

# Collusion with Public and Private Ownership and Innovation

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## Abstract

We argue that public ownership gives firms the option to collude and engage in rent seeking on existing technologies. While this option can enhance firm value, it also reduces the commitment to develop new technologies. We show that the option to collude is valuable when innovation is either not attractive or very attractive, resulting in a U-shaped relation between the attractiveness of innovation and the preference for public ownership. Control via equity stakes could also facilitate rent seeking, but is an imperfect substitute. The main predictions of our model are consistent with empirical patterns and shed light on several puzzling stylized facts.

**Keywords:** public and private ownership, innovation, coordination, collusion.

**JEL Classification:** G31, G32, L41, O31

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# 1 Introduction

The demise of the public corporation has been widely trumpeted in the news and academic literature (Gao et al., 2013; Doidge et al., 2016). Fewer firms go public nowadays than they have done historically, and new firms delay longer their initial public offerings. One explanation that stands out is the plethora of regulation, information requirements, and public scrutiny faced by public firms, which could lead to leaking of valuable information to competitors (Bhattacharya and Ritter, 1984) or to pressures to focus on the current share price and behave myopically (Stein, 1989). Despite such arguments, public firms are profitable like never before, calling into question such concerns and gloomy projections.<sup>1</sup>

To add to the contradictions surrounding public firms, recent empirical work has found evidence that private firms' innovation is more impactful (Bernstein, 2015). Yet public firms, such as Amazon, Apple, and IBM, seem to defy such findings, being at the forefront of innovation and aggressively pursuing long-shot game-changing technologies. For example, the common belief in technology circles is that “Google is furthest along in quantum technology” and “Microsoft has the most comprehensive plan to make the software required.”<sup>2</sup>

In this paper, we relate the decision to go public to a firm's innovation incentives and its ability to extract rents on existing technologies. We argue that a key argument in favor of public ownership is that by committing firms to the regular provision of transparent and vetted information, it creates collusion opportunities not available under private ownership.<sup>3</sup> Thus, new players go public when their technology is becoming a commodity and they seek coordination to maintain high margins.

Having the option to collude can diminish or increase the incentives for innovation. On the one hand, we show that this option makes it more difficult to commit not to abandon the development of a new technology in the face of early difficulties. This could lead to time-inconsistency problems not present under private ownership, and creates a trade-off between the option to collude and the ability to commit to long-term innovation. On the other hand, collusion can also be good for innovation if firms simultaneously work on developing similar technologies. One of our main findings is that these trade-offs lead to a

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<sup>1</sup>See “Larry Summers: Corporate profits are near record highs. Here's why that's a problem,” Washington Post, March 30, 2016.

<sup>2</sup>The Economist, Technology Quarterly, March 9, 2017.

<sup>3</sup>Naturally, private firms may also disclose information. However, the key differences are that both the vetting/verifiability standards for public firms are higher and that there is significant additional information production about public firms by third parties, such as analysts. Indeed, the conflict between the calls for more transparency in public firms and antitrust concerns has been recognized in the law literature (Steuer et al., 2011) and features in the OECD Competition Committee (2012) roundtable discussions.

U-shaped relation between the attractiveness of public ownership and the expected profitability of innovation, with private ownership dominating the middle ground—a finding that could shed light on why public firms can appear both leaders and laggards in innovation. By relating the going public decision to collusion possibilities, our paper could also shed light on why the recent decline in public ownership seems to go hand-in-hand with an increase in takeovers (Doidge et al., 2016), which offer an alternative way to coordinate.

Our model features two firms, an innovative player (‘the innovator’) and an incumbent that operate in the same market. This setting has two main elements. First, in the initial period, the innovator can start exploring a new technology, which requires hiring an R&D team that needs to be motivated to exert unobservable effort. At an interim date of that period, the innovator obtains a signal indicating the new technology’s profitability. At this point, exploration can be abandoned and the innovator can adopt the incumbent’s technology. However, if the new technology is not abandoned and is successful, the innovator obtains high returns. The second main element of our model is that, when both firms use the same technology, they might engage in collusion. What stands in the way of colluding, however, is that each firm faces a type of prisoner’s dilemma: Coordination over two periods is beneficial, but firms might have incentives to deviate since such deviations might be difficult to detect. This is because, by observing whether their own cash flows are low or high, firms draw imperfect signals about each other’s actions.

Our first main result is that public ownership helps in sustaining collusion when both firms use the same technology. The key distinguishing feature of public ownership is that it commits firms to truthfully reporting their cash flows (while in our baseline model, the cash flows under private ownership are unobservable). This has two implications for collusion under public ownership. The first one is immediate: when firms draw less noisy signals about each other’s actions (because signals are based on more information), a breakdown in collusion due to wrong inferences becomes less likely. The key implication, however, is the second one. The fact that a private firm’s cash flows are its private information could make collusion impossible even if its signals are just as precise as under public ownership.

Specifically, private ownership exposes the firm to the following time inconsistency problem. On the one hand, the firm would like to commit ex ante to punishing the other firm if its own cash flows are low, which would indicate that the other firm has deviated from a collusive equilibrium. On the other hand, when being in a supposedly collusive equilibrium, such a signal indicating a deviation can only be wrong, i.e., the firm’s low cash flows must be due to bad luck rather than to a deviation by the other firm. Thus, the private firm prefers ex post to neglect this signal and stick to the more profitable

collusive strategy. This is because, being unaware that it will be punished, the other firm would also most likely continue following a collusive strategy. The problem with this ex post incentive to avoid punishment means, however, that a collusive equilibrium cannot be sustained. Public ownership circumvents this problem by committing the firm to truthfully reporting its cash flows and, thus, effectively announcing signals that should lead to a punishment. Indeed, when such signals are made common knowledge, it also becomes common knowledge that both firms should revert to a non-collusive punishment strategy, making it, indeed, mutually optimal to stop colluding. With credible punishments, a collusion equilibrium can be sustained. Thus, where public ownership really matters is that it commits to the firm to high reporting standards of its cash flows.

Our second main result is that securing the ability to collude might not be beneficial if the firm pursues innovation. The option to collude on an existing technology, improving its profitability, makes it more likely that the innovator abandons the development of the new technology in the face of a discouraging signal. This could lead to another time-inconsistency problem, this time more acute under public ownership: abandonment becomes too likely, making it very expensive to motivate the R&D team to exert effort. Thus, public ownership leads to a trade-off between a higher cost of motivating effort and having a better abandonment option.

Which of these two effects dominates depends on the new technology's expected profitability. We show that, if that profitability is low, the innovator is better off under public ownership. In this case, the option to abandon the new technology in case of early difficulties and collude on the existing one is very valuable. Things change if the new technology's expected profitability becomes sufficiently high. Then, the option to collude on the existing technology associated with public ownership becomes relatively less important compared to the higher cost of motivating the R&D team. Finally, if the new technology's expected profitability is so high that also the incumbent decides to pursue it, such highly-profitable innovation opportunities are best developed in public firms. This is because public ownership now offers colluding opportunities on the new technology. This leads to a U-shaped relation between the attractiveness of public ownership and the new technology's expected profitability.

We extend the model along several dimensions. First, we analyze equity stakes as alternative ways to achieve collusion and discuss their impact on innovation incentives depending on whether they are controlling or non-controlling. Second, we analyze the effect of the relative size of the incumbent and innovator and show that a small innovator's ability to chip away market share from large incumbents without triggering a response (using the old technology) could reduce the innovator's innovation incentives. Third, we show that

voluntary reporting by private firms does not help much in terms of achieving collusion, as absent exogenous strict reporting requirements, private firms will have ex post incentives to add noise to their reporting, making collusion ultimately unsustainable.

We provide some tentative empirical support for the notion that being public facilitates collusion. Comparing the propensity of public and private firms to be engaged in antitrust lawsuits, we find that the likelihood that a firm is involved in an antitrust case in the four years after the filing for an IPO is ten percentage points higher for firms that actually completed their IPO than for firms that withdrew their IPO filing. While far from conclusive, the evidence is consistent with the claim that public ownership facilitates collusion. We further find evidence for the U-shaped relation between the attractiveness of innovation and that of public ownership.

The question when firms prefer public and when private ownership has a long history in the finance literature. Our main contribution is to address this question from a novel angle by building on insights from the game theoretic literature that more transparency among competitors facilitates collusion (Green and Porter, 1984; Bhaskar and Van Damme, 2001). Indeed, the higher transparency in public firms is one of the text-book differences between public and private ownership, but the implications for collusion and how that affects innovation incentives in public and private firms have not been thoroughly explored. The corporate finance view seems to be that the higher transparency associated with public ownership is the cost that an innovative firm needs to pay for gaining access to cheaper financing (Bhattacharya and Ritter, 1984; Maksimovic and Pichler, 2001). The cheaper access to capital can help the firm invest in more innovation, especially if the firm gains access to investors who have more aligned beliefs with those of the firms' managers (Allen and Gale, 1999). The empirical evidence is supportive of such theories. Acharya and Xu (2016) find that public firms in external finance dependent industries spend more on innovation and have a better innovation profile than private firms, while the same is not true for internal finance dependent industries. We depart from this discussion, as financial constraints do not feature in our model. In line with our view that public ownership may help facilitate collusion, the law literature has discussed the recent attention of regulators to conference calls with stock analysts as means of disclosing unscripted sensitive information to rivals, helping to support collusion (Steuer et al., 2011). Furthermore, Bourveau et al. (2017) show that the tightening of antitrust laws prompts firms to disclose more information in their reports. The authors argue that this may help firms shift from explicit cartel agreements to supporting tacit collusion.

One of the advantages of private ownership in our model is that it features more tolerance for failure, in the sense of a lower likelihood of abandoning innovation after a

discouraging signal. Specifically, the inability to commit to a new technology gives rise to time inconsistency problems, which might be exacerbated under public ownership. These insights contrast with Ferreira et al. (2014) who argue that the lack of transparency with private financing helps early investors to exit. In their model, the lack of transparency associated with private ownership prevents outside investors from inferring whether the true reason for exit is an illiquidity shock or that the firm’s innovation has failed. Somewhat reminiscent of Grossman and Stiglitz’s (1980) information efficiency paradox, this noise makes it less costly for investors to exit, making early private investors ex ante more willing to invest in risky innovations. There are no time inconsistency problems in Ferreira et al. (2014). Another key difference is that private ownership in their paper always dominates when exploring new ideas. By contrast, we show that, new ideas are better explored under public ownership if they are expected to be either very profitable or only slightly profitable. Private ownership dominates only for intermediate values for the new technology’s profitability. Furthermore, we discuss the effect of equity stakes and the relative sizes of the firms involved for the ability to collude and how that affects innovation and the public-private choice. These different perspectives generate an interesting contrast in empirical predictions.

The U-shaped relationship between the attractiveness of public ownership and the new technology’s profitability is also the main difference with the managerial myopia literature (Stein, 1989) in which public ownership creates time inconsistency due to a manager’s focus on the current stock price. In our model, the reason for time inconsistency is that the firm undermines ex ante innovation incentives when it can fluently respond to interim signals on the new technology. This becomes particularly acute when it can collude on the existing technology, and thus faces an attractive exit option. A further difference is that in our model the ability to collude under public ownership is also valuable when firms compete to develop the new technology, as then they could collude not to eat into each other’s profits once both have successfully developed the new technology.

Our analysis relates also to the vast industrial organization literature analyzing whether market concentration is good for innovation. The conceptual difference in our paper is that we are not interested in the effect of competition on innovation per se,<sup>4</sup> but in the endogenous interaction between the choice of public and private ownership, buying equity

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<sup>4</sup>The question whether competition is good for innovation goes at least back to Schumpeter (1934, 1942). Key factors are whether innovation would have a similar advantage to all firms (Arrow, 1962) or would allow some firms to price discriminate (Greenstein and Ramey, 1998); the extent of competition before or after innovation (Dasgupta and Stiglitz, 1980); the dynamics of R&D (Harris and Vickers, 1985); and whether innovation is preemptive (Gilbert and Newbery, 1982). Another key question is whether patenting is good for innovation (Kultti et al., 2007). See Gilbert (2006) for an extensive literature review.

stakes, and collusion and innovation incentives.<sup>5</sup> We show that such interactions could help explain stylized facts, such as why the recent decrease in public ownership coincides with increased takeover activity (Doidge et al., 2016).

Our paper continues as follows. Section 2 describes the baseline model. Sections 3–5 contain our main results, extensions, and empirical implications, and Section 6 concludes. All proofs are in the Appendix.

## 2 Model

There are two firms, an innovator and an incumbent, operating in a two-period economy with three dates,  $t = 0$ ,  $t = 1$ , and  $t = 2$ . Both firms are risk neutral and there is no discounting.

**The technologies** At  $t = 0$ , the innovator has access to two technologies—an innovative (new) technology and an incumbent (old) technology. Neither technology requires an initial investment, but the innovator has the capacity to choose only one. The new technology is risky. It is viable and returns positive cash flows with probability  $\theta$  and is unviable, returning 0, with probability  $1 - \theta$ . This probability is unknown at date  $t = 0$  when the technology choice is made. It is only commonly known that it can take on three values  $\theta \in \{0, \theta_B, \theta_G\}$  where the ex ante probabilities of  $\theta_B$  and  $\theta_G$  are  $p_B$  and  $p_G$ , respectively, and where  $0 < \theta_B < \theta_G < 1$ . At the interim date  $t = 0.5$ , an observable but not verifiable signal is realized that shows the value of  $\theta$ . At this point in time, if the innovator has started the new technology, it can abandon it and switch to the incumbent technology. In either case, the first-period cash flows are realized only at the end of the period.

If the innovator decides to start the new technology, it needs to hire an R&D team. If the R&D team exerts effort, it can increase the likelihood of  $\theta_B$  and  $\theta_G$  to  $p_B + \tau_B$  and  $p_G + \tau_G$ , respectively. However, the R&D team’s effort is not verifiable, and by shirking (which leaves the probabilities of  $\theta_B$  and  $\theta_G$  unchanged at  $p_B$  and  $p_G$ ), the R&D team can save a non-monetary cost  $c$ . We assume that the decision whether or not to abandon the new technology at  $t = 1$  lies with the innovator, and not the R&D team.<sup>6</sup>

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<sup>5</sup>Prior work shows that cross-ownership could reduce the need to compete (Reynolds and Snapp, 1986), may reduce innovation incentives (Matthews, 2006), but could also sometimes make collusion more difficult (Malueg, 1992). Related is also the literature relating the going public decision to product market competition absent collusion (Chod and Lyandres, 2010).

<sup>6</sup>This emerges naturally if the realization of  $\theta$  is the innovator’s private information. **That is, the innovator who proposes the idea has the bigger picture and is better informed about factors, such as market demand.**

Unlike the innovator, the incumbent firm operates for sure the incumbent technology in period one. It can additionally try to develop the new technology itself, but this would require hiring the necessary R&D talent to generate the ideas behind the new technology. For our purposes, it is sufficient to assume that this is associated with a deadweight cost of  $k$ , and a likelihood of  $\rho$  that the new technology is successful. Regardless of who develops the new technology, it replaces the incumbent technology in period two if it is successfully developed.

If only one of the two parties successfully develops the new technology, it enjoys first-mover cash flows of  $x_{FM}$  for periods one and two, while the other firm's cash flows are zero in both periods. If none of the firms is successful in developing the new technology, and the innovator has pursued it until the end of period one, the incumbent reaps the monopoly profits  $x_M$  from the incumbent technology, while the innovator obtains zero in both periods. If the new technology is abandoned or never undertaken in period one, both firms use the incumbent technology. If both firms use the same technology (either the new or the old one), collusion might come into play. Figure 1 summarizes the sequence of events.

**Coordination Problem if Both Firms Use the Same Technology** How does collusion work? In each period when using the same technology both firms decide whether to collude (action  $C$ ) or not collude (action  $NC$ ). The action affects the firms' cash flows, which are stochastic and realized at the end of the respective period. If both firms collude in a given period, their expected cash flows when utilizing the preferred (and available) technology in that period are  $x_C$  for each. If neither firm colludes, their expected cash flows are  $x_{NC} < x_C$ . If one of the firms tries to collude, while the other does not, the former firm's expected cash flow is  $x_C - m$ , while the latter firm's expected cash flow is  $bx_{NC}$ , with  $m > 0$  and  $b > 1$ . Intuitively, one can think of this case as one firm setting high prices, while the other firm undercutting it and stealing market share.

A feature of the model is that in a one-shot game (single period) both firms face a prisoner's dilemma, making collusion over one period impossible. However, collusion is potentially possible in a two period setting. To facilitate this, we assume that firms face a (one-time) cost  $K$  the first time they seek collusion, but no such cost in the following period. We now let  $x_C - K < bx_{NC}$ . This means that in a one-period setting, the prisoner's dilemma is acute: anticipating collusion by the other firm, makes choosing no collusion optimal. However, if collusion is chosen nonetheless, colluding again in the following period yields  $x_C > bx_{NC}$ . Assuming in addition that  $(x_C - K) + x_C > bx_{NC} + x_{NC}$  makes collusion over two periods potentially worth it. Summarizing:



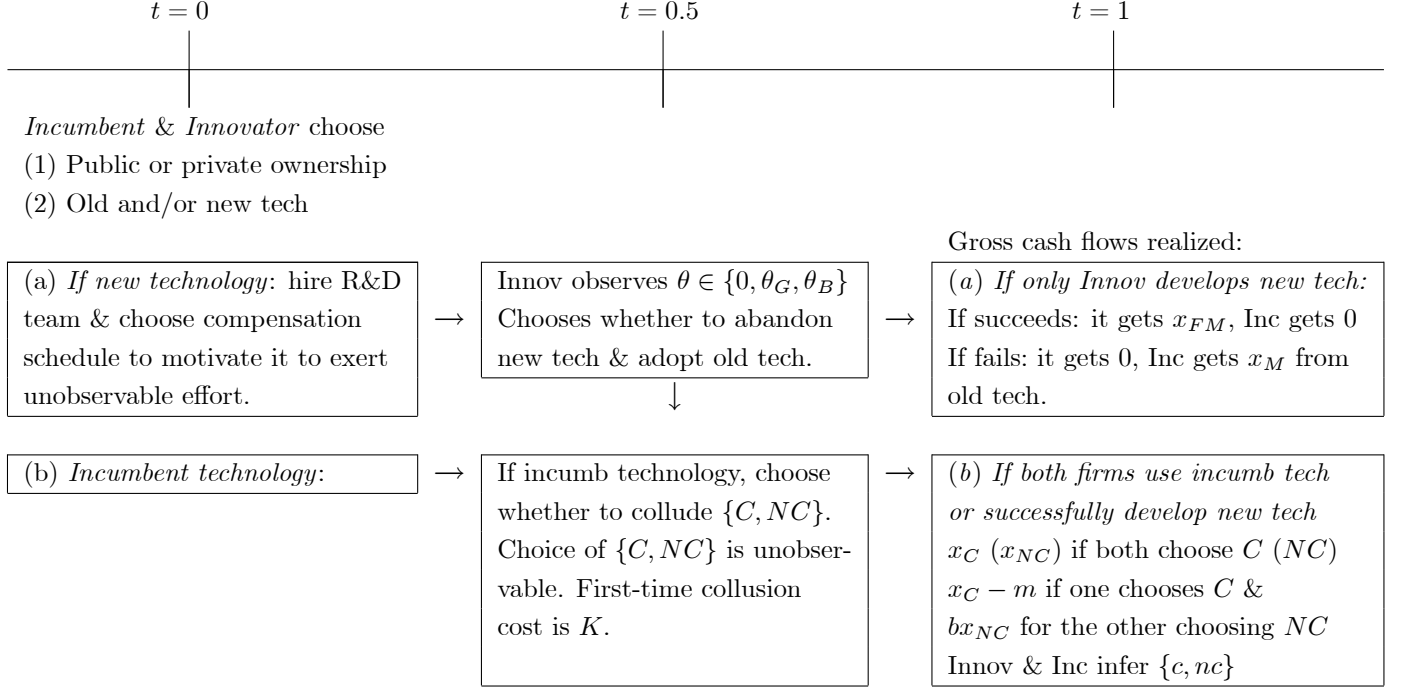


Figure 1: **Timeline of first period.**

**Assumption 1:**  $2x_C - (bx_C + x_{NC}) > K > x_C - bx_{NC} \geq 0$ .

These conditions are necessary (but not sufficient) that collusion is sustainable at least under some circumstances in a two-period setting.<sup>7</sup> A final condition we need is that collusion (e.g., setting high prices) cannot be optimal for a firm if the other firm does not collude (sets lower prices). In that case, not colluding (also setting lower prices) makes the firm better off:

**Assumption 2:**  $x_C - m < x_{NC}$ .

For simplicity, the expected cash flows  $x_C$  and  $x_{NC}$  (and the parameters  $m$  and  $b$ ) are initially the same for both firms. In practice, they might differ depending on the firms' size and first-mover status. Where relevant, we will discuss the consequences of allowing for different sizes between the innovator and the incumbent.

**Information Structure and Public vs. Private Ownership** We assume that direct collusion between the firms is not feasible or (legally) possible. Actions are not observable, but at the end of every period, each firm observes its own cash flows, from which it extracts a signal  $s = \{c, nc\}$  about whether or not the other firm has colluded. An intuitive way to think about these signals is that, upon observing that its own cash flows are low, a firm

<sup>7</sup>In the infinite horizon extension of this model,  $K$  can be set to zero and the second inequality is not necessary.

would infer that the other firm has played  $NC$ . Since cash flows are stochastic ( $x_C$  and  $x_{NC}$  are the expected values), the signal is noisy, and the inference is correct only with probability  $1 - \varepsilon$ .<sup>8</sup>

A critical difference between private and public ownership is that a public firm's cash flows are observable to the other firm. This implies that: (i) The signal a public firm extracts from its cash flows is observable to the other firm; (ii) The inference error  $\varepsilon$  (weakly) decreases, since the signal is based on both firms' cash flows. The decision whether the firm should be public or private is made at the beginning of the first period ( $t = 0$ ).

Naturally, private firms can also report information about themselves if that would be more beneficial. In Section 4.3, we extend the model to account for voluntary reporting by private firms under the assumption that a private firm has the choice to add ex post more noise to its reports. This assumption corresponds to the fact that reporting standards for private firms are typically not as strict. Finally, though outside the model, it is worth mentioning again that what adds to the transparency and the credibility of information about public firms is that third parties, such as stock analysts, actively engage in information production about such firms.

### 3 The Choice Between Public and Private Ownership

There are three main choices in this model: (i) whether firms that use the same technology will collude, (ii) whether the innovator abandons the new technology at  $t = 0.5$  and (iii) whether the innovator is better off innovating under public or private ownership.

In what follows, we show that public ownership facilitates collusion on the incumbent technology by helping it overcome a time-inconsistency problem related to supporting collusion. However, the ability to collude could lead to another time inconsistency problem in which the innovator responds too aggressively (from an ex ante perspective) to unfavorable intermediate signals on the viability of the new technology, i.e., abandons it too often. We proceed as follows. First, we explain how collusion works and how it depends on being public or private. Subsequently, we analyze the choice between public and private ownership and how it interacts with the incentives to innovate.

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<sup>8</sup>At the expense of introducing additional notation, we could derive  $\varepsilon$  from primitives using Bayes rule. However, this is not necessary for our purposes.

### 3.1 Public Ownership as a Coordination Mechanism

Both firms' cash flows are higher if they manage to collude. However, colluding only in one period is not feasible. If one firm intends to collude, it is optimal for the other not to do so, as its expected cash flow from not colluding,  $bx_{NC}$ , is higher than that from colluding,  $x_C - K$ .

The key insight in what follows is that collusion can be sustained if both firms use the same technology for two periods, but this crucially depends on whether the firms choose public or private ownership. The choice of ownership affects two ingredients. First, it affects the inference error on whether the other firm has colluded in the preceding period. Second, and more important, it affects what a firm learns about the other firm's signal. Since strategies can (and will) be based on past signals, knowing a firm's signal reduces the uncertainty about how it would act next. The key advantage of public ownership is that it commits the firm to making this information available.

We now clarify these two points by focusing, first, on the equilibrium under private ownership. Specifically, consider the following equilibrium candidate: Both firms collude in period one, and collude in period two if and only if they infer from their cash flows that the other firm has colluded as well (i.e., their signals are  $c$ ).

Private ownership hampers collusion for two reasons. First, by increasing the inference error  $\varepsilon$ , it makes it less likely that collusion in period two can be sustained. For collusion in period two following signal  $c$  to be preferable to not colluding, it must hold

$$(1 - \varepsilon)x_C + \varepsilon(x_C - m) > (1 - \varepsilon)bx_{NC} + \varepsilon x_{NC}. \quad (1)$$

Both sides of the inequality take into account that even if a firm colludes in period one, the other firm infers signal  $nc$  with probability  $\varepsilon$ , which prompts that firm not to collude in period two. Such punishment reduces the expected payoff from colluding in both periods.<sup>9</sup>

The second reason is that a private faces the following time-inconsistency problem. On the one hand, it would like to commit to punishing the other firm if it infers from its cash flows that firm has not colluded. On the other hand, when the private firm colludes in period one, it has incentives to collude also in the second period regardless of its own cash flows, i.e., regardless of the signal it infers about the other firm's actions. Clearly, without a credible punishment threat, the other firm would not collude in both periods, making it impossible to sustain a collusion equilibrium.

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<sup>9</sup>To get the expected payoff from colluding in period two, add  $x_C$  to the left-hand side of (1). To get the deviation payoff from not colluding twice, add  $bx_{NC}$  to the right-hand side of (1).

To see why a private firm that has colluded in the first period might ignore its signal and collude also in period two, consider the case in which both firms' signals are independent. Since both firms are supposed to collude in period one, they attribute signal  $nc$  to the inference error  $\varepsilon$ , as non-collusion is an out-of-equilibrium (i.e., zero probability) event. In particular, if a private firm colludes in period one, it expects that the other firm receives signal  $c$  with probability  $1 - \varepsilon$  and, thus, colludes also in period two with such probability. Hence, regardless of its signal, the private firm's expected payoffs from colluding and not colluding in period two are the same as on the left- and right-hand side of expression (1), respectively. Hence, if the firm colludes after inferring  $c$ , it has the same incentive to collude after inferring  $nc$ . Thus, it is ex post not optimal to go through with the threat of not colluding in that period. This is true for any inference error  $\varepsilon > 0$ .

This problem could be ameliorated if both firms' signals are dependent and if that dependence implies that the *conditional* likelihood  $\tilde{\varepsilon}$  after observing  $nc$  that also the other firm has inferred  $nc$  is higher than after signal  $c$  (in this case the inference error  $\varepsilon$  in (1) differs depending on whether the firm infers  $c$  or  $nc$ ). Then, if  $\tilde{\varepsilon}$  is sufficiently high, the expected payoff from not colluding in period two becomes higher than that from colluding (as  $x_C - m < x_{NC}$ ). Thus, not colluding following signal  $nc$  could become a credible threat.<sup>10</sup>

Public ownership circumvents the above two problems, as it makes both firms' signals mutually observable. Thus, the equilibrium candidate can be amended as: collude in the first period, and collude in the second period if and only if both firms observe signal  $c$ . In this case, if a firm observes signal  $nc$ , this becomes common knowledge and the expectation that it will not collude in period two makes it, indeed, a mutual best response not collude in that period. The opposite holds if both firms observe signal  $c$ .<sup>11</sup> What further simplifies collusion is that the inference errors decrease, making the expected payoff from colluding in both periods

$$x_C - K + (1 - \varepsilon)^2 x_C + (2\varepsilon - 1) x_{NC},$$

more likely to be higher than that from deviating and not colluding in both periods

$$bx_{NC} + (1 - \varepsilon) \varepsilon bx_{NC} + (1 - \varepsilon + \varepsilon^2) x_{NC}.$$

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<sup>10</sup>In practice, dependence could arise if both firms experience an unobservable common demand shock. Signal correlation could artificially arise also if firms play mixed strategies (Bhaskar and Van Damme, 2001).

<sup>11</sup>Observe that signal dependence is irrelevant for this argument. Furthermore, note that since signals are imperfect, equilibrium "price wars" occur despite the fact that both firms coordinate. However, this threat is needed to discipline both firms to start coordinating in the first place.

**Proposition 1 (*Public ownership as a collusion mechanism*):** (i) *Public ownership facilitates collusion. (ii) Collusion cannot be achieved under private ownership if the firms' signals are independent. Collusion under private ownership is feasible only if signals are sufficiently correlated (i.e., one firm observing signal  $nc$  goes hand-in-hand with a higher likelihood that the other firm also observes  $nc$ ), and the inference errors are sufficiently small.*

**Corollary 1** *Firms go public if they are ready to join the incumbents and collude with them on a commoditized technology. Alternatively, firms go public if their own technology is becoming commoditized and they seek collusion on it.*

To avoid trivial cases, we assume in what follows that collusion is always achieved under public, but never under private ownership.

### 3.2 Abandoning the New Technology with Public and Private Ownership

Given the option to increase the firm's cash flows through collusion with public ownership, one might wonder why not all firms go public in our model. Our answer is that collusion might undermine innovation incentives. Choosing private ownership might then become a commitment mechanism. To make the point, suppose for now that only the innovator can develop the new technology (i.e., the incumbent's success likelihood is  $\rho = 0$ ).

The problem is that if the innovator receives signal  $\theta_B$  about the new technology, it might be tempted to respond aggressively by dropping the innovative technology and adopting the incumbent firm's technology. This temptation is especially strong with public ownership, as then both firms can collude and obtain high profits from the existing technology.

Though the option of early termination might be valuable ex post, it could reduce the R&D team's incentives to exert effort ex ante. Let  $\mathbf{w} = \{w_0, w_A, w\}$  be the contract the innovator offers the R&D team, which pays  $w_0$  in case of zero cash flows,  $w_A$  in case the new technology is abandoned, and  $w$  in case the new technology is successful and yields positive cash flows. Note that the R&D team's wage can only be contingent on what is verifiable, i.e., the innovator's decision to continue or abandon the new technology and the subsequent cash flows. Since the innovator is protected by limited liability, we can set  $w_0 = 0$ . In case the contract is renegotiated at  $t = 0.5$ , we denote the R&D team's bargaining power with  $\gamma$  (formalized in Appendix A).

The R&D team's incentive constraint is

$$U(\mathbf{w}, \tau) - c \geq U(\mathbf{w}, 0), \quad (2)$$

where  $U(\mathbf{w}, \tau)$  denotes the R&D team's expected payoff if it exerts effort, and  $U(\mathbf{w}, 0)$  is its expected payoff if it exerts no effort. Since, by optimality for the innovator, (2) will be satisfied with equality and the R&D team's outside option is zero,  $U(\mathbf{w}, 0)$  represents the R&D team's agency rent. It is straightforward to show that it is optimal to pay the R&D team only if the new technology is continued (i.e.,  $w_A = 0$ ).

The tension between ex post optimality and ex ante incentives arises because the abandonment of the new technology in case of unfavorable  $\theta$  realizations has two effects. One is the standard positive disciplining effect of not getting paid ( $w_A = 0$ ) if the new technology is abandoned. The strength of this effect increases in the impact of effort ( $\tau_G$ ) on the likelihood of landing in state  $\theta_G$ . However, the second effect is negative. In particular, exerting effort increases also the likelihood of state  $\theta_B$  by  $\tau_B$ . Since this effort is wasted in case the new technology is abandoned in state  $\theta_B$ , such abandonment makes it more difficult to satisfy the R&D team's incentive constraint. This negative effect dominates if  $\tau_B > \tau_G \frac{p_B}{p_G}$ . Then, the better abandonment option at  $t = 0.5$  under public ownership makes it more expensive to motivate the R&D team compared to private ownership.

The key insight is that the resulting time inconsistency problem of not being able to commit not to abandon the new technology in case of state  $\theta_B$  could make private ownership preferable. This occurs if the ex ante expected profitability of the new technology is sufficiently high (i.e.,  $p_G$  is high). Then, the innovator needs to pay the R&D team a higher wage (as  $\tau_B > \tau_G \frac{p_B}{p_G}$ ), while benefiting less from the better collusion possibilities of public ownership in states  $\theta = \{0, \theta_B\}$ . Hence, unlike the time inconsistency problem related to collusion, the time inconsistency problem related to not abandoning the new technology is more acute under public ownership.

**Proposition 2** (*Time inconsistency with public and private ownership*): *The inability to commit not to abandon the new technology in case of signal  $\theta_B$  gives rise to a time inconsistency problem. At  $t = 0$ , such commitment would decrease the cost of hiring the R&D team, but sticking to this commitment at  $t = 0.5$  might be infeasible if the innovator observes  $\theta_B$ . (ii) There is a threshold for  $\hat{p}_G$ , such that the innovator prefers private ownership if  $p_G > \hat{p}_G$ , and public ownership otherwise.*

The second part of Proposition 2 states that, despite making it easier to overcome the

time-inconsistency problem, private ownership is preferable only if the new technology is sufficiently attractive. This is because, if abandonment is very likely, the firm is better off having the option to collude. Clearly, if the innovator does not even initiate the new technology's development, public ownership is always preferable.

### 3.3 Competition for Innovation and the Public-Private Choice

Consider now the possibility that the incumbent also develops the new technology. The incumbent firm would do that if its success likelihood  $\rho$  is sufficiently high to compensate it for its investment costs  $k$ . Note that in this case, the incumbent firm would not abandon the new technology at  $t = 0.5$ , as it does not face the innovator's trade off between developing the new or adopting the old technology.

Competition on the new technology has two key effects. First, if both firms successfully develop the new technology, they can benefit from colluding not to compete away each other's profits. Thus, collusion can have a positive effect on innovation, as it increases the reward in case of success. This effect becomes increasingly valuable for the innovator, the more likely it is that both firms successfully develop the new technology (i.e., if both  $p_G$  and  $\rho$  are high).

Second, competition makes it less likely that the innovator abandons the new technology at  $t = 0.5$ , as it will make zero profit from the incumbent technology if the incumbent develops the new technology. If the incumbent's success likelihood  $\rho$  is sufficiently high, this effect could make the innovator's continuation decision under both public and private ownership the same. Specifically, if  $\rho$  is high, the collusion prospects are not sufficiently likely to warrant abandonment in states  $\theta_B$  and  $\theta_G$  under both ownership types. But when the continuation decision under both ownership types is the same, the cost of hiring and motivating an R&D team is the same, making the collusion benefits of public ownership more beneficial.

**Proposition 3 (*Competition for innovation*)** *Suppose that both firms compete to develop the new technology. (i) An advantage of public over private ownership is that both firms can collude in case they both successfully develop the new technology. This advantage can dominate the effects in Proposition 2 if  $p_G$  and  $\rho$  are high. (ii) There is a threshold  $\hat{\rho}$ , such that the innovator does not abandon the new technology in states  $\theta_B$  and  $\theta_G$  under both ownership types, making public ownership preferable for  $\rho > \hat{\rho}$ .*

Since in practice,  $\rho$  and  $p_G$  are likely to be correlated, assume for simplicity that  $\rho = p_B\theta_B + p_G\theta_G + \delta$  (where  $\delta$  could be positive or negative). Summarizing the results from

this section, we obtain a U-shaped relationship between the attractiveness of innovation and that of public ownership:

**Corollary 2** *The innovator's choice between public and private ownership is U-shaped in the new technology's profitability. If that profitability is:*

- (i) low, it is optimal to choose public ownership;*
- (ii) medium, it is optimal to choose private ownership;*
- (iii) high, it is optimal to choose public ownership.*

**Discussion** Throughout the paper we refer to coordination between the innovator and the incumbent as collusion. In practice, collusion could refer tacit collusion or outright cartel agreements. Though our model does not differentiate between the two, we expect cartels and, in general, illegal activity to be more concentrated in case (i) of Corollary 2. This is because for coordination among firms to be deemed illegal by regulators, there must be a perceived harm to consumers. By contrast, given the positive effect on innovation in case (iii), regulators may be more likely to tolerate tacit coordination.

## 4 Extensions: Equity Stakes, Size, and Voluntary Reporting

A common practice of incumbents is to buy equity stakes in growth firms or acquire such firms. In what follows, we turn to the question whether such stakes can act as a substitute to public ownership of the growth firm for achieving collusion. We then extend our model to analyze the effect of size and voluntary reporting on collusion and innovation incentives.

### 4.1 Coordination Through Equity Stakes

Suppose that the incumbent buys a non-controlling stake  $\beta$  in the innovator, which gives him a proportional right to the firm's cash flows, but otherwise no control rights. A rationale for buying a non-controlling stake is that it could allow the incumbent to observe the innovator's cash flows, even if the innovator is private. Following the same arguments as in Proposition 1, this would imply that collusion can be achieved on the existing (incumbent) technology provided that the incumbent is public and, thus, also its cash flows can be observed by the innovator.

Both public ownership and buying a non-controlling equity stake discourage innovation by allowing for collusion on the incumbent technology. However, buying an equity stake



has a further negative effect on the incumbent’s innovation incentives. Specifically, if the innovator engages in the new technology, the incumbent benefits from it via its non-controlling equity stake which lowers its own incentives to innovate. This negative effect is stronger, the bigger the incumbent’s stake.

If the incumbent buys a controlling stake, however, collusion issues are no longer present. This leads to a natural specialization in which the incumbent firm’s incentives to innovate are even lower, while those of the innovator are higher compared to when the firms operate independently. Specifically, the incumbent has now the option to adopt the new technology, even without developing it itself, as long as the innovator is successful. This further decreases its own incentives to develop it. However, since coordination issues are no longer present, the two firms will not compete away the first-mover profits on the new technology. What is more, since the opportunity cost of abandoning the new technology in order to collude on the existing one is also no longer present, the innovator can keep developing the new technology even after receiving signal  $\theta_B$ . The latter two effects increase the likelihood that the innovator develops the new technology.

**Proposition 4** *(i) Buying a non-controlling equity stake in the innovator can help achieve collusion on the existing technology, but it reduces the incumbent’s innovation incentives. (ii) Buying a controlling equity stake further reduces the incumbent’s innovation incentives, but it increases the likelihood that the innovator develops the new technology.*

Overall, the main insight from this section is that buying equity stakes can help achieve collusion, but has additional effects on innovation incentives. Thus, collusion via public ownership and equity stakes are not perfect substitutes. However, one would expect that imposing additional (e.g., regulatory) costs on public ownership would make collusion through equity stakes more likely.

**Corollary 3** *An increase in the cost of public ownership increases the likelihood that collusion is achieved through controlling or non-controlling equity stakes.*

## 4.2 Size, Innovation, and Coordination

In this section, we extend our baseline model by introducing a date  $t = -1$  at which the innovator can choose to operate at larger scale at no additional cost. Let  $\varphi > 1$  be the scaling parameter, which increases expected profits to  $\varphi x_{NC}$ ,  $\varphi x_C$ , and  $\varphi x_{FM}$ . Thus, scaling up does not affect the relative attractiveness of colluding versus not colluding for the innovator. However, the incumbent is hurt more if the innovator is larger and does

not collude, as then the incumbent's profits fall by  $\varphi m$ . Specifically, for the incumbent's cash flows, we assume that  $x_C - \varphi m < x_{NC} < x_C - m$ . That is, Assumption 2 is satisfied if the innovator is large, but not if it is small.

If Assumption 2 does not hold and the innovator adopts the incumbent's technology, the incumbent chooses the colluding action regardless of the action taken by the innovator. Intuitively, the incumbent would not bother to respond to a player who can steal only a small market share. Thus, the innovator can free ride and choose non-collusion while expecting that the collusion action will be a dominant strategy for the incumbent. This makes abandoning the new technology and adopting that of the incumbent more attractive at  $t = 0.5$  compared to when the innovator is large. This has several implications.

First, if the innovator does not scale up, the choice between collusion and no collusion is the same under public and private ownership. Second, because the incumbent does not engage in price wars with the innovator, the innovator's incentives to abandon the new technology and adopt that of the incumbent are at least as high as those under public ownership in Proposition 1. Hence, its incentives to innovate are lower than those of the innovator, described in Section 3.2.

**Proposition 5** *(i) If the innovator remains small, the incumbent takes action C regardless of the innovator's action. In this case, the innovator is more likely to abandon the new technology and is indifferent between public or private ownership. (ii) The innovator is better off remaining small if the impact of size on the incumbent's payoff,  $\varphi m$ , is low relative to  $b$ . The incumbent can affect the innovator's decision to remain small by not offering collusion opportunities to the innovator, i.e., staying private and not buying equity stakes in the innovator.*

An important consequence of Proposition 5 is that without the option to collude, the innovator might strategically decide to remain small to stay "under the radar screen" and avoid responses by the incumbent. To illustrate this, note that if the new technology's attractiveness is low (i.e.,  $p_G$  is low), the innovator abandons it when observing  $\theta_B$  regardless of its size. This is because the cost of motivating the R&D team is the same regardless of the innovator's size. However, being small allows the innovator to steal market share from the incumbent technology, which could be more profitable than collusion. What is important, is that this might be preferable also for the incumbent. The latter can influence the innovator's size decision by choosing private ownership or not buying a stake in the innovator, since this precludes collusion opportunities even when the innovator is large.

### 4.3 Private Ownership and Voluntary Reporting

We have assumed so far that a firm can make its signal  $s \in \{c, nc\}$  public under public, but not under private ownership. However, a private firm could voluntarily report its cash flows. The key difference is that regulation governing public firms has explicit requirements regarding the type and quality of information that needs to be published. No such regulation applies to private firms, and when reporting requirements exist, the required quality is much coarser than that for public firms. In what follows, we analyze the consequences for collusion when both firms operate the same technology. Without loss for the qualitative results, we assume that one of the firms is public, while the other private. We continue to assume that a firm's signal is public information under public ownership. However, we now also allow the private firm to reports its cash flows, but (facing laxer regulation), the private firm can choose to communicate its report with noise, such that its true signal  $s$  is observed correctly with probability  $\eta \in (\underline{\eta}, 1]$ . The lower bound  $\underline{\eta} \geq \frac{1}{2}$  captures the private firm's discretion of communicating less precise information, when choosing  $\eta$ . In what follows, we maintain Assumption 2.

Consider the same candidate equilibrium as in Section 3.1 according to which each firm colludes in period one, and colludes again in period two if and only if it infers signal  $c$  following period one and infers from the information reported by the other firm that it has also observed  $c$ . Suppose that both firms follow the proposed equilibrium strategies of colluding in the first period, and suppose that at the end of that period the public firm infers  $c$  (which becomes then common knowledge). If the private firm infers signal  $nc$  from its cash flows, we know from Section 3.1 that it has incentives to neglect this negative signal and collude again. Consider, therefore, the consequences of adding noise to the private firm's report: With probability  $1 - \eta$ , the public firm infers  $c$  and colludes, and with with probability  $\eta$ , it infers  $nc$  and does not collude. Hence, the private firm's payoff from colluding in period two is  $(1 - \eta)x_C + \eta(x_C - m)$ , while from not colluding  $(1 - \eta)bx_{NC} + \eta x_{NC}$ . Two insights follow immediately. First, in both cases the private firm's period-two payoffs increase from adding noise to its report, as it is optimal to have  $\eta$  minimal. Thus, without the ability to commit not to add noise when its cash flows are low and it infers  $nc$ , the private firm will choose to have  $\eta = \underline{\eta}$ . Second, comparing the two payoffs, colluding in period two is ex post beneficial if

$$\eta \leq \eta^* \equiv \frac{x_C - bx_{NC}}{x_{NC} - bx_{NC} + m} \quad (3)$$

Hence if  $\underline{\eta} \leq \eta^*$ , the private firm will choose to collude also in the second period even if it

infers *nc*. But then, going back to period one, we have again the problem that, expecting this behavior, the public firm will not start colluding. Thus, collusion cannot be sustained.

Even if (3) is not satisfied ( $\underline{\eta} > \eta^*$ ), the private firm's ex post incentive to add the maximum level of noise to its report when its cash flows are low reduces the public firm's payoffs from following the proposed equilibrium strategy in period one relative to one in which it does not collude in both periods. Thus, overall, we continue to obtain that private ownership reduces the likelihood of collusion even when voluntary reporting is possible. This reinforces our result that, by committing the firm to an ex post high reporting quality, public ownership helps it overcome the time inconsistency problem leading to a break down in collusive equilibria.

**Corollary 4** *With voluntary disclosure in the case of private ownership, ex ante, the private firm would like to commit not to add noise to its report. Yet, ex post, time inconsistency kicks in with the firm adding the maximum amount of noise when its cash flows are low and it infers *nc*. This lack of commitment problem reduces the opportunities for collusion.*

## 5 Empirical Implications and Evidence

First, we discuss the implications of our model that are related to collusion on existing technologies. Subsequently, we discuss the model's predictions concerning the optimality of public or private ownership and buying equity stakes in light of their effects on innovation. Since our model is built around the notion that public firms are more likely to collude, we provide tentative empirical evidence for this result as well as the predicted U-shaped relationship between the attractiveness of innovation and that of public ownership (see Section 5.2).

### 5.1 Empirical Implications

The question why private firms choose to go public is long-standing in the finance literature. Key reasons that have been given include improving diversification opportunities and liquidity, raising capital for investment, exploiting favorable market conditions, facilitating acquisitions, and making the firm more visible (Ritter and Welch, 2002). We add one more reason to this discussion, which is surprisingly neglected in prior work: facilitating collusion.

**Implication 1** *Public firms are more likely to be able to collude than private firms.*

By endogenizing the choice of public ownership, our paper shows that firms choose public ownership if they fear that head-to-head competition will erode their future profits. Indeed, high profit margins in the tech, biotech and pharma industries, as well as in traditional, cartel-prone industries, such as rail and air travel are hard to square with a competitive market and have recently gained considerable media attention.<sup>12</sup> In Section 5.2 we offer empirical evidence consistent with Implication 1.

Recent advances in information technology have made it possible that private firms communicate valuable information about themselves to outsiders even without public ownership. As highlighted by Corollary 4, this could allow even private firms to achieve collusion. With the advance of new technologies, such as the blockchain, that further improve the verifiability of information, we expect such development to become even stronger in the future. This could have a negative impact on competition.

**Implication 2** *Advances in information technology that ease the credible dissemination of information would help collusion even under private ownership and would allow also private firms to retain high margins without going public.*

An open question in recent empirical work is what could explain the declining popularity of public ownership in the U.S. (Gao et al., 2013). It seems that information disclosure requirements and compliance costs play an important role. However, it has been argued that such increases alone cannot explain the decline of public ownership, which seems to be compounded by an increase in merger and acquisition activity (Doidge et al., 2016). Our paper suggests that these phenomena could be related, as acquiring equity stakes could substitute for public ownership in achieving collusion. Thus, when the cost of public ownership increases, firms are more likely to seek collusion over such equity stakes (Corollary 3).

**Implication 3** *An increase in the cost of public ownership will lead incumbent public firms to acquire private innovators (or public firms considering going private) or take equity stakes in such firms.*

Collusion can be achieved also through non-controlling equity stakes (Proposition 3). However, such collusion is not a substitute for public ownership, as it has additional negative effects on innovation. Furthermore, it is typically infeasible for small firms to buy stakes in much larger firms (Allen and Phillips, 2000). In such cases, collusion will only be achieved if the large firm is public. Thus, strategically buying non-controlling

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<sup>12</sup>See Larry Summer's article cited in footnote 1.

stakes in small innovators is more likely to emerge when public equity markets are more developed. This is consistent with the evidence that Corporate Venture Capital (CVC), which specializes in taking strategic minority stakes in innovators, is better developed, but not associated with stronger competition in developed markets (Dushnitsky, 2006).

In a recent paper Azar et al. (2016) find that financial investors, such as BlackRock, that own stakes in competing firms could contribute to softer competition among these firms. The paper's motivation is based on the argument that if the same investor owns 50% of two firms, the management of either firm will take both firms' profits equally into account in their optimization decisions. Implication 1 cautions against drawing stark regulatory implications based on such findings, as public ownership alone could also act as a collusion mechanism.

Our second set of implications investigates how collusion and the choice between public and private ownership interacts with innovation incentives. One of our first key insights is that private ownership could help overcome the time-inconsistency problem that a firm would like to commit to pursuing the development of a new technology. Specifically, it avoids the temptation of abandoning development in case of early difficulties created by the option to collude on the existing technology (Proposition 1).<sup>13</sup>

**Implication 4** *If an innovator seeks to develop a new technology (and faces no competition on this from the incumbent), private ownership makes it more tolerant for failure, in the sense that it is less likely to abandon the new technology in the face of early difficulties.*

However, a higher tolerance for failure is not necessarily in the best interest of the innovator. First, if the new technology is not expected to be very profitable, the innovator might prefer to have the option to collude on the existing technology and choose public ownership (Corollary 2). This hurts innovation, but benefits the innovator. Second, private ownership might even be bad for innovation if the innovator faces competition on innovation from the incumbent. Then the opportunity to collude on the new technology might spur innovation incentives.

**Implication 5** *Public ownership dominates private ownership (i) if the expected profitability of the new technology is low, so that the value of the option to fall back on high-margin existing technology is high; or (ii) if the expected profitability is high, so that the innovator could benefit from colluding with the incumbents on the existing technology. For*

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<sup>13</sup>On a separate note, we show that there is more tolerance for failure also if the incumbent buys the innovator, as then the incumbent operates the existing technology anyhow, so it faces no temptation to abandon the development of the new one.

*intermediate values, private ownership is more beneficial, as it helps to deal with the time inconsistency problem of not being able to commit not to prematurely abandon the new technology's development.*

Implication 5 could help understand why private firms are not always champions in innovation, despite the predictions of prior theory (Ferreira et al., 2012) and some empirical evidence (Bernstein, 2015). Indeed, many public firms, such as Apple, Google, and Tesla, are paramount examples of innovation. We predict that private ownership will be unambiguously better only when the innovation's expected profitability is intermediate. Then innovative firms can focus on technologies that are as of yet unattractive for incumbents. Instead, when the innovator's profitability is expected to be very high and public firms join the innovation race, Proposition 4 predicts:

**Implication 6** *If both the innovator and the incumbent seek to develop new technologies, public ownership could sharpen the incentives to innovate.*

Implications 5-6 imply a U-shaped relation between the attractiveness of innovation and that of public ownership. We offer some preliminary evidence for this relation in the next section. Finally, based on Proposition 5, we have the following prediction about how the firm's size interacts with collusion and its innovation incentives:

**Implication 7** *(i) Smaller private firms are more likely to switch to the incumbent technology compared to larger innovators, as they can undercut the incumbent without triggering a price war. (ii) Innovators might have incentives to remain small, but this is bad for their innovation incentives.*

## 5.2 Evidence

In what follows, we present patterns in the data that are consistent with our predictions that public ownership may facilitate collusion and that there is a U-shaped relation between the attractiveness of innovation and the benefit of public ownership. We construct a sample of firms that have filed an initial registration statement for an IPO with the SEC (Form S-1) and then compare firms that have gone through with their IPO to firms that have chosen to withdraw their IPO filing (by submitting Form RW). The data on U.S. IPO filings and withdrawals comes from Thomson One's New Issues database from 1985 until 2017. As it is standard, we exclude financial firms (SIC codes 6000-6999), unit offers, closed-end funds, American depository receipts, limited partnerships, special acquisition

vehicles, and spin-offs. Financial information comes from Compustat, Thomson One, and from the S-1 filing forms. We have such data for approximately 70% of the firms.<sup>14</sup>

## INSERT TABLE 1

To proxy for collusion, we collect all U.S. lawsuits related to antitrust or anticompetitive behavior from Thomson Reuters' Westlaw database for the period 1990-2017.<sup>15</sup> We then manually match the defendants in these lawsuits to our IPO filings sample. To allow for a four-year post-filing window, we restrict attention to IPOs between 1994–2013. In this period we have 4762 IPO filings, 22% of which were withdrawn. We have matched 308 of the filing firms to antitrust cases between 1990–2017.

Table 1 offers summary statistics comparing the firms going through with their IPOs and those withdrawing their filings within four years of their S-1 filing. The two groups are similar in terms of size and sales, but those that withdraw are slightly less profitable. The key notable difference is that the likelihood of being involved in an antitrust lawsuit in the four years surrounding the filing is insignificantly different before and after the filing for firms that withdraw, but increases threefold for firms that proceed with the IPO. It is also notable that withdrawals are associated with significantly lower two-month NASDAQ returns following the filing, while there is no difference in the pre-filing returns.

### 5.2.1 Empirical Challenges and Limitations

Testing our model's predictions faces two main empirical challenges. The first is finding comparable public and private firms. Comparing firms that complete to firms that withdraw their IPO has the advantage of comparing public to private firms at similar stages of their lifecycle. However, the decision to withdraw is still highly endogenous and ideally would need to be controlled for. One possibility is to follow Bernstein (2015) who proposes to instrument IPO withdrawal with the NASDAQ two-months ahead return following the IPO filing. The idea is that negative fluctuations in NASDAQ in the two months following the filing could drive firms to withdraw their filings for reasons that are orthogonal to how their fundamentals predispose them to collude.<sup>16</sup>

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<sup>14</sup>We thank Tolga Caskurlu for providing us with the financials of firms that withdraw their IPOs, which was manually extracted from the S-1 filings.

<sup>15</sup>The coverage of this database for lawsuits prior to 1990 is sparse.

<sup>16</sup>Reasons why firms do not wait for conditions to improve is that a filing registration automatically expires 270 days after its last amendment. Furthermore, firms are forbidden from issuing private placements while their application is pending as well as from disclosing new information to specific investors, such as banks. See Bernstein (2015) for details.



The second challenge is finding evidence for collusive behavior. Antitrust lawsuits are an imperfect proxy. One concern might be that the higher transparency of public ownership may also allow for better detection of antitrust behavior. Another concern is that, being cash-rich after an IPO could attract frivolous lawsuits that only aim for a settlement.

Because of these concerns, we emphasize that linking IPOs to antitrust lawsuits can only offer suggestive, but not conclusive, evidence. Still, there are factors that mitigate these concerns.

Detecting anticompetitive behavior mainly relies on leniency provision for whistle blowers. Even though economic analysis can be instrumental in prosecuting antitrust cases and estimating damages, it has not been a standard tool for detecting cartels (Harrington, 2008).<sup>17</sup> When it is used, it relies on micro industry data about costs, prices, and quantities (Viscusi et al., 2005). Public disclosures and financial statements by public firms do not play an explicit role, as they do not contain price and margins data.<sup>18</sup> What is also notable is that more than 90% of the cases in our sample were brought by businesses or individuals (rather than the FTC, DOJ or state attorney generals) that must further demonstrate an antitrust injury that is "inextricably intertwined" with the alleged conduct.

Furthermore, it is not clear that frivolous lawsuits are necessarily directed towards cash-rich firms. In fact, the law literature has discussed that such lawsuits are often targeted at cash-strapped firms that would rather avoid costly litigation; and such lawsuits could be of anticompetitive nature themselves (Meurer, 2003). What speaks against the frivolous lawsuits argument is that there is *no* increase in lawsuits in the first two years after the IPO. The effects (we document below) only emerge in the third year, and are strongest in the fourth and fifth years. This is consistent with public firms needing time to start colluding and inconsistent with plaintiffs initiating opportunistic antitrust lawsuits against newly-public firms.

### 5.2.2 Results

The first tests we present look at the determinants of whether or not an IPO proceeds

$$\begin{aligned}
 IPO_i = & \alpha + \beta_1 \Delta Industry R\&D + \beta_2 \Delta Industry R\&D^2 + \beta_3 Industry R\&D + \beta_4 Industry R\&D^2 \\
 & + \gamma NASDAQ_i + \delta X_i + \nu_k + \mu_t + \varepsilon_i,
 \end{aligned}
 \tag{4}$$

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<sup>17</sup>In the U.S., economic evidence is typically not sufficient for proving guilt, and there must be some evidence of coordination (Werden, 2004).

<sup>18</sup>Naturally, better detection does not necessarily speak against our arguments. A good example is when firms are prosecuted for using conference calls with analysts to disclose sensitive information that could facilitate collusion (see footnote 3), since such behavior directly supports our theory.

and the second set of tests look at the determinants of whether there is an antitrust lawsuit after the IPO filing

$$AT_i^{post} = \alpha + \beta_1 \Delta Industry R\&D + \beta_2 \Delta Industry R\&D^2 + \beta_3 Industry R\&D + \beta_4 Industry R\&D^2 + \gamma IPO_i + \delta X_i + \nu_k + \mu_t + \varepsilon_i, \quad (5)$$

where  $AT_i^{post}$  is a binary variable taking the value of one if the firm is involved in an antitrust lawsuit in the four years after the IPO filing;  $IPO_i$  takes the value of one if the firm goes through with its IPO;  $Industry R\&D$  are the average industry R&D expenses relative to total assets at two digit SIC level,  $\Delta Industry R\&D$  is the change in such expenses relative to the pre-filing year. These variables proxy for the attractiveness of innovation in the industry. The quadratic specifications considers non-linear effects, where the U-shaped prediction implies that  $\beta_1$  and  $\beta_3$  should be negative, while  $\beta_2$  and  $\beta_4$  positive. The control variables  $X$  account for whether there was an antitrust lawsuits in the four years prior to the IPO filing ( $AT_i^{pre}$ ), size (*Log total assets*, adjusted to inflation), revenues (*Sales/assets*), profitability (*Net income/assets*). The regressions further contain industry fixed effects at the two digit SIC level and IPO filing year fixed effects.

Columns (1) and (2) of Table 2 show the estimates of an OLS and a probit model of the determinants that an IPO proceeds. In these two models, the quadratic specifications of the change in R&D spending,  $\Delta Industry R\&D$ , is significant, indicating a convex (i.e., U-shaped) relation between the likelihood of completing the IPO and the attractiveness of innovation. Figure 2 in the Appendix plots this relation, which is consistent with Implications 5-6. The levels of *Industry R&D* spending convey a similar, but a statistically weaker, relation.<sup>19</sup>

#### INSERT TABLE 2

Column (3) in Table 2 shows a strong positive association between antitrust lawsuits in the four years after the IPO filing and whether the firm proceeds with its IPO. Such lawsuits increase by two percent, which is more than double the unconditional likelihood of being involved in such a lawsuit. This finding is consistent with Implication 1 that public ownership facilitates collusion. We find only very weak evidence for a U-shaped relation between *Industry R&D* spending and antitrust lawsuits. However, this may also be consistent with our discussion following Corollary 2 that collusion is less likely to be prosecuted when firms' coordination spurs innovation,

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<sup>19</sup>The significance is higher if the regressions are run without  $\Delta Industry R\&D$ . The results are also robust to using averages weighted by total assets or sales.

In Appendix B, we describe further statistical tests that take into account the endogeneity of the IPO completion by instrumenting it with the two-month NASDAQ return following the IPO filing as in Bernstein (2015). These tests offer further support for Implication 1 (columns (4) and (5) in Table 2). In unreported regressions, we further find that all these results are robust to considering antitrust lawsuits in the three and five year windows around the IPO filing, but there is no effect in the first two years after the filing.

Overall, to the extent that we could make inferences from antitrust lawsuits about collusion, the empirical patterns we present are consistent with Implication 1 that public ownership helps facilitate collusion and of Implications 5–6 that there is a U-shaped relation between the attractiveness of innovation and that of public ownership

## 6 Conclusion

We develop a model that shows that public ownership helps facilitate collusion. The problem with sustaining collusion under private ownership is that exposes firms to a time inconsistency problem. Supporting collusion requires that there is a credible threat to revert to a non-collusive equilibrium if one of the firms is suspected in deviating, which happens when the other firm’s cash flows are low. However, private firms have incentives to neglect such signals. The reason is that, if all firms collude, low cash flows can only be due to bad luck. Thus, private firms have ex post incentives not to go through with the punishment, which makes it ex ante impossible to support collusion. Public ownership circumvents this problem by committing firms to a high standard of reporting. Thus, if a firm’s cash flows are low, this and the fact that it should react with a punishment becomes common knowledge. With that knowledge, it becomes optimal for all parties to revert to a non-collusive equilibrium. Having a credible punishment ex post, it is possible to support collusion ex ante. Thus, firms will choose public ownership when their technology is becoming commoditized and they seek to retain high profits.

Not all firms benefit from public ownership, however. Being able to collude on an existing technology is a double-edge sword if an innovator seeks to develop a new technology, as then the temptation to abandon its development in case of early difficulties is high. This temptation to abandon the new technology gives rise to a second time inconsistency problem, this time more acute under public ownership. Hence, private ownership helps to commit to the long-term pursuit of innovation and improves incentives.

Taking these results as a starting point, we derive a number of novel implications about a firm’s choice between public and private ownership. We find that there is a U-shaped

relationship between the new technology's expected profitability and the attractiveness of public ownership. If the profitability is low, the option to collude on the incumbent's technology is very valuable, and public ownership dominates. However, if the new technology's expected profitability is higher, being able to commit not to abandon it in the face of early difficulties becomes more valuable. In that case, private ownership dominates. However, if the new technology is sufficiently profitable that it is never abandoned, public ownership dominates again. This is particularly true if the incumbent could also attempt to develop the new technology, as then being able to collude this time on the new technology becomes important.

Our analysis highlights three further aspects. First, though collusion can also be achieved through equity stakes, such stakes are an imperfect substitute to public ownership, as other effects on innovation incentives come into play. Second, size matters too. Since large incumbents would not bother to respond to small rivals, small innovators will tend to abandon the development of new technologies faster even under private ownership, as they can free ride on the high margins of the incumbent technology. This could create incentives to remain small to avoid the need to collude. Third, collusion would be difficult to achieve through voluntary reporting, as firms would have ex post incentives to add noise to their reports.

We offer some preliminary evidence that supports our basic premise that public ownership facilitates collusion and supports the prediction that there is a U-shaped relation between the attractiveness of innovation and that of public ownership. For future research, it would be interesting to expand on this evidence and further empirically investigate the relationship between collusion in public firms and its effect on innovation—not only in terms of investment, but also in terms of outcomes and types of innovation (e.g., exploitative vs. exploitative).

## References

- [1] Acharya, Viral, and Zhaoxia Xu, 2016, Financial dependence and innovation: the case of public versus private firms, *Journal of Financial Economics*, forthcoming.
- [2] Adams, Renee .B., Heitor Almeida, and Daniel Ferreira, 2009, Understanding the relationship between founder-CEOs and firm performance, *Journal of Empirical Finance* 16(1), 136–150.
- [3] Allen, Franklin, and Douglas Gale, 1999, Diversity of opinion and financing of new technologies, *Journal of Financial Intermediation* 8(1–2), 68–89.
- [4] Allen, Jeffrey W., and Gordon M. Phillips, 2002, Corporate equity ownership, strategic alliances, and product market relationships, *Journal of Finance* 55(6), 2791–2815.
- [5] Arrow, Kenneth J., 1962, Economic welfare and the allocation of resources to invention, In R.R. Nelson (Ed.), *The rate and direction of economic activity*, Princeton University Press, New York.
- [6] Azar, Jose, Martin C. Schmalz, and Isabel Tecu, 2016, Anti-competitive effects of common ownership, Working Paper, University of Navarra and University of Michigan.
- [7] Bernstein, Shai, 2015, Does going public affect innovation?, *Journal of Finance* 70(4), 1365–1403.
- [8] Bhaskar, V., and Eric van Damme, 2001, Moral hazard and private monitoring, *Journal of Economic Theory* 102(1), 16–39.
- [9] Bhattacharya, Sudipto, and Jay R. Ritter, 1983, Innovation and communication: signaling with partial disclosure, *Review of Economic Studies* 50(2), 331–346.
- [10] Bourveau, Thomas, Guoman She, and Alminas Zaldokas, 2017, Naughty firms, noisy disclosure: the effects of cartel enforcement on corporate disclosure, Working Paper, Hong Kong University of Science and Technology.
- [11] Chod, Jiri, and Evgeny Lyandres, 2011, Strategic IPOs and product market competition, *Journal of Financial Economics* 100, 45–67.
- [12] Dasgupta, Partha, and Joseph E. Stiglitz, 1980, Industrial structure and the nature of innovative activity, *Economic Journal* 90, 266–293

- [13] Denis, Diane K., and John J. McConnell, 2003, International corporate governance, *Journal of Financial and Quantitative Analysis* 38(1), 1–36.
- [14] Doidge, Craig, G. Andrew Karolyi, and Rene M. Stulz, 2016, The U.S. listing gap, *Journal of Financial Economics*, forthcoming.
- [15] Dushnitsky, Gary, 2006, Corporate venture capital: past evidence and future directions, in *Oxford Handbook of Entrepreneurship*, Edited by Anuradha Basu, Mark Casson, Nigel Wadeson, and Bernard Yeung, Oxford University Press, Oxford, UK.
- [16] Ferreira, Daniel, Gustavo Manso, and Andre C. Silva, 2014, Incentives to innovate and the decision to go public or private, *Review of Financial Studies* 27(1), 256–300.
- [17] Gao, Xiaohui, Jay R. Ritter, and Zhongyan Zhu, 2013, Where have all the IPOs gone?, *Journal of Financial and Quantitative Analysis* 48(6), 1663–1692.
- [18] Gilbert, Richard, and David Newbery, 1982, Preemptive patenting and the persistence of monopoly, *American Economic Review* 72(2), 514–526.
- [19] Gilbert, Richard, 2006, Looking for Mr. Schumpeter: where are we in the competition-innovation debate?, in *Innovation Policy and the Economy*, Volume 6, edited by Adam B. Jaffe, Josh Lerner and Scott Stern, MIT Press, Cambridge Massachusetts.
- [20] Green, Edward J., and Robert H. Porter, 1984, Noncooperative collusion under imperfect price information, *Econometrica* 52(1), 87–100.
- [21] Greenstein, Shane, and Garey Ramey, 1998, Market structure, innovation and vertical product differentiation, *International Journal of Industrial Organization* 16(3), 285–311.
- [22] Grossman, Gene M., and Elhanan Helpman, 1990, *American Economic Review, Papers and Proceedings* 80(2), 86–91.
- [23] Grossman, Sanford J., and Joseph E. Stiglitz, 1980, On the impossibility of informationally efficient markets, *American Economic Review* 70(3), 393–408.
- [24] Harrington, Joseph, 2008, Detecting Cartels, in *Handbook in Antitrust Economics*, Paolo Buccirossi, editor, MIT Press, Cambridge Massachusetts..
- [25] Harris, Chris, and John Vickers, 1985, Perfect equilibrium in a model of a race, *Review of Economic Studies* 52(2), 193–209.

- [26] Imbens, Guido W., and Joshua D. Angrist, 1994, Identification and estimation of local average treatment effects, *Econometrica* 62(2), 467–475.
- [27] Kultti, Klaus, Tuomas Takalo, and Juuso Toikka, 2007, Secrecy versus patenting, *RAND Journal of Economics* 38(1), 22–42.
- [28] Maksimovic, Vojislav, and Pegaret Pichler, 2001, Technological innovation and initial public offerings, *Review of Financial Studies* 14(2), 459–494.
- [29] Malueg David A., 1992, Collusive behavior and partial ownership of rivals, *International Journal of Industrial Organization* 10(1), 27–34.
- [30] Matthews, Richmond D., 2006, Strategic alliances, equity stakes, and entry deterrence, *Journal of Financial Economics* 80(1), 35–79.
- [31] Meurer, Michael J., 2003, Controlling opportunistic and anti-competitive intellectual property litigation, *Boston College Law Review* 44, 509–544.
- [32] OECD, 2012, Unilateral disclosure of information with anticompetitive effects, Competition Policy Roundtables .
- [33] Pagano, Marco, Fabio Panetta, and Luigi Zingales, 1998, Why do companies go public? An empirical analysis, *Journal of Finance* 53(1), 27–64.
- [34] Rajan, Raghuram G., 1992, Insiders and outsiders: The choice between informed and arm’s length debt, *Journal of Finance* 47(4), 1367–1399.
- [35] Reynolds, Robert J., and Bruce R. Snapp, 1986, The competitive effects of partial equity interests and joint ventures, *International Journal of Industrial Organization* 4(2), 141–153.
- [36] Ritter, Jay R., and Ivo Welch, 2002, *A review of IPO activity, pricing, and allocations*, *Journal of Finance* 57(4), 1795–1828.
- [37] Romer, Paul, 1990, Endogenous technological change, *Journal of Political Economy* 98(5), 71–102.
- [38] Schumpeter, Joseph A, 1934, *The theory of economic development*, Harvard University Press, Cambridge Massachusetts.
- [39] Schumpeter, Joseph A, 1942, *Capitalism, socialism, and democracy*, Harper and Brothers, New York.

- [40] Stein, Jeremy C., 1989, Efficient capital markets, inefficient firms: a model of myopic corporate behavior, *Quarterly Journal of Economics* 104(4), 655–669.
- [41] Viscusi, Kip W., Joseph E. Harrington, and John M. Vernon, 2005, *Economics of Regulation and Antitrust*, 4th Edition, The MIT Press, 2005.
- [42] Werden, Gregory J., 2004, Economic evidence on the existence of collusion: reconciling antitrust law with oligopoly theory, *Antitrust Law Journal* 71, 719–799.
- [43] Wooldridge, Jeffrey M., 2002, *Econometric analysis of cross section and panel data*. MIT Press, Cambridge, MA.



## Appendix A: Proofs

**Proof of Proposition 2.** Define  $y_C$  to be the innovator's two-period payoff when both firms use the incumbent technology and collude, and let  $y_{NC}$  be expected payoff when they do not collude. There is a trade-off between public and private ownership when the continuation decision differs for  $\theta = \theta_B$ . Suppose, therefore, that  $\theta_G x_{FM} > y_C > \theta_B x_{FM} > y_{NC}$  (note that there can be no single-period collusion on the new technology in period two). We treat the remaining cases at the end of the proof. In what follows, we consider in turn public (collusion) and private (non-collusion) ownership. Observe that when the new technology is abandoned, the R&D's wage cannot be made contingent on  $\theta$ , as  $\theta$  is non-contractible.

**Public ownership and collusion at  $t = 0.5$ .** The innovator takes the ex post efficient decision to abandon the new technology and collude with the incumbent after observing  $\theta_B$  if  $y_C - w_A > \theta_B (x_{FM} - w)$ . Since  $\theta_B x_{FM} < y_C$ , a sufficient condition is that  $\theta_B w \geq w_A$ . Suppose for now that this is satisfied (below we show that it is, as  $w_A = 0$ ). The innovator maximizes<sup>20</sup>

$$(1 - p_B - \tau_B - p_G - \tau_G)(y_C - w_A) + (p_B + \tau_B)(y_C - w_A) \\ + (p_G + \tau_G)\theta_G(x_{FM} - w)$$

subject to the R&D team's incentive constraint

$$-(\tau_G + \tau_B)w_A + \tau_B w_A + \tau_G \theta_G w \geq c. \quad (6)$$

It is optimal to set  $w_A = 0$ , implying that  $\theta_G w = \frac{c}{\tau_G}$ . Hence, the innovator's expected payoff is

$$(1 - p_B - \tau_B - p_G - \tau_G)y_C + (p_B + \tau_B)y_C + (p_G + \tau_G)\theta_G x_{FM} - \frac{(p_G + \tau_G)}{\tau_G}c. \quad (7)$$

**Private ownership and non-collusion at  $t = 0.5$ .** The innovator takes the ex post efficient decision to continue the new technology after observing  $\theta_B$  if  $y_{NC} - w_A < \theta_B (x_{FM} - w)$ . This requires that  $\theta_B x_{FM} - y_{NC} > \theta_B w - w_A$ . Suppose for now that this is satisfied (below we check when this is the case). The R&D team's incentive constraint is

$$-(\tau_G + \tau_B)w_A + (\tau_B \theta_B + \tau_G \theta_G)w \geq c. \quad (8)$$

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<sup>20</sup>Note that it is without loss that the R&D team is paid only in period one.

It is optimal to set  $w_A = 0$ , implying that  $w = \frac{c}{\tau_G \theta_G + \tau_B \theta_B}$ , and the innovator's expected payoff is

$$(1 - p_B - \tau_B - p_G - \tau_G) y_{NC} + (p_B + \tau_B) \theta_B x_{FM} + (p_G + \tau_G) \theta_G x_{FM} - \frac{(p_G + \tau_G) \theta_G + (p_B + \tau_B) \theta_B}{\tau_G \theta_G + \tau_B \theta_B} c. \quad (9)$$

Continuation after observing  $\theta_B$  requires

$$\theta_B x_{FM} - y_{NC} > \theta_B w = \frac{\theta_B c}{\tau_G \theta_G + \tau_B \theta_B} \quad (10)$$

(i.e.,  $y_{NC}$  is sufficiently low).

Suppose, next, that the inequality in (10) is not satisfied. Then the innovator does not have the right incentives at  $t = 0.5$  to take the efficient continuation decision. This creates scope for renegotiations, in which the R&D team extracts  $\gamma$  of the additionally generated surplus. Denoting the R&D team's payoff in that case with  $w_R$ , we have

$$w_R = w_A + \gamma(\theta_B x_{FM} - y_{NC}).$$

Hence, at the contracting stage  $t = 0$ , the R&D team's incentive constraint is

$$-(\tau_G + \tau_B) w_A + \tau_B (w_A + \gamma(\theta_B x_{FM} - y_{NC})) + \tau_G \theta_G w \geq c. \quad (11)$$

It is optimal to set  $w_A = 0$  and  $w = \frac{c - \tau_B \gamma(\theta_B x_{FM} - y_{NC})}{\tau_G \theta_G}$ .<sup>21</sup> The innovator's expected payoff is

$$\begin{aligned} & (1 - p_B - \tau_B - p_G - \tau_G) y_{NC} + (p_B + \tau_B) (\theta_B x_{FM} - \gamma(\theta_B x_{FM} - y_{NC})) \\ & + (p_G + \tau_G) \left( \theta_G x_{FM} - \theta_G \frac{c - \tau_B \gamma(\theta_B x_{FM} - y_{NC})}{\tau_G \theta_G} \right) \\ = & (1 - p_B - \tau_B - p_G - \tau_G) y_{NC} + (p_B + \tau_B) \theta_B x_{FM} \\ & + (p_G + \tau_G) \theta_G x_{FM} + \gamma(\theta_B x_{FM} - y_{NC}) \left( \frac{\tau_B}{\tau_G} p_G - p_B \right) - \frac{(p_G + \tau_G)}{\tau_G} c. \end{aligned} \quad (12)$$

Subtracting now the innovator's payoff under non-collusion from that under collusion,

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<sup>21</sup>Note that  $\theta_B x_{FM} - \theta_B w$  is indeed negative (and renegotiations in  $t = 0.5$  are needed) as

$$\theta_B x_{FM} - y_{NC} - \theta_B \frac{c - \gamma \tau_B (\theta_B x_{FM} - y_{NC})}{\tau \theta_G} = \left( 1 + \theta_B \frac{\gamma \tau_B}{\tau \theta_G} \right) (\theta_B x_{FM} - y_{NC}) - \theta_B \frac{c}{\tau \theta_G} < 0.$$

we obtain

$$(1 - p_B - \tau_B - p_G - \tau_G)(y_C - y_{NC}) + (p_B + \tau_B)(y_C - \theta_B x_{FM}) - c\theta_B \frac{\frac{\tau_B}{\tau_G} p_G - p_B}{\tau_G \theta_G + \tau_B \theta_B} \quad (13)$$

if there are no renegotiations under non-collusion, and

$$(1 - p_B - \tau_B - p_G - \tau_G)(y_C - y_{NC}) + (p_B + \tau_B)(y_C - \theta_B x_{FM}) - \gamma(\theta_B x_{FM} - y_{NC}) \left( \frac{\tau_B}{\tau_G} p_G - p_B \right) \quad (14)$$

if there are renegotiations. Hence, as long as  $\frac{\tau_B}{\tau_G} p_G > p_B$ , the R&D team's compensation is lower under non-collusion than under collusion, regardless of whether or not (10) is satisfied. Furthermore, both (13) and (14) decrease in  $p_B$ ,  $p_G$ , and  $\tau_B$ . Hence, there is a threshold  $\hat{p}_G$ , such that not colluding is better for the innovator for all  $p_G > \hat{p}_G$ . This threshold decreases (i.e., not colluding is more attractive) in  $\tau_B$ ,  $p_B$ , and  $x_{FM}$ .

Finally, note that if  $\theta_B x_{FM} > y_C$ , the continuation decision is the same under public and private ownership, and public ownership dominates. If  $y_C > \theta_G x_{FM} > y_{NC}$ , public ownership dominates again, but the innovation is never undertaken under public ownership.

**Q.E.D.**

**Proof of Proposition 3.** Observe, first, that the innovator's gross expected payoff is  $x_{FM}$  if only it successfully develops the new technology, 0 if it is unsuccessful in developing the new technology, and  $y_O$ , if both firms successfully develop the new technology, where  $O \in \{C, NC\}$  stands for whether or not the two firms collude. Given a probability  $\rho$  of the incumbent also successfully developing the new technology, it is optimal for the innovator to abandon the new technology at  $t = 0.5$  if  $(1 - \rho)\theta x_{FM} + \rho\theta y_O < (1 - \rho)y_O$  or equivalently if

$$\theta x_{FM} + \frac{\rho}{1 - \rho} \theta y_O < y_O. \quad (15)$$

Hence, the abandonment threshold is higher than without competition. In particular, since  $\frac{\rho}{1 - \rho}$  increases in  $\rho$ , abandonment is never optimal if  $\rho$  is sufficiently high. (In this case, private ownership would have no advantage, and public ownership would be always preferable.)

In what follows, we consider the case in which for  $\theta_B$ , condition (15) holds for  $y_C$ , but not for  $y_{NC}$ , such that abandonment in state  $\theta_B$  is optimal under public, but not under private ownership (in all other cases, public ownership dominates). We denote with  $w_{comp}$  the R&D team's wage in case both firms successfully develop the new technology.

**Public ownership and collusion at  $t = 0.5$ .** The R&D team's incentive constraint

is

$$-(\tau_B + \tau_G)w_A + \tau_B w_A + \tau_G \theta_G ((1 - \rho)w + \rho w_{comp}) \geq c$$

It is optimal to set  $w_A = 0$ , implying that  $\theta_G ((1 - \rho)w + \rho w_{comp}) = \frac{c}{\tau_G}$ . Hence, the innovator's expected payoff is

$$\begin{aligned} & (1 - p_B - \tau_B - p_G - \tau_G)(1 - \rho)y_C + (p_B + \tau_B)(1 - \rho)y_C \\ & + (p_G + \tau_G)((1 - \rho)\theta_G x_{FM} + \rho\theta_G y_C) - \frac{(p_G + \tau_G)}{\tau_G}c. \end{aligned}$$

**Private ownership and non-collusion at  $t = 0.5$ .** Suppose, first, that the innovator takes the ex post efficient continuation decision without renegotiations (below we check when this is the case). The R&D team's incentive constraint is

$$-(\tau_G + \tau_B)(1 - \rho)w_A + (\tau_G \theta_G + \tau_B \theta_B)((1 - \rho)w + \rho w_{comp}) \geq c$$

It is optimal to set  $w_A = 0$ , implying that  $(1 - \rho)w + \rho w_{comp} = \frac{c}{\tau_G \theta_G + \tau_B \theta_B}$ , and the innovator's expected payoff is

$$\begin{aligned} & (1 - p_B - \tau_B - p_G - \tau_G)(1 - \rho)y_C + (p_B + \tau_B)((1 - \rho)\theta_B x_{FM} + \rho\theta_B y_{NC}) \\ & + (p_G + \tau_G)((1 - \rho)\theta_G x_{FM} + \rho\theta_G y_{NC}) - \frac{((p_G + \tau_G)\theta_G + (p_B + \tau_B)\theta_B)}{\tau_G \theta_G + \tau_B \theta_B}c. \end{aligned}$$

Continuation after observing  $\theta_B$  requires that

$$(1 - \rho)\theta_B x_{FM} + \rho\theta_B y_{NC} - (1 - \rho)y_{NC} > \frac{\theta_B c}{\tau_G \theta_G + \tau_B \theta_B}. \quad (16)$$

Suppose, next, that the inequality in (16) is not satisfied. Then, the innovator does not have the right incentives at  $t = 0.5$  to take the efficient decision to continue. This creates scope for renegotiations, in which the R&D team extracts  $\gamma$  of the additionally generated surplus  $w_R := w_A + \gamma((1 - \rho)\theta_B x_{FM} + \rho\theta_B y_{NC} - (1 - \rho)y_{NC})$ . Hence, at the contracting stage  $t = 0$ , the R&D team's incentive constraint is

$$-(\tau_G + \tau_B)(1 - \rho)w_A + \tau_B w_R + \tau_G ((1 - \rho)\theta_G w + \rho\theta_G w_{comp}) \geq c$$

Hence, it is optimal to set  $w_A = 0$  and  $(1 - \rho)w + \rho w_{comp} = \frac{c - \tau_B w_R}{\tau_G \theta_G}$ .<sup>22</sup> The innovator's

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<sup>22</sup>It is straightforward to verify that for this wage, there are, indeed, renegotiations at  $t = 0.5$ .

expected payoff is

$$(1 - p_B - \tau_B - p_G - \tau_G)(1 - \rho)y_C + (p_B + \tau_B)((1 - \rho)\theta_B x_{FM} + \rho\theta_B y_{NC}) \\ + (p_G + \tau_G)((1 - \rho)\theta_G x_{FM} + \rho\theta_G y_{NC}) + \left(\frac{\tau_B}{\tau_G}p_G - p_B\right)w_R - \frac{(p_G + \tau_G)c}{\tau_G\theta_G}.$$

Subtracting the innovator's payoff under non-collusion from that under collusion, we obtain

$$(1 - p_B - \tau_B - p_G - \tau_G)(1 - \rho)(y_C - y_{NC}) \\ + (p_B + \tau_B)((1 - \rho)y_C - (1 - \rho)\theta_B x_{FM} - \rho\theta_B y_{NC}) \\ + (p_G + \tau_G)\rho\theta_G(y_C - y_{NC}) - c\theta_B \frac{\frac{\tau_B}{\tau_G}p_G - p_B}{\tau_G\theta_G + \tau_B\theta_B} \quad (17)$$

if there are no renegotiations under non-collusion, and

$$(1 - p_B - \tau_B - p_G - \tau_G)(1 - \rho)(y_C - y_{NC}) \\ + (p_B + \tau_B)((1 - \rho)y_C - (1 - \rho)\theta_B x_{FM} - \rho\theta_B y_{NC}) \\ + (p_G + \tau_G)\rho\theta_G(y_C - y_{NC}) - \left(\frac{\tau_B}{\tau_G}p_G - p_B\right)w_R \quad (18)$$

if there are renegotiations. The result follows from (17) and (18). **Q.E.D.**

**Proof of Corollary 2.** If  $p_G$  is very low, neither firm starts the new technology's development and public ownership dominates. If  $p_G$  is very high, both firms start the new technology's development and never abandon it (see (15)). The interesting case is when  $p_G$  is high enough that the innovator starts developing the new technology, but that this technology is abandoned if the innovator observes  $\theta_B$  under private, but not under public ownership. The difference in payoffs between public and private ownership is a convex function of  $p_G$ . To see this, use that  $\frac{\partial \rho}{\partial p_G} = \theta_G$  and take the second derivative of (17) with respect to  $p_G$  to obtain

$$2\theta_G(\theta_G + 1)(y_C - y_{NC}).$$

The second derivative of (18) with respect to  $p_G$  is the same. Thus, the attractiveness of public ownership is a convex function of  $p_G$ . Together, all of this implies a U-shaped relationship between  $p_G$  and the attractiveness of public ownership. **Q.E.D.**

**Proof of Proposition 4.** (i) Let  $\rho^{Innov}$  be the likelihood that the innovator successfully develops the new technology. Furthermore, let  $V^{Inc}$  be the incumbent's expected payoff

when starting the new technology's development, and  $V^{Innov,no\ comp}$  and  $V^{Innov,comp}$  be the innovator's expected payoffs depending on whether it is competing with the incumbent for the new technology. The incumbent starts the new technology's development if

$$V^{Inc} + \beta V^{Innov,comp} - k \geq (1 - \rho^{Innov}) y_C + \beta V^{Innov,no\ comp} \quad (19)$$

Differentiating both sides of (19) with respect to  $\beta$ ,  $V^{Innov,no\ comp} > V^{Innov,comp}$  implies that increasing  $\beta$ , makes condition (19) more difficult to satisfy.

(ii) If the incumbent firm buys a controlling stake in the innovator, it dictates that the innovator continues the new technology also if the signal realization is  $\theta_B$ . This is because the incumbent is guaranteed the monopoly profit on the incumbent technology if the new one fails, so it faces no opportunity cost from continuation. Hence, motivating the R&D team requires satisfying the incentive constraint

$$-(\tau_G + \tau_B) w_A + (\tau_B \theta_B + \tau_G \theta_G) w \geq c.$$

As shown in Proposition 2, this leads to a lower compensation cost than if the new technology is abandoned in case of  $\theta_B$  if  $\frac{\tau_B}{\tau_G} p_G > p_B$ . Moreover, absent competition, the incumbent's profit in case of success is higher, increasing the likelihood that the new technology's development is initiated. **Q.E.D.**

**Proof of Proposition 5.** (i) Suppose that both firms adopt the same technology in periods one and two and that Assumption 2 is not satisfied for the incumbent. Since  $2x_C - bx_{NC} > K$  and  $x_C - m > x_{NC}$ , playing  $C$  in both periods is a dominant strategy for the incumbent regardless of the action taken by the innovator.

(ii) One of four cases applies: The innovator is public and innovates alone; it is private and innovates alone; it is private and competes with the incumbent on innovation; it is public and competes with the incumbent on innovation.

In the first case, the innovator abandons the new technology following signal  $\theta_B$  regardless of whether it is large or small. Hence, the cost of motivating the R&D team is the same, and remaining small is preferable (cf. 7) if

$$\begin{aligned} & (1 - p_B - \tau_B - p_G - \tau_G) 2bx_{NC} + (p_B + \tau_B) 2bx_{NC} + (p_G + \tau_G) \theta_G x_{FM} - \frac{(p_G + \tau_G)}{\tau_G} c \\ & > (1 - p_B - \tau_B - p_G - \tau_G) 2\varphi x_C + (p_B + \tau_B) 2\varphi x_C + (p_G + \tau_G) \theta_G \varphi x_{FM} - \frac{(p_G + \tau_G)}{\tau_G} (2\theta) \end{aligned}$$

that is if  $\varphi$  is sufficiently small relative to  $b$ . We omit the argument for the remaining

regions, as it is analogous.<sup>23</sup>

Finally, note that if  $m$  is sufficiently small, the incumbent might prefer that the innovator remains small despite stealing market share. The incumbent can influence this decision by choosing private ownership or not buying an equity stake in the innovator. To see this, observe that in these cases, we have to replace  $x_C$  with  $x_{NC}$  in the right-hand-side of inequality (20), which makes remaining small more attractive for the innovator. **Q.E.D.**

## Appendix B: Further Evidence

As noted in Section 5.2.1, though it is hard to deal with the problem that antitrust lawsuits are an imperfect proxy for collusion, we can address to some extent the problem that the decision to withdraw an IPO can be related to unobserved factors related to antitrust lawsuits. Specifically, using model (1) in Table 2, we can instrument IPO completion using *NASDAQ* returns in the two months since the start of the book-building phase and use the predicted values of *IPO* from regression (4). The second-stage estimation results are presented in column (4) in Table 2. To account for the fact that *IPO* is a binary variable, we can further follow the three-stage procedure outlined in Wooldridge (2002, p. 623, procedure 18.1). In the first stage, we estimate a probit of the determinants that an IPO proceeds (column (2) in Table 2). In the second stage, we regress *IPO* on the fitted values from the first stage, the industry R&D variables, and  $X$ . In the third stage, we regress  $Y_i^{post}$  on the fitted values from the second stage, the industry R&D variables, and  $X$ .<sup>24</sup> Note that the coefficients estimates in columns (4) and (5) are determined only from the firms that would change their IPO decision due to a shift in NASDAQ, and therefore are sensitive to such shifts (Imbens and Angrist, 1994).

Columns (1) and (2) in Table 2 show that fluctuations in the NASDAQ in the two

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<sup>23</sup>For example, in the second case the innovator's compensation cost is higher when it is small, as it continues developing the new technology if large (and private), but not if it is small. Remaining small is, thus, profitable if (see (13)):

$$(1 - p_B - \tau_B - p_G - \tau_G)(2bx_{NC} - 2\varphi x_{NC}) + (p_B + \tau_B)(2bx_{NC} - \theta_B \varphi x_{FM}) \geq c\theta_B \frac{\frac{\tau_B}{\tau_G} p_G - p_B}{\tau_G \theta_G + \tau_B \theta_B},$$

or respectively

$$(1 - p_B - \tau_B - p_G - \tau_G)(2bx_{NC} - 2\varphi x_{NC}) + (p_B + \tau_B)(2bx_{NC} - \theta_B \varphi x_{FM}) \geq \gamma(\theta_B x_{FM} - y_{NC}) \left( \frac{\tau_B}{\tau_G} p_G - p_B \right)$$

giving again a critical value for  $\varphi$ .

<sup>24</sup>For an explanation of the procedure, see also Adams et al. (2009).

months after the IPO filing strongly affect the likelihood of withdrawal. Table 3 shows that it is unlikely that antitrust lawsuits depend stock market movements in general other than over the IPO continuation decision. Specifically, we show that one-year NASDAQ returns both in the years before and after the IPO filing are uncorrelated with whether there is an antitrust lawsuit four years after the filing. Hence, *NASDAQ* appears to be a valid instrument for the likelihood that the IPO is completed. Supportive of this claim is also that the F-statistic of the first stage of the 2-SLS has a value of 25.

The results from models (4) and (5) show a strong impact of the instrumented *IPO* variable on the likelihood of an antitrust lawsuit. The coefficients state that the likelihood of being involved in an antitrust lawsuit increases by about 10%, which is not only statistically, but also economically significant given that the unconditional likelihood of such a lawsuit for firms that withdraw their IPOs is 1%.



Table 1: **Summary Statistics.** This table compares the sample of firms that complete their IPO filings with the sample of firms that withdraws their filings. *AT case after/before filing* is a dummy variable equal to one if there is an antitrust case in the four years after/before the filing. *Postfiling NASDAQ returns* are the two months NASDAQ returns following the IPO filing, *Prefiling NASDAQ returns* are the three month return prior to the filing, *Total assets* are the total assets, adjusted to inflation (base year 1999), *Net income/assets* and *Sales/assets* are the ratios of net income and sales to total assets, winsorized at one percent, *Industry R&D* is the average R&D spending over total assets, weighted by total assets, for the respective industry in a given year. Industry is defined at the two-digit SIC level. \*, \*\*, and \*\*\* indicate that the differences in means are statistically significant at the 10%, 5%, and 1% level, respectively.

	Completed			Withdrawn			Difference
	Mean	Median	SD	Mean	Median	SD	
AT case before IPO filing	0.006	0.000	0.079	0.004	0.000	0.066	0.002
AT case after IPO filing	0.020	0.000	0.141	0.006	0.000	0.078	0.014***
Total assets	180.996	28.900	801.909	164.678	22.273	736.947	16.318
Net income/assets	-0.265	-0.044	0.692	-0.375	-0.061	0.917	0.11***
Sales/assets	1.074	0.818	1.099	1.186	0.729	1.356	-0.112***
Industry R&D	0.033	0.043	0.025	0.032	0.042	0.025	0.001
Postfiling NASDAQ returns	0.025	0.031	0.098	-0.018	-0.004	0.121	0.043***
Prefiling NASDAQ returns	0.058	0.051	0.115	0.051	0.041	0.139	0.007

Table 2: **Going Public and Antitrust Lawsuits.** This table reports the effect of an IPO on the likelihood of an antitrust lawsuit in the four years after the IPO filing. In models (1) and (2), the dependent variable is *IPO*, which is a dummy variable, equal to one if the firm does not withdraw its IPO. Model (1) presents the estimates from an OLS, while model (2) the estimates from a probit regression. In models (3)–(5), the dependent variable is *AT case after filing*, which is a dummy variable equal to one if there is an antitrust case in the four years after the filing. Model (3) shows OLS estimates. Model (4) presents the second stage of the 2SLS estimates, and model (5) presents the third stage of Wooldridge’s three-stage procedure (18.1). The latter two models are described in Appendix B. Variable definitions are as in Table 1. All regressions include filing year and industry fixed effects at the two digit SIC level. Robust t-statistics are reported in the parantheses. \*, \*\*, and \*\*\* indicate that the coefficient is statistically significant at the 10%, 5%, and 1% level, respectively.

	(1)	(2)	(3)	(4)	(5)
Dependent variable	IPO	IPO	AT case after filing	AT case after filing	AT case after filing
IPO			0.021*** (3.992)	0.139** (2.255)	0.083*** (2.664)
NASDAQ returns	0.406*** (5.433)	1.414*** (5.460)			
$\Delta$ Industry R&D	-0.120*** (-2.819)	-0.480*** (-2.656)	0.015 (0.859)	0.029 (1.559)	0.024 (1.324)
$\Delta$ Industry R&D <sup>2</sup>	0.026*** (2.706)	0.106** (2.512)	-0.003 (-0.769)	-0.006 (-1.453)	-0.005 (-1.216)
Industry R&D	-1.726 (-1.625)	-7.463*** (-1.970)	-0.786* (-1.867)	-0.582 (-1.328)	-0.723* (-1.730)
Industry R&D <sup>2</sup>	1.640 (0.702)	9.670 (1.176)	1.129 (1.437)	0.939 (1.147)	1.105 (1.400)
AT case before filing	-0.023 (-0.304)	-0.051 (-0.150)	0.224*** (2.623)	0.227*** (2.632)	0.234*** (2.650)
Log total assets	0.042*** (8.394)	0.163*** (8.655)	0.009*** (4.436)	0.004 (1.356)	0.007*** (3.151)
Net income/assets	-0.012 (-0.898)	-0.050 (-1.208)	-0.009*** (-3.149)	-0.008** (-2.336)	-0.008*** (-2.792)
Sales/assets	-0.017** (-2.161)	-0.069*** (-2.668)	0.002 (0.645)	0.004 (1.245)	0.003 (1.018)
Constant	0.221** (2.390)	1.427*** (3.890)	0.034 (0.674)	-0.105 (-1.598)	-0.052 (-1.181)
Filing year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Observations	3486	3432	3486	3486	3432
$R^2$	0.173		0.069	.	0.043
Pseudo $R^2$		0.180			

Table 3: **NASDAQ Drops and Placebo Test.** Panel A of this table compares firms that experience a two month post filing Nasdaq return in the bottom 10% and top 90% of the filing year, and the bottom 25% and top 75%, respectively. Variable definitions are as in Table 1. \*, \*\*, and \*\*\* indicate that the differences in means are statistically significant at the 10%, 5%, and 1% level, respectively. Panel B reports placebo tests for the validity of the instrumental variable exclusion restriction. The dependent variable is *AT case after filing* that takes the value of one if there was an antitrust case in the four years after the IPO filing. *Nasdaq returns* is defined as in Table 1. *Nasdaq 1 year post/pre filing* are defined as the NASDAQ one-year return following/preceding the IPO filing. The models are estimated using OLS, and robust t-statistics are presented in parantheses. \*, \*\*, and \*\*\* indicate that the coefficient is statistically significant at the 10%, 5%, and 1% level, respectively.

Panel A: NASDAQ Drops and Firm Characteristics	(1) Bottom 10%	(2) Top 90%	(3) Difference	(4) Botton 25%	(5) Top 75%	(6) Difference
AT case before IPO filing	0.000	0.006	-0.006*	0.007	0.006	0.001
AT case after IPO filing	0.015	0.026	-0.011	0.015	0.023	-0.008*
Total assets	124.980	113.320	11.660	208.715	176.806	31.909
Net income/assets	-0.317	-0.317	0.000	-0.283	-0.313	0.030
Sales/assets	1.162	1.057	0.105	1.125	1.060	0.065
Industry R&D	0.035	0.034	0.001	0.033	0.032	0.001

Panel B: Placebo test	(1)	(2)	(3)	(4)	(5)
Dependent variable	AT case after filing	AT case after filing	AT case after filing	AT case after filing	AT case after filing
NASDAQ returns	0.058** (2.451)			0.057** (2.510)	0.056** (2.390)
NASDAQ 1 year post filing		-0.008 (-0.447)		0 (-0.007)	
NASDAQ 1 year pre filing			0.009 (1.019)		0.005 (0.563)
Control variables	Yes	Yes	Yes	Yes	Yes
Filing year FE	Yes	Yes	Yes	Yes	Yes
Industry FE	Yes	Yes	Yes	Yes	Yes
Observations	3486	3486	3486	3486	3486
$R^2$	0.052	0.051	0.051	0.052	0.052

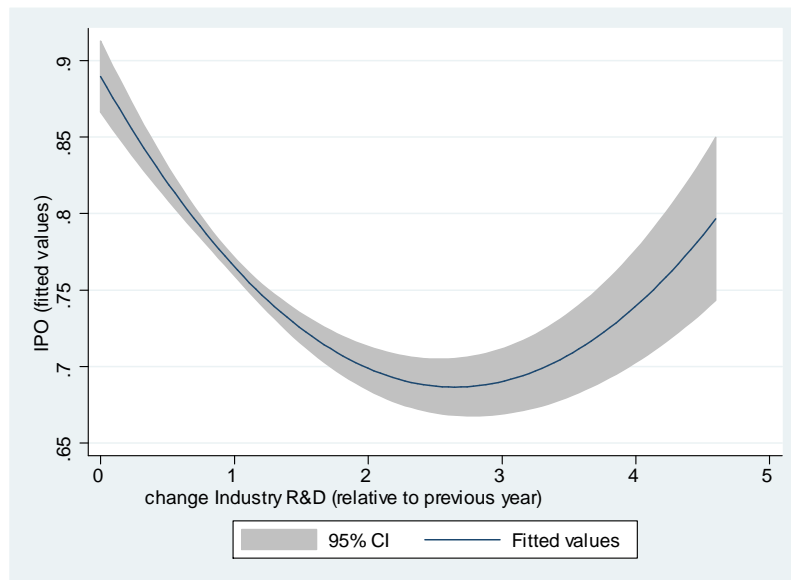


Figure 2: **Quadratically fitted relation between IPO and  $\Delta$ Industry R&D.** The figure plots the fitted values of IPO from model (1) in Table 2 against  $\Delta$ Industry R&D, which is the change in average R&D spending to total assets in the same two-digit SIC industry in the IPO filing year relative to the previous year. The gray area presents the 95% confidence interval.