield the following investment equilibria at the beginning of Period 2:

Proposition 1 *Let b_{ij} denote the belief of firm i on the probability that firm j is in stage $s_j = A$. Then the following investment equilibrium in Period 2 arises:*

Case	(x_{2i}, x_{2j})	condition
C2.1	$(1,1)$	$p + max(b_{ij}, b_{ji})r + q < \frac{v_1-c_2}{v_1-v_2}$
C2.2	$(0,1)$	$p + b_{ij}r + q < \frac{v_1-c_2}{v_1-v_2} < p + b_{ji}r + q$
C2.3	$(1,0)$	$p + b_{ji}r + q < \frac{v_1-c_2}{v_1-v_2} < p + b_{ij}r + q$
C2.4	(π_i, π_j)	$p + max(b_{ij}, b_{ji})r < \frac{v_1-c_2}{v_1-v_2} < p + min(b_{ij}, b_{ji})r + q$
C2.5	$(0,1)$	$p + b_{ji}r < \frac{v_1-c_2}{v_1-v_2} < p + min(b_{ij}r, b_{ji}r + q)$
C2.6	$(1,0)$	$p + b_{ij}r < \frac{v_1-c_2}{v_1-v_2} < p + min(b_{ji}r, b_{ij}r + q)$
C2.7	$(0,0)$	$\frac{v_1-c_2}{v_1-v_2} < p + min(b_{ij}, b_{ji})r$

where $\pi = \frac{1}{q}\left(\frac{v_1-c_2}{v_1-v_2} - (p + b_{ji}r)\right)$ is the probability that firm i makes the high investment in a mixed strategy equilibrium.

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The exact equilibrium that occurs is determined jointly by all the parameter values which are known. For example, consider a fully revealing equilibrium where $b_{ji} = 1$ and $b_{ij} = 0$ (i.e., firm i is at stage $s_i = A$ and firm j is at stage $s_j = P$) and suppose $r < q$. Then Proposition 1 implies the following:

Case	(x_{2i}, x_{2j})	condition
C2.1	(1,1)	$p + r + q < \frac{v_1 - c_2}{v_1 - v_2}$
C2.3	(1,0)	$p + q < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$
C2.4	(π_i, π_j)	$p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + q$
C2.6	(1,0)	$p < \frac{v_1 - c_2}{v_1 - v_2} < p + r$
C2.7	(0,0)	$\frac{v_1 - c_2}{v_1 - v_2} < p$

For interpretation purposes, assume that all parameters are fixed except for the cost parameter c_2. Observe that the fraction $\frac{v_1 - c_2}{v_1 - v_2}$ is decreasing in c_2. In case C2.1, the high investment made by both firms occurs because $\frac{v_1 - c_2}{v_1 - v_2}$ is sufficiently high, i.e., the incremental cost c_2 of high investment is sufficiently low. Even though firm j is at a premature stage and firm i will make the high investment, firm j still prefers the high investment because it is relatively cheap. In case C2.3, the cost c_2 is higher than in case C2.1. For

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firm i the likelihood of obtaining the innovation is still sufficiently high so that for firm i, the benefit of making the high investment still outweighs the cost even when firm j would make the high investment. However, for firm j, making the high investment is now too costly when firm i also makes the high investment. Hence, $(x_{2i}, x_{2j}) = (1,0)$ arises. In case *C2.4*, the cost parameter c_2 is higher than in *C2.3* and in this case, the investment decision of firm i depends on the investment decision of firm j and vice versa: firm i does not make the high investment when firm j does as the high investment of firm j increases the likelihood of firm j being successful, in which case firm i only obtains the benefit v_2 which is too low to justify the cost c_2. The same argument applies to firm j. Summarizing case *C2.4*, there are two equilibria in pure strategies $(x_{2i}, x_{2j}) = (1,0)$ and $(x_{2i}, x_{2j}) = (0,1)$ and one equilibrium in mixed strategies $(x_{2i}, x_{2j}) = (\pi_i, \pi_j)$. We assume in this case that the mixed equilibrium is chosen as it does not require any coordination of the investment strategies among the two firms. In case *C2.6*, the cost parameter c_2 is too high for firm j: firm j never wants to make the high investment. Because firm i is at the advanced stage, the likelihood $p + r + x_{2i}q$ of firm i obtaining the innovation is sufficiently high, which makes the expected benefit of firm j of making the high investment insufficient to outweigh the cost, even when firm i does not make the high investment. Firm i still wants

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to make the high investment since it anticipates firm j does not. Finally, in case *C2.7*, the cost parameter c_2 is too high for both firms so that the high investment never pays off.

After conducting a full analysis of all the possible combinations of the parameter values, we find that for sufficiently high and sufficiently low values of c_2, the investment cost dictates the second period investment decision. For intermediate values of c_2, the second period investment decision depends on the disclosure decision. For this reason, we will focus the remainder of our analysis on the values of c_2 satisfying $\frac{v_1-c_2}{v_1-v_2} \in (p + r, p + r + q)$ with the additional constraint that $q < r < (p+\hat{x}_{1j}q)r + q$.[5] Focusing on the interval $(p+r, p+r+q)$ provides the necessary tension with respect to the second period investment decision: the condition $p + r < \frac{v_1-c_2}{v_1-v_2}$ implies that a firm makes the second period high investment only if the other firm is at the premature stage or if the other firm does not make the second period high investment. The condition $\frac{v_1-c_2}{v_1-v_2} < p + r + q$ implies that a firm does not make the second period high investment when it knows

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[5] The purpose of the additional constraint is to ensure that the full disclosure equilibrium as well as the non-disclosure equilibrium can always obtain for some feasible parameter values.

that the other firm is at the advanced stage *and* makes the second period high investment. Knowledge about the other firm's stage is thus relevant for a firm's second period investment decision.

2.4 Disclosure decision

At the end of period 1, each firm observes the stage $s_i \in \{A,P\}$ of its own progress and then decides whether or not to disclose its progress. Recall that the disclosure strategy of firm i is described by $d_i = (d_i(A), d_i(P))$ where $d_i(s_i)$ $\in \{s_i, ND\}$. We refer to $d_i = (A,P)$ as a full-disclosure strategy, $d_i = (A,ND)$ and $d_i = (ND,P)$ as a partial disclosure strategy, and $d_i = (ND,ND)$ as a non-disclosure strategy. The disclosure strategy d_i of firm i determines the belief of the other firm j on firm i's probability of being at the advanced stage. If the strategy is a full disclosure strategy, i.e., $d_i = (A,P)$, then firm j's belief b_{ji} satisfies $b_{ji}(A) = 1$ and $b_{ji}(P) = 0$. In this case, non-disclosure is an out-of-equilibrium action and results in out-of-equilibrium beliefs $b_{ji}(ND) \in [0,1]$. If the strategy is a partial-disclosure strategy, i.e., $d_i = (A,ND)$ or (ND,P), non-disclosure is still fully revealing the private information of firm i due to rationality and the binary setting. For example, when $d_i = (A,ND)$ then $b_{ji}(ND)$ $= 0$ because non-disclosure by firm i only arises when firm i is in a premature stage, i.e. $s_i = P$. In the case of a nondisclosure strategy, i.e., $d_i = (ND,ND)$,

firm j's belief following non-disclosure is rational and equals $b_{ji}(ND) = p +$ $\hat{x}_{1i} q$, i.e., the probability that firm i is in the advanced stage given the conjectured firm i's first stage investment $\hat{x}_{1i}$. When firm j observes an out-of-equilibrium disclosure, truthful disclosure implies that $b_{ji}(A) = 1$ and $b_{ji}(P)$ $= 0$.

Observe that equation (2) implies that the expected payoff of firm i at the beginning of Period 2 is decreasing in firm i's conjecture $\hat{x}_{2j}$ about firm j's second period investment because a higher value of $\hat{x}_{2j}$ increases firm j's success rate $p + b_{ij} r + \hat{x}_{2j} q$. Furthermore, recall from equation (3) that firm j makes the high investment, i.e., $x_{2j} = 1$, when $p + b_{ij} r + \hat{x}_{2j} q < \frac{v_1 - c_2}{v_1 - v_2}$.

Hence, the likelihood of firm j making the high investment is weakly decreasing in firm j's beliefs b_{ji} about firm i being in the advanced stage. Combining both observations and the requirement that in equilibrium firm i's conjecture is correct, i.e., $\hat{x}_{2j} = x_{2j}$, it follows that the expected payoff of firm i is weakly increasing in b_{ji}. In other words, the expected payoff of firm i is weakly higher when firm j is more likely to believe that firm i is in the advanced stage as this may induce firm j to take the low investment $x_{2j} = 0$. Because $b_{ji} \geqslant 0$ and disclosure of $s_i = P$ by firm i yields $b_{ji}(P) = 0$, it follows

that disclosing the premature stage results in the worst possible beliefs b_{ji} from the perspective of firm i. Hence, firm i always prefers non-disclosure over disclosure when it is in the premature stage $s_i = P$ since non-disclosure saves the disclosure cost. We summarize this result in Lemma 1 below.

Lemma 1 *In equilibrium, firm i strictly prefers non-disclosure over disclosure of the premature stage $s_i = P$, i.e., $d_i^*(P) = ND$.*

Lemma 1 indicates that the full-disclosure strategy (A,P) is always dominated by a partial disclosure strategy (A,ND) because these two strategies are informationally equivalent but the latter would save firm i the disclosure cost k when $s_i = P$. Similarly, the partial disclosure strategy (ND,P) is dominated by the non-disclosure strategy (ND,ND). Consequently, we only need to consider two possible strategies, i.e., the partial disclosure strategy (A,ND) and the non-disclosure strategy (ND,ND) which can give rise to three types of disclosure equilibria: a full disclosure equilibrium where both firms play the fully revealing, partial disclosure strategy; a non-disclosure equilibrium where both firms play a non-disclosure strategy; and an asymmetric disclosure equilibrium where one firm plays the fully revealing, partial disclosure strategy and the other firm plays the non-disclosure strategy.

2.4.1 Full disclosure equilibrium

In a full disclosure equilibrium, both firms i and j play the fully revealing, partial disclosure strategy (A,ND) so that both firms know the stage of the other firm when they make the second period investment decision. The beliefs b_{ij} and b_{ji} thus satisfy $b_{ij}(A) = b_{ji}(A) = 1$ and $b_{ij}(ND) = b_{ji}(ND) = 0$ and these beliefs determine the second stage investment equilibrium (cf. Proposition 1). Furthermore, because both firms are assumed to be homogeneous when they make the first stage investment decision at $t = 0$ and when they choose the disclosure strategy, there is no additional information that could differentiate one firm from the other. For that reason, we conjecture a symmetric first stage investment strategy and assume that $\hat{x}_{1i} = \hat{x}_{1j} = \hat{x}_1$ so that $p + \hat{x}_1 q$ is the probability that the other firm is at the advanced stage and disclosure occurs. Section 2.3 will show that this conjecture is correct.

Proposition 2 *Let $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$. A full disclosure equilibrium* $(d_i^*, d_j^*) = (A,ND),(A,ND)$ *exists if and only if:*

(f.1) $k < \underline{k} := (p + \hat{x}_1 q)(p + r)\big((p + r + q)(v_1 - v_2) - (v_1 - c_2)\big) + (1 - p - \hat{x}_1 q)(p + r + q)q(v_1 - v_2)$

The corresponding second stage investments equal:

(d_i, d_j)	(x_{2i}^*, x_{2j}^*)
(A, A)	(π, π)
(A, ND)	$(1,0)$
(ND, A)	$(0,1)$
(ND, ND)	$(1,1)$

where $\hat{x}_1$ is one firm's conjecture on the first period investment of the other firm; $\pi = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + r)\right)$

The equilibrium condition imposes an upper bound $\underline{k}$ on k in (f.1) which is a weighted average of two terms that represent the benefit of disclosing the advanced stage when firm j is at the advanced or premature stage, respectively; therefore, the weights are simply the conjectured rate of firm j's progress. This upper bound ensures that disclosure is optimal for firm i when it expects firm j to make the first-period investment $\hat{x}_1$ and follow the second period equilibrium investment strategy as described in Proposition 1.

Observe that disclosure of being at an advanced stage only pays off for firm i when it influences the second stage investment decision(s) in a favourable way for firm i. Suppose firm i is at the advanced stage $s_i = A$. If firm j does not disclose (i.e., $s_j = P$), the disclosure decision of firm i determines whether the second stage investments equal $(x_{2i}, x_{2j}) = (1,0)$ or $(x_{2i}, x_{2j}) = (1,1)$. Observe that in this case firm i's investment decision is not affected by its disclosure

decision as firm i will always make the high investment in this case. However, firm i's disclosure decision does affect the investment of firm j: by disclosing that it is at the advanced stage, firm i can make firm j to choose the low investment level $x_{2j} = 0$, which is to the benefit of firm i. If firm j does disclose (i.e., $s_j = A$), the disclosure decision of firm i affects both the investment decision of firm i and firm j. More specifically, it increases the second period investment of firm i from $x_{2i} = 0$ to $x_{2i} = \pi$ and decreases the second period investment of firm j from $x_{2i} = 1$ to $x_{2i} = \pi$. Both changes are to the benefit of firm i.

Observe that $\underline{k}$ is increasing in the second period investment cost c_2. The explanation for this is in the mixed second period investment strategy that is played when both firms disclose that they are in the advanced stage. An increase in c_2 not only decreases the probability π that firm i makes the high second period investment, it also decreases the probability that the other firm j makes the high second period investment. Conditional on firm i achieving the innovation, the latter effect increases the probability that firm i is the only firm achieving the innovation, which in turn increases the expected benefit of achieving the innovation. Hence, disclosing firm i achieving the advanced stage is still optimal for higher values of disclosure cost k.

Finally, observe that $\underline{k}$ is decreasing in the conjectured first period investment $\hat{x}_1$ of the other firm. The explanation for this is that a higher value of $\hat{x}_1$ increases the probability that the other firm is in the advanced stage, which reduces the benefit of disclosing that the firm itself is at the advanced stage.

2.4.2 Non-disclosure equilibrium

In a non-disclosure equilibrium, both firms employ the non-disclosure strategy (*ND,ND*). From Lemma 1 we know that both firms prefer non-disclosure when it is in the premature stage *P*. Therefore, a non-disclosure equilibrium arises when firm $i = 1,2$ also prefers nondisclosure in the advanced stage $s_i = A$ when firm *j* follows a non-disclosure strategy. From firm *i*'s perspective, observing non-disclosure by firm *j* reveals no additional information about firm *j*'s progress so that firm *i*'s beliefs $b_{ij}(ND)$ equal the probability of firm *j* being at the advanced stage. Let $\hat{x}_{1j}$ denote firm *i*'s conjecture of of firm *j*'s first period investment decision. Then $b_{ij}(ND) = p + \hat{x}_{1j}q$. Because both firms are assumed to be homogeneous when they make the first stage investment decision at $t = 0$ and when they choose the disclosure strategy, there is no additional information that could differentiate one firm from the other. For that reason, we conjecture a symmetric first

stage investment strategy and assume that $\hat{x}_{1i} = \hat{x}_{1j} = \hat{x}_1$ so that we can write

$b_{ji}(ND) = b_{ij}(ND) = b$, with $b = p + \hat{x}_1 q$. Section 2.3 will show that this

conjecture is correct.

Proposition 3 *Let* $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ *and* $b = p + \hat{x}_1 q$. *A non-*

disclosure equilibrium $(d_i^*, d_j^*) = (ND, ND), (ND, ND)$ *exists if and only if:*

(n.1) $p + br + q < \frac{v_1 - c_2}{v_1 - v_2}$ *and* $k > \bar{k} := (p + r + q)q(v_1 - v_2)$

(n.2) $\frac{v_1 - c_2}{v_1 - v_2} < p + br + q$ *and* $k \geq 0$

The corresponding second stage investments equal $(x_{2i}^*, x_{2j}^*) = (1,1)$ *in*

(n.1) and $(x_{2i}^*, x_{2j}^*) = (\pi, \pi)$ *in (n.2).* $\pi = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + br)\right)$

In case *(n.1)*, the disclosure decision of firm *i* does affect the second stage

investment decisions. In particular, disclosure of $s_i = A$ deters firm *j* from

making the second period investment. However, the disclosure cost is

sufficiently high so that disclosure does not pay off. Specifically, case *(n.1)*

is the counterpart of case *(f.1)*. Observe that $\bar{k}$ is independent of the second

period investment cost c_2 or the conjectured first period investment level. The

explanation is that in equilibrium *(n.1)*, both firms make the second period

investment. Disclosing that a firm is at the advanced stage does not affect its

second period investment decision; it only affects the second period

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investment decision of the other firm. Hence, the cost c_2 is irrelevant for the disclosure decision. A similar argument applies to the conjectured first period investment level.

In case *(n.2)*, disclosure does not affect the second period investment decisions so that a non-disclosure strategy is always supported in equilibrium. Observe that the condition $\frac{v_1-c_2}{v_1-v_2} < p + br + q$ in case *(n.2)* implies that the second period investment cost parameter c_2 is sufficiently high so that firm j does not make the second period high investment when it expects that the non-disclosing firm i does make the high investment. A disclosure of $s_i = A$ by firm i does not affect firm j's decision as this only increases firm j's belief that firm i is at the advanced stage from $b_{ji}(ND) = b$ to $b_{ji}(A) = 1.$[6] Consequently, firm j still does not make the second period high investment when it expects that firm i does make the high investment.

2.4.3 Asymmetric equilibrium

In an asymmetric equilibrium, one firm employs the partial disclosure strategy while the other firm employs the non-disclosure strategy. Suppose

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[6] An extension of the condition in *(n.2)* is $p + br < p + r < \frac{v_1-c_2}{v_1-v_2} < p + br + q < p + r + q$, which makes it clear that a firm's second period investment is only affected by the investment of the other firm and that the stage of the other firm does not matter.

firm i and j play a partial disclosure and a non-disclosure strategy in equilibrium, respectively. Firm j's belief $b_{ji}(ND)$ given firm i making no disclosure equals 0 because it implies that firm i is at the preliminary stage. Firm i's belief $b_{ij}(ND)$ about firm j depends on firm i's conjecture of firm j's first stage investment decision, i.e., $b_{ij}(ND) = p + \hat{x}_{1j}q$ where $\hat{x}_{1j}$ is the conjectured first period investment decision of firm j. The following proposition summarizes the conditions for the asymmetric equilibrium:

Proposition 4 *Let $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ and denote $b_{ij} = p + \hat{x}_{1j}q$. The asymmetric equilibrium $(d_i^*, d_j^*) = (A, ND), (ND, ND)$ exists if and only if.*

(a.1) $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2}$ and $\underline{k} \leq k \leq \bar{k}$.

(a.2) $\frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$ and $k < k_{\hat{x}_{1j}}^* := (p + r)\left((p + (p + \hat{x}_{1j}q)r + q)(v_1 - v_2) - (v_1 - c_2)\right)$

The corresponding second stage investments (x_{2i}^*, x_{2j}^*) equal:

(d_i, d_j)	(a.1)	(a.2)
(A, ND)	*(1, 0)*	(π_i, π_j)
(ND, ND)	*(1, 1)*	*(0, 1)*

where $\pi_i = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + r)\right)$ and $\pi_j = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + b_{ij}r)\right)$

In case *(a.1)*, the inequality $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2}$ indicates that firm i always makes the high investment when observing non-disclosure by firm j.

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Disclosure of $s_j = A$ by firm j would deter firm i from making a high second period investment when firm i is at the premature stage because $\frac{v_1 - c_2}{v_1 - v_2} < p + r + q$. However, disclosure of $s_j = A$ by firm j results in a mixed investment strategy when firm i is at the advanced stage. Thus, disclosure also increases the expected second period investment cost for firm j. Then disclosure is too costly for firm j when $k \geqslant \underline{k}$. The condition $\frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ indicates that firm j does not make the second period high investment if it knows that firm i is at the advanced stage and firm i makes the second period high investment. The upper bound on disclosure cost k implies that it is beneficial for firm i to disclose when it is at the advanced stage $s_i = A$ so that firm j makes the second period low investment.

In case $(a.2)$, the condition $\frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$ implies that firm i only makes the second period high investment when firm j does not make the high investment. This decision does not depend on the stage s_j of firm j, and thus does not depend on the disclosure decision of firm j. Hence, firm j does not have any incentive to disclose when it is at the advanced stage. Because it also holds in this case that $\frac{v_1 - c_2}{v_1 - v_2} < p + r + q$, firm j again does not make the high investment if it knows that firm i is at the advanced stage and firm i makes the second period investment. The upper bound on disclosure cost k

then implies that it is beneficial for firm i to disclose when it is at the advanced stage $s_i = A$. It is easy to prove that $k^* < \underline{k}$.

2.5   Investment decision for Period 1

Denote by $V_{i1}(s_i, \hat{x}_{1j}, e)$ the expected payoff for firm i at the end of Period 1 when having observed its own stage s_i and taking as given the conjecture $\hat{x}_{1j}$ of firm i on the first period investment decision of firm j and the subsequent equilibrium e with respect to disclosure and second period investment decisions. The equilibrium e can be either the full disclosure equilibrium *(f.1)*, the non-disclosure equilibrium *(n.1)* or *(n.2)*, or the asymmetric disclosure equilibrium *(a.1)* or *(a.2)*.

Recall that the cost of the first period high investment equals $C_1 = c_1 q$. Then the expected payoff for firm i of making the high investment $x_{1i} = 1$ equals $(p + q)V_i(A, \hat{x}_{1j}, e) + (1 - p - q)V_i(P, \hat{x}_{1j}, e) - c_1 q$. The low investment $x_{1i} = 0$ yields expected payoff $pV_i(A, \hat{x}_{1j}, e) + (1 - p)V_i(P, \hat{x}_{1j}, e)$.

Hence, the first period high investment is optimal for firm i if and only if $V_i(A, \hat{x}_{1j}, e) - V_i(P, \hat{x}_{1j}, e) \geqslant c_1$. More specifically, define

$$\underline{\gamma_i}(e) = V_i(A, 1, e) - V_i(P, 1, e) \qquad (8)$$

$$\overline{\gamma}_i(e) = V_i(A, 0, e) - V_i(P, 0, e) \qquad (9)$$

When firm i expects firm j to make the first period high investment, i.e., $\hat{x}_{1j} = 1$, then firm i makes the first period high investment, i.e., $x_{1i} = 1$ if and only if $c_1 \leqslant \underline{\gamma}_i(e)$. Similarly, when firm i expects firm j to make the first period low investment, i.e., $\hat{x}_{1j} = 0$, then firm i makes the first period low investment, i.e., $x_{1i} = 1$ if and only if $c_1 \leqslant \overline{\gamma}_i(e)$. Table 1 presents the expressions for the threshold values $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$. For the asymmetric equilibrium *(a.1)* one can show that for $k < \overline{k} - qr^2(v_1 - v_2)$ it holds that $\overline{\gamma}_i(e) > \underline{\gamma}_i(e) > \overline{\gamma}_j(e) > \underline{\gamma}_j(e)$ whereas for $k > \overline{k} - qr^2(v_1 - v_2)\}$ it holds that $\overline{\gamma}_i(e) > \overline{\gamma}_j(e) > \underline{\gamma}_i(e) > \underline{\gamma}_j(e)$.

e	Expression of $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$
(f.1)	$\underline{\gamma}(e) = (p+q)\big(p\big((p+r+q)(v_1-v_2)-(v_1-c_2)\big)+rc_2\big)-k+(1-p-q)\big((p+q)q(v_1-v_2)$ $+r(v_1-p(v_1-v_2))\big)$
	$\overline{\gamma}(e) = p\big(p\big((p+r+q)(v_1-v_2)-(v_1-c_2)\big)+rc_2\big)-k+(1-p)\big((p+q)q(v_1-v_2)+r(v_1-p(v_1-v_2))\big)$
(n.1)	$\underline{\gamma}(e) = r(v_1-(p+(p+q)r+q)(v_1-v_2))$
	$\overline{\gamma}(e) = r(v_1-(p+qr+q)(v_1-v_2))$
(n.2)	$\underline{\gamma}(e) = rc_2$
	$\overline{\gamma}(e) = rc_2$
(a.1)	$\underline{\gamma}_i(e) = r\big(v_1-c_2-(p+(p+q)r)(v_1-v_2)\big)+(p+q)q(v_1-v_2)+rc_2-k$
	$\overline{\gamma}_i(e) = r\big(v_1-c_2-(p+pr)(v_1-v_2)\big)+(p+q)q(v_1-v_2)+rc_2-k$
	$\underline{\gamma}_j(e) = r(v_1-(p+(p+q)r+q)(v_1-v_2))$
	$\overline{\gamma}_j(e) = r(v_1-(p+qr+q)(v_1-v_2))$
(a.2)	$\underline{\gamma}_i(e) = p\big((p+(p+q)r+q)(v_1-v_2)-(v_1-c_2)\big)+rc_2-k$
	$\overline{\gamma}_i(e) = p\big((p+pr+q)(v_1-v_2)-(v_1-c_2)\big)+rc_2-k$
	$\underline{\gamma}_j(e) = (1-p-q)r\big(v_1-c_2-p(v_1-v_2)\big)+rc_2$
	$\overline{\gamma}_j(e) = (1-p)r\big(v_1-c_2-p(v_1-v_2)\big)+rc_2$

Table 1: Specification of the threshold values $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$. The subscript i is omitted when the values are the same for both firms i and j.

Similar to Proposition 1, we can derive the first period investment decisions:

Proposition 5 *Let $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ and let $e \in \{(f.1), (n.1), (n.2), (a.1), (a.2)\}$ denote the disclosure and second period investment equilibrium. Whenever an asymmetric equilibrium obtains, firm i and j always represent the disclosing firm and the non-disclosing firm, respectively. The first period equilibrium investment decisions $\left(x_{1i}^*, x_{1j}^*\right) = $ are as follows:*

Case	(x_{1i}^*, x_{1j}^*)	condition
C1.1	$(1,1)$	$c_1 \leq \min\{\underline{\gamma}_i(e), \underline{\gamma}_j(e)\}$
C1.2	$(1,0)$	$\overline{\gamma}_j(e) \leq c_1 \leq \overline{\gamma}_i(e)$
C1.3	$(0,1)$	$\max\{\underline{\gamma}_i(e), \overline{\gamma}_i(e)\} \leq c_1 \leq \overline{\gamma}_j(e)$
C1.4a	(τ_i, τ_j)	$\max\{\underline{\gamma}_i(e), \underline{\gamma}_j(e)\} \leq c_1$ $\leq \min\{\overline{\gamma}_j(e), \overline{\gamma}_i(e)\}$
C1.4b	(τ_i, τ_j)	$\max\{\overline{\gamma}_i(e), \underline{\gamma}_j(e)\} \leq c_1$ $\leq \min\{\overline{\gamma}_j(e), \underline{\gamma}_i(e)\}$
C1.5	$(1,0)$	$\max\{\overline{\gamma}_j(e), \overline{\gamma}_i(e)\} \leq c_1$

where $\tau_j = \frac{\overline{\gamma}_i(e) - c_1}{\overline{\gamma}_i(e) - \underline{\gamma}_i(e)}$.

The explanation is straightforward. In case *C1.1*, the cost c_1 is sufficiently low so that the first period high investment is always beneficial, i.e., even when the other firm is also making the first period high investment. In case *C1.5*, the cost c_1 is sufficiently high so that the first period high investment

is never beneficial. In case *C1.2*, the condition $\overline{\gamma}_j(e) \leqslant c_1$ implies that firm j does not make the high investment irrespective of firm i's investment decision whereas the condition $c_1 \leqslant \overline{\gamma}_i(e)$ implies that firm i does make the high investment when firm j does not. Case *C1.3* is almost the symmetric counterpart of *C1.2*. The only exception is equilibrium *(a.2)* in which $\overline{\gamma}_i(a.2) < \underline{\gamma}_i(a.2)$ such that firm i makes the high investment irrespective of firm i's investment decision when $\underline{\gamma}_i(a.2) < c_1$. Combining the exception and the normal cases yields the maximum term. In case *C1.4a*, the investment decision of one firm depends on the investment decision of the other firm, i.e., a firm makes the first period high investment decision only if the other firm does not. In this case, both $(x_{1i}, x_{1j}) = (1,0)$ and $(x_{1i}, x_{1j}) = (0,1)$ are also supported in equilibrium. As these two pure strategy equilibria require coordination among the two firms, we focus on the mixed strategy equilibrium where firm i makes the first period high investment with probability τ_i. In case *C1.4b*, there is no equilibrium in pure strategies. For any combination of pure first period investment decisions, there is always one firm that is better off changing its first period investment decision. In this case, only a mixed strategy equilibrium exists.

2.6   Discussion

2.6.1   Effects of first and second period investment costs on first period investment

Figure 2 presents the equilibrium first period investment levels when the full disclosure equilibrium *(f.1)* arises. Recall that a full disclosure equilibrium exists only if $k \leqslant \underline{k}$ and that $\underline{k}$ is increasing in c_2. Hence, if a full disclosure equilibrium exists for cost level c_2, it also exists for higher cost levels c_2. Figure 2 shows that a higher investment cost c_1 weakly decreases first period investment. This result is economically intuitive. It further shows that second and first period investment costs are substitutes in the sense that a higher investment cost c_2 weakly increases first period investment. The explanation for this is that the negative effect of a higher second period investment cost c_2 is lower for the advanced stage than the premature stage. To see this, recall that when both firms are at the advanced stage, the firms play a mixed investment strategy and the probability of making the investment is decreasing in c_2, which in turn lowers the negative effect of higher investment cost c_2. In contrast, when a firm is at the premature stage, the magnitude of c_2 does not affect the second period investment decision. Because the harm of a higher second period investment cost c_2 is lower for the advanced stage than the premature stage, the firm has an incentive to

increase the probability of obtaining the advanced stage, i.e., the first period investment becomes more attractive.

Figure 3 presents the equilibrium first period investment levels when the non-disclosure equilibrium *(n.1)* and *(n.2)* arise. Recall that the differences between *(n.1)* and *(n.2)* are twofold. First, the non-disclosure equilibrium *(n.1)* only exists when the disclosure cost is sufficiently large, i.e., $k \geqslant \bar{k}$. So for a certain level of k if *(n.1)* exists then *(n.2)* must exist too ; however, *(n.1)* does not always exist for a certain level of k when *(n.2)* exists. Second, in *(n.1)*, both firms always make the second period high investment whereas in *(n.2)* both firms play a mixed investment strategy in the second period. For equilibrium *(n.1)*, Figure 3 shows that a higher investment cost c_1 weakly decreases first period investment. Again, this result is economically intuitive. Furthermore, it shows that first period investment is dependent on the second period investment cost c_2 only for intermediate values of c_1 (i.e., $\underline{\gamma}(n.1) \leq c_1 \leq \bar{\gamma}(n.1)$). Higher investment cost c_2 may result in a switch from non-disclosure equilibrium *(n.1)* to *(n.2)*. When this happens, the first and second period investments act as substitutes as *(n.1)* features a mixed investment strategy in the first period and high investment by both firms in the second

period whereas *(n.2)* features high investment by both firms in the first period and a mixed investment strategy in the second period.

Recall that the non-disclosure equilibrium *(n.2)* exists for all disclosure cost levels and that it features a mixed investment strategy in the second period. For *(n.2)*, Figure 3 shows that a higher investment cost c_1 weakly decreases first period investment. It further shows that for intermediate values of c_2 (i.e., $p + pr + q < \frac{v_1 - c_2}{v_1 - v_2} < p + (p + q)r + q$), a higher investment cost c_1 may result in nonexistence of the non-disclosure equilibrium *(n.2)* and disclosure equilibrium shifts to a different type depending on the level of disclosure cost k. When the disclosure cost is sufficiently high, i.e., $k \geq \bar{k}$, the non-disclosure equilibrium *(n.1)* arises as shown in the Figure 3.

When disclosure cost is low (i.e., $k < \bar{k}$), higher investment cost c_1 may induce disclosure by one or both firms as either *(a.2)* or *(f.1)* obtains. The explanation for this is that when c_1 is sufficiently high, first period investment is no longer attractive. $p + pr + q < \frac{v_1 - c_2}{v_1 - v_2} < p + (p + q)r + q$ implies that given non-disclosure, both firms always want to make the high investment in the second period. This outcome is not desirable when one firm reaches the advanced stage and disclose it. Firms would always be better off with

disclosure as it influences the other firm's second period investment decision. Consequently, when disclosure cost is sufficiently low, disclosure becomes attractive for one or both firms. The non-disclosure equilibrium *(n.1)* only arises when the disclosure cost is sufficiently high, i.e., $k \geq \bar{k}$.

A similar argument applies when second period investment cost c_2 decreases. In that case, the non-disclosure equilibrium *(n.2)* may cease to exist and disclosure by one or both firms arises, provided that the disclosure cost is sufficiently low, i.e., $k \leq \bar{k}$.

For the asymmetric equilibrium *(a.1)*, we distinguish two cases: case 1 features $\underline{k} \leq k \leq \bar{k} - qr^2(v_1 - v_2)$ whereas case 2 features $\max\{\underline{k}, k - qr^2(v_1 - v_2)\} \leq k \leq \bar{k}.$ [7] Figures 4 and 5 present the first period investment levels for case 1 and 2 respectively. The main difference between the two cases is that in case 2, a mixed investment strategy in the first period can arise. In our discussion below, we primarily focus on case 1.

Figure 4 shows that first period investment levels are decreasing in c_1. More specifically, when $c_1 > \underline{\gamma} \, (n.1) = \underline{\gamma}_j(a.1)$, the non-disclosing firm j does no

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[7] This condition is derived from whether the inequality $\underline{\gamma}_i(a.1) > \bar{\gamma}_i(a.1)$ holds (case 1) or not (case 2).

longer make the high investment in the first period. The reason for this is that firm i benefits more from the first period investment than firm j. This additional benefit arises when firm i discloses that it is in the advanced stage, as this induces firm j to make the low investment in period 2. Consequently, when $c_1 < \overline{\gamma}_i(a.1)$ firm i still makes the high first period investments as this increases the probability of achieving the advanced stage. This additional benefit of the disclosing firm in making the high investment for the first period thus arises for cost levels $\underline{\gamma}_j(a.1) < c_1 < \overline{\gamma}_i(a.1)$. When $c_1 > \overline{\gamma}_i(a.1)$, the high first period investment is also too costly for firm i.

The effect of an increase in second period investment cost c_2 can be twofold. First, larger values of c_2 makes it more difficult for *(a.1)* to obtain. Because $\underline{k}$ is increasing in c_2, the condition $k \geqslant \underline{k}$ may no longer hold for sufficiently high values of c_2. In that case, a full disclosure equilibrium *(f.1)* arises. Disclosure becomes attractive for firm j because higher c_2 decreases the probability π of making the high investment in the second period. This has two positive effects for firm j: it reduces the expected second period investment cost for firm j; and it reduces the probability of firm i achieving the innovation so that, conditional on firm j achieving the innovation, firm j is more likely to be the only firm achieving the innovation. Second, if $k \geqslant \underline{k}$

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holds for all values of c_2, then Figure 4 shows that first period investment levels do not depend on the second period cost c_2 within the range that the asymmetric equilibrium *(a.1)* exists. The reason is that the disclosing firm i always prefers the second period high investment independent of its first period stage so that the benefit of achieving the advanced stage is not affected by c_2 directly.

When the second period investment cost c_2 becomes sufficiently high, then firm i stops disclosing and equilibrium *(n.2)* obtains. The explanation for this is that for sufficiently high c_2, firm i's stage is irrelevant for firm j's investment decision. To see this, recall that in the asymmetric disclosure equilibrium *(a.1)* firm i always makes the high investment in the second period, irrespective of what second period investment firm j will make. When firm i is at the advanced stage, firm j only makes the high investment in the second period when firm i does not. Hence, firm j does not make the high investment in *(a.1)* when it knows that firm i is in the advanced stage. However, when c_2 is sufficiently high, this argument no longer holds true. Because second period investment has become more costly, firm i does not always benefit from making the high investment. Firm i now only wants to make the high investment in the second period when firm j does not. Firm j

still only makes the high investment in the second period when firm i does not. Hence, when c_2 is sufficiently high, disclosing that firm i is in the advanced stage does no longer benefit firm i as firm j knows that firm i only wants to make the high investment when firm j does not. The stage of firm i has become irrelevant to firm j's second period investment decision.

Figure 5 presents the first period equilibrium investment levels for case 2. The difference with case 1 is that for $\underline{\gamma_i}(a.1) < c_1 < \overline{\gamma}(n.1)$ a mixed investment strategy also exists for the first period investment levels besides the equilibrium $(x_{1i}^*, x_{1j}^*) = (1,0)$. Because the disclosure cost k is relatively high in case 2, $\underline{\gamma_i}(a.1)$ is relatively low and for $c_1 \geq \underline{\gamma_i}(a.1)$, firm i only makes the high first period investment when firm j does not. In other words, firm j now also has an incentive to make the high first period investment.

Effects of disclosure on second period investment

Consider the full disclosure equilibrium *(f.1)*. From Proposition 2 it follows that disclosure of the advanced stage by one firm reduces second period investment by the other firm. When both firms do not disclose, i.e., both firms

are in the premature stage, then both firms make the high second period investments. When only one firm discloses that it is in the advanced stage, the other firm will not make the high second period investment. When both firms disclose that they are in the advanced stage, a mixed investment strategy arises. This implies that for the second period investment decision of firm i, information about the stage s_j of firm j is more important than the information about its own stage s_i.

Next, let us compare the second period investment decisions across the full disclosure equilibrium and non-disclosure equilibrium. Let us start with comparing second period investment decisions across *(f.1)* and *(n.1)*. In non-disclosure equilibrium *(n.1)*, both firms always make the high second period investment, which is (weakly) higher than in the full disclosure equilibrium *(f.1)*. Hence, disclosure (weakly) reduces second period investment compared to the non-disclosure equilibrium *(n.1)*. Recall though that the equilibrium *(f.1)* and *(n.1)* are mutually exclusive and which equilibrium arises depends on the disclosure cost k. It implies that industries where disclosure is prohibitively costly feature higher investment levels in the second period than industries where disclosure is relatively cheap and firms disclose their intermediate stage.

The comparison across *(f.1)* and *(n.2)* is less straightforward. In non-disclosure equilibrium *(n.2)*, firms play a mixed strategy and make the high second period investment with probability $\pi = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + (p + \hat{x}_1 q)r)\right)$. In contrast, in the full disclosure equilibrium *(f.1)*, when both firms are at the advanced stage, they make the high second period investment with probability $\pi = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + r)\right)$, which is strictly lower than in *(n.2)*. However, when both firms are at the premature stage, both firms make the high second period investment, which is strictly higher than in *(n.2)*. Summarizing, comparison of second period investment levels critically depends on the stage of each firm, the probability of which depends on the first period investment decisions. When first period investment levels are high, it becomes more likely that both firms are in the advanced stage, in which case the full disclosure equilibrium *(f.1)* results in lower second period investment than the non-disclosure equilibrium *(n.2)*. The following proposition shows when the expected second period investment in *(f.1)* is lower than in *(n.2)*.

Proposition 6 *Let $\hat{x}_1(f.1)$ and $\hat{x}_1(n.2)$ denote the conjectured first period investment levels in equilibrium (f.1) and (n.2), respectively. If $\hat{x}_1(f.1) \geqslant \hat{x}_1(n.2)$, the expected second period investment level in (f.1) is lower than in*

(n.2). If $\hat{x}_1(f.1) < \hat{x}_1(n.2)$, the expected second period investment level in (f.1) is lower than in (n.2) only if

$$\Pr\left(s_i = A\middle|\hat{x}_1(f.1)\right) > \frac{1}{2\pi} - \sqrt{\left(1 - \frac{1}{2\pi}\right)^2 + \frac{r}{q\pi}(1 - p - \hat{x}_1(n.2)q}$$

(10)

where $\pi = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + r)\right)$.

To explain Proposition 6, let us first consider the case that $\hat{x}_1(f.1) = \hat{x}_1(n.2)$, i.e., the probability of achieving the advanced stage is the same across *(f.1)* and *(n.2)*. The full disclosure equilibrium *(f.1)* results in higher second period investment than the non-disclosure equilibrium *(n.2)* when both firms are at the premature stage whereas it results in a lower second period investment when both firms are at the advanced stage. In this case, the latter effect dominates the first so that the expected second period investment is lower in the full disclosure equilibrium *(f.1)*. The result for $\hat{x}_1(f.1) \geqslant \hat{x}_1(n.2)$ is then intuitive as it implies that both firms are more likely to be in the advanced stage in the full disclosure equilibrium *(f.1)* than in the nondisclosure equilibrium *(n.2)*, so that expected investment level in the full disclosure equilibrium *(f.1)* is even lower. For $\hat{x}_1(f.1) < \hat{x}_1(n.2)$, expected investment is lower in *(f.1)* only if the probability of obtaining the advanced stage is

sufficiently high as this is the case where firms make a lower second period investment than in the non-disclosure equilibrium *(n.2)*.

2.6.2 Effects of disclosure cost on first period investment

This subsection analyses how the first period investment decision changes with the disclosure cost k for given cost parameters c_1 and c_2. To analyse the relation in more detail, Table 2 presents the threshold values $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$ in two different ways, once relative to the thresholds values of the non-disclosure equilibrium *(n.1)* and once relative to *(n.2)* (when applicable). We start with analysing the equilibria *(f.1)*, *(a.1)*, and *(n.1)*.

e	**Expression of $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$**		
(f.1)	$\underline{\gamma}(e) =$	$\underline{\gamma}(n.1) + \underline{k} - k$	$= \underline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_1^* - k$
	$\overline{\gamma}(e) =$	$\overline{\gamma}(n.1) + \underline{k} - k$	$= \overline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_0^* - k$
(n.1)	$\underline{\gamma}(e) =$	$r(v_1 - (p + (p+q)r + q)(v_1 - v_2))$	
	$\overline{\gamma}(e) =$	$r(v_1 - (p + qr + q)(v_1 - v_2))$	
(n.2)	$\underline{\gamma}(e) =$	$= rc_2$	
	$\overline{\gamma}(e) =$	$= rc_2$	
(a.1)	$\underline{\gamma}_i(e) =$	$\underline{\gamma}(n.1) + \overline{k} - k$	
	$\overline{\gamma}_i(e) =$	$\overline{\gamma}(n.1) + \overline{k} - k$	
	$\underline{\gamma}_j(e) =$	$\underline{\gamma}(n.1)$	
	$\overline{\gamma}_j(e) =$	$\overline{\gamma}(n.1)$	
(a.2)	$\underline{\gamma}_i(e) =$	$= \underline{\gamma}(n.2) - \frac{r}{p+r}k_1^* - k$	

$\overline{\gamma}_i(e) =$	$= \overline{\gamma}(n.2) - \frac{r}{p+r}k_0^* - k$
$\underline{\gamma}_j(e) =$	$= \underline{\gamma}(n.2) + (1 - p - q)r(v_1 - c_2$ $- p(v_1 - v_2))$
$\overline{\gamma}_j(e) =$	$= \overline{\gamma}(n.2) + (1 - p)r(v_1 - c_2$ $- p(v_1 - v_2))$

Table 2: Alternative representation of the threshold values $\underline{\gamma}_i(e)$ and $\overline{\gamma}_i(e)$

Recall that the equilibria *(f.1)*, *(a.1)*, and *(n.1)* are mutually exclusive and exist when $k \leq \underline{k}$, $\underline{k} < k \leq \overline{k}$, and $k \geq \overline{k}$, respectively. The following corollary presents how first period investment levels change with disclosure cost k for the full disclosure equilibrium *(f.1)* for given cost parameters c_1 and c_2.

Corollary 1 *Let c_2 be such that the full disclosure equilibrium (f.1) exists. Then*

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1) & if\ k \leq \min\{\underline{k}, \underline{\gamma}(n.1) + \underline{k} - c_1\} \\ (\tau, \tau) & if\ \underline{\gamma}(n.1) + \underline{k} - c_1 < k < \min\{\underline{k}, \overline{\gamma}(n.1) + \underline{k} - c_1\} \\ (0,0) & if\ \overline{\gamma}(n.1) + \underline{k} - c_1 < k < \underline{k} \end{cases}$$

$$(11)$$

To explain Corollary 1, observe that in a full disclosure equilibrium, a high first period investment by firm i comes with two benefits and two costs. The first benefit of high first period investment is that it increases the probability

of firm i obtaining the advanced stage, which in turn increases the probability of firm i obtaining the innovation. The magnitude of this benefit also depends on the investment decision of firm j as this determines the probability that firm i is the only firm obtaining the innovation.

The second benefit arises from disclosure: when firm i discloses its advanced stage, it may deter firm j from making the high investment in the second period, which in turn increases the probability that firm i is the only firm that obtains the innovation.

The first cost is the first period investment cost c_1. The second cost is the increase in expected disclosure cost. When firm i makes the high first period investment, it is more likely to obtain the advanced stage, in which case it discloses and incurs the disclosure cost k.

Consequently, a higher disclosure cost k may reduce first period investment. A higher disclosure cost k increases the expected cost of disclosure so that the total cost of the high first period investment no longer outweighs the total benefits. When $k \leqslant \underline{k}$ is sufficiently low, investment is always optimal. For intermediate values of $k \leqslant \underline{k}$, investment is only optimal when the other firm is not expected to invest. In that case, the first benefit is still relatively high

and compensates for the increased expected disclosure cost. For high values of $k \leqslant \underline{k}$, investment no longer occurs because the expected disclosure cost are too high.

A similar results hold for the asymmetric equilibrium *(a.1)*:

Corollary 2 *Let c_2 be such that the asymmetric disclosure equilibrium (a.1) exists. Then*

$$
\left(x_{1i}, x_{1j}\right)
= \begin{cases}
(1,1) & if \ \underline{k} < k \leq \min\{\overline{k}, \gamma(n.1) + \overline{k} - c_1\} \\
(1,0) & if \ \max\{\underline{k}, \gamma(n.1) + \overline{k} - c_1\} < k \leq \min\{\overline{k}, \overline{\gamma}(n.1) + \overline{k} - c_1\} \\
(0,0) & if \ \max\{\underline{k}, \overline{\gamma}(n.1) + \overline{k} - c_1\} < k \leq \overline{k}
\end{cases}
$$

(12)

If $c_1 \leqslant \overline{\gamma}$ (n.1) then first period investments can also equal $(x_{1i}, x_{1j}) = (\tau_i, \tau_j)$ for $\max\{\underline{k}, \ \overline{k} - qr^2(v_1 - v_2), \ \underline{\gamma} \ (n.1) + \overline{k} -- c_1\} < k \leqslant \overline{k}$

For the disclosing firm i, the benefits and costs of making the high first period investment are the same as for the full disclosure equilibrium *(f.1)*. For the non-disclosing firm j, however, only the first benefit and cost c_1 are relevant. For intermediate values of k, the non-disclosing firm j no longer makes the high first period investment because the first benefit is less than the investment cost. For firm i investment is still attractive because the first

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benefit is higher when firm j does not invest, and firm i also receives the second benefit, which still outweighs the expected disclosure cost. For relatively high values of $k \leqslant \underline{k}$, this no longer holds and firm i also no longer makes the high first period investment.

When c_1 is sufficiently low, a mixed investment strategy can also arise for intermediate values of k. In that case, the benefit of firm j of making the high first period investment only outweighs the investment cost c_1 when firm i does not make the high first period investment, as this increases the benefit to firm j. Similarly for firm i, when firm j makes the high first period investment, this reduces the first and second benefit for firm i, so that investment is only attractive when firm j does not make the investment. Consequently, a mixed investment strategy is also supported in equilibrium.

The analysis for the asymmetric equilibrium *(a.2)* is as follows:

Corollary 3 *Let c_2 be such that the asymmetric disclosure equilibrium (a.2) exists. Then*

- *If $c_1 < \underline{\gamma_j}(a.2)$:*

$$
(x_{1i}, x_{1j}) = \begin{cases} (0,1), & rc_2 + \frac{p}{p+r}k_1^* - c_1 < k < k^* \\ (1,1), & 0 < k < \min\{k^*, rc_2 + \frac{p}{p+r}k_1^* - c_1\} \end{cases}
$$

- If $\underline{\gamma}_j(a.2) < c_1 < \overline{\gamma}_j(a.2)$:

$$
(x_{1i}, x_{1j}) = \begin{cases} (0,1), & rc_2 + \frac{p}{p+r}k_1^* - c_1 < k < k^* \\ (\tau_i, \tau_j), & \min\{k^*, rc_2 + \frac{p}{p+r}k_0^* - c_1\} < k \\ & < \min\{k^*, rc_2 + \frac{p}{p+r}k_1^* - c_1\} \\ (1,0), & 0 < k < \min\{k^*, rc_2 + \frac{p}{p+r}k_0^* - c_1\} \end{cases}
$$

- If $\overline{\gamma}_j(a.2) < c_1$:

$$
(x_{1i}, x_{1j}) = \begin{cases} (0,0), & rc_2 + \frac{p}{p+r}k_0^* - c_1 < k < k^* \\ (1,0), & 0 < k < \min\{k^*, rc_2 + \frac{p}{p+r}k_0^* - c_1\} \end{cases}
$$

Like in the asymmetric equilibrium *(a.1)*, both benefits and costs are relevant to firm *i* while only the first benefit and cost c_1 are relevant for firm *j*. The special feature about the asymmetric equilibrium *(a.2)* is that firm *i* is more willing to invest in the first period when firm *j* makes a high first period investment than when firm *j* makes a low first period investment. The explanation for this is that if firm *j* makes a high first period investment compared to when firm *j* makes a low first period investment, firm *i*'s expected payoff when it achieves the advanced stage is constant while the expected payoff when it achieves the premature stage is decreased. Hence,

the incremental benefit of being in the advanced stage increases and firm i is more willing to make a high investment in the first period.

When c_1 is small, the non-disclosing firm j always prefers a high first period investment. The disclosing firm i also prefers a high first period investment when the disclosure cost k is sufficiently low. When the disclosure cost is sufficiently high, a high first period investment is not beneficial because the resulting increase in expected disclosure cost is too high.

When c_1 is intermediate, firm j prefers a high first period investment if and only if firm i makes a low first period investment. Since the disclosure cost k only affects firm i's investment decision, it follows for relatively low disclosure cost k that firm i always prefers a high first period investment so that firm j makes the low first period investment. For intermediate disclosure cost k, firm i's investment decision depends on firm j's investment decision. When firm i makes the high first period investment, the expected disclosure cost increase. This increase is sufficiently high so that the high first period investment is only beneficial to firm i when firm j does not make the high first period investment. Consequently, a mixed investment strategy obtains. For high disclosure cost k, a high first period investment is not beneficial

even when firm j makes a low investment so that firm i always prefers the low investment.

When c_1 is high, the non-disclosing firm j always prefers a low investment. Firm i only prefers the high first period investment when disclosure cost k is sufficiently low as in the case the expected increase in disclosure cost is sufficiently low as well.

An interesting observation from Corollary 3 is that for intermediate investment cost c_1, rising disclosure cost k leads to a switch of first period investment from the disclosing firm i to the non-disclosing firm j. In this case, disclosure cost k thus also affects the investment decision of the non-disclosing firm j.

2.6.3 Effects of disclosure on first period investment

This subsection focuses on the equilibria *(f.1)*, *(a.2)*, and *(n.2)* that can exist simultaneously. In particular, we analyse how the type of equilibrium, i.e., full disclosure, asymmetric disclosure or non-disclosure, affects first period investment levels. Recall that the equilibria *(f.1)*, *(a.2)*, and *(n.2)* exist when $k \leq \underline{k}$, $k \leq k^*_{\hat{x}_{1j}}$ and $k \geqslant 0$, respectively. Furthermore, one can prove that $k^*_0 < k^*_1 < \underline{k}$. The following corollary presents how first period investment

levels differs across the equilibria *(f.1)* and *(n.2)* for given cost parameters c_1 and c_2.

Corollary 4 *Let k and c_2 be such that the equilibrium (f.1) and (n.2) exist simultaneously.*

(1) For $k \leq \underline{k} - \frac{p}{p+r}k_1^*$: If $\underline{\gamma}(n.2) < c_1 < \overline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_0^* - k$, then first period investment in the full disclosure equilibrium (f.1) is higher than in the non-disclosure equilibrium (n.2).

(2) For $\underline{k} - \frac{p}{p+r}k_1^* < k < \underline{k} - \frac{p}{p+r}k_0^*$: If $\underline{\gamma}(n.2) < c_1 < \overline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_0^* - k$, then first period investment in the full disclosure equilibrium (f.1) is higher than in the non-disclosure equilibrium (n.2). If $\overline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_1^* - k < c_1 < \overline{\gamma}(n.2)$, then first period investment in the full disclosure equilibrium (f.1) is lower than in the non-disclosure equilibrium (n.2).

(3) For $\underline{k} - \frac{p}{p+r}k_0^* \leq k$: If $\overline{\gamma}(n.2) + \underline{k} - \frac{r}{p+r}k_1^* - k < c_1 < \overline{\gamma}(n.2)$, then first period investment in the full disclosure equilibrium (f.1) is lower than in the non-disclosure equilibrium (n.2).

The explanation is based on the same benefits and costs as for Corollary 1. To explain part (1): for low disclosure cost and intermediate values of c_1, the full disclosure equilibrium results in higher first period investment than the non-disclosure equilibrium because the increase in expected disclosure cost

of making the first period investment is low and does not outweigh the benefit of disclosure.

To explain part (2), observe that for intermediate disclosure cost and intermediate investment cost, the effect critically depends on the cost parameters. When c_1 is relatively high and k is relatively low, the investment cost exceeds the first benefit so that no investment occurs in *(n.2)*. However, in *(f.1)*, first period investment yields a small increase in expected disclosure cost because k is relatively low. Consequently, the benefit of disclosure exceed the expected cost. Furthermore, this net benefit is high enough to cover the net deficit between the first benefit and the investment cost c_1, so that the high first period investment is made in *(f.1)*.

When c_1 is relatively low and k is relatively high, the opposite applies. The investment cost is less than the first benefit so that investment occurs in *(n.2)*. In *(f.1)*, first period investment yields a large increase in expected disclosure cost because k is relatively high. The expected cost of disclosure now exceeds the benefit and this net cost is higher than the excess between the first benefit and the investment cost c_1. Consequently, it does not pay to make the high first period investment in *(f.1)*.

The explanation for part (3) is similar to the explanation above.

For the comparison of first period investment levels between *(a.2)* and *(n.2)*, we first consider the first period investment level of the disclosing firm i in Corollary 5 and then the non-disclosing firm j in Corollary 6.

Corollary 5 *Let k and c_2 be such that the equilibrium (a.2) and (n.2) exist simultaneously.*

*(1) For $k \leq rc_2 + \frac{p}{p+r}k_0^* - c_1$: If $c_1 > rc_2$, then first period investment of **firm i** in the asymmetric disclosure equilibrium (a.2) is higher than in the non-disclosure equilibrium (n.2).*

*(2) For $rc_2 + \frac{p}{p+r}k_0^* - c_1 < k < rc_2 + \frac{p}{p+r}k_1^* - c_1$: If $rc_2 < c_1 < rc_2 + (1 - p - q)r(v_1 - c_2 - p(v_1 - v_2))$, then first period investment of **firm i** in the asymmetric disclosure equilibrium (a.2) is higher than in the non-disclosure equilibrium (n.2).*

*(3) For $rc_2 + \frac{p}{p+r}k_1^* - c_1 \leq k < k^*$: If $c_1 < rc_2$, then first period investment of **firm i** in the asymmetric disclosure equilibrium (a.2) is lower than in the non-disclosure equilibrium (n.2).*

To explain part (1), when k is relatively small and c_1 is large, disclosing the advanced stage is beneficial for firm i. Investment in the first period becomes always attractive due to low disclosure cost and disclosing the advanced

stage by firm i deters firm j from making a high second period investment. In the non-disclosure equilibrium *(n.2)*, firm i does not enjoy the benefit of disclosure. Furthermore, because the first period investment cost c_1 is large, firm i does not make the high first period investment.

For part (2) with both intermediate k and c_1, firm i only prefers a high investment in the first period when firm j makes a low investment. The intermediate c_1 makes firm j also only prefer a high investment only when firm i makes a low investment. This results in a mixed investment strategy in *(a.2)*. While in *(n.2)* firm i never makes a high investment even with intermediate c_1.

For part (3), when k is relatively large but c_1 is small, firm i does not make the high first period investment in *(a.2)* because of the high expected disclosure cost. Because of the low investment cost c_1, firm i does make the high firs period investment in the non-disclosure equilibrium *(n.2)*.

Corollary 6 *Let k and c_2 be such that the equilibrium (a.2) and (n.2) exist simultaneously.*

*(1) For $k \leq rc_2 + \frac{p}{p+r}k_1^* - c_1$: If $rc_2 < c_1 < rc_2 < c_1 < rc_2 + (1 - p - q)r(v_1 - c_2 - p(v_1 - v_2))$, then first period investment of **firm j** in the*

asymmetric disclosure equilibrium (a.2) is higher than in the non-disclosure equilibrium (n.2).

*(2) For $rc_2 + \frac{p}{p+r}k_1^* - c_1 \leq k < k^*$:   If $rc_2 + (1 - p - q)r(v_1 - c_2 - p(v_1 - v_2)) < c_1 < rc_2 < c_1 < rc_2 + (1 - p)r(v_1 - c_2 - p(v_1 - v_2))$, then first period investment of **firm j** in the asymmetric disclosure equilibrium (a.2) is higher than in the non-disclosure equilibrium (n.2).*

To explain part (1), when k is small and c_1 is intermediate, firm i prefers a high investment in the first period when firm j makes a high investment such that firm j also prefers a high investment in the first period. In the asymmetric equilibrium *(a.2)*, the disclosure of firm i fully reveals its private information to firm j which enables firm j to make an investment decision dependent on firm i's first period stage. This differential investment decision enlarges the incremental expected payoff of firm j achieving the advanced stage. In the non-disclosure equilibrium, firm j prefers a low investment in the absence of the above effect from firm i's disclosure[8]. As both k and c_1 increases as in part (2), firm i only prefers a low investment since the increase of both these two costs works against a high investment for firm i. Firm j's investment

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[8] This effect is represented as the second component of $\gamma_j(e)$, i.e., $(1 - p - qx_{1i})r(v_1 - c_2 - p(v_1 - v_2)$, which is always positive.

stays at a high level simply because the lower investment level of firm i offsets the higher investment cost c_1. In the non-disclosure equilibrium *(n.2)* firm j still prefers a low investment level for an even higher investment cost.

2.6.4 Asymmetric disclosure mandate – the STAR market case

The STAR market in China was established with a mandatory R&D disclosure regulation. Since it is a separate market segment from the existing capital market, all firms listed on the existing market are not subject to the STAR regulation. This creates a setting with asymmetric disclosure mandate in which one group of firms (the STAR firms) are required to make R&D disclosure and the other group of firms (non-STAR firms) are not required to make R&D disclosure.[9]

Regarding the effect of an asymmetric disclosure mandate on firms' first period investment, there are two different scenarios depending on whether or not the unregulated firm makes a disclosure prior to the regulation as summarized in Table 3. In both scenarios, the unregulated firm does not disclose prior to the regulation. For this section, we assume that firm j is always the unregulated firm and firm i is always the newly regulated firm.

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[9] A more detailed introduction of the STAR market is included in Chapter 3.

Unregulated setting	Regulated setting
Non-disclosure equilibrium (n.1): • Both firms invest at t=1 • Both firms mix at t=1 • Both firms do not invest at t=1	Asymmetric disclosure eq. (a.1): • Firm i invests at t=1, firm j not • Firm i invests at t=1, firm j not • Firm i invests at t=1, firm j not
Asymmetric disclosure eq. (a.1): • Firm i does not disclose nor invest • Firm j discloses and invests at t=1	Asymmetric disclosure eq. (a.1): • Firm i discloses and invests at t=1 • Firm j does not disclose nor invest

Table 3. Asymmetric disclosure mandate

In the first case, both firms make no disclosure prior to the regulation and the disclosure mandate applies to firm i which makes a disclosure after the regulation. The mandate changes the disclosure equilibrium from *(n.1)* to *(a.1)*. The unregulated firm (firm *j*) still prefers the nondisclosure strategy due to high disclosure cost assuming that the mandate does not directly affect the disclosure cost k which still stays above $\bar{k}$. In this case, firm i increases the investment and/or firm j decreases the investment at t=1.

In the second case, firm i makes a disclosure in an unregulated setting which leads to an asymmetric disclosure equilibrium *(a.1)*. Since our model assumes both firms start the same, either firm can be the disclosing firm which leaves the other firm not beneficial to make a disclosure anymore. So if it follows the comparative statics between the initial and the new

asymmetric equilibrium and peer firms' voluntary disclosure goes down after the mandate, then the asymmetric disclosure mandate also increases the investment of the regulated firm but reduces the investment of the unregulated firm. The rationale is that the marginal benefit of own disclosure decreases once the other firm discloses. Hence, when firm i is required to disclose it is no longer optimal for firm j to disclose any more.

2.7   Conclusion

This paper analyses the interaction between investment and voluntary disclosure in an R&D race with two firms. The model considers two investment periods and a costly voluntary disclosure at the interim date where firms can disclose their current stage in the R&D process taking the disclosure strategies given. We obtain the conditions for the cost parameters under which each of the three types of disclosure strategy combination obtains, i.e., the full disclosure, asymmetric disclosure and non-disclosure equilibria. To streamline the results we focus on a selected interval of the second period investment cost c_2 where full disclosure can always obtain under certain conditions. We then analyse how disclosure cost affects first

period investment levels and how investment levels differ across the three equilibria.

Firstly, we find that a low disclosure cost k is sufficient to obtain the full disclosure equilibrium. This result is intuitive: given the relevance of one's interim stage to the rival, disclosing the result when it is good reduces the rival's subsequent investment and pays off when the cost of disclosing is sufficiently low. We also find that a nondisclosure equilibrium always obtains with a large disclosure cost k but can also obtain when k approaches zero. The latter case arises when one's stage becomes irrelevant for the rival and thus costly disclosure never pays off.

Secondly, our results for the relation between disclosure and second period investment are relatively more robust due to simpler cost-benefit structure. Specifically, we find that disclosure typically but not always results in lower expected level of investment subsequent to disclosure.

Thirdly, we find that disclosure and first period investment are linked in the following way. First period investment by firm i comes with two benefits and two costs. The first benefit of high first period investment is that it increases the probability of obtaining the innovation in a direct way. The second

benefit arises from disclosure: when firm i discloses its advanced stage, it may deter firm j from making the high investment in the second period, which in turn increases the probability that firm i is the only firm that obtains the innovation. The first cost is the investment cost c_1 and the second cost is the increase in expected disclosure cost. When firm i makes the high first period investment, it is more likely to obtain the advanced stage, in which case it discloses and incurs the disclosure cost k.

In short, disclosure affects first period investment because a high first period investment increases the expected cost of disclosure. This cost would not arise when the firm knows that it will not disclose at the intermediate date.

Our findings imply that higher disclosure cost makes first period investment less attractive. The model does not explicitly specify what drives the disclosure cost. Besides the cost of collecting and disseminating information, it can also include proprietary costs that are not explicitly captured in the model (i.e., the response by the competing firm in the R&D race) or legal liability costs when the disclosure includes soft information or forward looking information. Consequently, to incentivise first period investment, a regulator may introduce policy or regulations that reduce the disclosure cost.

The comparison from *(n.1)* to *(a.1)* hints at the effect on the investment of an asymmetric disclosure mandate on one (non-disclosing) firm but not on the other firm. When the unregulated firm does not disclose before the regulation, i.e., from *(n.1)* to *(a.1)* and k is high, the now regulated firm will increase its first period investment when the cost c_1 is moderately high while the unregulated firm does not change its investment level.

When the unregulated firm already discloses, regulating the non-disclosure firm to disclose switches the disclosing firm with the non-disclosing firm together with their investment strategy. In this case, the benefit of disclosure is only sufficient to sustain the disclosure strategy of one firm. So when the non-disclosure firm is mandated to make a disclosure the previously disclosing firm ceases to disclose rendering a negative disclosure spillover. The pure disclosure equilibrium in the regulated setting does not specify which firm discloses and which firm does not. the disclosure regulation resolves the selection issue.

Our findings also show that when multiple equilibria exist, the difference in first period investment levels between the full disclosure and non-disclosure equilibrium critically depends on the first period investment cost and the disclosure cost. When the first period investment cost is relatively high and

the disclosure cost is relatively low, first period investment is higher in the full disclosure equilibrium. In such cases, mandatory disclosure regulation may be desirable as it eliminates the equilibrium selection problem and mandates firms to play the equilibrium with the higher first period investment levels. However, the opposite holds when the first period investment cost is relatively low and the disclosure cost is relatively high. In that case, the non-disclosure equilibrium results in higher first period investment and mandatory disclosure regulation may not be desirable.

Appendix: mathematical proofs

Proof of Proposition 1. All cases except for case *C4* follow directly from conditions (4)-(7). For case *C4*, observe that when $b_{ij} \geqslant b_{ji}$, firm i makes the high investment if and only if firm j does not; similarly, firm j makes the high investment if and only if firm j does not. This gives rise to a mixed strategy equilibrium . Let π_i denote the probability that firm $i = 1,2$ makes the high investment. Recall that the expected payoff for firm j equals

$$V_j(r_j, b_{ji}, x_{2i}) = (p + r_j + x_{2j}q)(v_1 - (p + b_{ji}r + x_{2i})(v_1 - v_2)).$$

In equilibrium, $x_{2i} = \pi_i$ makes firm j indifferent between $x_{2j} = 1$ and $x_{2j} = 0$. Hence, it should hold that $(p + r_j)(v_1 - (p + b_{ji}r + \pi_i q)(v_1 - v_2)) = (p + r_j + q)(v_1 - (p + b_{ji}r + \pi_i q)(v_1 - v_2)) - c_2 q$. Rearranging terms yields $\pi_i = \frac{1}{q}\left(\frac{v_1 - c_2}{v_1 - v_2} - (p + b_{ji}r)\right)$.

Proof of Proposition 2. Since we know that a firm never discloses the preliminary stage, it suffices to derive conditions under which firm i prefers disclosing its advanced stage.

First, assume firm j is at the advanced stage so that $s_j = A$ and $b_{ij}(A) = 1$. If firm i discloses $s_i = A$, firm j also knows firm i's stage so that $b_{ji}(A) = 1$. It then follows from Proposition 1 and $p + b_{ij}r + q = p + b_{ji}r + q = p + r + q$ that second period equilibrium investment strategies equal $(x_{2i}, x_{2j}) = (\pi, \pi)$.

If firm i does not disclose $s_i = A$, then firm j is going to interpret and act as if firm i remains at the preliminary stage, i.e., $b_{ji}(ND) = 0$ and it follows from Proposition 1 and $p + b_{ji} + q = p + q$ and $p + b_{ij}r + q = p + r + q$ that second period equilibrium investment strategies equal $(x_{2i}, x_{2j}) = (0,1)$.

Second, assume firm j is at the preliminary stage so that $s_j = P$ and $b_{ij}(ND) = 0$. If firm i discloses $s_i = A$, then firm j knows firm i's stage, i.e., $b_{ji} = 1$ and it follows from Proposition 1 and $p + b_{ji} + q = p + r + q$ and $p + b_{ij}r + q = p + q < p + r$ that second period equilibrium investment strategies equal $(x_{2i}, x_{2j}) = (1,0)$.

If firm i does not disclose $s_i = A$, then firm j interprets and acts as if firm i is at the preliminary stage, i.e., $b_{ji}(ND) = 0$ and it follows from Proposition 1 and $p + b_{ji} + q = p + b_{ij}r + q = p + q < p + r$ that second period equilibrium investment strategies equal $(x_{2i}, x_{2j}) = (1,1)$.

Next, recall from equation (2) that the expected payoff of firm i given $s_i = A$, b_{ij} and x_{2j} equals

$$(p + r + x_{2i}q)(v_1 - (p + b_{ij}r + x_{2j})(v_1 - v_2) - x_{2i}c_2q.$$

One can show that in a mixed strategy investment equilibrium (π, π), the expected payoff of firm i reduces to $(p + r)c_2$. Hence, the expected payoff for firm i of disclosing $s_i = A$ equals

$$Pr(s_j = A)(p + r)c_2 + Pr(s_j = P)[(p + r + q)(v_1 - p(v_1 - v_2)) - c_2q] - k.$$

Similarly, the expected payoff for firm i of not disclosing $s_i = A$ equals

$$Pr(s_j = A)[(p + r)(v_1 - (p + r + q)(v_1 - v_2)]$$

$$+Pr(s_j = P)[(p + r + q)(v_1 - (p + q)(v_1 - v_2)) - c_2q].$$

Consequently, disclosure of $s_i = A$ is preferred if and only if $k \leq Pr(s_j = A)[(p+r)((p+r+q)(v_1-v_2)-(v_1-c_2)]+Pr(s_j = P)(p+r+q)q(v_1-v_2)$. Substituting $Pr(s_j = A) = p + \hat{x}_{1j}q$ yields condition (f.1).

Proof of Proposition 3. In a non-disclosure equilibrium, firm j never discloses its stage s_j so that $b_{ij} = p + \hat{x}_{1j}q = b \in (0,1)$. If firm i discloses $s_i = A$, then $b_{ji} = 1$ and it follows from Proposition 1 that $(x_{2i}, x_{2j}) = (1,0)$ for $p + br + q < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ and $(x_{2i}, x_{2j}) = (\pi, \pi)$ for $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + br + q$.

If firm i does not disclose $s_i = A$, then $b_{ji} = b$ and it follows from Proposition 1 that $(x_{2i}, x_{2j}) = (1,1)$ for $p + br + q < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ and $(x_{2i}, x_{2j}) = (\pi, \pi)$ for $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + br + q$.

As discussed earlier in the full disclosure equilibrium, two conditions need to be fulfilled at the same time such that a full disclosure exists, i.e., (i) disclosure has to affect the investment decision(s) at $t = 3$; and (ii) the disclosure cost has to be sufficiently low. If either of these two conditions does not hold, a non-disclosure equilibrium obtains.

Next, recall from equation (2) that the expected payoff of firm i given $s_i = A$, $b_{ij} = b$ and x_{2j} equals

$$(p + r + x_{2i}q)(v_1 - (p + br + x_{2j})(v_1 - v_2) - x_{2i}c_2q.$$

For case *(n.1)*, the expected payoff for firm i of disclosing $s_i = A$ equals

$$Pr(s_j = A)[(p + r + q)(v_1 - (p + r)(v_1 - v_2))]$$

$$+Pr(s_j = P)[(p + r + q)(v_1 - p(v_1 - v_2)) - c_2q] - k.$$

Similarly, the expected payoff for firm i of not disclosing $s_i = A$ equals

$$Pr(s_j = A)[(p + r + q)(v_1 - (p + r + q)(v_1 - v_2))]$$

$$+Pr(s_j = P)[(p + r + q)(v_1 - (p + q)(v_1 - v_2)) - c_2q].$$

Consequently, non-disclosure of $s_i = A$ is preferred if and only if

$k \geq Pr(s_j = A)(p + r + q)q(v_1 - v_2) + Pr(s_j = P)(p + r + q)q(v_1 - v_2) = (p + r + q)q(v_1 - v_2)$.

For case *(n.2)*, observe that the second stage investments do not depend on the disclosure decision of firm i as (x_{2i}, x_{2j}) always equals (π, π). Hence, firm i is indifferent between disclosure and non-disclosure of $s_i = A$, i.e., non-disclosure is always preferred in equilibrium due to the positive disclosure cost k.

Proof of Proposition 4. The asymmetric equilibrium is a partial disclosure equilibrium in which one firm, denoted as firm i, takes the disclosure strategy and the other firm, denoted as firm j, takes the non-disclosure strategy. Since firm i's stage is fully revealed, we have $b_{ji}(A) = a$ and $b_{ji}(ND) = 0$. Firm j never discloses, so we have $b_{ij}(ND) = p + \hat{x}_{1j}q \in (0,1)$. It follows Proposition 1 that when firm i discloses $s_i = A$, $(x_{2i}, x_{2j}) = (1,0)$ obtains; for $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$, $(x_{2i}, x_{2j}) = (1, 0)$ obtains. When firm i does not disclose its being advanced stage, firm j interprets it as if firm j reaches a premature stage then for $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2}$, $(x_{2i}, x_{2j}) = (1, 1)$ obtains; for $p + q < \frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$, $(x_{2i}, x_{2j}) = (0,1)$ obtains. The last part changes to $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$, $(x_{2i}, x_{2j}) = (0,1)$ since we assume $\frac{v_1 - c_2}{v_1 - v_2} \in (p + r, p + r + q)$ and $r > q$.

As discussed before, we have to check whether the two conditions for a disclosure strategy hold for the disclosing firm but at least one condition does not hold for the non-disclosing firm.

For the disclosing firm, the first condition does hold in the sense that disclosing the status when achieving the advanced stage does affect the subsequent investments in equilibrium for both $p + b_{ij}r + q < \frac{v_1 - c_2}{v_1 - v_2} < p + r + q$ and $p + r < \frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$. The second condition also holds when disclosure cost is sufficiently low. So for *(a.1)*, the expected payoff for firm i of disclosing $s_i = A$ equals

$(p + r + q)(v_1 - (p + b_{ij}r)(v_1 - v_2)) - c_2 q - k$

The expected payoff for firm i of not disclosing $s_i = A$ equals

$(p + r + q)(v_1 - (p + b_{ij}r + q)(v_1 - v_2)) - c_2 q$

Consequently, disclosure is preferred if and only if

$$k \leq (p + r + q)q(v_1 - v_2)$$

For the non-disclosing firm, disclosing $s_j = A$ changes (x_{2i}, x_{2j}) from $(1,0)$ to (π, π) when $s_i = A$ and from $(1,1)$ to $(0,1)$ when $s_i = P$. Since the benefit of disclosure is the same as in *(f.1)* from Proposition 2, we know when $k \geq \underline{k}$ non-disclosure is preferred. Since $\bar{k} > \underline{k}$, we have when $\underline{k} \leq k \leq \bar{k}$ the asymmetric equilibrium holds.

For *(a.2)*, expected payoff for firm i of disclosing $s_i = A$ equals

$(p + r)c_2 - k$

The expected payoff for firm i of not disclosing $s_i = A$ equals

$(p + r)(v_1 - (p + b_{ij}r + q)(v_1 - v_2))$

Consequently, disclosure is preferred if and only if

$$k \leqslant (p + r)((p + b_{ij}r + q)(v_1 - v_2) - (v_1 - c_2))$$

For the non-disclosing firm, disclosing $s_j = A$ does not change the subsequent investments in equilibrium such that non-disclosure is always preferred.

Proof of Proposition 6. We derive the expected investment level in period 2 from Proposition 2 and 3 and denote as $E(x_2(f.1))$ and $E(x_2(n.1))$ respectively.

We have:

$$E\big(x_2(f.1)\big) = (p + \hat{x}_1(f.1)q)^2 \pi(f.1)$$
$$+ (p + \hat{x}_1(f.1)q)(1 - p - \hat{x}_1(f.1)q)$$
$$+ (1 - p - \hat{x}_1(f.1)q)^2$$

$$E\big(x_2(n.2)\big) = \pi^n = \pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

Let $E(x_2(f.1)) > E(x_2(n.2))$, we have:

$$(p + \hat{x}_1(f.1)q)^2 \pi(f.1) + (p + \hat{x}_1(f.1)q)(1 - p - \hat{x}_1(f.1)q)$$
$$+ (1 - p - \hat{x}_1(f.1)q)^2 > \pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

Rearrange the terms as follows:

$$(p + \hat{x}_1(f.1)q) - (p + \hat{x}_1(f.1)q)^2 + 1 - 2(p + \hat{x}_1(f.1)q)$$
$$+ (p + \hat{x}_1(f.1)q)^2(1 + \pi(f.1))$$
$$> \pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$1 - (p + \hat{x}_1(f.1)q) + (p + \hat{x}_1(f.1)q)^2 \pi(f.1)$$
$$> \pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$\pi(f.1)\left(p + \hat{x}_1(f.1)q - \frac{1}{2\pi(f.1)}\right)^2 + 1 - \frac{1}{4\pi(f.1)}$$
$$> \pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$\pi(f.1)\left(p + \hat{x}_1(f.1)q - \frac{1}{2\pi(f.1)}\right)^2$$
$$> \frac{4(\pi(f.1))^2 - 4\pi(f.1) + 1}{4\pi(f.1)} + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$\pi(f.1)\left(p + \hat{x}_1(f.1)q - \frac{1}{2\pi(f.1)}\right)^2 > \frac{(2\pi(f.1)-1)^2}{4\pi(f.1)} + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$\left(p + \hat{x}_1(f.1)q - \frac{1}{2\pi(f.1)}\right)^2 > \left(\frac{2\pi(f.1)-1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

$$\left(p + \hat{x}_1(f.1)q - \frac{1}{2\pi(f.1)}\right)^2 > \left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

Then at least one of the following two conditions has to hold:

$$p + \hat{x}_1(f.1)q > \frac{1}{2\pi(f.1)} + \sqrt{\left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)}$$

or

$$p + \hat{x}_1(f.1)q > \frac{1}{2\pi(f.1)} - \sqrt{\left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)}$$

Because

$$p + \hat{x}_1(f.1)q > \frac{1}{2\pi(f.1)} + \sqrt{\left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)} > 1$$

cannot be satisfied, only the condition

$$p + \hat{x}_1(f.1)q > \frac{1}{2\pi(f.1)} - \sqrt{\left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)}$$

remains, which is the condition in Proposition 6.

Furthermore to verify whether

$$\frac{1}{2\pi(f.1)} - \sqrt{\left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)} \text{ is a fraction:}$$

First suppose we have,

$$\frac{1}{2\pi(f.1)} - \sqrt{\left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)} < 0$$

Then we could derive the following,

$$\left(\frac{1}{2\pi(f.1)}\right)^2 < \left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

$$0 < 1 - \frac{1}{\pi(f.1)} + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

$$\pi(f.1) > 1 - \frac{r}{q}(1 - p - \hat{x}_1(n.2)q)$$

$$\pi(f.1) + \frac{r}{q}(1 - p - \hat{x}_1(n.2)q) > 1$$

$$\pi^n > 1$$

which does not hold true; second we assume:

$$\frac{1}{2\pi(f.1)} - \sqrt{\left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)} \geq 1$$

This is equivalent to:

$$\frac{1}{2\pi(f.1)} - 1 \geq \sqrt{\left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)}$$

This is not satisfied when $\pi(f.1) \geq \frac{1}{2}$. For $\pi(f.1) < \frac{1}{2}$ it holds that

$$\left(\frac{1}{2\pi(f.1)} - 1\right)^2 \geq \left(1-\frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

$$0 \geq \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)$$

so that the inequality is also not satisfied. Hence,

$$0 \ll \frac{1}{2\pi(f.1)} - \sqrt{\left(1 - \frac{1}{2\pi(f.1)}\right)^2 + \frac{r}{q\pi(f.1)}(1 - p - \hat{x}_1(n.2)q)} < 1 \; .$$

Back to the original inequality comparing the expected investment, whether this inequality holds depends on the relation between $\hat{x}_1(f.1)$ and $\hat{x}_1(n.2)$.

Rearranging the terms we get:

$$E\big(x_2(f.1)\big) - E\big(x_2(n.2)\big)$$
$$= \left(1 - \frac{r}{q}\right)(1 - p) - q\hat{x}_1(f.1) + r\hat{x}_1(n.2)$$
$$+ ((p + \hat{x}_1(f.1)q)^2 - 1)\pi(f.1)$$

Since we assume $r > q$, the above expression is always negative for $\hat{x}_1(f.1) \geqslant \hat{x}_1(n.2)$ for which the proof is as follows:

When $\hat{x}_1(f.1) = \hat{x}_1(n.2)$, we have

$$\left(1 - \frac{r}{q}\right)(1 - p) - q\hat{x}_1(f.1) + r\hat{x}_1(n.2) + ((p + \hat{x}_1(f.1)q)^2 - 1)\pi(f.1)$$

$$= \left(1 - \frac{r}{q}\right)(1 - p) - \left(1 - \frac{r}{q}\right)q\hat{x}_1(f.1) + ((p + \hat{x}_1(f.1)q)^2 - 1)\pi(f.1)$$

$$= \left(1 - \frac{r}{q}\right)(1 - p - \hat{x}_1(f.1)q) + ((p + \hat{x}_1(f.1)q)^2 - 1)\pi(f.1)$$

since $1 - \frac{r}{q} < 0$, $1 - p - \hat{x}_1(f.1)q > 0$, $(p + \hat{x}_1(f.1)q)^2 - 1 < 0$, $\pi(f.1) > 0$, the above expression is always negative.

When $\hat{x}_1(f.1) > \hat{x}_1(n.2)$:

$$\left(1 - \frac{r}{q}\right)(1 - p) - q\hat{x}_1(f.1) + r\hat{x}_1(n.2)$$

$$< \left(1 - \frac{r}{q}\right)(1 - p) - q\hat{x}_1(f.1) + r\hat{x}_1(f.1) < 0$$

Therefore, the condition in equation 10 is only necessary for $\hat{x}_1(f.1) < \hat{x}_1(n.2)$.

Proof of Corollary 3 For the asymmetric equilibrium *(a.2)* it holds that $\underline{\gamma}_i(a.2) > \overline{\gamma}_i(a.2)$ and $\overline{\gamma}_j(a.2) > \underline{\gamma}_j(a.2) > \underline{\gamma}(n.2) = \overline{\gamma}(n.2)$. This yields the following six possibilities:

$(C1)$ $\overline{\gamma}_i(a.2) < \underline{\gamma}_i(a.2) < \underline{\gamma}_j(a.2) < \overline{\gamma}_j(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \overline{\gamma}_i(a.2) \\ (1,1), & if\ \overline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,1) & if\ \underline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_j(a.2) \\ (0,1) & if\ \underline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (0,0), & if\ \overline{\gamma}_j(a.2) < & c_1 \end{cases}$$

$(C2)$ $\overline{\gamma}_i(a.2) < \underline{\gamma}_j(a.2) < \underline{\gamma}_i(a.2) < \overline{\gamma}_j(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \overline{\gamma}_i(a.2) \\ (1,1), & if\ \overline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_j(a.2) \\ (\tau_i, \tau_j) & if\ \underline{\gamma}_j(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,1) & if\ \underline{\gamma}_i(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (0,0), & if\ \overline{\gamma}_j(a.2) < & c_1 \end{cases}$$

$(C3)$ $\overline{\gamma}_i(a.2) < \underline{\gamma}_j(a.2) < \overline{\gamma}_j(a.2) < \underline{\gamma}_i(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \overline{\gamma}_i(a.2) \\ (1,1), & if\ \overline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_j(a.2) \\ (\tau_i, \tau_j) & if\ \underline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (0,0) & if\ \overline{\gamma}_j(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,0), & if\ \underline{\gamma}_i(a.2) < & c_1 \end{cases}$$

$(C4)$ $\underline{\gamma}_j(a.2) < \overline{\gamma}_i(a.2) < \underline{\gamma}_i(a.2) < \overline{\gamma}_j(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \underline{\gamma}_j(a.2) \\ (1,0), & if \ \underline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_i(a.2) \\ (\tau_i, \tau_j) & if \ \overline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,1) & if \ \underline{\gamma}_i(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (0,0), & if \ \overline{\gamma}_j(a.2) < & c_1 \end{cases}$$

$(C5) \ \underline{\gamma}_j(a.2) < \overline{\gamma}_i(a.2) < \overline{\gamma}_j(a.2) < \underline{\gamma}_i(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \underline{\gamma}_j(a.2) \\ (1,0), & if \ \underline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_i(a.2) \\ (\tau_i, \tau_j) & if \ \overline{\gamma}_i(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (0,0) & if \ \overline{\gamma}_j(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,0), & if \ \underline{\gamma}_i(a.2) < & c_1 \end{cases}$$

$(C6) \ \underline{\gamma}_j(a.2) < \overline{\gamma}_j(a.2) < \overline{\gamma}_i(a.2) < \underline{\gamma}_i(a.2)$:

$$(x_{1i}, x_{1j}) = \begin{cases} (1,1), & if & c_1 < \underline{\gamma}_j(a.2) \\ (1,0), & if \ \underline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_j(a.2) \\ (1,0) & if \ \overline{\gamma}_j(a.2) < & c_1 < \overline{\gamma}_i(a.2) \\ (0,0) & if \ \overline{\gamma}_i(a.2) < & c_1 < \underline{\gamma}_i(a.2) \\ (0,0), & if \ \underline{\gamma}_i(a.2) < & c_1 \end{cases}$$

Cases *(C2)-(C5)* are the cases with the new mixed strategy equilibrium.

Observe that:

- $\underline{\gamma}_i(a.2) < \underline{\gamma}_j(a.2)$ *if and only if* $k > \frac{p}{p+r}k_1^* - (1 - p - q)r(v_1 - c_2 - p(v_1 - v_2))$

- $\underline{\gamma}_i(a.2) < \overline{\gamma}_j(a.2)$ *if and only if* $k > \frac{p}{p+r}k_1^* - (1 - p)r(v_1 - c_2 - p(v_1 - v_2))$

- $\overline{\gamma}_i(a.2) < \underline{\gamma}_j(a.2)$ *if and only if* $k > \frac{p}{p+r}k_0^* - (1 - p - q)r(v_1 - c_2 - p(v_1 - v_2))$

- $\bar{\gamma}_i(a.2) < \bar{\gamma}_j(a.2)$ *if and only if* $k > \frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$

Because $k_1^* > k_0^*$, it follows that:

(C1)	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k$
(C2)	$\frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k < \frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k$
(C3)	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k < \frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$
(C4)	$\frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k < \frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C5)	$\frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k < \frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
		$k < \frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$
(C6)		$k < \frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$

Observe that *(C3)* only exists when $qr(v_1 - c_2 - p(v_1 - v_2) < \frac{p}{p+r}(k_1^* - k_0^*)$ and that *(C4)* only exists when

$qr(v_1 - c_2 - p(v_1 - v_2) > \frac{p}{p+r}(k_1^* - k_0^*)$. Because $k_1^* - k_0^* = (p+r)qr(v_1 - v_2)$, this inequality reduces to

$qr(v_1 - c_2 - p(v_1 - v_2)) > \frac{p}{p+r}(p+r)qr(v_1 - v_2)$

$$qr\big(v_1 - c_2 - p(v_1 - v_2)\big) > pqr(v_1 - v_2)$$

$$(v_1 - c_2) > 2p(v_1 - v_2)$$

$$\frac{v_1 - c_2}{v_1 - v_2} > 2p$$

Recall that *(a.2)* also implies $\frac{v_1 - c_2}{v_1 - v_2} < p + b_{ij}r + q$.

For *(C2)* and *(C5)*, observe that $\frac{p}{p+r}k_1^* - (1-p)r\big(v_1 - c_2 - p(v_1 - v_2)\big) < \frac{p}{p+r}k_0^* - (1-p-q)r\big(v_1 - c_2 -$

$p(v_1 - v_2)\big)$ if and only if $qr(v_1 - c_2 - p(v_1 - v_2)) > \frac{p}{p+r}(k_1^* - k_0^*)$, i.e., $\frac{v_1 - c_2}{v_1 - v_2} > 2p$.

Hence, for $\frac{v_1 - c_2}{v_1 - v_2} > 2p$, we have:

(C1)	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k$	
(C2)	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C4)	$\frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C5)	$\frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C6)		$k <$	$\frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$

and for $\frac{v_1 - c_2}{v_1 - v_2} < 2p$, we have:

(C1)	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k$	
(C2)	$\frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_1^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C3)	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_1^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$
(C5)	$\frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$	$< k <$	$\frac{p}{p+r}k_0^* - (1-p-q)r(v_1 - c_2 - p(v_1 - v_2))$
(C6)		$k <$	$\frac{p}{p+r}k_0^* - (1-p)r(v_1 - c_2 - p(v_1 - v_2))$

Figures

Figure 1. The R&D process represented by the model
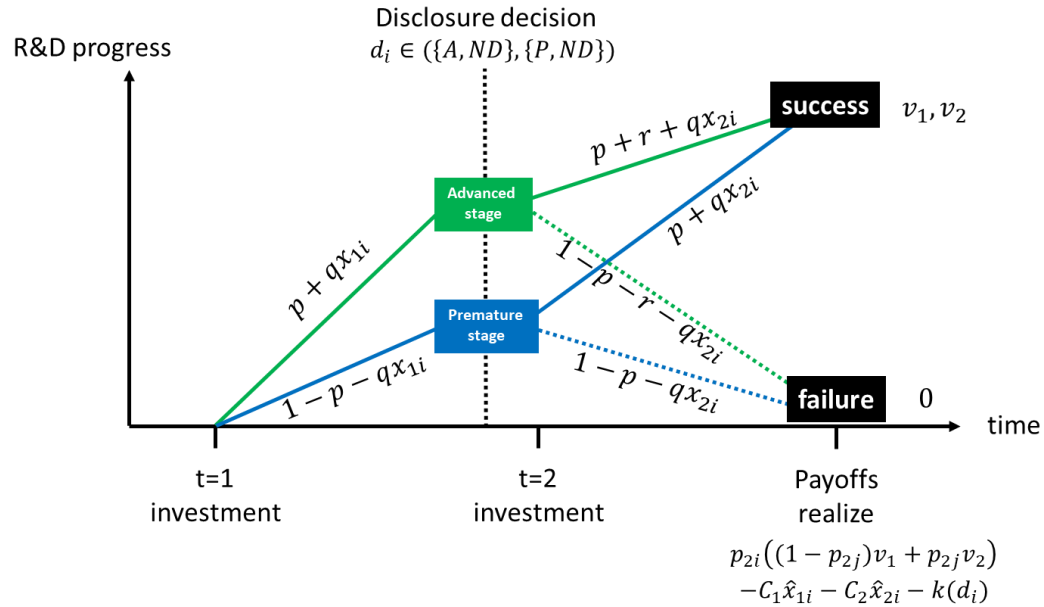
Figure 2: First period investment levels in the full disclosure equilibrium for different values of $\frac{v_1-c_2}{v_1-v_2}$ and c_1. Recall that for the full disclosure equilibrium it holds that $k \leqslant \underline{k}$.
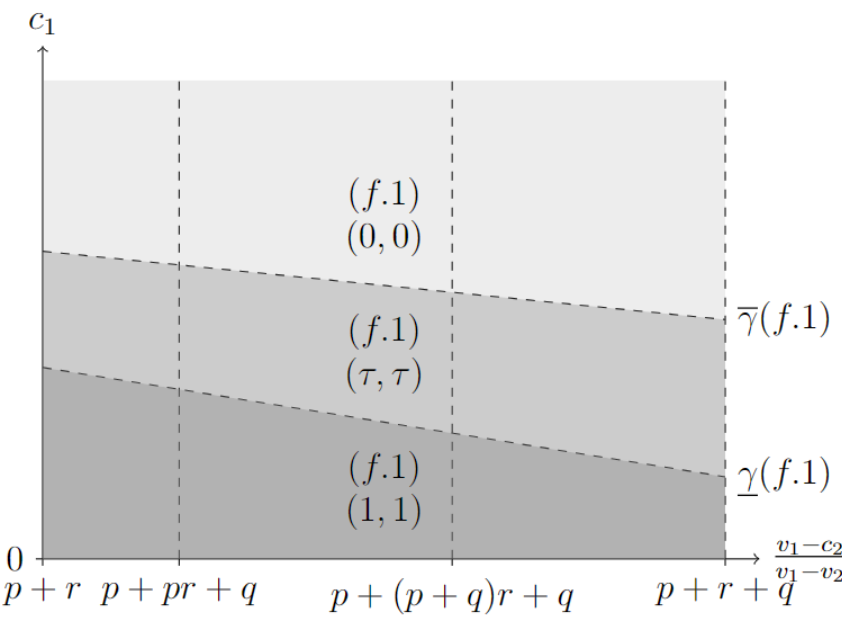
Figure 3: First period investment levels in the non-disclosure equilibrium for different values of $\frac{v_1-c_2}{v_1-v_2}$ and c_1. Recall that for the non-disclosure equilibrium $(n.1)$ it holds that $k \geq \bar{k}$.
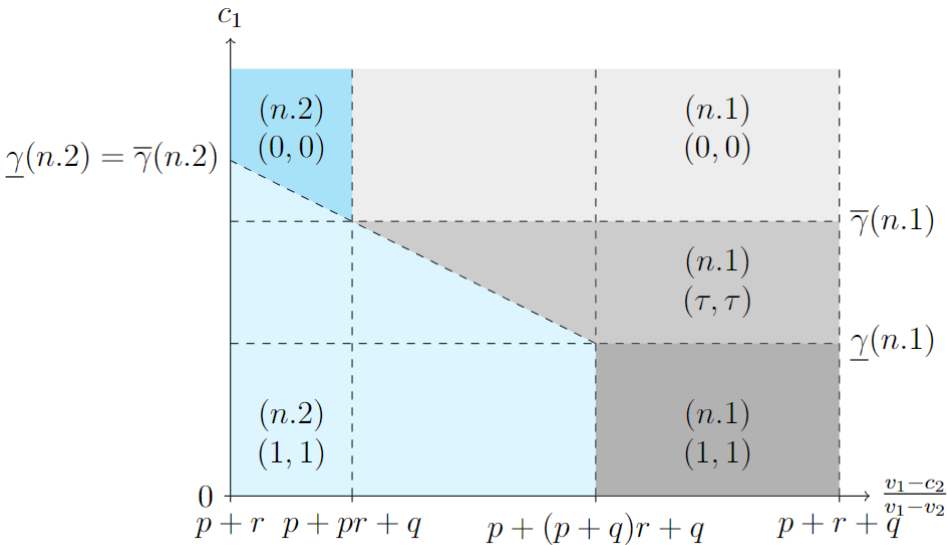
Figure 4: First period investment levels in the asymmetric disclosure equilibrium for different values of $\frac{v_1-c_2}{v_1-v_2}$ and c_1 and $\underline{k} \leqslant k \leqslant \bar{k} - qr^2(v_1 - v_2)$.
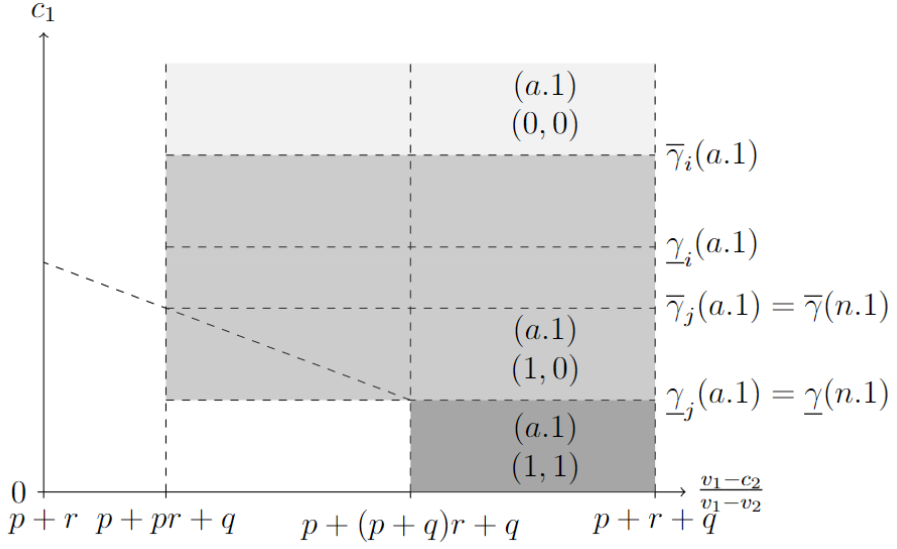
Figure 5: First period investment levels in the asymmetric disclosure equilibrium for different values of $\frac{v_1-c_2}{v_1-v_2}$ and c_2 and $\max\{\underline{k}, \overline{k} - qr^2(v_1-v_2)\}$ $\leqslant k \leqslant \overline{k}$.
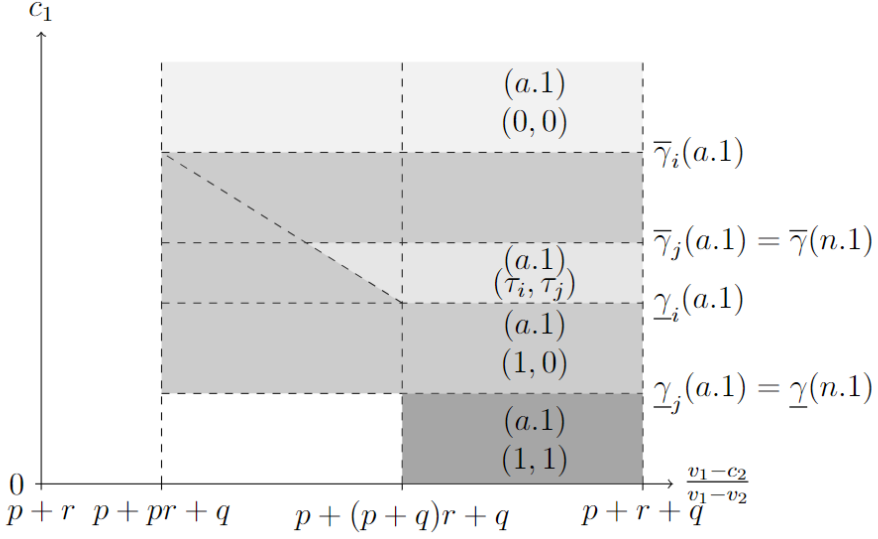
3 The effect of mandatory R&D disclosure on peer's voluntary disclosure

3.1 Introduction

The information spillover literature has primarily concentrated on the utilization of peer disclosure by investors or other stakeholders, with the central premise that correlated peer information provides insights into a firm's own fundamental characteristics (e.g., Foster, 1980; Savor and Wilson, 2016). However, the impact of peer disclosure on firms' own disclosure choices has received less attention (with a few exceptions, such as Baginski and Hinson, 2016; Breuer, et al., 2022; Seo, 2021). This paper explores how and why firms adjust their disclosure in response to increased peer disclosures, with a specific emphasis on R&D information. The focus on R&D disclosure is motivated by two reasons. Firstly, by limiting the disclosure to a particular area - R&D-related information - the study can analyse spillover effects within that scope and uncover the underlying motivations when categorization is applied to the disclosure items. Secondly,

the examination of the spillover effect on R&D information enhances our understanding of the cost-benefit balance of R&D disclosure, a trade-off that may differ from other forms of disclosure due to the potential high level of proprietary costs and the high uncertainty of its value relevance (e.g., Cao et al., 2018; Jones, 2007).

Using the establishment of China's Science-Technology and Innovation Board (the STAR market) as a research setting that creates a shock in the provision of R&D disclosure, I investigate the causal impact of R&D disclosure by the STAR market applicants on the voluntary R&D disclosure of non-STAR peer firms. [11] The STAR market – specializing in the technology industry as a segment of the Shanghai Stock Exchange (SSE) – was established in 2019 and introduced a large set of regulatory innovations, among which is a substantial requirement for the disclosure of R&D information in listing application documents. In contrast, firms in the non-STAR market are subject to more lenient R&D disclosure requirements. Thus the publication of application documents in the STAR market resulted in a setting where only the non-STAR firms that have a peer firm going

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[11] Non-STAR firms are listed firms in China's A-Share market other than the STAR market.

public on the STAR market experience a substantial shock in the R&D disclosure by their peers, while other non-STAR firms are not directly affected. Since the establishment of the STAR market or the decision of the peers to list on the STAR market is arguably exogenous to non-STAR firms, the introduction of the STAR market allows for a cleaner test for the effects of increased peer R&D disclosure on a firm's own voluntary R&D disclosure.[12]

R&D disclosure is a specific category of firms' financial disclosure and understanding the value relevance of a certain piece of technology can be difficult for investors without all the relevant knowledge. Details of the core technology stock, R&D activities, and research staff are particularly vital for the valuation of firms that heavily rely on technology. However, this information may also be the most commercially sensitive.[13] The cost-benefit trade-off for non-STAR firms to disclose R&D information can be affected by STAR firms' R&D disclosure and/or STAR firms raising equity publicly

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[12] ItI is not possible to simultaneously list on the STAR market and another segment of the China A-share market and I do not observe any A-share firms that switch to the STAR market in practice.

[13] Firms in the STAR market are required to disclose these items but disclosure is largely voluntary for non-STAR firms. This information is likely required for the STAR firms for its value relevance, since the key role of the disclosure regulation is to stimulate trading by reducing information asymmetry. See the mission of the STAR market at: http://star.sse.com.cn/en/gettingstarted/overview/

in different ways. The new STAR market results not only in more R&D disclosure but also offers all private firms better access to finance, thereby increasing the competition with their non-STAR peers. Hence, product market competition-related arguments could support a reduction in non-STAR firms' R&D disclosure due to higher proprietary costs (Verrecchia, 2001) or an increase in disclosure due to entry deterrence incentives (Darrough and Stoughton, 1990; Glaeser and Landsman, 2021). Capital market-related arguments can support a reduction of non-STAR firms' R&D disclosure due to free-riding (Foster, 1980), or an increase in disclosure due to lower investor response uncertainty (Dutta and Trueman, 2002; Suijs, 2007) or lower uncertainty with respect to information endowment (Dye, 1985; Jung and Kwon, 1988). Which explanation prevails is an empirical question which I test in this paper.

To test non-STAR firms' response to more STAR peers' R&D disclosures, I use all manufacturing firms listed in the non-STAR market as my full sample and employ a difference-in-difference (DiD) approach in which the treatment is whether or not a non-STAR firm is named as a direct competitor by a

STAR market applicant in its prospectus.[14] I use as my control group the non-STAR firms that are matched to each treated firm via propensity score matching (PSM).[15] Next, I use two distinct methods to capture different dimensions of R&D disclosure. The first approach (*Disc_items*) is similar to LaRosa and Liberatore (2014) and builds a disclosure index based on R&D-related information items that are required by STAR market regulation. The second approach (*RD_sent_ratio*) follows Merkley (2014) and counts the R&D-related sentences in annual reports based on pre-established keywords as a proportion of the total number of sentences.

I find that after observing the R&D disclosures of their STAR peers, non-STAR firms reduce their disclosure of R&D information by 4 percent (*RD_sent_ratio*) or 4.3 percent (*Disc_items*) relative to the matched control group. The main results support either the free-riding argument or the proprietary cost argument since the effects are negative. To investigate the underlying incentive for this reduction, I conduct several additional tests. First, I find that the identified negative peer effects only appear for the subsample of treated firms in a poor information environment, while the

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[14] The non-STAR tech firms and the treatment sample/firms are used interchangeably in the paper.
[15] The matching approach will be discussed in more details in Section 3.4.1.

effects are not different for treated firms in more versus less competitive industries. Next, I classify the disclosure items as revealing proprietary or non-proprietary information and find that the reduction in disclosure occurs mainly in the non-proprietary category. Finally, I test how the stock market responds to the decrease in disclosure by analysing the change in stock liquidity of the treated firms after the introduction of the STAR market and find that the stock liquidity is unchanged. The results are robust to the use of alternative control firms as well as to the exclusion of the event year 2018. Overall, the evidence supports the free-riding argument as the incentive for the negative spillover of firms' R&D disclosure.

My study contributes to the literature that studies the peer effects of disclosure or disclosure spillover in several ways. Firstly, I focus on a specific type of information (R&D disclosures), while the previous studies (Baginski and Hinson, 2016; Breuer et al., 2022; Seo, 2021) study changes in disclosure more generally. Restricting the disclosure in question to a specific scope not only facilitates examining the spillover effect on disclosure that contains the same set of information, but also reveals the underlying incentive(s) of the spillover by revealing potential different effects to subgroups of information. Besides, studying the disclosure

spillover of R&D information by itself reflects a trade-off for which the proprietary costs are highly relevant (e.g., Kim and Valentine, 2021). Secondly, the context of my study also differs from prior studies. For instance, Baginski and Hinson (2016) study market exit while my work focuses on market entry, which is a different market dynamic. Meanwhile, the going-private firms in Baginski and Hinson (2016) were subject to the same disclosure regulation as the remaining public firms before they were delisted while the going public STAR firms in my setting face a more stringent disclosure regulation than the focal firms from the non-STAR market. Furthermore, both Baginski and Hinson (2016) and Breuer et al. (2022) start with a setting where the free-riding is the primary focus, while my work focuses on a comparison of different incentives including the free-riding incentive and allows for multiple incentives *ex ante*. Finally, my study extends spillover literature by documenting differential effects to different types of information.

The novel setting of the STAR market has some features that allow me to draw a clean, albeit imperfect, causal conclusion when documenting the spillover effects. First, the increase in peers' disclosure is arguably exogenous to the non-STAR focal firms since their STAR peers' decision to go public

on the STAR market and to name non-STAR firms as their competitors are outside of the treatment firms' control. Second, I identify treatment firms as those firms mentioned by STAR peers as their competitors rather than merely relying on industry classification. Finally, my detailed analysis of specific R&D disclosure items helps me to document spillover effects on a granular level, as I examine whether the disclosure of a specific information item by a STAR peer results in the reduced disclosure of the same information by the treated non-STAR firms.

This study also contributes to the strand of literature that studies a firm's narrative R&D disclosure in the annual reports and its relevance to market participants (e.g., Guo, et al., 2004; Jones, 2007; Merkley, 2014; Cao et al., 2018; Glaeser, 2018). My findings suggest that a firm's narrative R&D disclosure is also relevant to peer firms and leads to a change of peer firms' R&D disclosure. This work also sheds light on the trade-off of the costs and benefits of a firm's R&D disclosure. Specifically, the entry of competitors in a new market is a complex event which may affect existing firms' voluntary disclosure in multiple ways. The observed net effects indicate that the free-riding incentive dominates in companies' voluntary disclosure decision process.

Finally, this study also contributes to the literature that studies the externalities of disclosure regulation (e.g., Admati and Pfleiderer, 2000; Bushee and Leuz, 2005) by providing insights on both the market-wide change in information supply after an introduction of disclosure requirement and the potential market response. It also answers the call for research on the externalities of disclosure regulation from Leuz and Wysocki (2016). The negative spillover effects together with the absence of stock liquidity consequences suggest that the mandatory R&D disclosure requirement does not affect the overall information environment for the broader unregulated but related market sectors; however it may achieve unintended benefits beyond informational benefits like cost saving in information production.

3.2   Background and Hypothesis Development

3.2.1   The Chinese stock market and the launch of the STAR market

The STAR Market in China was announced in November 2018 for its launch in 2019.[16] This new market only allows listings of high-tech firms and aims to promote the technology sector by alleviating the financing constraint and

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[16] See:
http://www.sse.com.cn/star/en/infodisclosure/newsrelease/c/c_20190711_4860930.shtml

stimulating innovation investments.[17] In China's bank-dominated capital market, small and medium enterprises (SMEs) cannot easily get bank loans with affordable interest rates without collateral. Tech companies that have fewer tangible assets than traditional manufacturing firms normally face even more severe financial constraints. The new STAR market was therefore introduced to alleviate the financial constraints faced by the technology SMEs.

Prior to the establishment of the STAR market, the A-share stock market in China consisted of the Main Board, the SME Board, and the ChiNext Board.[18] The Main Board comprises the large-cap stocks, while the SME Board consists of the mid-cap stocks traded on the first-tier market. ChiNext is the second-tier market, targeting start-up or early-stage companies and employing different regulations than the first-tier market. ChiNext was the

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[17] The regulation document (in Chinese) is available on the Shanghai Stock Exchange website under: http://kcb.sse.com.cn/lawandrule/regulations/csrcorder/ According to the Guideline of the SSE, the focal industries include New Information Technology, High-end Equipment, New Materials, New Energy, Energy Saving, Bio Technology, and other new technological and strategic industries. The new market likely has a domino effect on the capital allocation into the technology sector. Due to the access to the public equity market, the tech SMEs will become a more feasible business sector for other finance providers, such as banks and private equity. For instance, banks are likely more willing to lend to a listed firm than to a comparable private firm due to potentially lower screening and monitoring costs. Private equity is likely more willing to invest in a firm that has a visible and reliable exit channel.

[18] A-share stands for all the CNY-denominated stocks traded on the Shanghai or Shenzhen Stock Exchange, issued by mainland China based firms.

first trial to establish a Nasdaq-style board but seems to have failed to attract some of the most prominent technology firms.[19] The objective of the STAR market to serve the tech firms is expected to be achieved by promoting disclosure transparency for R&D-intensive tech companies and by shifting the regulator's role from screening towards supervision.

The plan to introduce the STAR market can be traced back to November 2013 in the Third Plenary Session of the 18th Central Committee of the China Communist Party. However, regulatory details, and especially details on disclosure regulation, were only gradually released between January and March 2019 shortly after the official announcement to set up the market on 5 Nov 2018. [20] The application opened on March 18, four days before the first batch of nine applications were submitted on March 22 when the relevant prospectuses were published online.

3.2.2   R&D disclosure requirements in the non-STAR market

The disclosure regulation in the non-STAR market, concerning firms' R&D activities as well as other types of information, has become more stringent

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[19] See http://theconversation.com/chinas-nasdaq-fails-to-get-off-the-ground-as-venture-capitalists-look-to-the-us-24170.
[20] See the press release at the People.cn: http://politics.people.com.cn/n/2013/1115/c1001-23559207.html (in Chinese)

over the past decades, but remains rather lenient. The most recent and stringent regulatory amendment for annual reports of listed firms that came into effect in 2017 requires disclosure of a limited set of information. According to this regulation, firms need to discuss both their R&D activities during the current fiscal year and their R&D plans for the future. Relating to the R&D activities during the current fiscal year, the regulation stipulates a list of information items. To illustrate the regulation evolvement over time, Appendix 1.1 summarizes the information items concerning R&D activities since 2012, which is the first year when firms needed to discuss their R&D activities in a separate section of the annual report.[21] However, in practice the regulation and firms' actual disclosure of their future R&D plans have remained general.[22]

3.2.3   R&D disclosure requirements in the STAR market

Detailed mandatory disclosure regulation on R&D-related information is a key difference in the STAR market compared to the non-STAR markets. The exact information items have a much broader scope and are explicitly

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[21] In spite of the regulation on R&D disclosure, it is possible to observe firms not disclosing certain information even if when they are required to do so potentially due to difficulty of enforcement.
[22] For instance, it is common for firms to include a one-sentence discussion on which technology sphere they will focus their R&D activities.

clarified in the disclosure regulation rules and were also explained later in a Q&A session held by the exchange to ensure that firms' managers understand what is expected.[23] Specifically, firms need to provide detailed information on at least four aspects of their R&D activities: (a) the core technology, (b) ongoing R&D projects, (c) research personnel, and (d) research capability. The information about the core technology, aiming at demonstrating a company's business persistence in the long run, needs to include the source of the technology, contributors, technological advantage, strength and weakness in the domestic and overseas markets, its market position, market dynamics, intellectual property (IP) management, as well as contribution to corporate revenue. The ongoing R&D projects section should at least include detailed information on individual projects: the corresponding expense, personnel, current phase, expected goals, comparative advantage within the industry, as well as contribution to corporate revenue within the reporting

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[23] The disclosure of regulation refers to *Standards for the Contents and Formats of Information Disclosure by Companies Offering Securities to the Public No. 41— Prospectuses of Companies Listed on the Science and Technology Innovation Board*, which is available at http://www.sse.com.cn/lawandrules/regulations/csrcannoun/c/4745606.pdf (in Chinese). The press release is reported at: http://kcb.sse.com.cn/announcement/notification/c/c_20190423_4779810.shtml; the context of this press release is that the information contained in the initial submitted documents by most of the 1st batch applicants was far from sufficient with large variation in quality. Therefore, the exchange intended to push those firms towards more and higher-quality disclosure.

periods. The introduction of research personnel needs to clarify, among other things, the overall ratio of the research staff to total staff, the members of the core research team, the credentials of each core staff, and changes in the core research team in the short run as well as its impacts on the firm. [24] Research capability mainly concerns firms' ability to conduct research, which includes innovation awards, and publications.

Appendix 1.2 presents an example of the disclosure contents from a STAR applicant compared to a similar non-STAR applicant. R&D disclosure reported by the STAR applicant contains more details in its final version of the prospectus than both its first version and that of a similar non-STAR firm. This comparison reflects the difference between the STAR and non-STAR markets concerning both disclosure rules and regulatory enforcement. Since this paper focuses on the effects of disclosure in the STAR prospectuses on the annual reports of non-STAR firms, it is important to note that these two types of documents contain information details to different extents. The scope of information provided in the prospectus is also generally broader due to its nature as the very first public disclosure made by a to-be-listed firm,

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[24] The credentials of each core member include education background, working experience, publication track records, awards, detailed contribution to the firm, as well as the incentive schemes.

while annual reports serve to update readers on the development and changes that have realized in the current fiscal period. I incorporate the differences while constructing the disclosure measures.

Due to intensive media coverage, it is unlikely that the listed firms from the non-STAR markets are not aware of the STAR applicants as well as the prospectuses submitted, which are published on the exchange's website.[25] Moreover, the relevance of the new information to various stakeholders is also intuitive. For instance, the industry analysis could support a more precise relative firm valuation. A company's core technology helps investors assess the company's cash flow generating ability. Details of the ongoing projects give information on the company's progress in updating its current technology. The budgeting and research team information of each ongoing research project hint at the possible success rate or the extent of maturity. While this information likely benefits the disclosing firm in attracting investors, it could also induce the rivals to adjust their R&D plans

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[25] For instance, it is often labelled as the Chinese version of Nasdaq in news reports. See http://www.xinhuanet.com/fortune/2019-07/22/c_1210207515.htm. The market is also a key step towards the capital market development in China, so it is unlikely that a manager of a listed company is not aware of this event.

accordingly which in turn dampens the potential return of the disclosing firm's own R&D investments.

3.3 Hypothesis development

The establishment of the STAR market may affect the disclosure of R&D-related information of the non-STAR firms in multiple dimensions, which can be summarized as either capital market or product market-related incentives.

On the one hand, the non-STAR firms may change their R&D disclosure policy for **capital market incentives**.[26] I consider free-riding, information endowment uncertainty, and investor response uncertainty as three potential capital market incentives of how the STAR market would affect the non-STAR firms' R&D disclosure. The free-riding argument posits that peer disclosure can be used as a substitute for the firm's disclosure to infer a firm's fundamentals (Foster, 1980). Baginski and Hinson (2016) document a negative association between peer disclosure of management earnings forecasts and a firm's own forecast disclosure using a setting with cessation of peer forecast disclosure. The newly available information about STAR

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[26] I use capital market incentives to refer to incentives that relate to a firm's market valuation.

firms, if relevant to the fundamentals of the non-STAR firms, likely decreases the marginal benefits of non-STAR firms' own disclosure, therefore incentivizing the non-STAR firms to **decrease** their voluntary disclosure to save the costs of information collection and dissemination. The overall upward trend in R&D disclosure indicates it is feasible for both upward and downward adjustments. An upward adjustment on top of the increasing trend is possible as long as firms have not disclosed everything they know. A downward adjustment is also possible since firms can choose a slower increase.

The other two capital market incentives relate to two types of uncertainty from the investor's perspective which then affect a firm's disclosure decision, i.e., how much private information a firm *can* disclose (information endowment uncertainty) and whether this private information is perceived as good or bad (investor response uncertainty). Regarding the information endowment uncertainty argument, Dye (1985) and Jung and Kwon (1988) find that firms can withhold bad private information if investors are not able to differentiate them from non-informed firms. Dye and Sridhar (1995) find that when more firms receive firm-specific and private information in an industry, it updates investors' perception of whether a non-disclosing firm is

also informed of that information. For example, prior to the STAR market, a non-STAR firm may not disclose its lack of progress in R&D because investors may not be aware of how quickly progress in R&D is feasible. When a STAR firm discloses its progress in R&D, investors update their perceptions and may want to know how much progress the non-STAR firm has made. Reduced uncertainty about a non-STAR firm's private information endowment **increases** the amount of information that the non-STAR firms will disclose.[27]

The uncertainty on the value implication perceived by investors leads to response uncertainty from the firm's perspective. Such *ex-ante* response uncertainty may result in more or less disclosure of "high" or "low" information by firms depending on prior valuation (Dutta and Trueman, 2002; Suijs, 2007).[28] In my setting, the nature of complicated technical information is likely obscure to investors, which makes it difficult for firms to anticipate how investors will respond to the disclosure of this technical information. STAR firms are required to disclose more contextual or industry

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[27] To illustrate this argument with a real real-world case: when startup Tesla Motors started the evolution of electric vehicles to a commercial mass production, other car manufacturers were pressured by the market to disclose their progress on in the development of electric vehicles. See https://www.energy.gov/timeline/timeline-history-electric-car

[28] In these papers, "high" or "low" information refers to the type of information that likely faces high level of uncertainty of investor interpretation.

information and to use "investor-friendly" language to facilitate investors' interpretation of value-relevant yet otherwise obscure information. [29] Meanwhile, only institutional investors and experienced retail investors are allowed to participate in directly trading STAR stocks, which further enhances the accuracy of the pricing. The response to R&D information disclosures in the STAR market may therefore serve as a benchmark for the non-STAR listed firms. Non-STAR firms may **increase** (do not change) their R&D disclosure when STAR investors respond positively (negatively) to R&D disclosure in the STAR market.

On the other hand, increased access to capital for **product market competitors** may affect disclosure incentives for firms due to the change in proprietary costs (Verrecchia, 1983).[30] The proprietary costs can take the form of either inducing existing rivals to operate against a firm's interests or encouraging potential entry. The ability of existing rivals to exploit the information disclosed induces firms to withhold commercially sensitive

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[29] The use of "investor-friendly" language has been explicitly clarified and required in this press release:
http://kcb.sse.com.cn/announcement/notification/c/c_20190423_4779810.shtml

[30] Based on my full sample, the average increase in the number of listed firms between 2012 and 2019 is around 8% excluding the STAR firms. In 2019, the STAR market brings on average 1.4% more listed firms for the tech industries based on two-digit industry code, which is a substantial change. I assume that compared to a private firm, a similar public firm more likely acts effectively in exploiting peer information due to better access to finance and thus a broader action space.

information. Huang et al. (2017) find that an exogenous increase in competition leads to reductions in voluntary disclosures. For the non-STAR firms, the newly listed firms of the STAR market become new competitors due to their access to finance. Therefore, the non-STAR firms are expected to withhold more proprietary information. The reason proprietary costs might increase is that the increased access to external funding makes the STAR firm better able to exploit the information disclosed by any non-STAR firms.

When the incumbent uses disclosure to discourage entry as modelled in the entry game in Darrough and Stoughton (1990) a higher probability of potential entry induces more disclosure of both favourable and unfavourable news. [31] Since the establishment of the STAR market broadens the financing channel for the technology industries, especially for the early-stage firms, the whole sector is likely going to face a higher probability of entry. [32] Therefore, disclosure of both good and bad news will increase.

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[31] They do not assume the uncertainty of manager's information endowment but rather that every firm has private information, either favorable or unfavorable. Both a full disclosure and a partial disclosure equilibrium are found. The condition for a partial equilibrium is either (a) the prior belief of market potential is pessimistic or (b) the entry cost is high, both of which suggest a lower entry probability. A full disclosure equilibrium is achieved when conditions are consistent with a higher entry probability suggesting that the increase in entry probability encourages disclosure.

[32] Here the new entrants refer to potential entrants into the product markets in the future rather than the entrants to the capital markets. This argument may work because the IPO is

Overall, the above theories provide predictions for a firm's disclosure policy in response to an increase in peer disclosures and/or change in market competition. It is unclear *ex-ante* how the non-STAR firms would respond and which mechanism dominates in explaining the changed disclosure policy, if any. The proprietary cost and free-riding arguments predict a **reduction** in the non-STAR firms' voluntary R&D disclosure whereas the entry deterrence, and the uncertainty arguments predict an **increase** in the non-STAR firms' voluntary R&D disclosures. The above arguments lead to the following hypotheses:

H1a: the non-STAR tech firms increase their R&D disclosure after the establishment of the STAR market.

H1b: the non-STAR tech firms decrease their R&D disclosure after the establishment of the STAR market.

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one of the major exit channels for early stage investors, e.g., the private equity and angel investors. Higher chances of going public encourage more investors to enter the tech industry which in turn encourages entrepreneurship.

3.4 Sample selection and Research design

3.4.1 Treatment and control samples

The treatment sample consists of all listed firms on China's A-share market that are named by any STAR market applicant from the manufacturing sector as its direct competitor. [33] I focus on the manufacturing sector for the following reasons. Firstly, the manufacturing sector covers a broad range of industries from food processing firms to pharmaceutical companies, making it by far the largest sector for both the STAR market and the non-STAR market. [34] Secondly, manufacturing firms are more likely to engage in substantial R&D activities in order to sustain their competitiveness in the long run, which is supported by the overrepresentation of manufacturing firms in the STAR market applicants.

The very first batch of applications to the STAR market were submitted on March 22, 2019. Every year April 30 is the deadline for non-STAR firms to submit their annual report for the past fiscal period. [35] I collect all STAR

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[33] A few cases are such that the named direct competitor is a daughter company of a listed firm, while the daughter company's financial data nor its annual reports are available. In these cases, the data of the parent company is used instead. An untabulated text shows that these cases do not affect the main results to be presented later.

[34] The manufacturing sector contains all firms with a CSRC industry code that starts with "C". The full list of public firms is available at CSRC website and is updated every quarter: http://www.csrc.gov.cn/pub/newsite/scb/ssgshyfljg/

[35] In China, the fiscal year is the same as the calendar year for all listed firms.

applicants that submitted their application dossier before April 30, 2020, and I manage to identify a total of 199 STAR applicants/prospectuses. I manually collect the direct competitors mentioned in those prospectuses.[36] 379 non-STAR firms are identified, out of which one is a newly listed firm on the non-STAR market, 42 firms are from the non-manufacturing industries and 91 do not have market value data available as of 2018. As shown in Table 1, excluding these companies results in 246 candidates of treatment firms to be matched with a control firm. I use Propensity Score Matching (PSM) to match the control sample mainly to offset the overall trend of disclosure dynamics throughout the sample period. I employ matching with replacement using the covariates that load in a logit model predicting the propensity to be treated as of 2018. This results in a control sample that does not exhibit a difference in any of the covariates from the treatment sample as shown in Panel B of Table 2. The PSM drops 12 firms from the initial candidate pool since no similar control firm can be identified. The final sample used for the main results consists of 234 (197) unique treated (control) firms. 819 (out of 959) firm-year observations from the control group enter into the main results once while the remaining observations re-

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[36] In case there are multiple versions of prospectuses submitted throughout the application process, the last version before April 30, 2020 is used to identify the treated sample.

enter the analysis up to 5 times. Since the sample period is 2014 through 2019, not all firms existed in 2014, leading to an unbalanced sample with more observations for more recent years.

Since I focus on firms' disclosure in the annual reports, the sample consists of annual observations. 2012 was the first time when non-STAR firms were required to disclose their R&D activities in a separate section in the annual reports with a set of specific information, so annual reports before 2012 contain little R&D information.[37] Appendix 1.1 summarizes the regulatory requirement regarding R&D disclosure in the non-STAR market and shows that even after 2012 the R&D disclosure requirements in the non-STAR market have remained brief. Due to missing values for the R&D expenses in years 2012 and 2013 in *Compustat Global,* my final sample consists of 2,136 firm-year observations from 2014 to 2019.

3.4.2 Disclosure measures

I use two measures to capture different dimensions of firms' R&D disclosure strategies. The first measure follows Merkley (2014) and captures the total number of sentences related to R&D activities (*RD_sent_ratio*). The second

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[37] See the official regulation at:
http://www.csrc.gov.cn/pub/newsite/flb/flfg/bmgf/xxpl/xxplnr/201310/t20131017_236414.html (in Chinese)

measure is a self-constructed disclosure index consisting of unique R&D information items (*Disc_items*) derived from the mandatory disclosure requirements for the STAR market.

RD_Sent_ratio

I develop the list of keywords based on the keyword list of Merkley (2014) and adjust it according to the Chinese language norms.[38] The full list of keywords in Chinese together with the corresponding English translation is presented in Appendix 4. Every sentence in the annual reports is classified as R&D-related or not R&D-related based on the list of keywords. The measure *RD_Sent_ratio* is calculated as the number of R&D-related sentences divided by the total number of sentences in the annual report.

Disc_Items

To construct this measure, I start with the required items in the regulation and then make adjustments according to their relevance to the annual reports. I include the final list of the 48 disclosure items in Appendix 3. *Disc_Items*

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[38] For instance, all the keywords that contain "research" or "clinical", e.g., [research project, research collaboration, research facility, etc.] or [clinical data, clinical study, clinical development, etc.] are merged to "R&D" and "clinical" respectively since these two words are almost unique and irreplaceable in Chinese.

is the count of unique items disclosed over the total number of items, multiplied by 100. For instance, when a company discloses 10 items in its annual report *Disc_Items* equals 10/48 *100= 20.83. This variable can be interpreted as the average likelihood of any items to be disclosed. I construct *Items* based on STAR regulation not only because it is the best reference to build a disclosure index but also to analyse a spillover effect on the information level, a spillover from R&D disclosure to R&D disclosure.

Each disclosure item is coded as 1 when that item is identified in the file regardless of how many times and as 0 when that item is not identified. I code the items individually in a semi-manual way combining an initial screening using Regular Expression and a subsequent manual check. Appendix 5 includes more details on the coding process.

3.4.3 Baseline model

I use a difference-in-difference (DiD) approach to test the hypothesis, using the following model:

$$Disclosure = \beta_0 + \beta_1 STARpeer + \beta_2 Post + \beta_3 STARpeer \times Post +$$
$$\sum \beta_4 Controls + \varepsilon \qquad (1)$$

where the dependent variables are either *Disc_Items* or RD_*sent_ratio*. *STARpeer* serves as the indicator for the treatment group and *Post* variable is a time indicator that equals 1 for the fiscal period 2019 and 0 otherwise. The variable of interest is the interaction of *STARpeer* and *Post,* which captures the average treatment effect. The model includes industry-fixed effects based on *Indcd*.[39] Throughout the paper, I follow the same set of control variables for a firm's voluntary R&D disclosure as in Merkley (2014). The financial data is obtained from CSMAR and Compustat Global.

As summarized in Merkley (2014), the control variables are mainly used to proxy for firms' earnings performance, information environment, investment mix, uncertainty, and financing. Firms voluntarily disclose more when they are in a richer information environment, i.e., when they are larger in size, are more influenced by external stakeholders, or have longer history of being public. Firms' disclosure strategy is also in line with their underlying investment activities in the sense that firms disclose more when they report high R&D expenses, more intangible investments or less tangible investments. I also control for uncertainty (proxied by *ROA_SD* and *Volatility*) although its relation to demand for information is ambiguous.

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[39] *Indcd* is the industry code issued by the CSRC which is equivalent to two-digit SIC.

Despite that demand for information is higher when uncertainty is higher, the supply of accurate information is either more difficult or more costly. Finally, firms' need for equity financing also leads to more voluntary disclosure, i.e., when a firm has more equity in its capital or issues new shares in the current fiscal period. Appendix 2 presents the variable definition in more detail.

3.5   Results

3.5.1 Descriptive statistics

Table 2 Panel A provides the descriptive statistics for the variables. The mean of *Disc_items* indicates that on average firms disclose about a quarter of the list of R&D items which is 12 items out of a possible 48. The mean number of R&D-related sentences a firm discloses is 264. Given the average total number of sentences (i.e., 8,510), R&D-related sentences make up roughly 3 percent of the entire report.

The summary statistics of all control variables are provided in Table 2. The distribution of Total Assets is right-skewed, so I use log(Total Assets) in the analyses. The sample firms on average have been listed for 10 years. Firms spend around 6 percent of the total operating expense on R&D activities.

The last three columns of Table 2 provide a means comparison across the variables between the treated and the matched control sample. In general, the

PSM works well in balancing the covariates between the treated and the control sample. The treated firms disclose significantly more R&D information on average than the control firms. All other control variables are statistically insignificant between the treated and control firms.

3.5.2 The peer effect on R&D disclosure

The main analysis of this study tests how non-STAR firms adjust their R&D disclosures when observing more R&D disclosure from their STAR peers. Table 3 summarizes the regression results of estimating the baseline model following Model (1). Columns (1)-(4) ((5) – (8)) present the regression results regarding *RD_sent_ratio (Disc_Items)*.

Prior to the STAR market setup, treated firms on average use more sentences to discuss R&D activities, suggesting the treated firms may face lower costs and/or higher benefits of disclosure. After controlling for the determinants of disclosure, this difference in *RD_sent_ratio* accounts for 7 percent (13 percent) of the mean with (-out) the industry fixed effects; the corresponding difference measured by the *Disc_items* is 3.4 percent (5.8 percent). The time trend, as indicated by *Post*, is inconsistent between the sentence and item measures, implying that the report is getting longer over time but the R&D information per page does not change substantially.

When it comes to the spillover effects of interest, the treated firms tend to **reduce** their R&D disclosure relative to control firms when observing more R&D disclosure from their peers and the results are robust across specifications. The univariate analysis in column (1) and (5) shows that the estimated coefficient of the peer effects on R&D disclosure is -0.112 and -0.973 measured in sentences and items respectively. This coefficient indicates that the treated firms **reduce** their R&D disclosure by 3.4% (3.9%) of the average level of disclosure prior to the establishment of the STAR market when the disclosure is measured in *RD_sent_ratio* (*Disc_items*). Adding controls and/or fixed effects does not change the size of the estimated peer effects. In column (2) and (6), the results show that the magnitude of the peer effects are almost the same after controlling for observable firm characteristics. In column (3) and (7), adding industry fixed effects does increase the effect magnitude slightly to 4% (4.3%) of the pre-period mean value.[40] Finally, as shown in column (4) and (8) adding firm fixed effects provides the most conservative estimate of the treatment effect, which also subsumes the *STARPeer* dummy. In this specification, the magnitude of the peer effects is not substantially different with the results with industry fixed

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[40] The average value for the treated firms for 2014-2018 is around 3.25 (24.52) for *RD_sent_ratio* (*Disc_items*).

effects. In fact, the coefficient (t-statistic) even turns larger with *RD_sent_ratio* (*Disc_items*). Overall, the main results in Table 3 imply that the non-STAR tech firms decrease their R&D disclosure after the establishment of the STAR market, consistent with hypothesis H1b.

The main results show the effects as of the fiscal year 2019 (t+1) compared to the average of all previous years (t-4 to t). To examine whether the establishment of the STAR market precedes the changes in peer firms' R&D disclosure but not vice versa, I conduct a placebo test using artificial treatment years for each year 2016-2018 (t-2 to t). Specifically, I estimate the regression as indicated in the following model:

$$Disclosure = \beta_0 + \beta_1 STARPeer + \sum \beta_2 FY + \sum \beta_3 STARPeer \times FY + \sum \beta_4 Controls + \varepsilon \tag{2}$$

, where $\sum FY$ are the year dummies and $\sum STARPeer \times FY$ are the corresponding interaction terms with the treatment dummy and the interaction terms serve as the variables of interest. Table 4 presents the results of this model. The results for *RD_sent_ratio* indicate that the reduction in disclosure identified in the study is only present in 2019. On the contrary, the results for *Disc_items* suggest there also appears to be a relative reduction in

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disclosure for treated firms in both 2017 (t-1) and 2018 (t), compared to the base period 2014-2015 (t-4 and t-3), even though the negative effect in 2019 appears to be the largest. One possible reason for this reduction prior to the introduction of the STAR market is the change in R&D disclosure regulation described in Section 3.2.2 which came into force in 2017 and requires firms to briefly discuss their R&D activities in the current fiscal period as well as future R&D plan. It is possible that the negative coefficient on the interaction term in 2017 and 2018 is primarily due to control firms starting to disclose relatively more R&D information compared to treatment firms. Overall, for the R&D sentence measure, these analyses suggest the negative spillover start after the introduction of the STAR market, although the *Disc_items* results should be interpreted with some caution.

3.5.3 Cross-sectional tests

The documented negative spillover effects could be due to the free-riding argument and/or the proprietary cost argument. Next, I test which explanation prevails in my setting using two sets of tests.

First, I partition my sample based on two variables measuring the extent of the free-riding incentive and the proprietary costs non-STAR focal firms face. The information environment is a proxy for the costs of producing and

disseminating information. The higher the costs of disclosure the greater the incentives for free-riding to reduce these disclosure costs. I construct a principal component from four variables that are documented by prior studies to be related to firms' information environment, namely, *logMV*, *Analyst Following*, *Firm Age,* and *Institutional Ownership* (Lang and Lundholm, 1993; Healy and Palepu, 2001) and I label this outcome variable *Info Environment*. I partition the treated sample into two subsamples within each industry with either a rich or poor information environment based on the industry median value of *Info Environment* in 2018.

Similarly, I use six variables to build the latent variable *competition*, i.e., *HHI, IndConfour, IndCapx, IndRD, logEntcost* and *IndMrkts,* (Li, 2010) which proxies for proprietary costs. Since competition is measured at the industry level, the partition is performed within the pooled treated sample based on the global median of *competition* in 2018.

Table 5 shows the results. Panel A shows that the negative peer effects only appear for the subsample in a poor information environment, therefore supporting the free-riding argument. The results for *RD_sent_ratio* indicate that the absolute magnitude of the peer effects is more than double of that for the pooled treated sample as shown in Table 3. Relative to the pre-period

mean of the treated firms, the magnitude of this effect is 12.6% reduction of disclosure. Instead of a convergence of R&D disclosure between the treated and control sample for the main results, the *STARPeer* and the interaction term show that the R&D disclosure level of only the treated firms in a poor information environment flipped in sign in the post period relative to the matched control firms. The results for *Disc_items* also provide a reversed pattern for the relative disclosure level for the poor information environment sample. The magnitude of this effect is around 8.4 percent of reduction in R&D disclosure of the treated firms from their average disclosure level in the pre-period.

Panel B shows that though the coefficients are slightly larger in magnitude for the subsample in low-competitive industries, the difference is not statistically significant. Had proprietary costs mattered, the effects would have been more pronounced for the subsample in more competitive industries. The results suggest that industry competition or proprietary costs do not appear to have a moderating effect. The results in Table 5 lend support for the free-riding incentive as an explanation for the reduction in disclosure by non-STAR focal firms.

3.5.4 Proprietary vs non-proprietary items

The second test examines what type of information is reduced by the treated firms. I classify the disclosure items into proprietary vs. non-proprietary using three criteria. First, proprietary items need to be firm-specific, otherwise the information cannot be exploited by competitors. Thus industry information or contextual information for instance is likely non-proprietary. Second, the information is not available elsewhere. Information such as patents and government grants is available in the patents database or the websites of government entities. The assumption is that the competitors already have the information available elsewhere since they have strong incentives to collect it. The final criterion is that the information needs to be actionable from the competitor's perspective. In this respect, I assume that proprietary costs arise from: either a) competitors adjusting R&D plans according to the focal firm's disclosure which in turn affects the return of the focal firm's own R&D investments, or b) competitors poaching the focal firm's research personnel by offering better employment terms.

The content-based grouping of items follows the STAR disclosure regulation and consists of four categories, i.e., *Stocktech, Capability, Flowtech and Staff*. The group *Stocktech* relates to the stock of technology the firm relies

on to generate its revenue. The *Flowtech* contains items that describe the status, plans, inputs and outcomes of the ongoing R&D projects or projects that are completed during the fiscal period. The group *Capability* consists of information related to the disclosing firm's innovation ability as well as a peer comparison of R&D input. *Staff* comprises information on firms' research personnel.

The classification results in 15 items being classified as proprietary items as shown in Appendix 3, which shows that these items primarily belong to two categories *Flowtech* and *Staff*. Table 6 Panel A summarizes the results using the proprietary and non-proprietary items as the outcome variables with the other specifications the same as in Model (1). The negative peer effects only load significantly for the non-proprietary items despite the larger magnitude of the coefficient for the proprietary category. The time trend exhibits growth in disclosure for both categories and the faster growth for the proprietary items is consistent with the overall trend in promoting transparency through the disclosure that likely focuses more heavily on proprietary information. In the pre-period, treated firms are not more likely to disclose proprietary information than the control firms. Combined with the results based on content in Panel B, it suggests that the strongest reduction in

disclosure occurs in the proprietary information on R&D projects and research staff. The evidence on proprietary vis-a-vis non-proprietary information therefore does not support the proprietary cost argument.

3.5.5 Market consequences – stock liquidity

One of the key benefits of any disclosure is to reduce information asymmetry and to facilitate trading (e.g., Verrecchia, 2001). Substituting peer disclosure for one's own disclosure may or may not have consequences for stock liquidity depending on the relative marginal benefits of the two. Theoretically, a firm's own disclosure should have a larger impact on its stock liquidity than similar peer disclosure. Under the free-riding incentive, the focal firm most likely tries to save the costs of disclosure while keeping the overall benefit constant. To test this conjecture, I follow Daske et al., (2019) and use *Zero Return* (Lesmond et al., 1999) and *Price Impact* (Amihud, 2002) to proxy for stock illiquidity. While *Zero Return* is the proportion of trading days in which the stock realizes zero return and relates to the transaction costs, *Price Impact* is the stock return in percentage over the CNY trading volume and measures the ability of investors to trade in a stock without moving its price. For both measures, the higher the value the less liquid a stock is. I employ a DiD regression similar to Model (1):

$$Illiquidity = \beta_0 + \beta_1 STARPeer + \beta_2 Post + \beta_3 STARPeer \times Post + \beta_4 Controls' + \varepsilon.$$

(3)

The results of estimating Model (3) using these two illiquidity variables as the dependent variables are shown in Table 7. The coefficient on *STARPeer_x_Post* is statistically insignificant across all specifications, indicating that the stock liquidity is not affected by the free-riding behaviour. Furthermore, both a firm's own disclosure and peer disclosure serve to inform investors and thus contribute to bridge the information gap between the company and external investors. Assuming there is no significant impact on the information provided by other information intermediaries, the combination of the insignificant interaction terms in Table 7 with the coefficients of the interaction term in the main results suggest when the informational benefit is kept constant the relative magnitude of the marginal benefits of a firm's own disclosure versus peer disclosure is around 14:1 (*RD_sent_ratio*) to 30:1 (*Disc_items*). Specifically, The main effects are -0.130 (-1.064) for the *RD_sent_ratio* (*Disc_items*) in the main results and represent 7 (3.4) percent of the disclosure by the treated firms prior to the STAR market was established. The unchanged stock liquidity suggests the reduction in a firm's own disclosure is a substitute for the peer disclosure of

the STAR applicant. Assuming the STAR applicant discloses a full set of R&D information and quantifying it as one, the relative benefit is 100:7 percent (1:3.4 percent) for the *RD_sent_ratio* (*Disc_items*), or around 14:1 and 30:1 respectively.

3.5.6 Alternative explanations

One may argue that the documented results are driven by the underlying operational adjustments in the R&D activities because the disclosure and/or the IPO of STAR firms deters firms from investing in R&D, resulting in a reduction in non-STAR firms' disclosure. This is unlikely in my setting for the two following reasons. First, the main difference between the treated and the control firms is whether or not they are peer firms of any STAR applicants. If STAR peers affect the treated firms' underlying operations and the disclosure thereof, it is likely due to the proprietary effect mentioned above; however, this argument is not supported by the evidence in Tables 5-7. Second, if both firms' real operations and resulting disclosure are affected, I expect the disclosure adjustment is more agile and thus observable earlier than the costly operational adjustment. Nevertheless, I run a formal test on the R&D expense changes for the treated firms using a simple regression with only industry fixed effects as control variables (untabulated) and find

the R&D expense ratio of the treated firms does not change while the natural logarithm of R&D expense even increases relative to the control firms. This helps to rule out the alternative argument that the underlying R&D activities are driving the reduction in disclosure.

3.5.7   Robustness tests

To rule out the possibility that the results are driven by the selection of control firms or by the matching procedure, I conduct robustness tests using two alternative control samples and tabulate the results in columns (1)-(4) of Table 8. The first alternative control sample is matched by only using *Total Assets* since in this way it is always possible to find a match such that no treated firm is dropped in the matching process. The second approach is to use all firms as the control sample from the same industries as the treated firms without using any matching methods. The negative spillover from the main results survives both of these two approaches and it supports that the main results are driven by the treated firms reducing disclosure rather than the control firms increasing disclosure.

My second robustness test examines whether the results still hold after excluding the year 2018. Due to the timing of the first batch of applications submitted in March 2019, it is technically possible for the treated firms that

are peers of the first applicants to already react in the annual reports of 2018. Considering the first batch of prospectuses make up only a small proportion of the entire sample of prospectuses, 2019 as the treatment year is used in the main setting but there it provides a robustness check by excluding 2018. As shown in columns (5)-(6) in Table 8, my main results still hold. I find the peer effects remain significant and even have greater magnitude. This confirms that the actual spillover occurs in the year when the treatment effects are the strongest.

3.6   Concluding remarks

In this study, I find that firms facing more R&D disclosure from peers reduce their own R&D disclosure. Furthermore, I find evidence that supports the free-riding incentive dominating in my setting. Specifically, the negative response is more pronounced for firms in a worse information environment where the costs of information production are higher such that free-riding helps save more costs. Meanwhile, the negative spillover effect is mainly driven by the group of information items that are non-proprietary. For firms that engage in free-riding, the market appears to maintain the same level of informational benefit from the disclosure. The main results are robust to using alternative control groups.

This study is among the first to examine firms' R&D disclosure strategy in response to increased peer disclosure. It is also the first of its kind that documents a spillover effect at the information level by restricting the peer disclosure as well as the outcomes in firms' own disclosure to the same set of information. The free-riding argument suggests that there is a replacement of non-STAR firm's disclosure with STAR firm's disclosure without benefiting nor hurting the informational benefit for the non-STAR firms. This study also quantifies the relative marginal benefit of a firm's own disclosure versus similar peer disclosure which is estimated to be 14:1 to 30:1. Given the primary goal of the STAR market to promote technological progress, whether or not this new market with R&D disclosure regulation indeed facilitates trading and thus helps increase R&D investment by the corporate sector or the whole society at large is an interesting topic for future research.

Appendix

Appendix 1.1. Evolvement of R&D disclosure regulation on non-STAR market

Period	2012-2015	2016-present
Current ongoing R&D projects	√	√
Goals	√	√
Progress	√	√
Expected outcome	√	√
Potential impacts on performance	√	√
Annual R&D input as a percentage of its audited net assets/revenue	√	√
Reasons for a change over 30% of the above ratios	√	√
Total number, proportion as all employees, of the R&D staff, and changes thereof		√
Capitalized proportion of total R&D input and changes thereof		√
Feasibility analysis of the above		√

Appendix 1.2. Comparison between R&D disclosure in STAR and non-STAR prospectus

Note: this table lists the items that are disclosed in the first and final versions of the prospectus of a STAR applicant (Beijing Worldia Diamond Tool, or Worldia)[41] and that of a similar applicant in the non-STAR market (Shandong Liancheng Precision Manufacturing, or SLPM)[42]. The categorization of disclosure items is provided in the disclosure regulation.

	Worldia (STAR applicant)	First version	Final version	SLPM (non-STAR applicant)
Core technology	Narrative introduction of 4 pieces of core technology	√	√	√ introduction is much shorter
	Comparative advantage analysis within the industry and the supply chain		√	
	Conclusion on whether or not the company has a comparative advantage	√	√	
	Revenue proportion contributable to all core technology as a whole	√	√	
	Process of how the relevant technology is acquired		√	
Research capability	R&D expenditure peer comparison		√	√
	Research personnel and patents peer comparison		√	√
	One story on the self-innovated technology and how it replaces the imported products		√	
Ongoing research projects	current phase, research team, total budget, content and target	√	√	√ without budget and team
	research method, strategic goal		√	
	government grants		√	
	dissection of R&D expenditure into HR, materials, depreciation and other	√	√	
	dissection of R&D expenditure as per each project category	√	√	
Research personnel	composition of the core research personnel, incl. research experience, awards, external positions, contributions to the firm	√	√	√

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[41] The first version and last version available at:
http://static.sse.com.cn/stock/information/c/201904/8077a756d3fd4ee5865c9141f0bbb12b.pdf;
http://static.sse.com.cn/stock/information/c/201907/576084654490480abbe4eeb6495065b1.pdf.
[42] Available at:
http://www.cninfo.com.cn/new/disclosure/detail?plate=szse&orgId=9900033213&stockCode=002921&announcementId=1204218167&announcementTime=2017-12-12%2017:00

	qualifying criteria for the core research personnel	√	√	√
	brief information of the incentive scheme	√	√	√
	changes of the core research personnel and the impacts thereof	√	√	√
Others	Summary statement on the research efficiency and sustainability	√	√	√
	Research equipment and their numbers	√	√	√

Appendix 2. Variable Definition

Disclosure measures
Disc_items: number of R&D related items disclosed in the annual report, all item measures are scaled by the total number of items considered in the corresponding category
Disc_stocktech: the composite of Disc_item on the core technology
Disc_flowtech: the composite of Disc_item on the ongoing R&D projects
Disc_capab: the composite of Disc_item on the research capability
Disc_rdstaff: the composite of Disc_item on the research staff
Disc_proprietary: the composite of Disc_item on proprietary
Disc_nonprop: the composite of Disc_item on non-proprietary

RD_sentence: a sentence that contains any R&D related keywords
RD_sent_ratio: number of R&D related sentences / total number of sentences

STARPeer: 1 if the firm is nominated as a direct competitor by any of the STAR applicants whose prospectus is submitted before April 30, 2020, and 0 otherwise

Post: 1 if the fiscal period is 2019, and 0 if the fiscal period is 2018 or earlier

adjusted ROA: operating income before R&D expense scaled by ending total assets

log(Total Assets): natural logarithm of total assets at year-end

Analyst Following: number of equity reports issued against a firm's stock,

Institutional Ownership: shares owned by all institutions / total shares to the firm,

Firm Age, Firm Age SQ: number of years since IPO; SQ stands for squared,

R&D Ratio, R&D Ratio SQ: R&D expense / total operation expense; SQ stands for square,

Book-to-Market: book to market value of total shareholder's equity at year end,

Capital Intensity: (net fixed assets + inventories) /total assets at year end

Volatility: standard deviation of monthly stock returns during the year,

ROA_SD: standard deviation of ROA (Net Income/Total Assets) of the past 3 years,

Leverage: (short-term debt + long-term debt)/total assets,

SEO (seasonal equity offering): 1 if firm issues stock during the year and 0 otherwise,

HHI: the Herfindahl–Hirschman index, the sum of squared market shares (by sales) of all firms in the industry, based on the industry code *Indcd;* the same applies for the industry-level variables below

IndConfour: the sum of squared market shares of the four largest firms by market share

IndCapx: industry average of capital expenditure weighted by market share

IndRD: industry average of R&D expense weighted by market share

logEntcost: industry average of net fixed assets weighted by market share

IndMrkts: natural logarithm of industry total sales

Zero Return: trading days with zero return over the total number of trading days during the year

Price Impact: stock return in percentage over the trading volume in million CNY

Turnover: annual trading volume in CNY over the market value of tradable shares in CNY

Appendix 3. List of Disclosure Items

Note: This table summarizes the items included in each category/composite of the disclosure measures defined in Appendix 2. The greyed items belong to the proprietary category.

Cat.		Item	Cat.		Item
Stocktech	1	Names of core tech	*Flowtech*	25	Project total budget
	2	Narrative introduction of core technology		26	Project spent budget
	3	Comparative advantage analysis within the industry		27	Project estimated time to completion
	4	Core product - technology link		28	Market potentials of new products
	5	Competitors for each core product		29	Reason for low R&D expense/R&D decrease
	6	Core tech is acquired or self-developed		30	Total number of projects
	7	Number of patents backing each core tech		31	Number of commissioned projects
	8	Sales core products breakdown		32	Number of collaborative projects
	9	Sales contribution all core tech		33	R&D expense reported separately
Capability	10	Discussion of peer firms for comparison		34	R&D expense / revenue
	11	R&D expense of peer firms		35	Decomposition of R&D expenditure into subclasses
	12	Revenue of peer firms		36	Number of subclasses of R&D expenditure breakdown
	13	R&D/revenue ratio of peer firms		37	Decomposition of R&D expenditure as expensed and capitalized
	14	Number of patents of peer firms		38	Criteria for R&D expenditure capitalization
	15	Number of own patents	*Staff*	39	Composition of the core research personnel
	16	Breakdown for different types of patents		40	Total compensation core member
	17	Innovation awards		41	Compensation components core member
	18	R&D equipment		42	Role core member
	19	Value of the R&D equipment		43	Ownership total core member
Flowtech	20	Names of ongoing R&D projects		44	Patents core member
	21	Project contents		45	Ad hoc disclosure file
	22	Project targets		46	Changes of the core research personnel and the impacts thereof
	23	Plan for future research projects		47	Number of R&D employees
	24	Project current phase		48	Average compensation R&D employees

Appendix 4. Keyword list for the *RD_Sentence*

Chinese	English Translation	Chinese	English Translation
研发	R&D	临床	clinical
产品开发	product development	药品	medicine
研究和开发	research and development	药物	medicine
研究、工程和开发	research, engineering and development	取得进展	breakthrough in
研究开发	research development	专有技术	proprietary technology
研究项目	research project	建立合作	established a collaboration
研究和评估项目	research and evaluation project	开展合作	announced a collaboration
立项	have a project registered or authorized	在研	projects in development
实施研究	conduct research	里程碑	milestones
技术	technology	评估	evaluation
项目合作	project collaboration	安全评估	safety study
开展	implement/conduct	安全评价	safety study
产品的开发	product development	试点	pilot
项目进展	project progress	初步研究	baseline study
产品转化	product transformation	专利	patent
产品升级	product upgrade	实用新型	utility model
产品改造	product alteration	外观设计	exterior design
科技	science and technology	发明	invention
技术成果	technological breakthrough	创新	innovation
突破创新	breakthrough innovation		

Appendix 5. Additional information on coding procedure of *Items*.

For the coding of each individual item, I use Python Regular Expression (RE) as a first step to screen sentences from the entire annual report that are likely relevant to this individual item. The initial RE patterns are derived from the STAR prospectuses as well as a dozen randomly selected non-STAR annual reports.[43] The list is then used to match a certain number of non-STAR annual reports and subsequently modified according to the matched results.[44] Specifically, a certain pattern starts as inclusive as possible and is either dropped out or combined with additional conditions if the matching results contain much more irrelevant than relevant cases, i.e., when the irrelevant cases exceed 90%. An extra step is applied for item 37 of which the dummy is defined as whether or not the firm breaks down the R&D expense into the number of items above the median value. For each annual report the output of the Python RE algorithm is a vector of 48 dummy variables for each annual report.

To offer a brief example of how the original narratives are coded as information items, the translated excerpts are provided in Appendix 6. Both cases in the examples belong to the scenarios where the firm discloses more information in 2019. The first case concerns the company's core technology and how they are acquired, where the firm discusses the exact technologies it relies on and that they are developed from the original ones acquired from oversees. This has potential implications for e.g., the company's ability to achieve a high product quality and maintain a low rate of defects. The second case relates to peer comparison, where the firm discusses at the product level who their competitors are and where the firm stands compared to those competitors. This could potentially facilitate a relative valuation.

Coding the narratives is realized by building up an RE algorithm consisting of positive and negative patterns and by manually correcting the residuals. The plain English equivalent of the corresponding positive pattern for Case I is "key/core technologies such as ..". However, this above pattern would include many cases where the firm actually describes the general trend at the industry level. To exclude the misidentified cases, additional negative patterns are added and for this particular case the plain English equivalent of the negative pattern is "key/core technologies

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[43] Using the STAR prospectus as the starting point is because of its organized structure in the sense that a group of items usually locate in a single chapter which facilitates the initial build-up of the RE patterns. Absence of information items is also relatively rare especially in the final version of the prospectus.

[44] The number of checked files varies across items. If a pattern is relatively common to observe or has little variation, 50 files could be sufficient, e.g., [8] sales core products breakdown. When a patter is rarely seen, I try to search as many as 2000 files. If an item is absent in all 2000 files, it is removed from the list, e.g., qualification criteria of core tech personnel.

such as .. are advancing/developing quickly". Sentences that match either/both the positive and negative patterns are stored and used for improving the algorithm. Every round of algorithm modification is followed by another match with a different group of random documents until the new match results reach an accuracy level of at least 70%. During the verification of the last round I store the corrected results which are to be used in the analysis. Overall, a particular item is coded as 1 if there is at least one sentence within a document that matches any of the positive patterns and it does not match any negative patterns, otherwise it is coded as 0 for that item. The output of the RE algorithm is a vector of 48 dummy variables for an individual annual report.

Appendix 6. Example R&D Information Items (Translated)

Case I

[*Tieliu*: 603926, 2017 Annual Report Revised page 7-8; 2018 Annual Report page 13]

(II) Company Strength on technology and R&D

We are equipped with a provincial level clutch tech centre and a testing centre that is the first one in the industry approved by CNAS. These labs are equipped with over 60 R&D and testing machines either produced by global leaders, such as a Three coordinate precision measuring machine by the British LK, a Metallographic microscope and an Electronic universal material tensile testing machine by the German ZEISS or by the company itself, such as a Spring fatigue testing machine, a Driven plate assembly torsion testing machine and a Double-acting clutch testing machine. (…) We have set up a postdoc workstation that is approved by Zhejiang Province. The Firm-University collaboration will promote the exploration and R&D of the frontier technology.

Our firm works with a research team of 150 (160) people, gaining a solid strength within the industry. We have been tech oriented with a special focus on developing new products, enhancing clients communications, maintaining high-quality service with both new and old clients, forming eventually client strength that is built on tech and service.

[*Tieliu*: 603926, 2019 Annual Report page 14]

[The same as the first paragraph above]

Meanwhile, our strength in technology and R&D is what ensures our leading role in the industry. With a ultimate focus on R&D, making advantage of the Diaphragm spring clutch manufacturing technology and key equipment introduced from oversees in the early years, **the firm has made technical breakthroughs in multiple key technologies such as dual mass flywheel and flywheel shock absorber.**

[The same as the second paragraph above.]

Case II

[*Tianyi*: 300504, 2017 Annual Report page 10]

(I) Company main business

(…) Our company's main business belongs to telecom industry. After many years, the telecom industry in China has combined the import and self-development of technologies and formed a complete supply chain. Innovation ability has been

improving and many technical breakthroughs have been achieved. (…) This industry will for sure embrace a bright future.

[*Tianyi*: 300504, 2018 Annual Report page 11-12]

(IV) Overview of Company's Industry

The company main business belongs to Telecommunication Manufacturing with the domestic telecom operators as the major clients.

The development of telecom industry is influenced by clients' demand, government support, technological advancement among other factors. The whole industry is promoting the network setup focusing on building the infrastructure. It is concentrating on new technologies such as optical communication, wireless communication, cloud computing, Internet of things, with special focus on promoting 5G, Internet of things, Smart +, which determines the future of and creates better opportunities of the whole IT industry.

[*Tianyi*: 300504, 2019 Annual Report page 10-12]

(III) Overview of Company's Industry and Market Competition

The company main business belongs to Telecommunication Manufacturing with the domestic telecom operators as the major clients.

1. Network   Terminal   Services
    (…) **The main competitors are the industry leaders such as Huawei, ZTE, Fiberhome, Nokia Shanghai Bell,** all of which have strong capital support and large market shares. **The size of our firm's R&D expense and sales are also ranked high**.

2. Wireless   Router
    (…) **The main competitors are Huawei, ZTE, Xiaomi, TP-Link, Asus**. During this year thanks to the national initiative to promote the whole-house WIFI coverage, our product WIFI6 Routers have realized mass production. **The production capacity and sales of routers are ranked in the average level**.

3. SHD   Video
    (…) **The main competitors are** (…) **ranked in the average level.**

4. Mobile   Network
    (…) **The main competitors are** (…) **catching up with the leaders.**

5. FTTH
    (…) **The main competitors are** (…) **ranked in the upper-middle place**.

Tables

Table 1. Sample composition

Panel A describes the sample selection process which starts from the total number of non-STAR firms identified in the STAR prospectuses submitted during the sample period. Panel B provides the control firm composition for the main results; the bottom line of this panel is the total number of observations. *Weight* indicates how many times a control firm is matched to a treated firm. Panel C describes the composition of the unique firm-year observations across fiscal periods.

Panel A: Sample selection		Observation	Note
Total prospectuses submitted to STAR market until 30/04/2020		199	
Total non-STAR firms mentioned in the above prospectuses		379	
less: Firms from the non-manufacturing industries		-42	
less: Firms without trading data or financial information		-91	
less: Firms unmatched through PSM		-12	
Total treated firms in the sample		234	
Total treated firm-year in the sample		1177	(1)
Total control firms in the sample		197	
Total control firm-year in the sample		959	(2)
Total unique firm-year in the sample		2136	(3)
Panel B: Weights from the Propensity Score Matching Control sample			
Weight	Freq.	Total	
1	819	819	
2	116	232	
3	9	27	
4	9	36	
5	6	30	
Total	959 (2)	1144	(4)
Total observations in the main table		2321	=(1)+(4)
Panel C: Fiscal period composition			
2014		290	
2015		300	
2016		329	
2017		361	
2018		431	
2019		425	
Total unique firm-year in the sample		2,136	(3)

Table 2. Descriptive statistics

This table reports the descriptive statistics of all variables used for the main results. The last three columns compare the variable means between the treated and control sample as of fiscal year 2018 based on which the matching was performed. *MeanDiff* is the variable mean of the control sample minus that of the treated sample with the significance level from the student t test indicated after the difference. (*** p< 1% ** p<5% * p<10%) Refer to Appendix. 2 for detailed variable definitions.

| Variables | Total unique firm-year (N=2136) | | | | | Control (N=197) | Treated (N=234) | |
	Mean	Std. Dev.	p25	Median	p75	Mean	Mean	MeanDiff
RD_sent_ratio	3.04	1.35	1.98	2.83	3.87	2.951	3.392	-0.441***
Disc_items	24.48	6.33	20.83	25	29.17	26.819	27.769	-0.950*
R&D_sentence	263.57	149.05	157	231	335.5	259.919	306.017	-46.098***
Total_sentence	8509.83	2087	7067	8200	9607	8683.401	8900.863	-217.462
Log(Total Assets)	8.33	1.1	7.54	8.22	8.92	8.322	8.424	-0.102
Book-to-Market	0.37	0.23	0.21	0.32	0.48	0.53	0.528	0.002
Leverage	0.11	0.11	0.01	0.08	0.18	0.11	0.118	-0.008
Capital Intensity	0.33	0.14	0.23	0.32	0.42	0.325	0.328	-0.003
Volatility	0.13	0.06	0.09	0.12	0.16	0.103	0.107	-0.004
adjusted ROA	0.08	0.08	0.04	0.07	0.11	0.084	0.079	0.005
ROA_SD	0.02	0.03	0.01	0.01	0.02	0.023	0.021	0.003
SEO	0.16	0.37	0	0	0	0.066	0.111	-0.045
Firm Age	10.13	6.16	5	8	14	10.381	10.047	0.334
Firm Age SQ	140.61	160.59	25	64	196	152.127	140.338	11.789

R&D Ratio	0.06	0.04	0.04	0.05	0.08	0.06	0.066	-0.006
R&D Ratio SQ	0.01	0.01	0	0	0.01	0.005	0.006	-0.001
Analyst Following	21.33	26.27	1	10	31	22.056	22.816	-0.76
Institutional Ownership	7.25	6.88	1.84	5.52	10.54	6.388	6.473	-0.085

Table 3. Baseline results – peer effects on R&D disclosure

The table presents the main results as described in Model (1): $Disclosure = \beta_0 + \beta_1 STARPeer + \beta_2 Post + \beta_3 STARPeer \times Post + \sum \beta_4 Controls + \varepsilon$. Columns (1)-(4) ((5)-(7)) summarize results using RD_sent_ratio ($Disc\_items$) as the outcome variable. $STARPeer$ indicates whether or not the firm is named by any STAR applicant as their direct competitor during the event period. $Post$ equals 1 for year 2019 and 0 for years 2014 through 2018. The variable of interest is the interaction term $STARPeer\_x\_Post$. $Log(Total\ Assets)$ is the natural logarithm of total assets. Refer to Appendix. 2 for detailed variable definitions. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard Errors are clustered at the industry level.

	RD_sent_ratio				Disc_items			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
STARPeer	0.492***	0.413***	0.210**		1.551**	1.428***	0.837**	
	(3.40)	(4.87)	(2.06)		(2.45)	(3.01)	(2.40)	
Post	0.115***	-0.045	0.018	-0.284***	3.983***	3.340***	3.480***	0.616
	(3.34)	(-1.01)	(0.42)	(-6.09)	(9.91)	(6.87)	(7.46)	(1.38)
STARPeer x Post	-0.112***	-0.117**	-0.130***	-0.137**	-0.973**	-0.983**	-1.064**	-1.048***
	(-3.51)	(-2.24)	(-3.39)	(-2.43)	(-2.52)	(-2.21)	(-2.53)	(-3.04)
log(Total Assets)		-0.015	-0.009	0.338***		-0.938***	-0.791***	1.874***
		(-0.13)	(-0.10)	(3.16)		(-3.30)	(-3.95)	(4.32)
Book-to-Market		-0.137	0.194	-0.314**		4.719***	4.910***	2.732***
		(-0.50)	(1.05)	(-2.18)		(4.81)	(4.87)	(3.42)
Leverage		1.099**	1.374***	0.006		5.492**	4.517**	-0.145
		(2.32)	(4.29)	(0.02)		(2.57)	(2.22)	(-0.10)
Capital Intensity		-2.129***	-1.525***	-0.155		-5.536***	-3.855**	1.059
		(-6.74)	(-4.97)	(-0.43)		(-3.82)	(-2.47)	(0.75)
Volatility		-0.014	-0.028	0.093		-2.826	-1.619	2.664
		(-0.04)	(-0.10)	(0.56)		(-0.88)	(-0.45)	(0.91)
adjusted ROA		-1.479**	-1.378***	-0.127		-0.867	-3.201	-0.189
		(-2.22)	(-2.80)	(-0.53)		(-0.25)	(-1.50)	(-0.07)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
ROA SD	0.827	0.344	-0.202			-4.946	-2.330	-9.599
	(1.69)	(0.71)	(-0.42)			(-1.53)	(-0.88)	(-1.31)
SEO	0.176***	0.206***	0.049			0.311	0.175	0.055
	(3.68)	(5.22)	(0.90)			(1.09)	(0.65)	(0.20)
Firm Age	0.080***	0.050**	0.084***			-0.054	-0.182	0.646***
	(3.52)	(2.33)	(3.63)			(-0.40)	(-1.43)	(3.83)
Firm Age SQ	-0.003***	-0.003***	0.002**			0.000	0.004	0.008
	(-4.29)	(-3.53)	(2.05)			(0.05)	(0.71)	(1.20)
R&D Exp Ratio	24.078***	16.542***	5.931*			83.130***	63.231***	20.252
	(6.72)	(5.35)	(1.91)			(5.30)	(5.52)	(1.36)
R&D Exp Ratio SQ	-61.762***	-41.862***	-16.210			-254.006***	-185.171**	-50.179
	(-4.20)	(-3.38)	(-1.13)			(-3.15)	(-2.62)	(-0.83)
Analyst Following	-0.002	-0.000	-0.004**			0.023**	0.032***	-0.009
	(-1.42)	(-0.02)	(-2.59)			(2.76)	(3.34)	(-1.52)
Institutional Ownership	0.003	0.003	0.003			-0.013	-0.019	0.001
	(0.33)	(0.28)	(1.12)			(-0.45)	(-0.60)	(0.04)
Constant	2.760***	2.176**	2.378***	-0.890	22.974***	27.235***	27.216***	-0.982
	(11.42)	(2.69)	(3.42)	(-0.87)	(51.81)	(12.51)	(17.20)	(-0.29)
Observations	2,321	2,321	2,321	2,321	2,321	2,321	2,321	2,321
F.E.	No	No	IND	Firm	No	No	IND	Firm
Adj-R-squared	0.030	0.281	0.378	0.847	0.058	0.169	0.216	0.639

Table 4. Placebo test on the timing of treatment

This table presents the regression results of the model $Disclosure = \beta_0 + \beta_1 STARPeer + \sum \beta_2 FY + \sum \beta_3 STARPeer \times FY + \sum \beta_4 Controls + \varepsilon$, where FY is the year indicator and ranges from t-2 (2016) to t+1 (2019) and $STARPeer \times FY$ is the relevant interaction term with the *STARPeer* (treatment) dummy. The sample and the set of control variables are the same as in Model (1). This model also includes industry fixed effects based on *Indcd*. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the industry level.

	RD_sent_ratio	Disc_items
	(1)	(2)
Peer	0.241**	1.609***
	(2.11)	(3.73)
After STAR(t+1)	0.353***	6.280***
	(4.32)	(12.07)
Peer x After STAR(t+1)	-0.173**	-1.925***
	(-2.57)	(-4.19)
STAR Year(t)	0.540***	6.313***
	(5.64)	(11.96)
Peer x STAR Year(t)	-0.111	-1.585***
	(-1.50)	(-3.20)
Before STAR(t-1)	0.496***	2.101***
	(5.91)	(4.14)
Peer x Before STAR(t-1)	-0.068	-1.612***
	(-0.81)	(-3.07)
Before STAR(t-2)	0.253***	1.259***
	(4.41)	(2.97)
Peer x Before STAR(t-2)	0.012	-0.448
	(0.22)	(-0.82)
Constant	1.845**	22.381***
	(2.62)	(13.43)
Controls	YES	YES
F.E.	IND	IND
Observations	2,321	2,321
Adj-R-squared	0.391	0.284

Table 5. Cross-sectional tests on the potential mechanism

This table presents the results based on partitioned sample using the same model as in Model (1). In Panel A, the companies are partitioned based on the median value of *information environment* within each industry in year 2018, where *information environment* is the principal component of *logMV, Analyst Following, Firm Age* and *Institutional Ownership*, calculated after varimax rotation. Panel B performs the analysis using partitioned sample based on the global median of *competition* in year 2018, where competition is the principal component of *HHI, IndConfour, IndCapx, IndRD, logEntcost* and *IndMrkts*, calculated after varimax rotation. For detailed definition, refer to Appendix. 2. The χ^2 as well as the relevant *p* value are the results of a Wald test on the equality of the coefficients for *STARPeer _x_Post* between the two partitioned samples.

	RD_sent_ratio		Disc_items	
Panel A: info. env.	poor	rich	poor	rich
	(1)	(2)	(3)	(4)
STARPeer	0.210**	0.219	0.684	1.215
	(2.78)	(1.24)	(1.12)	(1.70)
Post	0.083**	-0.050	3.286***	3.536***
	(2.27)	(-0.87)	(7.08)	(5.90)
STARPeer _x_Post	-0.404***	0.071	-2.062**	-0.298
	(-3.96)	(1.01)	(-2.69)	(-0.59)
Wald test on coefficients of STARPeer _x_Post	(1)=(2):	χ^2: **10.20** p: **0.001**	(3)=(4):	χ^2: **3.39** p: **0.066**
Constant	2.891***	2.456***	25.762***	29.006***
	(3.99)	(2.83)	(7.26)	(7.58)
Controls	YES	YES	YES	YES
FE	IND	IND	IND	IND
Observations	1,086	1,235	1,086	1,235
Adjusted R-squared	0.40	0.39	0.22	0.23
Panel B: competition	high	low	high	low
	(1)	(2)	(3)	(4)
STARPeer	0.400***	0.068	0.980	0.328
	(3.55)	(1.03)	(1.68)	(0.47)
Post	-0.127**	0.106*	3.081***	3.700***
	(-2.21)	(1.77)	(5.16)	(7.47)
STARPeer _x_Post	-0.113	-0.147**	-1.103	-1.293**
	(-1.41)	(-2.24)	(-1.40)	(-2.67)
Wald test on coefficients of STARPeer _x_Post	(1)=(2):	χ^2: **0.10** p: **0.753**	(3)=(4):	χ^2: **0.06** p: **0.801**

Constant	1.165	2.970***	28.812***	26.019***
	(1.23)	(3.02)	(6.73)	(9.55)
Controls	YES	YES	YES	YES
FE	IND	IND	IND	IND
Observations	1,001	1,320	1,001	1,320
Adjusted R-squared	0.24	0.20	0.41	0.38

Table 6 Category of disclosure items

This table presents the results using subcategories of the disclosure items as the outcome variable. Panel A presents the results on subcategories of items that are either likely proprietary or non-proprietary. The model specification is the same as Model (1). An item is classified as proprietary if it meets all three criteria: i) specific on the disclosing firm, ii) not available elsewhere, iii) likely actionable for competitors. In Panel B, I classify items into four categories according to the STAR market disclosure regulation. Appendix 3. lists the classification results along these two dimensions. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the industry level.

Sub-categories	Panel A: Proprietary		Panel B: Contents			
	Disc_proprietary	Disc_nonprop	Disc_stocktech	Disc_flowtech	Disc_capab	Disc_rdstaff
	(1)	(2)	(3)	(4)	(5)	(6)
STARPeer	0.750	0.877***	1.572*	0.427	0.104	1.688
	(1.15)	(3.01)	(1.85)	(1.33)	(0.14)	(1.61)
Post	6.232***	2.230***	0.566	6.283***	0.922	3.337***
	(6.83)	(5.90)	(0.75)	(10.97)	(1.59)	(4.53)
STARPeer_x_Post	-1.439	-0.894*	-0.389	-1.129	-0.657	-1.954**
	(-1.38)	(-1.94)	(-0.26)	(-1.49)	(-0.89)	(-2.24)
Constant	23.514***	28.898***	12.167**	33.528***	25.988***	29.994***
	(10.06)	(16.21)	(2.14)	(16.69)	(8.29)	(10.38)
Controls	YES	YES	YES	YES	YES	YES
FE	IND	IND	IND	IND	IND	IND
Observations	2,321	2,321	2,321	2,321	2,321	2,321
Adj. R-squared	0.22	0.13	0.08	0.27	0.13	0.10

Table 7. Stock illiquidity

The model and variables follow Daske et al., (2009) of which the model is as: $Illiquidity = \beta_0 + \beta_1 STARPeer + \beta_2 Post + \beta_3 STARPeer \times Post + \sum \beta_4 Controls' + \varepsilon$. The illiquidity measures include: (1) *Zero Return*: trading days with zero return as a proportion of total trading days within a certain period; (2) *log(Price Impact)*: natural logarithm of variable *Price Impact*, being defined as the median value of (daily absolute return in percentage over trading volume in *million CNY*) within a certain period. The sample consists of all observations used in the main results that contain both the illiquidity and the control variables. In the control variables, the prefix *L.* stands for lagged term and *log* is for natural logarithm. *Market Value* is the market value of equity; *Turnover* is the annual trading volume over market value of equity; *Volatility* is the annual standard deviation of monthly stock returns. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the industry level.

Dependent variable	Zero Return				log(Price Impact)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
STAR	-0.073	-0.052	-0.032		-0.049**	-0.035**	-0.036***	
	(-0.49)	(-0.30)	(-0.17)		(-2.66)	(-2.66)	(-2.81)	
Post	0.242	-0.023	-0.016	0.359**	-0.020	-0.111***	-0.112***	-0.109***
	(1.51)	(-0.17)	(-0.12)	(2.48)	(-1.16)	(-5.50)	(-5.68)	(-5.36)
STARPeer_x_Post	-0.068	0.008	0.019	-0.045	-0.023	-0.012	-0.008	-0.017
	(-0.33)	(0.04)	(0.09)	(-0.23)	(-0.90)	(-0.45)	(-0.33)	(-0.64)
L.log(Market Value)		-0.065	-0.022	0.837***		-0.158***	-0.152***	-0.102***
		(-0.86)	(-0.34)	(11.03)		(-14.09)	(-14.16)	(-6.25)
L.log(Turnover)		-0.487***	-0.486***	-0.379***		-0.050***	-0.044***	-0.028***
		(-7.16)	(-7.71)	(-6.28)		(-9.47)	(-9.36)	(-3.42)
L.log(1+Volatility)		1.939***	1.795***	0.101		-0.019	-0.045	-0.300**
		(3.28)	(3.18)	(0.14)		(-0.37)	(-0.92)	(-2.29)
Constant	2.221***	2.044***	1.664***	-5.760***	0.317***	1.687***	1.642***	1.227***
	(18.45)	(3.23)	(3.15)	(-8.63)	(13.84)	(15.30)	(16.86)	(8.63)

FE	IND	IND	IND	IND	IND	IND	IND	IND
Observations	2,294	2,294	2,294	2,294	2,294	2,294	2,294	2,294
Adjusted R-squared	0.00	0.04	0.08	0.39	0.01	0.29	0.32	0.41

Table 8 Robustness Tests

The main robustness tests include three specifications as shown in this table: (A) the control group is matched by *Total Assets*; (B) all non-treated firms from the same industry are used as control; (C) the same specification as the main results except that fiscal year 2018 is excluded. Robust t-statistics in parentheses *** p<0.01, ** p<0.05, * p<0.1. Standard errors are clustered at the industry level.

Specifications	Matching by Total Assets		Without matching		Excluding 2018	
	RD_sent_ratio	Disc_items	RD_sent_ratio	Disc_items	RD_sent_ratio	Disc_items
	(1)	(2)	(3)	(4)	(5)	(6)
STARPeer	0.316***	1.170**	0.273**	1.169***	0.236**	1.067***
	(2.97)	(2.19)	(2.49)	(3.02)	(2.60)	(3.63)
Post	0.110**	3.583***	0.039	3.199***	0.096	5.296***
	(2.36)	(8.12)	(1.16)	(18.69)	(1.59)	(9.65)
STARPeer_x_Post	-0.243***	-0.781**	-0.184***	-0.568*	-0.169***	-1.447***
	(-4.35)	(-2.54)	(-3.33)	(-1.86)	(-3.41)	(-2.90)
Constant	3.057***	26.585***	2.158***	21.561***	2.318***	23.686***
	(7.12)	(15.05)	(6.31)	(15.82)	(3.28)	(15.39)
Controls	YES	YES	YES	YES	YES	YES
FE	IND	IND	IND	IND	IND	IND
Observations	2,387	2,387	8,133	8,134	1,854	1,854
Adjusted R-squared	0.288	0.195	0.321	0.206	0.371	0.242

4 Are Political Connections Really Conducive to Corporate Innovation? A Regression Discontinuity Design

4.1 Introduction

A growing literature has been devoted to understanding how political connections impact corporate innovation (Akcigit, Baslandze, & Lotti, 2023; Krammer & Jiménez, 2020). Research in this area has often viewed political connections as a valuable resource that can help firms secure market-relevant information (Christensen, Mikhail, Walther, & Wellman, 2016), government support (Correia, 2014; Thompson, 2022), and access to finance (Claessens, Feijen, & Laeven, 2008; Houston, Jiang, Lin, & Ma, 2014), all of which are ultimately conducive to corporate innovation (Zhou, Gao, & Zhao, 2017). Notwithstanding this theoretical narrative, empirical attempts at verifying it have been equivocal, rendering supporting (Su, Xiao, & Yu, 2019), opposing (Hou, Hu, & Yuan, 2017), non-linear (Zhou et al., 2017), and ambiguous results (Liu, Du, Zhang, Tian, & Kou, 2021).

Two plausible reasons might explain the mixed findings. First, extant work has almost exclusively focused on the rent-generating implications of having

connections with politicians at the expense of insights into how these connections are used by managers. This is an important oversight because, as Hansen, Perry, and Reese (2004: 1280) remark, "what a firm does with its resources [e.g., political connections] is at least as important as which resources it possesses." Therefore, the variation in *how* managers use political connections might hold the key to explaining the previous mixed findings. For example, whether scholars would anticipate a positive or negative impact of political connections on corporate innovation depends on the intertemporal preference of managers. If managers act as short-term-oriented decision-makers, then we might expect political connections to nudge managers to exploit the immediate benefits of connecting with politicians, crowding out the incentives to invest in innovation given the substantial uncertainty of future returns (referred to as *managerial short-termism mechanism*). If managers, instead, act as long-term-oriented decision-makers, we might expect them to leverage political connections to bundle resources to conduct innovation activity for long-term competitiveness (referred to as *managerial long-termism mechanism*).

Second, previous empirical work has almost exclusively employed correlational analyses when investigating the impact of political connections

on corporate innovation. Given the endogenous nature of corporate choices to build political connections, confounders, such as monopoly power (Akcigit et al., 2023) and firm competence, might bias the empirical findings. For example, on the one hand, market leaders are more likely to be politically connected and yet have lower incentives to innovate (Rikap, 2022), on the other hand, competent firms are more likely to attract politicians and yet are more likely to be innovative. Thus, the relationships between political connections and corporate innovation identified in prior research might just reflect some confounding effects rather than causal impacts.

So far, there has been limited research that aims to address the above theoretical and empirical concerns. We aim to address this gap, using an abductive design (e.g., Gatignon & Bode, 2023; Vakili & Zhang, 2018). Given the competing conceptualizations of managerial preferences in leveraging political connections in innovation activity, attempting to develop a set of tightly argued hypotheses would be ambiguous at best. Instead, we build a rich understanding of the phenomenon and its conceptual implications through an exploratory approach (Graebner, Knott, Lieberman, & Mitchell, 2023).

Empirically, we use a regression discontinuity design (Lee & Lemieux, 2010), wherein we exploit a quasi-random discontinuity that occurred in the closely contested U.S. special elections (Akey, 2015).[46] We focus on firms whose political action committees (PACs) used campaign contributions to support political candidates who run for special elections and consider that firms successfully built new political connections if their supported candidates won the elections. Following Akey (2015), we focus on closely contested elections, defined as elections in which the candidates' margin of victory (MoV) is less than 5% . The results of these closely contested elections can be considered quasi-random (Lee, 2008) because neither the candidates nor the firms can *precisely* control the voting results (Lee & Lemieux, 2010). We then use a firm's victory in a closely contested election to identify a quasi-random change in the firm's political connections and therefore estimate its causal effect on the firm's post-election innovation activity. During the period from 1990 to 2020, we identified 29 closely contested special elections and 904 firms that made campaign contributions to the candidates running these elections. We use this rich data to explore our

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[46] Special elections refer to elections used to fill vacancies that occur when the former officers die or resign before the general elections. We provide detailed rationale of why we focus on special elections rather than general elections in the Data and Methodology section.

theoretical interest, i.e., the causal impact of political connections on corporate innovation.

Our analysis denotes that political connections have a negative impact on corporate innovation, as evidenced by the reduced number of patent applications and reduced number of forward citations that the patents receive, suggesting that firms with political connections reduce efforts at innovation both quantitatively and qualitatively relative to those without connections. Additional analysis suggests that firms with political connections tend to gain more patents through mergers and acquisitions (M&A) activities than those without political connections. This finding suggests that managers use patent acquisitions to compensate for their reduced efforts of innovation on their own though it doesn't entirely offset the impact of political connection. These "stylized facts" (Helfat, 2007: 185) appear to offer tentative support for the managerial short-termism mechanism, i.e., managers tend to reduce efforts at innovation in response to political connections.

Next, we further probe the plausibility of the managerial short-termism mechanism by conducting three sets of cross-sectional analyses. First, we explore whether CEOs who tend to have short-term preferences exacerbate the treatment effect. Second, we explore whether situational pressures such

as deteriorating performance and earnings pressures that nudge managerial short-termism amplify the treatment effect. Third, we explore whether the presence of disciplining forces such as the compensation package, the board of directors and research partners will curb managerial short-termism with regard to how firms use their political connections. We find supportive evidence for all these moderating factors. These results lend support to managerial short-termism as a potential yet underrecognized mechanism in explaining the impact of political connections on corporate innovation.

Finally, we conduct supplemental analyses, aiming to understand the shifts in managerial efforts in response to political connections. The results show that politically connected firms are more likely to engage in tax settlements with the government, and make more donations in the future to support politicians to run for elections. This suggests that these politically connected firms spend more effort maintaining their relationships with the government. We also find some evidence that politically connected firms are more likely to engage in empire-building activities such as mergers and acquisitions (M&A). Collectively, these two sets of supplemental analyses provide tentative evidence for where managerial efforts shift toward in response to political connections.

The findings of this study advance extant research by identifying managerial short-termism as an undertheorized factor that helps make sense of the previously mixed findings (e.g., Hou et al., 2017; Liu et al., 2021; Su et al., 2019; Zhou et al., 2017). Political connections may impede corporate innovation because managers often tend to exploit the immediate payoffs of such connections at the expense of long-term interests. These results suggest different conclusions might be drawn about the possible impact of political connections on corporate innovation, depending on the theoretical space researchers grant to accommodate managerial agency in the resource allocation process. Thus, this study suggests that the link between political connections and corporate innovation might be more complex than has been documented previously.

4.2   Data and methodology

4.2.1   Research design

To establish causality, we follow Akey (2015) and employ a regression discontinuity design (RDD) to isolate exogenous changes in firms' political connections and then estimate how these exogenous changes will subsequently impact corporate innovation. To do so, we look into firms'

political contributions made to candidates involved in closely contested special elections in the United States.

Compared to general elections that take place on a regular basis, the occurrence of special elections is unpredictable because such elections only take place when a politician's seat is unexpectedly vacated before their term ends (e.g., sudden deaths or resignations). For these special elections, the candidates running campaigns are often unforeseen till a few months or weeks before the election date. Meanwhile, the candidates running for special elections are often "first-time challengers" (Akey, 2015: 3190) that have not held any political positions previously. This means normally these politicians have not built any active connections with the firm. The focus on first-time challengers is particularly helpful since it offers a cleaner setting to observe the changes in firm behaviours just before and after the onset of the political connections. Overall, the above mentioned two facts—special elections and first-time challengers—help ease the concerns over the confounding effects of firms' previous connections with these candidates.

More importantly, we only focus on closely contested special elections, defined as elections that candidates win or lose with a minor margin of votes, i.e., the vote difference between the winning candidate and the first opponent

does not exceed 5%. Given that neither the candidates nor the firms that support the candidates' campaign contributions can precisely manipulate voting outcomes (Lee & Lemieux, 2010), the odds of a candidate marginally winning or losing a closely contested special election are as good as random (Akey, 2015). We assume based on Akey (2015) and our sample statistics that prior to the special election in question firms supporting the winning candidate and firms supporting the losing candidate are indifferent from each other along relevant covariates.[47]

Moreover, firms supporting the losing candidate are used as the counterfactual for firms had the election not taken place. The advantage of this is that it controls for all unobservable factors that affect a firm's decision to make donation, e.g., capabilities or market power, which also affect the innovation outcome. The only difference between the winning firms (the treated group) and the losing firms (the control group) can be attributed to activating the political connection through the candidate's victory. Hence,

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[47] Table 2 in Akey (2015) shows that the winning firms are indifferent from the losing firms in all the financial controls. Since our sample is an extension of Akey (2015), we find that most of our control variables as well as the outcome variable do not differ significantly between the winning firms and the losing firms in our sample.

we interpret the difference in innovation outcomes between the treated group and the control group as the treatment effect of political connection.

Within those closely contested special elections, we identity treatment (control) firms that *only* made campaign contributions to candidates that won (lost) the elections with a small margin of votes, and then compare the innovation outcomes of these two types of firms in the subsequent year.

4.2.2 Data

Patent application data

Our patent application data is collected from European Patent Office's (EPO) PATSTAT Global database (2022 Autumn edition), which is widely recognized as the most comprehensive resource for global patenting activities (Chen & Lee, 2023). As of the year 2022, the database contains approximately 80 million patent applications filed worldwide. A notable advantage of utilizing the latest version of PATSTAT is that it exhibits minimal truncation bias, as the dataset already encompasses patent information two years beyond the end of our sample period. [48] The

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[48] Two years is the average length of the review process at the patent office, i.e., the lag of patent applications being filed and the patent information becoming publicly visible (e.g., see Hall et. al., 2001). The lag is the primary cause of the well-known truncation bias.

comprehensive nature of PATSTAT allows us to examine various aspects of corporate innovation activities. For example, the precise dates of patent applications and publications enhance our measurement accuracy, as we aim to capture the effects of an unexpected win in a political election, which materialize over time following the event. Furthermore, information on patent applicants discloses whether a firm undertakes a project independently or in collaboration with other parties, enabling us to test whether having a collaborator moderates the main effect as a disciplining force. To capture a more comprehensive view of our sample firms' patenting activities, PATSTAT allows us to take advantage of the information on global patent applications rather than relying solely on those submitted to the United States Patent and Trademark Office (USPTO). Firms may conduct their R&D activities outside their home country for various reasons, including personnel costs and the application process (Papanastassiou, Pearce, & Zanfei, 2019; Siedschlag, Smith, Turcu, & Zhang, 2013).

Following the approach of previous studies (e.g., Lou & Wu, 2021), we match the patent data with Compustat using PATSTAT standardized company names (*psn_name)*. The dataset of standardized names is diligently maintained and enhanced by a team of experts, and undergoes a multi-level

harmonization process (OECD, 2022: 294). Utilizing Python packages that employ standard Natural Language Processing techniques (e.g., preprocessing, cosine similarity, fuzzy string matching, and post-processing), we can effectively match large-scale datasets.[49] The package produces a score ranging from 0 to 100, indicating the quality of individual matching results, with 100 signifying an exact match. We select 80 as the threshold value to identify a matched result.[50]

Data on patent citation and purchases

For patent citation data, we rely on the dataset from Kogan, Papanikolaou, Seru, and Stoffman (2017), which contains U.S. patents from 1926-2020 linked to the Center for Research in Security Prices (CRSP)-Compustat merged data.[51] The patent acquisition data from M&A is obtained from Arora, Belenzon, and Sheer (2021) who accurately reassign patent ownership to companies. As reassignment resulting from M&A constitutes a significant

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[49] We use the Python package *name_matching* for which a description of the package is available at https://medium.com/dnb-data-science-hub/company-name-matching-6a6330710334 .

[50] We validate the matching results by randomly selecting observations and discover an accuracy rate of 80% when setting the minimum score threshold at 80. More importantly, our main results are robust to the alternative threshold at 90.

[51] The KPSS data is available at: https://github.com/KPSS2017/Technological-Innovation-Resource-Allocation-and-Growth-Extended-Data/find/master

event leading to these changes, we opt to use this dataset to measure patent acquisition from M&A activities.

Election data

We obtain election data from the MIT Election Data Lab,[52] which contains information on all federal special elections in the U.S. between 1990 and 2020. This results in a dataset containing 157 special elections, inclusive of both House and Senate campaigns. By focusing on closely contested elections (MoV $\leq$ 5%), our sample consists of 29 special elections. Details pertaining to these 29 special elections are presented in Table 1.

[Table 1 about here]

Political contribution data

We gather data on corporate donations from the U.S. Federal Election Commission (FEC) and retain records of contributions made by firms to the winning and losing candidates in our set of 29 elections (i.e., 58 candidates in total).[53] We then follow Correia (2014) and match the organization names

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[52] https://electionlab.mit.edu/data

[53] These donation records are publicly available and can be directly downloaded from the FEC's website (www.fec.gov)

in the FEC's donation data to the company names in Compustat. In doing so, we identity 1,286 firms.[54] 230 out of these 1,286 firms hedged themselves against the election outcomes by making contributions to both the winning and losing candidates (in the same campaign). We follow Akey (2015) to remove these hedging firms from our sample because it is ambiguous to assign them with a treatment or a control status in our RDD setup. As a result, our sample consists of 1,056 firms in total, with 706 (350) firms making contributions to the winning (losing) candidates in the closely contested campaigns.

Other data

We obtain firm-level accounting data from Compustat, board size and director independence data from BoardEx, government sales data from Compustat Historical Segments, analysts forecast data from IBES, and CEO compensation data from ExecuComp. After merging political contributions data, patent application data, and other data, our sample consists of 904 firms, with 621 (283) firms contributing to the winning (losing) candidates. Since

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[54] The 1,286 firms are the total number of firms donating only to winning candidates plus the total number of firms donating only to losing candidates and hence may contain duplicate firms. However, our sample contains only unique observations on the firm-election level.

some firms made contributions to different elections in multiple years, our final sample consists of 2,265 firm-year observations. Table 2 summarizes the sample construction process.

[Table 2 about here]

4.2.3 Variables

Dependent variable

We use patent application as a primary focus of our analysis, as it represents firm efforts in innovation activities, and it is noted that the overall benefits of such activities may materialize over time. Our primary dependent variable, *Log(Patent Applications) (12M),* represents the number of patent applications filed by an entity whose *psn_names* correspond with the firm's standard company name in Compustat, within 12 months following the corresponding election date.[55] We set the threshold value for the company name-matching score at 80 to avoid excluding too many observations, though our results remain largely similar when using 90 as a cutoff point. The distribution of our patent counts aligns with prior studies (e.g., Faleye,

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[55] We follow prior research on corporate innovation to use a 12 month lag between our independent variable and dependent variable (Bronzini & Piselli, 2016). Our results remain robust when using 18- or 24- month lag.

Kovacs, & Venkateswaran, 2014) that utilized the widely-used NBER data for patents submitted to the USPTO. This bolsters confidence in our measurement.[56]

To measure patent quality, we follow Aghion, Van Reenen, and Zingales (2013) and employ the natural logarithm of total patent citations (*Log(Total Patent Citation)*) as our second dependent variable. This measure aggregates the overall citations received by patents granted to a firm in the year following the elections.[57]

In addition to patent applications and citations, firms can also acquire patents through M&A. We define our third dependent variable, *Log(Patent Purchase from M&A),* as the natural logarithm of patents procured through merger and acquisition activities. The patent stock without reassignment is the accumulated number of patents that a firm or its subsidiary is the initial assignee and the value of the stock is depreciated by 15% every year. The

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[56] We refrain from adjusting the patent data for truncation bias primarily because our data allows ample time for patent information to accumulate. Additionally, combining log transformation with normalization could potentially introduce a new bias (Gormley and Matsa, 2014).

[57] We are aware of the truncation bias that leads to an underestimation of patents that are filed close to our sample period due to the lack of time for the accumulation of citations. However, this is hardly a significant issue given our RD design that randomizes the treated and the control group as well as the use of year fixed effects that account for systematic variations across years.

patent stock with reassignment is the patent stock without reassignment plus the number of patents that are reassigned to a firm and its subsidiaries. We use the difference between the patent stock with reassignment and the patent stock without reassignment to get the number of patents that are reassigned to a firm and its subsidiaries.

Explanatory variables

Our independent variable, *Politically Connected Firms,* is an indicator variable coded as one (zero) for firms who donated to candidates who just won (lost) the special election with a small margin of votes (MOV $\leq$ 5%) (Akey, 2015). In the end, we have, at the firm-election level, 1,849 Politically Connected Firms (the treatment group) and 416 Losing Networking Firms (the control group).[58] Figure 1 shows the logical connections among each type of firm.

[Figure 1 about here]

Control variables

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[58] A potential explanation for an unbalanced sample is that the donation could be positively associated with the voting outcome such that the winners are more likely to be the candidates that receive more money from the donors.

We follow the corporate innovation literature and incorporate a wide array of control variables potentially related to firms' innovation activities. These variables fall into two categories: firm- and industry-level characteristics. Concerning firm characteristics, we control for the following: (1) firm size, using the logarithm of total assets (*Log(Total Assets)*), as Hall and Ziedonis (2001) and Atanassov (2013) document that larger firms exhibit greater innovation due to their informational benefits and the economies of scale they experience in research and development and the patent application process; (2) firm growth, using the book to market value ratio of equity (*Book-to-Market Ratio*), as innovation is fostered by growth opportunities, as managers may be required to innovate in order to take advantage of these prospects (Brown, Fazzari, and Petersen, 2009); (3) *Leverage*, calculated as the ratio of the sum of long-term debt and debt in current liabilities to total assets, as Brown, Fazzari, and Petersen (2009) and Faleye, Hoitash, and Hoitash (2011) find that higher leverage hinders innovation by increasing managerial risk aversion and reducing resources allocated for high-risk, long-term projects; (4) profitability, proxied by the rate of *return on assets (ROA)*, as managers of profitable firms may use free cash flow for long-term innovative projects (Jia, Huang, & Man Zhang, 2019a; Lin, Liu, & Manso, 2021; Ovtchinnikov, Reza, & Wu, 2020); (5) recourses and capabilities,

proxied by *Firm Age* (Jia et al., 2019a; Ovtchinnikov et al., 2020), defined as the number of years since the firm's first appearance in the Center for Research in Security Prices (CRSP) database; (6) firm research and development expense (*R&D*) to control for the firm's innovative capability or capacity (Jia et al., 2019a; Jia, Huang, & Zhang, 2019b; Lin et al., 2021); and (7) CEO option grants measured by CEO portfolio *vega*, represents the sensitivities of a CEO's options value to a 1% change in stock volatility (i.e., risk-taking incentives), as Francis, Hasan, and Sharma (2011) document a positive relation between corporate innovation and CEO option grants.

To control for the effect of industry dynamics on firm behaviours, we incorporate *Industry Competition (HHI)*, represented by the Herfindahl-Hirschman Index, which is calculated as the sum of the squared market share (based on sales) for each firm in the industry. Additionally, we include *Industry R&D Intensity*, determined as the sum of squared R&D expenses for each firm in the industry (Jia et al., 2019a; Lin et al., 2021).

4.2.4 Identification strategy

The use of the number of patent applications as the dependent variable suggests employing a count model, such as a Poisson model. However, standard Poisson models may struggle to address the presence of excess zero

counts in the patent application data. To tackle this issue, a zero-inflated Poisson regression model (ZIP) is a more suitable estimation technique. The ZIP model is a mixture of an ordinary Poisson and a Binomial distribution degenerated at zero, which allows for a specification that helps predict instances of structural zeros and is particularly suitable to model excess-zero demands (Greene, 2011; Vuong, 1989).

Our ZIP estimation is:

$$Log(Number\ of\ Patent\ Application_{i,t+1}) = \alpha *$$

$$Politically\ Connected Firms_{i,t} + \gamma * Controls_{i,t} + \eta_t + \delta_j + \varepsilon_{i,t} \quad (1)$$

where $Number\ of\ Patent\ Application_{i,t+1}$ is the count number of patent applications filed by firm i in year t +1. The independent variable, $Politically\ Connected\ Firms_{i,t}$, is coded as one (zero) for firms who donated to candidates who just won (lost) the close special election in year t. The coefficient of interest, α, captures the differences in the patent application numbers between winning and losing firms. If political connections promote corporate innovation, we would expect α to be positive and significant. Conversely, if political connections jeopardize corporate innovation, we would expect α to be negative. $Controls_{i,t}$ is a vector of

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observable and time-varying control variables shown by prior literature to be associated with corporate innovation. As firms with less research and development investment or constrained in cash are less likely to file patent applications, we use a firm's R&D expense (*R&D*), cash holdings (*CASH*), and an indicator for negative net income (*LOSS*) to predict instances of structural zero's in the patent application (*Number of Patent Application*). η_t and δ_j represent year and industry fixed effects, respectively. $\varepsilon_{i,t}$ is the error term and we use robust standard errors in the regressions.

4.3   Causal impact of political connections on corporate innovation

Table 2 Panel B shows the descriptive statistics, while Table 3 presents the regression results. Overall, the results in Table 3 indicate that the control variables predicting *Log(Patent Applications) (12M)* are consistent with the literature. For instance, firms with higher values of *Log(Total Assets),* lower values of *Book-to-Market* ratio, and higher *R&D* expenses tend to file more patents. In contrast, firms with as higher level of *Leverage* tend to file fewer patents. Firms operating in more innovation-competitive industries or those with lower values of *Industry R&D Intensity* tend to file more patents to maintain their competitive edge.

Most importantly, Column 1 shows that the estimated coefficient α on *Politically Connected Firms* indicates 65.3% less patent applications one year after the elections relative to the control group.[59] This result remains robust when we use alternative MoV cut-off points to define our sample and when we use alternative event-windows to calculate patent applications (see Table 9). These analyses suggest that, quantitatively speaking, firms with political connections reduce their efforts at innovation activity relative to those without connections.

Next, we explore whether reduced efforts also manifest in terms of how they develop the patent (i.e., patent quality) conditional on submitting a patent. To do so, we move our analytical focus to the citation patterns of the granted patents. Column 2 in Table 3 shows that the total patent citation (*Log(Total Patent Citation))* significantly decreases for Politically Connected Firms (p-value<0.05). The coefficient of *Politically Connected Firms* in column 2 implies that the average *Total Patent Citation* for a winning firm is approximately 36.9% lower or around 3 citations less than for a losing firm.[60]

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[59] In presenting all results using a Poisson regression model, we report the incidence rate ratio (IRR) instead of the raw coefficients. The seemingly large effect is primarily driven by the fact that patent application data contains many zeros and a low average.

[60] Exp(2.14) ≈ 8.5 , 8.5 x 36.9% ≈ 3, in which Exp(2.14) is the mean value of Total Patent Citation and 0.369 is the IRR of the Poisson regression.

This suggests that, relative to the control group, the politically connected firms not only reduce their overall innovation efforts but also shift towards less influential projects.

Finally, given the quantitative and qualitative reduction in innovation efforts, we explore whether and how firms engage in other activities to compensate for the reduced innovation efforts. As Capron and Mitchell (2012) observed, when firms stop doing in-house innovation, they often "buy" patents to sustain their competitiveness in the innovation contests. Thus, we explore whether politically connected firms will engage in merger and acquisition (M&A) activity to get new parents. Column 3 in Table 3 shows that the coefficient of *Politically Connected Firms* is positive and significant (p-value < 0.05), indicating that winning firms prefer quicker options to acquire technology and obtain more patents through mergers and acquisitions.[61] In economic terms, the result in column 3 suggests that the average *Patent Purchase from M&A* for a winning networking firm is approximately 21.4% higher than for a losing networking firm. [62] The relatively smaller economic magnitude of the purchased patents through M&A (21.4%) against that of

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[61] Since the data only covers the patent data until 2015 and we use the one-year lead variable as the outcome, the sample in column (3) ends in 2014 which explains the loss of observations.

[62] Exp (0.53) $\approx$ 1.7 , 1.7 x 21.4% $\approx$ 0.36

the own patents (48%) may suggest a net reduction of overall innovation activities and impaired long-term interests.

Overall, our initial analyses paint a picture of politically connected firms that lower innovation efforts in response to political connections. This pattern is robust as the reduced efforts not only manifest in a quantitative sense of patent applications but also in the qualitative sense of patent merit. This robust pattern is also corroborated by the evidence that politically connected firms strive to purchase patents via M&As as partial compensation for their reduced in-house innovation activities. This set of triangulated evidence points to a "stylized fact" (Helfat, 2007: 185) that supports the plausibility of the theoretical conjecture that firms with short-term-oriented managers reduce innovation efforts.

[Table 3 about here]

4.4   Exploring the mechanisms: the role of managerial short-termism in explaining the impact of political connections on corporate innovation

In this section, we further probe the plausibility of managerial short-termism in explaining why political connections may have a negative impact on

corporate innovation. We do so by exploring the heterogenous treatment effects.

4.4.1 CEO short-term orientation

If managerial short-termism is the mechanism that drives our findings, we would expect the treatment effect will become stronger when firms are led by CEOs who tend to have a short-term focus. To do so, we use a set of three proxies that are often used to capture CEO short-termism: career horizon, patience, and wealth.

CEO career horizon

CEO career horizon—the number of years that a CEO has till reaching retirement age—has implications for firm decisions, because research has routinely shown that the priorities and incentives of the CEOs will be more myopic as they are closer to retirement (Krause & Semadeni, 2014). This is understandable because long-term-oriented strategies may benefit the firm in the far future, but near-retirement CEOs will not enjoy those benefits given their distant nature (Matta & Beamish, 2008). Thus, near-retirement CEOs often make decisions that can generate immediate payoffs, so that they can gain more financially and even leave a legacy with those immediate, good performance.

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Building on these arguments, it seems reasonable to assume that firms with near-retirement CEOs are more likely to exploit the short-term benefits of political connections at the expense of firms' long-term innovation-based competitiveness. Thus, we explore whether our treatment effect will become stronger when the firms are led by near-retirement CEOs. We use a dummy variable to capture the presence of near-retirement CEOs as, which takes the value of one if the CEO's age is above the sample median of 56 and zero otherwise. Empirical evidence (see Table 4 column 1) confirms that near-retirement CEOs are more likely than their counterparts to shirk innovation efforts in response to political connections. The main effect is observed only among near-retirement CEOs, as indicated by the insignificant coefficient of *Politically Connected Firms*.

[Table 4 about here]

CEO patience

CEOs also differ from each other in terms of their intertemporal preferences. Some CEOs focus more on long-term value creation and the strategic growth of the firm, while others focus on short-term performance outlooks. Scholars use the notion of CEO patience to measure a CEO's observed willingness to

forgo immediate rewards in favour of long-term benefits (Buyl, Boone, & Wade, 2019; Graham, Harvey, & Puri, 2013). Research shows that even under shareholder pressure for short-term performance improvements, patient CEOs tend to maintain a focus on long-term value creation through investments in R&D and innovation (Laverty, 1996).

Based on these arguments, we expect that if managerial short-termism is indeed the working mechanism that drives our findings, firms that are led by less patient CEOs are more likely to forgo innovation efforts to exploit the immediate benefits of political connections. Prior research often uses the CEO's observed willingness to defer the execution of vested options to measure CEO patience (Graham et al., 2013). We follow this tradition and measure CEO patience as the industry-adjusted delay in exercising vested options. The exploratory analysis in Table 4 Column 2 shows a negative moderating effect of CEO patience, suggesting that our treatment effect becomes stronger when the CEO is less patient. The coefficients suggest that a decrease in the value of CEO Patience of the interquartile range (3.77) leads to a reduction of patents with a similar magnitude of the main effects.

CEO wealth

CEO wealth, the total financial assets accumulated by a CEO over their career influences their behaviours and decision-making patterns (Gomez-Mejia, Tosi, & Hinkin, 1987). CEOs with higher levels of wealth may be less likely to let go of long-term-oriented investments such as R&D and innovation. First, their wealth may provide a cushion against potential financial setbacks, leading to reduced sensitivity to risk (Malmendier & Tate, 2005). This could result in CEOs being more inclined to invest in uncertain long-term projects that involve delayed returns. Second, wealthier CEOs may not feel pressured to accumulate additional wealth through short-term focused performance-based compensation (Hambrick & Finkelstein, 1987), potentially leading to less focus on short-term performance metrics and greater emphasis on long-term value creation through R&D and innovation. Third, CEOs with lower wealth may be more inclined to engage in empire-building (Bertrand & Mullainathan, 2003), focusing on expanding the firm's size and scope rather than investing in long-term growth and innovation. This can result in a reallocation of resources as the CEO prioritizes acquisitions and expansionary activities over R&D and innovation efforts.

Based on these arguments, we expect that CEOs with higher levels of wealth are less likely to reduce long-term innovation investments after building

connections with politicians. As their wealth provides them with financial security and reduced sensitivity to risk, they may be less inclined to exploit the immediate benefits of political connections at the expense of long-term investments in innovation. Results in Table 4 column 3 confirms our conjecture that a CEO with higher levels of wealth is less likely to cut long-term innovation. The coefficients suggest that CEOs who would reduce patents by a similar scale as the main effects are among the top 20 percent of wealthiest CEOs.

4.4.2 Firm-level situational pressures

In addition to being a proactive choice by short-term CEOs, short-term focus can also emerge as a response to situational pressures that firms have to face. These situational pressures can be internally derived due to performance shortfalls or externally imposed by financial intermediaries in the market. Thus, to further probe the plausibility of the managerial short-termism mechanism, we next explore whether our treatment effect will become stronger when firms are encountered with situational pressures that call for immediate performance improvement. Our assumption is that managers will *have to* pay attention to the short-term benefit exploration when under situational pressures. More specifically, we explore two situational

contingencies that may justify short-term actions for performance improvement: deteriorating performance, and earnings pressures.

Deteriorating performance

Research has shown that when experiencing performance declines in consecutive years, firms are motivated to engage in activities that can help reverse the performance trends (Vidal & Mitchell, 2015). For example, Kuusela, Keil, and Maula (2017) find that when operating performance is falling short of their previous performance levels, firms often use divestitures to not only drop the performance-deteriorating units but also gain additional cash to recover performance. As another example, Harris and Bromiley (2007) find that deteriorating performance also encourages firms to engage in financial misconduct to disguise the performance decline.

Building on these arguments, it seems reasonable to assume that if managerial short-termism is driving our findings, we would expect politically connected firms to be more likely to shift their efforts from innovation to short-term profitability exploitation when their performance has been deteriorating over the years. We use *Aggregated ROA Growth* as a proxy for firms' deteriorating performance, measured as the sum of ROA

growth rates over the past two years. Empirical analysis in Table 5 Column (1) suggests that *Aggregated ROA Growth* attenuates our treatment effect, suggesting that politically connected firms are more likely to reduce innovation efforts when they are experiencing performance declines. The coefficients suggest that politically connected firms that face more deteriorating performance (at the 25th percentile of *Aggregated ROA Growth*) reduce patents by roughly 8.65 percent more than their counterparts that face less deteriorating performance (at the 75th percentile of *Aggregated ROA Growth*).

[Table 5 about here]

Earnings pressures

A second contingency factor that may be relevant is earnings pressures. Research has long suggested that financial analysts nudge managers to withhold their commitment to long-term innovation activities (He & Tian, 2013) because financial analysts often impose short-term performance targets for firms to meet (Washburn & Bromiley, 2014). Firms have to meet these targets because failing to do so will result in stock price fluctuations which may have ramifications for firms. Thus, to avoid stock price

fluctuations, firms often do whatever they can do to meet analysts-defined performance targets. For example, Gentry and Shen (2013) found that firms tend to cut R&D expenses and withdraw their innovation commitment when they have pressures to meet the performance targets set by the financial analysts.

Building on these arguments, we expect that politically connected firms are more likely to exploit the immediate benefits of connections with politicians when they failed to meet the performance targets defined by financial analysts. To investigate this possibility, we measure *Analyst Forecast Pressure* which is the distance of actual EPS to the analyst consensus forecast in the past year (analyst forecast minus actual EPS), and then explore how *Analyst Forecast Pressure* moderates our treatment effect. We find a negative moderating effect in Table 5 Column (2), suggesting that politically connected firms will further reduce their innovation efforts when they have missed analysts-defined performance targets in the past. The coefficients suggest that politically connected firms that miss the analyst consensus forecast by 2 percent reduce on average 2.3 percent more patents relative to connected firms that just meet analyst forecasts.

4.4.3 Disciplining forces

Not all managerial short-termism will manifest because of disciplining forces inside and outside firm boundaries. Thus, if managerial short-termism is a mechanism driving the negative relationship between political connections and corporate innovation, we would expect to see a weaker treatment effect when disciplining forces are present to curb managerial short-termism. Thus, we explore three different disciplining forces to further explore the plausibility of the managerial short-termism mechanism.

CEO incentive-based compensation

CEO incentive-based compensation refers to a remuneration structure designed to align the interests of a CEO with those of shareholders and stakeholders (Hall & Liebman, 1998; Jensen & Murphy, 1990), encouraging the CEO to make strategic decisions that enhance the long-term value of the firm (Bebchuk & Fried, 2003). CEO risk-taking incentives, a specific aspect of incentive-based compensation, are designed to encourage executives to take calculated risks that can lead to higher growth and innovation opportunities. These incentives often come in the form of stock options, restricted stocks, or performance shares tied to specific performance metrics (Edmans & Gabaix, 2016).

Risk-taking incentives can motivate CEOs to make more long-term-oriented decisions, such as investing in R&D and innovation. Long-term investments in R&D and innovation have the potential to generate significant growth and competitive advantages for firms. When CEO compensation is tied to the long-term performance of the firm, executives are more likely to prioritize such investments, as they can yield higher returns for both the company and the CEO's compensation (Sanders & Hambrick, 2007). Consequently, CEOs are more inclined to invest in long-term projects, including R&D, capital expenditures, and overall innovation (Coles, Daniel, & Naveen, 2006; Tosi, Werner, Katz, & Gomez-Mejia, 2000).

Based on this evidence, we conjecture that CEOs with higher risk-taking incentives are more likely to maintain or focus on long-term value creation through R&D and innovation. Therefore, we further examine whether the negative treatment effects will be attenuated when CEOs have higher levels of risk incentives in their compensation packages. We find evidence in line with our expectations that CEO's with higher level of *Log(CEO Total Vega)* are less likely to reduce long-term innovation. Specifically, an one-standard deviation increase in *CEO Total Vega* leads to roughly 20 percent less reduction in patent fillings for the connected firms.

[Table 6 about here]

Board independence

The board of directors is the governing body of the firm, preventing CEOs from entrenchment behaviours (Boivie, Bednar, Aguilera, & Andrus, 2016). However, directors' interests might be at CEO's disposal if they also work as executives in the firm (Rosenstein & Wyatt, 1997). Thus, extant research suggests that the more independent directors—directors who are not part of the top management team—on the board, the more effectively the board can fulfil its monitoring functions (Nguyen & Nielsen, 2010).

We build on this literature and expect that politically connected firms with a less-independent board are more likely to shirk innovation efforts. We measure board independence as the percentage of independent directors on the board. Table 6 Column (2) suggests that a one standard deviation increase in the percentage of independent directors curbs the innovation reduction by roughly 65 percent, which lends further support for the managerial short-term mechanism.

Innovation partnership

Last but not least, innovation activities are often done in collaboration with peers. In this case, politically connected firms might not be able to freely shirk innovation efforts, because peer firms may function as external monitors in the innovation process. Despite being willing to reduce efforts in innovation, peer firms may nudge the politically connected firms to honour their commitment to collaborative innovation projects.

We use this line of arguments to further probe the managerial short-termism mechanism. Specifically, we expect that our treatment effect may become weaker if politically connected firms have more joint patent applications, because peer firms may monitor the politically connected firms' commitment to their joint projects. To explore this possibility, we use *Co-Developed Patents* as a proxy of peer monitoring strength, measured as the number of patents filed by the firm together with a second entity. Empirical analyses show that when peer monitoring strength is higher (as proxied by Co-Developed Patents), politically connected firms will be less likely to reduce their innovation efforts. Compared to connected firms without any co-developed patents, firms that have filed 19 patents together with a second entity refrain from patent reduction by roughly 91.2%. This adds further plausibility to the managerial short-termism mechanism.

4.5 Corroborating evidence: actual benefits

A central assumption in interpreting the evidence above is that firms will exploit their political connections to gain immediate benefits. In this section, we conduct a series of analyses to validate this assumption. The focus of these analyses is to empirically explore whether firms in our treatment group, in comparison to their peers, gain actual advantages following their victories in close elections. [63] We accomplish this by employing the following specification:

$$\Delta Outcomes_i = \alpha_1 * Networking\ Firms_{i,t} + \gamma * Controls_{i,t+1} + \eta_t +$$

$$\delta_j + \varepsilon_{i,t} \tag{3}$$

We measure the actual benefits for treatment firms relative to their peer firms (outside the control group of our sample) after the close election using the change in sales to the government *($\triangle Log(GOV\ Sales)$)*, change in sales growth *($\triangle Sales\ Growth$)*, change in market capitalization *($\triangle MK$)*, and

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[63] We use firm pairs in Hoberg and Phillips data to identify the non-donating peers of the networking firms. There are two reasons why we use the peer firms of politically connected firms as control group in this analysis rather than losing donating firms: firstly, the losing donating firms may use subsequent tit-for-tat actions to recalibrate their performance as a response, so it is not clean as a comparison group; second, the actual benefits that politically connected firms would obtain, if any, are most likely at the expense of their direct rivals (i.e., peer firms), making peer firms a more appropriate comparison group. Nevertheless, our analysis using losing donating firms as control groups show qualitatively similar results.

change in the number of employees *(△Employee)*. These change values are calculated based on the differences between the election year and the two years following the elections.[64] *Networking Firms$_{i,t}$* is a binary variable, which takes the value of one if the firms is a politically connected firm in our sample, and zero if the firm is a peer firm of the politically connected firms. *Controls$_{i,t}$* consists of the same set of variables used in Eq. (1). The results derived from the same close election sample as our primary findings are presented in Table 7, columns 1-4. Additionally, we utilize the complete special election sample and present the estimation results in Table 7, columns 5-8. The results generally suggest that new political connections will lead to a variety of benefits in the short term. These results validate the assumption we made when we use the heterogenous treatment effects to explore the plausibility of the managerial short-termism mechanism.

[Table 7 about here]

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[64] As our outcome variables are available on an annual basis, an accurate matching based on the election day is not feasible., therefore, we measure all outcome variables using two consecutive periods after the election year to alleviate the imperfect time matching.

4.6 Supplemental analyses: where do managerial efforts shift?

Where do politically connected firms allocate their resources if they are cutting back on long-term innovation projects? Exploring this question sheds additional light on the managerial short-termism mechanism. Since political connections do not only come with benefits because they will require firms to spend efforts to maintain a good relationship with the government, we expect politically connected firms may shift their attention to relationship maintenance activities. In addition, we expect politically connected firms may make use of the political connections to facilitate their empire-building through M&A activities.

Tax settlement with the authorities

To maintain a good relationship with the government, politically connected firms may use an increase in tax payments to signal their goodwill. In doing so, politically connected firms can further solidify their relationship with the government and maintain their advantageous position in the political marketplace. We use the natural logarithm of tax expenses as the dependent variable, and investigate whether political connections have a positive impact

on it. The empirical result confirms such a positive impact (Table 8, Column 2: p-value <0.01).

[Table 8 about here]

PAC donations

Another way to maintain a good relationship is to make donations to more politicians to run for elections. In this way, politically connected firms can further strengthen their ties with policymakers and increase their influence. This strategy can help them secure future support from politicians and potentially gain a competitive advantage in their industry. We then explore this possibility by examining whether politically connected firms are more likely to make political donations made through their PACs. Using log-transformed values of the *PAC Donations,* we find supportive evidence (see Table 8).

Domestic mergers and acquisitions

We investigate whether firms are more likely to exploit the benefits of political connections to build a larger corporate empire. Since M&A deals can provide immediate growth and expansion opportunities for a company, we use M&A activities as a proxy for corporate empire-building, similar to

prior research (Gantchev, Sevilir, & Shivdasani, 2020). Since a connection with US politicians are more likely to facilitate M&A deals within the US context, we focus on domestic M&As only. Empirically, we explore the impact of political connections on the number of domestic mergers and acquisitions (*Number of Domestic M&A)* made by the firms. Empirical results suggest that politically connected firms engage in more domestic M&A (see Table 8).

4.7 Discussion

4.7.1 Interpretation

This abductive research aimed to shed light on what might explain the mixed findings in the literature with regard to the impact of political connections on corporate innovation (e.g., Hou et al., 2017; Su et al., 2019). Using a quasi-random discontinuity that occurred in the closely contested U.S. special elections (Akey, 2015), this study finds a negative treatment effect, wherein firms that successfully built connections with politicians who marginally won elections are more likely to subsequently lower their efforts at in-house innovation, as reflected in a reduction of both quantity and quality of innovation output. To compensate partially for the reduced innovation effort, relative to losing firms, winning firms acquire more patents through M&A

activities. These findings stand in sharp contrast to extant research because the conventional wisdom in this literature is that political connections are conducive to corporate innovation (despite occasionally conflicting findings). We interpret these stylized findings in this research as an empirical indication that managerial short-termism might be an understudied mechanism underlying the negative impact of political connections on corporate innovation.

We explore the plausibility of managerial short-termism by investigating the heterogenous treatment effects. Empirical explorations show a stronger treatment effect when the CEOs tend to be oriented toward short-termism and when they have to pay attention to situational pressures that encourage short-term actions for performance improvement. However, the treatment effect becomes weaker when disciplining forces, such as risk-encouraging compensation design, board impendence, and innovation partnership, are present to curb managerial short-termism. These findings collectively plausiblise managerial short-termism as the underlying channel that explains the negative impact of political connections on corporate innovation.

Additional analysis suggests that, by scaling down on innovation efforts, politically connected firms are more likely to divert resources toward settling

more taxes, engaging in more M&A transactions, and making more future donations, suggesting that political connected firms shift their *attention* and efforts toward maintaining a good relationship with the government and politicians while using existing connections to engage in empire-building activities. These findings further lend credence to the notion that politically connected firms are short-term oriented because their attention and efforts shift away from value creation (via innovation) to value appropriation (via exploitation of immediate payoffs).

4.7.2 Theoretical contribution

The findings of this abductive research have implications for theory advancements. First, this research contributes to the literature intersecting political connections and corporate innovation. As Wei, Jia, and Bonardi (2022: 25) note, "our understanding of CPCs [corporate political connections] and firm innovation remains in its infancy and needs to be extended." Our research aims to extend this front by substantiating the importance of managerial short-termism in understanding the impact of political connections on corporate innovation. Extant research often takes a resource-based argument that views political connections as a value-creating resource that is conducive to corporate innovation. Although the conceptual

narrative for this inference is powerful, empirical observations have been mixed. This study aims to offer a potential explanation for the mixed findings in the literature. The departure point of our abductive efforts builds on a frequently overlooked fact that "what a firm does with its resources is at least as important as which resources it possesses" (Hansen et al., 2004: 1280). Our key message is thus that, despite the rent-generating implications of political connections, managers may be less incentivized and therefore attentive to use politically connected advantages for investment in innovation, unless they are carefully monitored and disciplined. This highlights an important assumption made in the literature: political connections "create value whenever firms decide to use them" (Wei et al., 2022: 23). In doing so, we extend extant literature by emphasizing the importance of in what ways firms use political connections in understanding the impact of political connections on corporate innovation.

In addition, this study also contributes to the literature on value creation and appropriation. Extant research has often taken a dichotomous view of value creation vs. value appropriation, exploring the antecedents of either activity. Little is known about when firms likely switch from one activity to another. Our research shows political connections encourage firms to shift their

attention away from innovation-based value-creation activity toward empire-building and other value-appropriation activities. Managerial short-termism appears crucial in this effort shift. Thus, this research moves extant literature on the relationship between value creation and appropriation away from a dichotomous view toward a contingent view.

More broadly, this research makes an integrative contribution (Okhuysen & Bonardi, 2011) by synthesizing the highly complementary but thus far frequently separated streams of resource-based research and managerial short-termism research. Despite their common interests in explaining why firms act the way they do, these two lines of research have evolved largely in parallel, with fairly little cross-pollination. An integrative approach provides significant theoretical leverage by allowing for room to theorize how managers use the value-added resources that firms acquired through networking activity. It thus enables a richer and more complete approach to understanding why possession of valuable resources can counterintuitively encourage the short-term oriented behaviour of the firms.

4.7.3 Limitations and future research

This research is not without limitations. First, political connections may take different forms (Wei et al., 2022), such as relationship-based connections

(e.g., hiring politicians as board members) and equity-based connections (shares owned by politicians). To exploit a quasi-experimental variation in firms' political connections, we only focus on connections via campaign contributions. Despite the benefits of inferring causality, our narrow focus also alerts us to the generalizability of our findings to other forms of political connections. Thus, future research might find it fruitful to explore which aspects of our findings apply to other forms of political connections, and which aspects differ.

Second, given the nature of our archival data, we cannot observe how decisions are made by firms, but simply infer managerial short-termism from empirical patterns of our findings. This is a common limitation among studies of causal inference with observational data but substantive nonetheless. Although we find a variety of supportive evidence for managerial short-termism inference, it remains a strong assumption. Future research could explore its validity using experimental decisions or qualitative data.

4.8   Conclusion

With this research, we have aimed to offer an explanation to make sense of the previous mixed findings with regard to the impact of political connections on corporate innovation. Using a regression discontinuity design, this study

represents the first attempt to investigate the causal impact of political connections on corporate innovation. Our abductive analyses suggest that political connections nudge firms to shirk efforts at innovation, especially when the firms are led by short-term-oriented CEOs or have situational pressures for short-term returns. We hope that future research will take note of the present study and draw managerial short-termism further into theoretical understandings of politically connected firms.

Appendix

Appendix: Regression Discontinuity Design (RDD)

The research discontinuity design (RDD) is first introduced by Thistlethwaite and Campbell (1960), which is a quasi-experimental method that allows identifying a causal effect by controlling for observables and unobservable, even when scholars do not have the luxury of randomization. RDD identifies causality by taking advantage of arbitrarily setting eligibility thresholds to mimic randomization. RDD can be used when a membership in a given category (e.g., elected officials) is not randomly assigned and there are some eligibility criteria for who can access that membership (Lee & Lemieux, 2010). The rationale for RDD to identify causation is based on the following logic: those who are just eligible will be very similar to those who are just ineligible. This comparability will mimic randomization in that the ineligible sample will be the same on average as those who are just eligible (Imbens & Lemieux, 2008).

We use one example to illustrate how RDD works for causal identification. Consider a program to support the job search of unemployed workers who are below 25 years old. How effective is the programming in increasing their chances of finding a job? The challenge of estimating the causal effect of the job training program on employment is the non-random assignment of the treatment (i.e., participation in the job search training). Factors such as intrinsic motivation and competence may affect both the likelihood of people participating in job search training and their future employment outcomes. In this regard, even if the job search training does not add any value to the participants' future employment outcome, we will still find people who joined the training are more likely to find a job in the end, simply because the participation in job search training is given to people with higher motivation and are more competent ex-ante.

RDD takes advantage of precise knowledge of threshold rules that determine participation in a certain program. This makes RDD a very powerful method to evaluate the impact of policies and programs. Continuing with our example of job search training, RDD looks at individuals who are slightly above the threshold of age 25 and those who are slightly below it. The fact that rules can be discretionary ensures that people close to the threshold are very similar except for the fact of participating in the job search program. For example, Group One consists of people aged between 24 and 25, and Group Two consists of people aged between 26 and 27. These two groups should

have on average the same income, education, motivation, and other observable and unobservable factors, etc. However, only Group One can participate in the job search training while Group Two cannot. Then the difference in the average employment rates between the two groups, the so-called RDD estimate, can therefore be argued as a causal impact of the participation in the job search training.

Appendix: List of Variables

Patent Applications (12M): the count of patent applications filed by the firm within 12 months following the election date,

Total Patent Citation: the sum of patent citations received by all patents granted to a firm in the year following the election date and all citations are counted towards the end of our sample period,

Patent Purchase from M&A: the number of patents a networking firm acquires through M&A,

Politically Connected Firms: an indicator coded as one (zero) for networking firms who donated to candidates that just won (lost) the special election with a small margin of votes (5%),

CEO Short Career Horizon: an indicator coded as one (zero) if the CEO is above (below) the age of 56,

CEO Patience: the industry-adjusted delay in exercising vested options,

CEO Wealth: the aggregate value of CEO firm-related wealth, which is the sum of the value of CEO option grants, restricted stock grants and long-term incentives.

Net Operating Loss: an indicator coded as one (zero) if the firm has negative (positive) net income,

Aggregated ROA Growth: the sum of ROA growth rates of past two years,

Analyst Forecast Pressure: the magnitude of actual EPS in short of the EPS from analysts' consensus in the year prior to the election,

Log (Total Assets): natural logarithm of total assets,

Book-to-Market Ratio: The book value of total assets relative to the sum of the market value of equity and the book value of liabilities,

Leverage: long-term debt plus debt in current liabilities over total assets,

ROA: net income over total assets,

Firm Age: the number of years since the firm's first appearance in CRSP,

Industry R&D Intensity: sum of squared R&D expense share for each firm in the industry (2-digit SIC),

CEO Total Delta: the sum of the sensitivities of a CEO's total equity holdings to a 1% change in stock price,

CEO Total Vega: the sum of the sensitivities of a CEO's total equity holdings to a 1% change in stock volatility,

Industry Competition (HHI): the sum of the squared market share (based on sales) for each firm in the industry (2-digit SIC),

Board Independence: proportion of independent directors on the board,

Co-Developed Patents (3Y): number of patents filed by the firm together with a second entity within 3 years before the election date,

Number of Domestic M&A: number of mergers and acquisitions that a firm performs in the year after the election,

Log (Tax Settlement): natural logarithm of tax expenses in the year after the election,

Log (PAC Donation): natural logarithm of the amount of donation the firm makes through PAC in the year after the election year.

Figures

Figure 1. Logical Connections among Each Type of Firms That the Paper Focuses on

Special Elections (1990-2020)
with MOV <=5% [N=29]

Winning Candidates [N=29]

Losing Candidates [N=29]

Firms donating **only** to the Winning Candidates
[*Politically Connected Firms* =1]
[N= 706 firm observations]
[N= 2,391 firm-election observations]

After Merging with Patent and Other Data
[N= 621 firm observations]
[N=1,849 firm-election observations]

Politically Connected Firms
[N=2,982 firm-election observations]

After Merging with Patent and Other Data
[N=2,265 firm-election observations]

Firms donating **only** to the Losing Candidates
[*Politically Connected Firms* =0]
[N= 350 firm observations]
[N=591 firm-election observations]

After Merging with Patent and Other Data
[N= 283 firm observations]
[N= 416 firm-election observations]

Tables

Table 1. A List of Close Special Elections from 1990 to 2020

This table summarizes the cases of special elections in the US at the federal level during the period 1990 – 2020, in which the candidate only marginally secures or loses the election, i.e., the margin of victory (*MoV* <=5%). *Office* indicates whether the election is related to a position in the House (H) or Senate (S). Both the winning and losing candidates' name are included in *Candidate*. *Date* is the election date. *MoV* is the voting result for each candidate where a positive value indicates a winning and a negative value indicates a losing candidate.

Office	No	Candidate	Date	State	MOV
H	1	JOHN OLVER	6/18/1991	MA	1.40%
H	1	STEVEN PIERCE	6/18/1991	MA	-1.40%
H	2	CARLOS ROMERO BARCELO	3/4/1992	Puerto Rico at-large	0.90%
H	2	ANTONIO COLORADO	3/4/1992	Puerto Rico at-large	-0.90%
H	3	PETER W. BARCA	5/4/1993	WI	0.61%
H	3	MARK W. NEUMANN	5/4/1993	WI	-0.61%
H	4	WILLIAM T. REDMOND	5/13/1997	NM	2.96%
H	4	ERIC P. SERNA	5/13/1997	NM	-2.96%
H	5	HEATHER WILSON	6/23/1998	NM	4.97%
H	5	PHILLIP J. MALOOF	6/23/1998	NM	-4.97%
H	6	DAVID VITTER	5/29/1999	LA	1.50%
H	6	DAVE TREEN	5/29/1999	LA	-1.50%
H	7	J. RANDY FORBES	6/19/2001	VA	4.20%
H	7	LOUISE LUCAS	6/19/2001	VA	-4.20%
H	8	RANDY NEUGEBAUER	6/3/2003	TX	1.04%
H	8	MIKE CONAWAY	6/3/2003	TX	-1.04%
H	9	STEPHANIE HERSETH	6/1/2004	SD	1.18%
H	9	LARRY DIEDRICH	6/1/2004	SD	-1.18%
H	10	JEAN SCHMIDT	8/2/2005	OH	3.28%
H	10	PAUL HACKETT	8/2/2005	OH	-3.28%
H	11	PAUL BROUN	7/17/2007	GA	0.84%
H	11	JIM WHITEHEAD	7/17/2007	GA	-0.84%
H	12	DON CAZAYOUX	5/3/2008	LA	2.93%
H	12	WOODY JENKINS	5/3/2008	LA	-2.93%
H	13	SCOTT MURPHY	3/31/2009	NY	0.46%
H	13	JIM TEDISCO	3/31/2009	NY	-0.46%
H	14	BILL OWENS	11/3/2009	NY	2.37%

H	14	DOUG HOFFMAN	11/3/2009	NY	-2.37%
H	15	KATHY HOCHUL	5/24/2011	NY	4.96%
H	15	JANE CORWIN	5/24/2011	NY	-4.96%
H	16	DAVID CURSON	11/6/2012	MI	2.29%
H	16	KERRY BENTIVOLIO	11/6/2012	MI	-2.29%
H	17	DAVID JOLLY	3/11/2014	FL	1.80%
H	17	ALEX SINK	3/11/2014	FL	-1.80%
H	18	KAREN HANDEL	6/20/2017	GA	3.56%
H	18	JON OSSOFF	6/20/2017	GA	-3.56%
H	19	RALPH NORMAN	6/20/2017	SC	3.10%
H	19	ARCHIE PERNELL	6/20/2017	SC	-3.10%
H	20	DEBBIE LESKO	4/24/2018	AZ	4.80%
H	20	HIRAL TIPIRNENI	4/24/2018	AZ	-4.80%
H	21	TROY BALDERSON	8/7/2018	OH	0.80%
H	21	DANNY O'CONNOR	8/7/2018	OH	-0.80%
H	22	SUSAN WILD	11/6/2018	PA	0.20%
H	22	MARTY NOTHSTEIN	11/6/2018	PA	-0.20%
H	23	CONOR LAMB	3/13/2018	PA	0.40%
H	23	RICK SACCONE	3/13/2018	PA	-0.40%
H	24	DAN BISHOP	9/10/2019	NC	2.08%
H	24	DAN MCCREADY	9/10/2019	NC	-2.08%
S	25	RON WYDEN	1/30/1996	OR	1.60%
S	25	GORDON H. SMITH	1/30/1996	OR	-1.60%
S	26	MARK KRIK	11/2/2010	IL	1.90%
S	26	ALEXI GIANNOULIAS	11/2/2010	IL	-1.90%
S	27	SCOTT BROWN	1/19/2010	MA	4.80%
S	27	MARTHA COAKLEY	1/19/2010	MA	-4.80%
S	28	MARK KELLY	11/3/2020	AZ	2.40%
S	28	MARTHA MCSALLY	11/3/2020	AZ	-2.40%
S	29	RAPHAEL WARNOCK	11/3/2020	GA	2.00%
S	29	KELLY LOEFFLER	11/3/2020	GA	-2.00%

Table 2. Sample Selection Process

This table summarizes our sample selection process. Panel A shows the distribution of special elections based on the margin of victory and that of firms that have donated to the close elections. We exclude firms that donate to both the winning candidate and the losing candidate of the same campaign. Panel B presents the descriptive statistics of all variables used in the paper.

Panel A: Sample selection for close special elections.		
	N	N (candidates)
Special Election from 1990 -2020	157	314
less: margin of victory (MOV) larger than 5%	(128)	(256)
Final close special elections from 1990 - 2020	**29**	**58**
Among Firms covered by *Compustat*	N (Donating Firms)	N (Firm-Elections)
Firms donating to the winning candidates	706	2,391
Firms donating to the losing candidates	350	591
Networking firm sample	**1,056**	**2,982**
less: firms with missing data for regression	(152)	(717)
Final sample for regression	**904**	**2,265**

Panel B: Descriptive Statistics						
	N	Mean	SD	p25	p50	p75
Patent Applications (12M)	2265	124.59	638.62	0.00	0.00	8.00
Patent Applications (18M)	2265	188.71	965.79	0.00	0.00	12.00
Patent Applications (24M)	2265	227.69	1160.94	0.00	1.00	15.00
Log(Total Patent Citation)	2265	2.14	2.84	0.00	0.00	4.48
Log(Patent Purchase from M&A)	1629	0.53	1.44	0.00	0.00	0.00
Politically Connected Firms	2265	0.82	0.39	1.00	1.00	1.00
Log(Total Assets)	2265	9.47	1.64	8.36	9.62	10.75
Book-to-Market	2265	0.43	0.76	0.25	0.42	0.64
Leverage	2265	0.28	0.18	0.15	0.27	0.38
ROA	2265	0.04	0.08	0.01	0.04	0.08
Firm Age	2265	36.58	23.63	16.00	33.00	58.00
R&D	2265	0.02	0.04	0.00	0.00	0.01
Industry Competition (HHI)	2265	0.07	0.07	0.03	0.04	0.08
Industry R&D Intensity	2265	0.30	0.31	0.06	0.17	0.48
Log(CEO Total Delta)	2265	5.98	2.16	5.19	6.28	7.35
Log(CEO Total Vega)	2265	4.22	2.41	2.89	4.81	6.06
CEO Short Career Horizon	2265	0.63	0.48	0.00	1.00	1.00
CEO Patience	2126	1.06	6.78	-0.22	1.50	3.55
CEO Wealth	2265	9.98	3.06	9.48	10.61	11.53
Aggregated ROA Growth	2265	-3.72	115.87	-0.31	0.02	0.62
Analyst Forecast Pressure	1599	-0.01	0.28	-0.02	-0.01	0.00

Board Independence	1410	0.69	0.09	0.64	0.68	0.72
Co-Developed Patents	2265	285.50	1437.78	0.00	1.00	19.00

Table 3: Close Election and Patent Application at Networking Firms

This tables shows the main results. Column (1) is the results of the zero-inflated Poisson (ZIP) regression as described in Model (1):
$Log(Patent\ Applications_{i,t+1}) = \alpha * Politically\ Connected\ Firms_{i,t} + \gamma * Controls_{i,t} + \eta_t + \delta_j + \varepsilon_{i,t}$. Columns (2) – (3) use *Log(Total Patent Citation)* and *Log(Patent Purchase from M&A)* as the outcome variables respectively and both employ an OLS regression. The variable of interest is *Politically Connected Firms* which indicates that the firm donates to the winning (*Politically Connected Firms*=1) or the losing candidate (*Politically Connected Firms*=0)* of a close special election. Refer to the Appendix for the detailed definition of all variables. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Dependent Variables =	Log(Patent Applications) (12M)	Log(Total Patent Citation)	Log(Patent Purchase from M&A)
	(1)	(2)	(3)
Politically Connected Firms	-0.653***	-0.369*	0.214*
	(0.188)	(0.173)	(0.093)
Log(Total Assets)	0.646***	0.472***	0.220***
	(0.060)	(0.039)	(0.028)
Book-to-Market	-0.199*	-0.065	-0.142*
	(0.097)	(0.053)	(0.061)
Leverage	-3.822***	-0.137	0.049
	(0.776)	(0.263)	(0.156)
ROA	0.698	1.792+	2.623***
	(0.805)	(0.953)	(0.595)
Firm Age	0.007	0.017***	0.009***
	(0.004)	(0.002)	(0.002)
R&D	9.325***	22.656***	10.811***
	(1.302)	(3.622)	(1.931)
Industry Competition (HHI)	2.694	1.544*	-1.745***
	(1.834)	(0.684)	(0.425)
Industry R&D Intensity	-0.826*	-0.349**	-0.055
	(0.338)	(0.132)	(0.058)
Log(CEO Total Delta)	-0.053	0.042	-0.029
	(0.049)	(0.033)	(0.019)
Log(CEO Total Vega)	0.048	0.001	0.000
	(0.052)	(0.023)	(0.019)
Constant	-0.508	-3.258***	-1.893***
	(0.944)	(0.331)	(0.234)
Year F.E.	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes
S.E.	Robust	Robust	Robust

Observations	2,265	2,265	1,629
Chi-squared	1327	1383	1302
Prob > chi2	<0.0001		0
Adj-R-Squared		0.531	0.327

Table 4: Short-Termism at CEO Level: CEO Career Horizon, Patience and Wealth

This tables shows the results of the zero-inflated Poisson (ZIP) regression as described in Model (2): $Log(Patent\ Applications_{i,t+1})$
$= \alpha_1 = \alpha_1 * Winning\ Networking\ Firms_{i,t} + \alpha_2 * Moderator_{i,t} + \alpha_3 *$
$Winning\ Networking\ Firms_{i,t} * Moderator_{i,t} + \gamma * Controls_{i,t} + \eta_t + \delta_j + \varepsilon_{i,t}$
where *Moderator* is a set of CEO-level characteristics. Specifically, Column (1)-(3) correspond to *CEO Short-Career Horizon* (CEO age above or below 56), *CEO Patience* (industry-adjusted delay of vested options) and *CEO Wealth* (CEO wealth accumulated from the firm), respectively. The variable of interest is the interaction term *Politically Connected Firms * Moderator* which indicates the moderating effect of the *Moderator* on the main effect. Refer to the Appendix for the detailed definition of all variables. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Dependent Variables =	Log(Patent Applications) (12M)		
	(1)	(2)	(3)
Politically Connected Firms	0.007	-0.706***	-1.628**
	(0.354)	(0.199)	(0.618)
CEO Short Career Horizon	0.497		
	(0.331)		
	0.133		
Politically Connected Firms x CEO Short Career Horizon	-0.931*		
	(0.399)		
CEO Patience		-0.071*	
		(0.031)	
		0.021	
Politically Connected Firms x CEO Patience		0.108**	
		(0.034)	
CEO Wealth			-0.024
			(0.122)
			0.842
Politically Connected Firms x CEO Wealth			0.104+
			(0.061)
Controls	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes
S.E.	Robust	Robust	Robust
Observations	2,265	2,126	2,265
Chi-squared	1296	1422	1345
Prob > chi2	0	0	0

Table 5: Firm Level Situational Pressures

This tables shows the results of the zero-inflated Poisson (ZIP) regression as described in Model (2): $Log(Patent\ Applications_{i,t+1}) = \alpha_1 * Politically\ Connected\ Firms_{i,t} + \alpha_2 * Moderator_{i,t} + \alpha_3 * Politically\ Connected\ Firms_{i,t} * Moderator_{i,t} + \gamma * Controls_{i,t} + \eta_t + \delta_j + \varepsilon_{i,t}$, where *Moderator* is a set of proxies for firm-level situational constraints. Specifically, Column (1)-(2) correspond to *Aggregated ROA Growth (t-2, t-1)* (sum of change in ROA growth rate in the past two years) and *Analyst Forecast Pressure (t-1)* (the distance of actual EPS to the analyst consensus forecast in the past year), respectively. The variable of interest is the interaction term *Politically Connected Firms * Moderator* which indicates the moderating effect of the *Moderator* on the main effect. Refer to the Appendix for the detailed definition of all variables. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Dependent Variables =	Log(Patent Applications) (12M)	
	(1)	(2)
Politically Connected Firms	-0.511+	-0.500+
	(0.291)	(0.287)
Aggregated ROA Growth (t-2, t-1)	-0.073	
	(0.046)	
Politically Connected Firms x Aggregated ROA Growth (t-2, t-1)	0.093*	
	(0.046)	
Analyst Forecast Pressure (t-1)		0.790***
		(0.205)
Politically Connected Firms x Analyst Forecast Pressure (t-1)		-1.183*
		(0.474)
Controls	Yes	Yes
Year F.E.	Yes	Yes
IND F.E.	Yes	Yes
S.E.	Robust	Robust
Observations	2,265	1,599
Chi-squared		1856
Prob > chi2		0

Table 6: Disciplining Forces: Internal and External Disciplines

This tables shows the results of the ZIP regression as described in the following model:

$$Log(Patent\ Applications_{i,t+1})$$
$$= \alpha_1 * Politically\ Connected\ Firms + \alpha_2 * Discipline_{i,t}$$
$$+ \alpha_3 * Politically\ Connected\ Firms_{i,t} * Discipline_{i,t} + \gamma * Controls_{i,t} + \eta_t + \delta_j + \varepsilon_{i,t}$$

, where *Discipline* is a set of proxies various disciplining forces. Specifically, Column (1)-(3) correspond to *Log(CEO Total Vega)* (sensitivity of CEO compensation to stock volatility), *Board Independence* (proportion of independent directors on board) and *Co-Developed Patents (3Y)* (number of co-developed patents filed by the firm during the past three years), respectively. The variable of interest is the interaction term *Politically Connected Firms * Discipline* which indicates the disciplining effect of the disciplining effect proxied by *Discipline* on the main effect. Refer to the Appendix for the detailed definition of all variables. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Dependent Variables =	Log(Patent Applications) (12M)		
	(1)	(2)	(3)
Politically Connected Firms	-1.242***	-4.990*	-4.990*
	(0.323)	(2.097)	(2.097)
Log(CEO Total Vega)	-0.047+		
	(0.027)		
Politically Connected Firms x Log(CEO Total Vega)	0.082*		
	(0.035)		
Board Independence		-3.229	
		(2.972)	
Politically Connected Firms x Board Independence		7.218*	
		(3.273)	

Co-Developed Patents (3Y)			0.106***
			(0.020)
Politically Connected Firms x Co-Developed Patents (3Y)			0.048*
			(0.021)
Controls	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes
S.E.	Robust	Robust	Robust
Observations	2,265	1,410	2,265
Chi-squared	1797	1361	2537
Prob > chi2	0	0	0

Table 7: Actual Benefits of Winning: Comparing Politically Connected Firms with their non-donating Peer firms (t, t+2)

This table summarizes the analysis on the benefits of winning in the close special elections over the focal firm's non-donating peers. Column (1)-(4) use the sample of close elections (MoV <=5%), while Column (5)-(8) use the sample of all special elections. Outcome variables tested measure changes over subsequent two years (as indicated by △) and include *Log(GOV Sales)* (sales to government agencies), *Sales Growth* (growth rate of total sales), *MK* (market capitalization) and *Employee* (number of employees). Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Sample	Close Elections				All Special Elections			
Dependent Variables =	△Log(GOV Sales)	△Sales Growth	△MK	△Employee	△Log(GOV Sales)	△Sales Growth	△MK	△Employee
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Networking Firms	0.005**	0.053***	0.074***	0.019***	0.007***	0.058***	0.098***	0.026***
	(0.002)	(0.014)	(0.020)	(0.006)	(0.001)	(0.009)	(0.011)	(0.003)
Log(Total Assets)	-0.000*	-0.025***	-0.004	0.003***	-0.001***	-0.022***	-0.007*	-0.002*
	(0.000)	(0.004)	(0.004)	(0.001)	(0.000)	(0.004)	(0.003)	(0.001)
Book-to-Market	0.000	0.005	-0.015	-0.011***	-0.000	0.005	-0.027*	-0.011***
	(0.000)	(0.006)	(0.012)	(0.001)	(0.000)	(0.006)	(0.011)	(0.001)
Leverage	0.000	-0.071+	0.017	-0.024***	0.001	-0.061+	0.023	-0.024***
	(0.000)	(0.037)	(0.028)	(0.004)	(0.001)	(0.033)	(0.026)	(0.004)
ROA	0.000*	-0.174***	-0.018	0.013***	0.001***	-0.169***	-0.011	0.019***
	(0.000)	(0.046)	(0.021)	(0.002)	(0.000)	(0.045)	(0.021)	(0.002)
Firm Age	0.000*	0.003***	-0.001+	-0.002***	0.000	0.002***	-0.001**	-0.002***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
R&D	-0.000	-0.339*	0.332***	-0.036***	-0.003*	-0.341**	0.307***	-0.042***
	(0.001)	(0.135)	(0.066)	(0.006)	(0.001)	(0.131)	(0.064)	(0.007)
Industry Competition (HHI)	-0.004	0.162+	0.148	-0.021	-0.003	0.129*	0.030	-0.042*
	(0.006)	(0.090)	(0.097)	(0.022)	(0.005)	(0.065)	(0.074)	(0.018)

Industry R&D Intensity	0.002***	0.043**	0.145***	0.016***	0.004***	0.034**	0.134***	0.025***
	(0.001)	(0.016)	(0.016)	(0.004)	(0.001)	(0.013)	(0.014)	(0.003)
Log(CEO Total Delta)	0.000*	0.008***	0.013***	0.013***	0.001***	0.007***	0.013***	0.016***
	(0.000)	(0.003)	(0.003)	(0.001)	(0.000)	(0.002)	(0.002)	(0.001)
Log(CEO Total Vega)	0.000	0.003	-0.005	-0.007***	0.000	0.004*	-0.010***	-0.009***
	(0.000)	(0.003)	(0.003)	(0.001)	(0.000)	(0.002)	(0.002)	(0.001)
Constant	-0.000	0.032	0.013	0.040***	0.001	0.026	0.067**	0.062***
	(0.001)	(0.031)	(0.025)	(0.004)	(0.001)	(0.026)	(0.022)	(0.004)
Year F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
S.E.	Robust	Robust	Robust	Robust	Robust	Robust	Robust	Robust
Observations	44,452	36,114	37,582	35,114	54,551	45,886	47,333	44,767
Adj-R-squared	0.00629	0.0121	0.0455	0.0602	0.0155	0.0123	0.0507	0.0771

Table 8: Other Short-Term Activities: Where to Spend the Money

This table presents the analysis using different short-term activities as the outcome variables along other dimensions. Column (1) – (3) correspond to *Number of Domestic M&A* (number of domestic M&A conducted), *Log(Tax Settlement)* (total tax expenses) and *Log(PAC Donation)* (total donation through PAC). The variable of interest is *Politically Connected Firms*. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1.

Dependent Variables =	Log(Tax Settlement)	Log(PAC Donation)	Number of Domestic M&A
	(1)	(2)	(3)
Politically Connected Firms	0.332**	0.658*	0.219+
	(0.128)	(0.307)	(0.120)
Log(Total Assets)	0.538***	0.969***	0.148***
	(0.036)	(0.060)	(0.033)
Book-to-Market	-0.175**	-0.249*	-0.179
	(0.061)	(0.109)	(0.119)
Leverage	0.290	-1.059**	-0.520*
	(0.243)	(0.373)	(0.249)
ROA	1.637**	3.301**	1.992*
	(0.535)	(1.253)	(0.925)
Firm Age	-0.006**	-0.003	-0.003+
	(0.002)	(0.003)	(0.002)
R&D	6.524***	2.766	-1.302
	(1.233)	(3.245)	(1.479)
Industry Competition (HHI)	3.069***	4.772***	-0.358
	(0.877)	(0.919)	(0.758)
Industry R&D Intensity	-1.072***	-0.115	-0.119
	(0.141)	(0.212)	(0.139)
Log(CEO Total Delta)	-0.075**	0.252***	0.064+
	(0.025)	(0.052)	(0.033)
Log(CEO Total Vega)	0.052*	-0.009	-0.030+
	(0.024)	(0.032)	(0.017)
Constant	-3.688***	11.747***	-0.393
	(0.305)	(0.640)	(0.490)
Controls	Yes	Yes	Yes
Year F.E.	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes
S.E.	Robust	Robust	Robust
Observations	2,021	1,921	2,265
Adj-R-squared	0.470	0.438	
Chi-squared			466.8
Prob > chi2			0

Table 9 Robustness Tests

This table presents the results of robustness tests that use the model as in the main results and alternative sample (Column (1)-(2)), alternative event window to capture patent filing (Column (3)-(4)) or alternative threshold in company name matching (Column (5)). In Column (1)-(2) we use a more (3%) or less (7%) strict threshold of MOV to define close elections. In Column (3)-(4) we extend the event window to capture patent applications to either 18 or 24 months subsequent to the election date. In Column (5) we use a more stringent matching criterium to define a "good" match, i.e., the similarity score of the match exceeds 90. Robust standard errors in parentheses *** p<0.001, ** p<0.01, * p<0.05, + p<0.1

Dependent Variables =	Log(Patent Applications) (12M)		Log(Patent Applications) (18M)	Log(Patent Applications) (24M)	Log(Patent Applications) 90%(12M)
	|MOV|<=3%	|MOV|<=7%			
	(1)	(2)	(3)	(4)	(5)
Politically Connected Firms	-0.465+	-0.513**	-0.607***	-0.514**	-0.634***
	(0.238)	(0.165)	(0.184)	(0.198)	(0.191)
Log(Total Assets)	0.621***	0.637***	0.657***	0.660***	0.663***
	(0.081)	(0.050)	(0.063)	(0.063)	(0.062)
Book-to-Market	-0.092	-0.208*	-0.167+	-0.190*	-0.325*
	(0.134)	(0.094)	(0.091)	(0.090)	(0.143)
Leverage	-3.194**	-3.321***	-4.039***	-4.140***	-3.805***
	(1.094)	(0.623)	(0.777)	(0.777)	(0.881)
ROA	0.187	1.555+	0.790	0.750	0.608
	(1.536)	(0.805)	(0.838)	(0.825)	(0.782)
Firm Age	0.006	0.008*	0.007	0.006	0.007
	(0.005)	(0.004)	(0.004)	(0.004)	(0.004)

R&D	8.734***	10.356***	9.591***	9.581***	8.870***
	(1.963)	(1.289)	(1.335)	(1.322)	(1.333)
Industry Competition (HHI)	-0.141	3.621*	3.006	3.499+	5.081**
	(2.858)	(1.417)	(1.840)	(1.790)	(1.835)
Industry R&D Intensity	-0.907+	-0.829**	-0.926**	-0.755*	-0.923*
	(0.527)	(0.282)	(0.337)	(0.325)	(0.363)
Log(CEO Total Delta)	0.015	-0.076+	-0.056	-0.049	-0.046
	(0.072)	(0.041)	(0.049)	(0.048)	(0.052)
Log(CEO Total Vega)	0.023	0.042	0.061	0.068	0.060
	(0.060)	(0.041)	(0.051)	(0.051)	(0.054)
Constant	-0.387	-1.168+	-0.090	-0.167	-0.987
	(1.257)	(0.696)	(0.978)	(0.991)	(0.939)
Year F.E.	Yes	Yes	Yes	Yes	Yes
IND F.E.	Yes	Yes	Yes	Yes	Yes
S.E.	Robust	Robust	Robust	Robust	Robust
Observations	1,475	3,107	2,265	2,265	2,265
Chi-squared	1103	1955	1383	1302	1275
Prob > chi2	0	0	0	0	0

5 Conclusion

This dissertation investigates the incentives behind firms' R&D disclosure and investment decisions. Through a combination of empirical and analytical evidence, it explores three main areas: (i) firms' strategic considerations regarding R&D disclosure in financial reporting within the context of an R&D race, (ii) the spillover effects of R&D disclosure in a new market with a disclosure mandate, and (iii) the impact of political connections on innovation.

Chapter 2, co-authored with Jeroen Suijs, focuses on firms competing in a multiperiod R&D race and examines their disclosure strategies when they have the option to disclose interim progress in financial reports. The chapter identifies different disclosure equilibria based on the investment cost in the subsequent period. It demonstrates that an asymmetric equilibrium, where one firm discloses while the other does not, can be resolved through an asymmetric disclosure mandate. The findings also reveal that disclosure reduces the attractiveness of preceding investments. A static comparison of preceding investments across equilibria highlights the differential effects of an asymmetric disclosure mandate depending on whether the non-regulated firm discloses or not in the absence of the mandate.

In Chapter 3, the dissertation explores a new stock market in China that mandates detailed R&D disclosure, examining the shock of peer disclosure on firms not subject to the mandate. The research reveals that firms with peer firms going public on the new market tend to reduce their voluntary R&D disclosure, particularly in weaker information environments. Surprisingly, the reduction in their own disclosure does not negatively impact stock liquidity. The analysis also indicates that the reduction mainly occurs in the non-proprietary information category and does not vary along industry competition. These findings suggest that the negative spillover effect is primarily driven by the free-riding incentives of focal firms seeking to save costs associated with their own disclosure.

Chapter 4, a collaborative effort with Wenjiao Cao and Zhiyan Wu, investigates the impact of political connections on firm innovation. Using closely contested US special elections as a quasi-natural experiment, the study documents a negative effect of political connections on firm innovation. Specifically, it reveals a shift in firms' operations from long-term to short-term activities, with the effect being amplified by CEO short-term preferences and situational pressures. However, various disciplining forces

act as constraints. The evidence suggests that managerial short-termism explains the negative effect observed.

Collectively, these three chapters of this dissertation provide a comprehensive exploration of firm behaviour, encompassing voluntary R&D disclosures, inter-firm information spillover, and the impact of political connections on innovation strategies. By connecting these areas of research, this thesis offers a holistic understanding of the complex dynamics influencing firms' decision-making processes and subsequent outcomes in the context of innovation activities. The findings contribute to the literature on strategic disclosures, inter-firm dynamics, and the intersection of politics and business.

Samenvatting (Summary in Dutch)

Dit proefschrift onderzoekt de prikkels achter R&D-openbaarmakingen en beleggingsbeslissingen van bedrijven. Aan de hand van een combinatie van empirisch en analytisch bewijsmateriaal worden drie belangrijke gebieden beschouwd: (i) de strategische overwegingen van bedrijven met betrekking tot R&D-openbaarmaking in financiële rapportage binnen de context van een R&D-race, (ii) de spillover-effecten van R&D-openbaarmaking in een nieuwe markt met een openbaarmakingsverplichting, en (iii) de invloed van politieke connecties op innovatie.

Hoofdstuk 2, met Jeroen Suijs als co-auteur, richt zich op bedrijven die gedurende meerdere perioden verwikkeld zijn in een R&D-race. Het onderzoekt wat de openbaarmakingsstrategieën van deze bedrijven zijn wanneer ze de optie hebben om tussentijdse vooruitgang openbaar te maken in financiële rapportage. In het hoofdstuk worden verschillende openbaarmakingsevenwichten geïdentificeerd aan de hand van de investeringskosten in de erop volgende periode. Het toont aan dat een asymmetrisch evenwicht, waarbij het ene bedrijf wel informatie openbaar maakt en het andere niet, kan worden opgelost door middel van een asymmetrische openbaarmakingsverplichting. Uit de bevindingen blijkt ook

dat openbaarmaking de aantrekkelijkheid van voorafgaande investeringen vermindert. Uit een statische vergelijking van voorafgaande investeringen over verschillende evenwichten blijkt hoe de differentiële effecten van een asymmetrische openbaarmakingsverplichting afhangen van de vraag of bij het ontbreken van een verplichting het niet-gereguleerde bedrijf wel of niet informatie openbaar maakt.

In hoofdstuk 3 van het proefschrift wordt een nieuwe Chinese effectenbeurs onderzocht die gedetailleerde R&D-openbaarmaking verplicht stelt, en wordt er gekeken naar de schok die openbaarmaking door collega-bedrijven teweeg brengt bij ondernemingen die niet onder de verplichting vallen. Uit het onderzoek blijkt dat bedrijven waarvan collega-bedrijven op deze nieuwe beurs een beursgang maken, de neiging hebben om hun vrijwillige openbaarmaking op het gebied van R&D te verminderen, met name in zwakkere informatieomgevingen. Verrassend genoeg heeft de vermindering van de eigen openbaarmaking geen negatieve invloed op hun aandelenliquiditeit. Uit de analyse blijkt ook dat de vermindering voornamelijk betrekking heeft op niet-bedrijfseigen informatie, en niet varieert met de concurrentie in de sector. Deze bevindingen suggereren dat het negatieve spillover-effect voornamelijk wordt gedreven door de free-

riderprikkels voor focusbedrijven die willen besparen op de kosten die verband houden met hun eigen openbaarmaking.

Hoofdstuk 4, een samenwerking met Wenjiao Cao en Zhiyan Wu, onderzoekt de impact van politieke connecties op bedrijfsinnovatie. Uit het onderzoek, op basis van tussentijdse verkiezingen in de VS waarin het erom spande, blijkt er een negatief effect te zijn van politieke connecties op bedrijfsinnovatie. Concreet wordt een verschuiving blootgelegd bij bedrijven van langetermijn- naar kortetermijnactiviteiten, waarbij het effect wordt versterkt door situationele druk en een voorkeur van de CEO voor kortetermijnactiviteiten. Verschillende disciplinerende krachten werken daarbij echter als remmende factor. Het bewijs suggereert dat kortetermijndenken van het management het waargenomen negatieve effect verklaart.

Gezamenlijk bieden de drie hoofdstukken van dit proefschrift een omvattende verkenning van het gedrag van bedrijven, onder andere op het gebied van vrijwillige R&D-openbaarmakingen, informatie-spillover tussen bedrijven en de impact van politieke connecties op innovatiestrategieën. Door deze onderzoeksgebieden met elkaar te verbinden, biedt dit proefschrift een holistisch overzicht van de complexe dynamiek die van invloed is op de

besluitvormingsprocessen van bedrijven en de daaruit voortvloeiende innovatieresultaten. De bevindingen verrijken de literatuur over strategische openbaarmaking, de dynamiek tussen bedrijven, en het spanningsveld tussen politiek en bedrijfsleven.

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Mengfan Liu was born in Hunan, China. In 2011, he completed his Bachelor's study in Economics at Huazhong University of Science and Technology in China before moving to Frankfurt, Germany where he obtained his Master's degree in Finance at Frankfurt School of Finance and Management in 2013. Mengfan had worked as a consultant for around three years in the field of development finance. In 2018 Mengfan started his PhD in Accounting at Erasmus Research Institute of Management of the Erasmus University Rotterdam. His research interests include financial disclosure and innovation. He has been investigating corporations' incentives or disincentives to voluntarily disclose technology-related information and/or make R&D investments. During his PhD, Mengfan visited the London School of Economics and Political Sciences in Spring 2022. Mengfan has been appointed as Assistant Professor at the Vrije University Amsterdam since September 2023.

Portfolio

Working in progress

- "Foreign institutional ownership and technology diffusion" with Ray Zhang (Simon Fraser University) and Zheng Wang (City University of Hong Kong)
- "ESG disclosure mandate and green patenting" with Edith Leung (Erasmus University Rotterdam) and Nico Lehmann (Erasmus University Rotterdam)

Doctoral coursework

- Erasmus Research Institute of Management: Economic Foundations, Mathematics and Statistics, R, Seminar Corporate Finance, Micro Economics, Applied Econometrics, Modern Applied Statistics, Scientific Integrity and Publishing Strategy
- London School of Economics and Political Sciences: PhD Seminar in Accounting (audited)
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