Received 21 June 2016
Revised 29 September 2016
Accepted 30 September 2016

Product market competition, R&D investment choice, and real earnings management

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Abstract

Purpose – Recent studies in the accounting literature have investigated the economic consequences of R&D capitalization. Discretionary R&D capitalization for target beating can be characterized as a firm signaling private information on its future economic benefits or as opportunistic earnings management. R&D capitalization also has an impact on a firm's marginal costs and product market competition. The purpose of this paper is to address how firms choose R&D levels for the purpose of meeting or beating their earnings targets and how this influences sequential product market competition.

Design/methodology/approach – The authors study this issue in a stylized game-theoretic model where R&D choices of a firm are not only strategically made but also used to convey proprietary information to its rival. The model provides a rationale for a firm distorting its R&D level to earn more profits and meet its earnings target.

Findings – The equilibrium result indicates that before the realization of common cost shock, a firm can influence the output of its accounting system (i.e. meeting an earnings target) through adjusting its R&D choices. This firm will overinvest in R&D, and this will give an opportunity to create some reserves to be used later to earn a higher profit and reach the earnings target.

Originality/value – This paper contributes to the research on real earnings management in terms of how R&D capitalization affects a firm's R&D choices by influencing the output of its accounting system through adjusting its R&D choices and the strategic impact of those choices.

Keywords Earnings target, Oligopoly Competition, One-sided incomplete information, R&D investment, Real earnings management

Paper type Research paper

1. Introduction

Several studies in the accounting literature examine the consequences of R&D capitalization[1] (Aboody and Lev, 1998; Oswald and Zarowin, 2007; Seybert, 2010; Dinh *et al.*, 2015a, 2015b). As underinvestment in R&D may not yield much earnings management benefit and may limit a

The authors acknowledge National Social Science Foundation of China under Grant (grant #15BJY011).

International Journal of Accounting & Information Management
Vol. 25 No. 3, 2017
pp. 296-312

1834-7649
DOI 10.1108/IJAIM-06-2016-0067

firm's long-term growth and profitability[2], capitalizers may be reluctant to do it (Oswald *et al.*, 2016).

Hughes and Kao (1991) examine the effects of different rules regarding R&D costs on oligopoly competition. Hughes and Kao consider incomplete information between firms as to each firm's marginal cost. Hughes and Kao argue that capitalization is more informative than expensing, because it requires estimates of future benefits and auditor verification of such estimates.

Similar to Hughes and Kao (1991), we examine the informational impact of R&D choice on a game that two firms play in product market competition. However, the present study focuses on how R&D capitalization[3] affects a firm's R&D choice in terms of influencing the output of its accounting system (i.e. meeting an earnings target) through adjusting its R&D choices and the strategic impact of those choices[4]. In a one-sided incomplete information setting, the rival is uncertain about a firm's type, which can be either profit-maximizing or target-meeting. The profit-maximizing type pursues profit maximization in product market competition, while the target-meeting type attempts to earn more profits, meets the earnings target and incurs a cost for missing the target[5]. The less informed firm revises its assessments of the informed firm's type depending on the informed firm's R&D investment level and realization of common cost shock (e.g. raw material price).

This study will investigate how an earnings target can affect the privately informed firm's R&D choice, and the impact which this has on Cournot competition in terms of earning more profits, and more generally, in terms of whether the earnings target is met or beaten. When the informed firm has diverse purpose in its R&D investment, this creates an additional uncertainty and in turn affects the two firms' decisions in Cournot competition. We investigate whether the informed firm takes advantage of its rival's uncertainty regarding its identity and makes the rival over-invest in R&D, thereby benefiting its own plans to meet its earnings target. We also examine whether the informed firm changes its R&D choice before the common cost shock (e.g. raw material price) is realized, to exceed expectation for the purpose of maintaining its rival's uncertainty about the informed firm's type. Such uncertainty is mentioned in the empirical studies conducted by Burgstahler and Eames (2003) and Yu (2008). They discuss whether analysts are able to identify the specific firms engaged in earnings manipulations[6] but with diverse results. The present study further explores this issue on a rival firm's decisions in its real activities.

This study, based on the above scenario, involves a two-stage game. In the first stage, two players take an action that bears both strategic and informational effects that will influence the decisions in product market competition in the second stage. This class of games has been studied by researchers in an attempt to explain why the action choice in the first stage may deviate from the choice that maximizes profits directly influenced by that choice. The reason is that the choice affects the belief of rivals who will be involved in product market competition in the subsequent stage.

Several studies claim that meeting or beating an earnings target induces R&D underinvestment (i.e. aggressive reporting) (Bushee, 1998; Graham *et al.*, 2005; Roychowdhury, 2006; Gunny, 2010). However, these studies ignore the sequential impact of R&D investment. Contrary to such studies, R&D choices for meeting an earnings threshold in the present study have both strategic and informational impact. For the informational impact of meeting or beating the earnings target (MBT, hereafter) for an R&D firm, investing in R&D for meeting or beating earnings targets will convey a positive image of a firm that cares more about its future prospects. This is consistent with recent experimental evidence that firms responsible for the external reporting consequences of their R&D project are more likely boost their R&D investment (Seybert, 2010). For the competitive impact of

MBT for an R&D firm, a firm has the incentive to conceal its identity by taking on a mixed strategy. Here, R&D overinvestment can give an opportunity to create some reserves to be used later to earn a higher profit and reach the earnings target.

In what follows, we briefly summarize major results of this study. A profit-maximizing Firm 1's R&D investment level can influence Firm 2's conjecture, which in term affects the success of MBT for the target-meeting Firm 1. In separating equilibrium, when the profit-maximizing Firm 1 has no incentive to set a higher R&D level (i.e. will not act as the target-meeting type), and further to mislead Firm 2 about Firm 1's objective type, the higher earnings target for the target-meeting Firm 1 cannot be achieved.

In a hybrid equilibrium, the profit-maximizing type of informed firm could distort its R&D level to confuse the uninformed firm. Specifically, the target-meeting type of informed firm is motivated to conceal its identity by adopting a mixed strategy and overinvesting in its R&D level (i.e. will act as the target-meeting type partially). This will increase the outputs and profits of the profit-maximizing type of informed firm and will let it meet the earnings target as well. In this sense, the earnings target will be beneficial for this firm to maintain an edge in market share in oligopoly competition.

The remainder of this paper proceeds as follows. In Section 2, we describe a two-stage non-cooperative R&D competition model with one-sided incomplete information. The private information is about the signaling firm's objective type: profit maximization or target meeting. The objective function for each type and the sequence of actions are also provided. Section 3 characterizes the separating and hybrid Bayesian equilibrium results of the game. Section 4 discusses our model as well as related literature. Section 5 presents the conclusion. For the ease of presentation, all long derivations and proofs are relegated to the Appendix.

2. The model

To examine how a firm's R&D level affects the likelihood of meeting or beating its earnings targets and how this influences sequential product market competition, this section describes the strategic use of R&D investment in a two-stage game with one-sided incomplete information, and firms decide their R&D investment level before engaging in Cournot competition. In this model, R&D decisions not only are investment decisions but also involve accounting discretion. R&D-based earnings management about meeting or beating earnings targets is associated with informational asymmetry and managerial incentives, such as reputation and informational concern (Bange and De Bondt, 1998; Seybert, 2010). Some studies provide evidence that R&D capitalized expenditure is positively and significantly associated with the firm's future earnings. For example, Ahmed and Falk (2016) demonstrate the value relevance of R&D capitalization for Australian firms; Oswald and Zarowin (2007) for UK firms; and Seybert (2010) for experimental evidence. Other studies find that managers use the discretion involved in R&D capitalization for opportunistic earnings management. For example, Dinh *et al.* (2015a) find a negative association between capitalized R&D for benchmark beating and market values in a sample of German firms and attribute the results to an opportunistic use of R&D capitalization for benchmark beating. In addition, Dinh *et al.* (2015b) find that the capitalization of R&D is significantly associated with both higher individual analysts' forecast errors and forecast dispersion. In our model, we consider one-sided incomplete information which is related to uncertainty about an informed firm's objective type. We demonstrate that with this uncertainty, the earnings target will not be fully anticipated by the competitors, and thus, we will show the informed firm meeting or beating the earnings target but not necessarily using real earnings management.

The Environment. Specifically, we consider two firms competing in an industry. Firms 1 and 2 both provide homogeneous products. Following Shy (1995), we assume the following demand structure:

$$p(q_1, q_2) = A - q_1 - q_2$$

where q_1 and q_2 denote the outputs of Firms 1 and 2, respectively.

Following D'Aspremont and Jacquemin (1988), we assume that these two firms have small investment size and non-cooperatively engage in cost-reduction R&D in the same research lab. The unit production cost function is described in the following manner. x_1 denotes the amount of R&D undertaken by Firm i, i = 1, 2. $c_i(x_1, x_2)$ represents the unit production cost of Firm i, which is assumed to be a function of the R&D investment levels of both firms. Formally, let:

$$c_i(x_1, x_2, \varepsilon) = a - x_i - bx_j + \varepsilon, \ i \neq j, \ b > 0$$

where b measures the spillover effect of Firm j's R&D level on the unit production cost of Firm i, $0 < b < 1$. The random term ε encompasses the common cost shocks. This is uniformly distributed over $[-\bar{\varepsilon}, \bar{\varepsilon}]$ according to a non-decreasing distribution function $F(\varepsilon)$ with a density $f(\varepsilon)$.

We also assume that investing in R&D activities is costly for firms. Formally, let $TC_i(x_i)$ be the cost for Firm i of operating an R&D lab at a research level of x_i. Then:

$$TC_i(x_i) = \frac{(x_i)^2}{2}$$

The Timeline. Figure 1 presents the sequence of actions in this game. To illustrate the uncertainty about a firm's purpose of effort in R&D activity, we assume that before competition, Firm 1 is privately informed of its type, which can be either profit maximizing (*m*) or target meeting (*l*). The profit-maximizing type pursues profit maximization in product market competition, while the target-meeting type attempts to meet or beat its earnings target and incurs a cost of missing the target. The uncertainty about Firm 1's objective type reflects doubts concerning its R&D action and its related strategic intentions. Under such one-sided incomplete information, Firms 1 and 2 determine how much to invest in cost-reduction R&D activities and then compete in the product market in the second stage. At the end of the first stage, Firm 2 updates its belief about Firm 1's objective type after observing its first-stage R&D investment level. In the second stage, the two firms compete on outputs, and the two firms' profits are realized in the end.

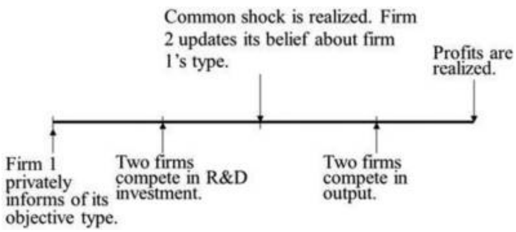

Figure 1.
The sequence of moves

Information. To describe the uncertainty about Firm 1's objective type, the following definitions are used. First, ρ^t, t = 1, 2, denotes the rival firm's belief (prior and ex post) that Firm 1 is a profit-maximizing type, while $1-\rho^t$ represents a belief that it is a target-meeting type. We use a superscript t to denote the variables in stage t. Second, to distinguish the R&D investment and output strategy for each type of Firm 1, let $x_1(k)$ and $q_1(k)$ denote the R&D investment and output, respectively, set by a type k (k = m, l) Firm 1.

Thus, Firm i's profits over two stages are written as Π_i, where:

$$\begin{aligned}\Pi_1 &= \left(A - q_1(k) - q_2 - c_1\left(x_1(k), x_2, \varepsilon\right)\right) q_1(k) - TC_1\left(x_1(k)\right)\\ &= \pi_1\left(q_1(k), q_2, c_1\left(x_1(k), x_2, \varepsilon\right)\right) - TC_1\left(x_1(k)\right)\end{aligned}$$

$$\begin{aligned}\Pi_2 &= \Big[\rho^2\left(A - q_2 - q_1(m) - c_2\left(x_2, x_1(m), \varepsilon\right)\right)q_2 + \left(1-\rho^2\right)\\ &\quad\times\left(A - q_2 - q_1(l) - c_2\left(x_2, x_1(l), \varepsilon\right)\right)q_2\Big] - TC_2\left(x_2, \rho^1\right)\\ &= \pi_2\left(q_2, q_1(k), \rho^2, c_2\left(x_2, x_1(k), \varepsilon\right)\right) - TC_2\left(x_2, \rho^1\right)\end{aligned}$$

Next, we describe the objective functions of each type of Firms 1 and 2.

Objective Function. If Firm 1 is a profit-maximizing type, then for both Firms 1 and 2, the first-stage objectives will be:

$$\max_{x_i} E(\Pi_i),\ \text{for } i = 1, 2 \tag{1}$$

where E is the expectation over the cost shock, ε.

Given the R&D investment in the first stage, the second-stage objectives for both firms are:

$$\begin{aligned}&\max_{q_1} \pi_1,\\ &\max_{q_2} \pi_2\end{aligned} \tag{2}$$

If Firm 1 is a target-meeting type, then Firm 2's first-stage objective remains the same as in Equation (1), but the former's first-stage objective is to find x_1 to meet some of the earnings pressure, $\bar{\Pi}$. Thus:

$$\begin{cases}\bar{\Pi}, & \bar{\Pi}_1 \geq \bar{\Pi}\\ \Pi_1 - k, & \textit{otherwise}\end{cases} \tag{3}$$

where k is the cost of missing the target. As a benchmark for comparison, we consider a two-stage non-cooperative R&D competition in a full information setting. The equilibrium can be obtained by first solving for the output level in the second stage and then for the first-stage R&D levels. We denote $\left(q_1^*, q_2^*\right)$ as the output which maximizes $q_i^* \equiv \arg\max \pi_{iq_i}(q_i, q_j, c_i, c_j)$, i, j = 1, 2, i $\neq$ j, where π_i^* is the obtained profit and $\left(x_1^*, x_2^*\right)$ is the R&D level which maximizes $x_i^* \equiv \underset{x_i}{\operatorname{argmax}}\, E\Pi_i(q_i^*, q_j^*, c_i(x_i, x_j), \varepsilon)$; Π_i^* and c_i^* are the obtained total profit and unit production cost, respectively. We set $\bar{\Pi} = \Pi_i^*$.

With this setting, the target-meeting type will behave differently from the profit-maximizing type. Earnings pressure is the pressure on managers to beat or meet some benchmarks about a firm's performance (e.g. zero earnings or past year's earnings). For example, Levitt (1998, p. 16) mentions that:

> While the problem of earnings management is not new, it has swelled in a market that is unforgiving of companies that miss their estimates. I recently read of one major US company that failed to meet its so-called "numbers" by one penny, and lost more than six per cent of its stock value in one day.

Missing the earnings target may also persuade investors to sue the firm for recovery under the Securities Acts (Evans *et al.*, 2006; Li, 2009) and increase the cost of capital (Ronen *et al.*, 2011).

In the second stage, as the cost shock has been realized, the target-meeting Firm 1 could strategically plan its output to meet the second-stage target as well. That is, the target-meeting Firm 1 will choose a q_1 such that:

$$\pi_1 \geq \hat{\pi}(x_1(m),\ x_1(m),\ x_1(l),\ x_2,\ \varepsilon), \tag{4}$$

where $\hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon)$ is the earnings target when both the R&D investment and cost uncertainty are realized. If the earnings target, $\hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon)$, is missed, then the payoff of the target-meeting type of Firm 1 is $\pi_1 - k$. Notice that Firm 2's objective remains the same as in Equation (2).

Beliefs. Following convention, we assume that the first-stage belief ρ^1 with $0 < \rho^1 < 1$ is exogenously given as prior belief. The second-stage belief ρ^2 will be endogenously determined by the prior belief ρ^1, Firm 1's first-stage R&D investment ($x_1(m)$, $x_1(l)$) and the realization of common cost shock. We will discuss the off-equilibrium path beliefs in a subsequent section on characterizing the equilibrium.

Real Earnings Management. According to existing literature (Ewert and Wangenhofer, 2005), real earnings management occurs when a manager undertakes decisions that depart from the first best ones and have an impact on a firm's value. When a firm has incentive to meet or beat its earnings target, it can systematically alter its operational strategies. For example, recent experimental evidence on reputation-driven real earnings management indicates that firms responsible for initiating R&D projects are more likely to distort their R&D investment to protect them from impairing the firms' future prospects (Seybert, 2010).

In this study, real earnings management, b_{REM}, is defined as the difference between the R&D investment level of the target-meeting type firm and that of the profit-maximizing type firm, $b_{REM} = x_1(l) - x_i^*$. We consider the situation in which the privately informed firm may attempt to distort reported R&D activity to maintain its earnings target. This will be more costly in R&D investment for this firm when it pursues a higher earnings target (where $b_{REM} > 0$) and will have a negative impact on the firm's product market competitiveness when it myopically sacrifices its R&D investment (where $b_{REM} < 0$).

3. Equilibrium

In this section, we first characterize the second-stage product market equilibrium ($q_1(m)$, $q_1(l)$, q_2), for a given level of posterior belief ρ^2 and the common cost shock, ε. Then, we discuss the first-stage R&D investment equilibrium ($x_1(m)$, $x_1(l)$, x_2) and interpret the on- and off-equilibrium path ρ^2. This section especially considers the rival firm's reaction to real earnings management in the second stage, with particular interest in the strategic actions that have to be taken in the first stage when Firm 1 might take advantage of its private information for a higher profit.

3.1 Product market equilibrium result in the second stage

At the beginning of the second stage, both Firms 1 and 2 can observe their first-stage R&D investment and the realized random shock ε. The second-stage belief ρ^2 (on- and off-equilibrium path) will be discussed in more detail when we characterize the R&D investment equilibrium of the first stage in a later section of this paper. For the moment, the value of ρ^2 is treated as constant. Firms 1 and 2 determine (q_1(m), q_1(l), q_2) simultaneously in the second stage.

The Profit-maximizing Firm 1 First, for the profit-maximizing Firm 1, let $q_1(m) = \underset{q_1}{\operatorname{argmax}}\ \pi_1$, where:

$$\pi_1 = (A - q_1 - q_2 - c_1)q_1$$

Then, the best reply to q_1 is:

$$q_1(m) = \frac{1}{2}(A - q_2 - c_1) \tag{5}$$

The Target-meeting Firm 1. For the target-meeting Firm 1, $q_1(l)$, is denoted as the output to satisfy Equation (4), that is:

$$q_1(l) \in \{q_1 | (A - q_1 - q_2 - c_1)q_1 \geq \hat{\pi}(x_1(l),\ x_1(m),\ \varepsilon)\} \tag{6}$$

Such a q_1(l) may not be found, which depends on both the posterior belief (ρ^2) of Firm 2 and $\bar{\Pi}$. In this case, the target-meeting type of Firm 1 will miss the earnings target, $\hat{\pi}$ (x_1(l), x_1(m), ε).

Next, Firm 2 chooses q_1 to maximize $\rho^2\pi_2$ (q_1(m), q_2) + (1 − ρ^2) π_2 (q_1(l), q_2), that is:

$$\max_{q_2}\ \rho^2(A - q_2 - q_1(m) - c_2)q_2 + (1 - \rho^2)(A - q_2 - q_1(l) - c_2)q_2$$

or equivalently:

$$\max_{q_2}\ \rho^2\Big(A - q_2 - \rho^2 q_1(m) - (1 - \rho^2)q_1(l) - c_2\Big)q_2$$

Hence, the best reply to q_1(m) and q_1(l) is:

$$q_2 = \frac{1}{2}\Big(A - \rho^2 q_1(m) - (1 - \rho^2)q_1(l) - c_2\Big) \tag{7}$$

q_1(m) is assumed to be given, as this value will be uniquely determined by Equation (5). In contrast, the target-meeting Firm 1 can choose among a range of feasible outputs to meet the target, which is the best replies of q_1(l). Accordingly, one can expect many equilibrium outputs in the second stage. As there is no obvious criterion to rule out any equilibrium, we will focus on those that are more realistic to expect. The second-stage product market equilibrium is determined by Equations (5) through (7) simultaneously.

To describe the equilibrium properties, it is important to note first that the R&D investment in the first stage will affect the continuation payoff through the Bayesian updating for ρ^2; as well as through the level of $\hat{\pi}$ (x_1(l), x_1(m), ε), which will determine q_1(l). We will examine the impact of real earnings management on meeting the earnings target with the setting of q_1(l), especially when the target-meeting Firm 1 needs to meet or beat a $\hat{\pi}$(x_1(l), x_1(m), ε) > π_1^*. Now, we address the specific conditions applicable to this.

Lemma 1. For the target-meeting Firm 1 to meet a $\hat{\pi}$ (x_1(l), (x_1(m), ε) > π_1^* in the second stage, it needs to set a q_1(l) higher than q_1^*, where $\rho^2 < 1$.

Proof. Note that $\pi_1(\rho^2, q_1(l), q_2)$ is concave in $q_1(l)$ and decreasing in q_2. If the target-meeting Firm 1 is to set a profit higher than π_1^*, then it requires a q_2 lower than q_2^*. As Firm 2 faces an expected output $-(\rho^2 q_1(m) + (1-\rho^2)\, q_1(l))$ even as $q_1(m)$ stays the same as q_1^* when $q_2 = q_2^*$, it requires a $q_1(l)$ higher than q_1^*.

Lemma 1 shows that the target-meeting Firm 1 could raise its output level to gain more profits in a product market competition of the second stage when $\rho^2 < 1$. This will also help the target-meeting type firm meet or beat its earnings target. We will demonstrate shortly that there exists equilibrium where firms increase R&D investments in the first stage and then boost their outputs in the second stage. However, when $\rho^2 \geq 1$, say, $\rho^2 = 1$, setting $q_1(l)$ higher than q_1^* is not possible. Then, the earnings target, π_1^*, is not achievable.

As the set of $q_1(l)$ is affected by the level of $\hat{\pi}(x_1(l), x_1(m), \varepsilon)$, we rewrite the second-stage payoff as $\pi_1\left(\rho^2, \hat{\pi}\left(x_1(l), x_1(m), \varepsilon\right) q_1(l), q_2\right)$. The next lemma describes the properties of the equilibrium payoff when the target-meeting type of Firm 1 needs to meet a target higher than π_1^*.

Lemma 2 If the target-meeting Firm 1 needs to meet or beat an earnings target higher than π_1^*, as ρ^2 decreases and approaches 0, $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(m), \varepsilon), q_1(l), q_2)$ increases; the lower bound of $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(m), \varepsilon), q_1(l), q_2)$ for the target-meeting type will increase with $\hat{\pi}(x_1(l), x_1(m), \varepsilon)$.

Proof. (i) It is noted that $\pi_1(\rho^2, q_1(l), q_2)$ decreases with q_2. Next, as described, $q_1(l)$ is higher than q_1^*, and thus, $-(\rho^2 q_1(m) + (1-\rho^2) q1(l))$ will increase with ρ^2. With the fact $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(m), \varepsilon), q_1(l), q_2)$ decreases with q_2, $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(m), \varepsilon), q_1(l), q_2)$ decreases with ρ^2. (ii) As $\hat{\pi}(x_1(l), x_1(m), \varepsilon)$ increases, the necessary profit set for the target-meeting type will increase.

Lemma 2 explains how the second-stage earnings target ($\hat{\pi}(x_1(l), x_1(m), \varepsilon)$) and the posterior belief (ρ^2) affect the equilibrium profit. As both of them are influenced by the R&D investment in the first stage of Firm 1, such effects are important for the strategic concerns of the target-meeting Firm 1 in the first stage.

Lemma 3 If the target-meeting Firm 1 needs to meet or beat an earnings target higher than π_1^*, the lower bound of and feasible set of $q_1(l)$ for the target-meeting type will increase with $\hat{\pi}(x_1(l), x_1(m), \varepsilon)$.

Proof. As the size of $\hat{\pi}(x_1(l), x_1(m), \varepsilon)$ surpasses π_1^* and increases, the extent of $q_1(l)$ that is higher than q_1^* will increase.

3.2 R&D investment equilibrium result in the first stage

R&D investment of the informed firm in the first stage has two effects:

(1) Firm 1's R&D investment directly relates to the unit production cost, which together with the realization of common cost shock, indirectly determines the required profits for the target-meeting Firm 1 in the second stage. Thus, Firm 1's R&D investment and the realization of common cost shock have an impact on the second-stage outputs for the target-meeting Firm 1, which in turns affects q_2.

(2) Firm 1's R&D investment will change Firm 2's belief (ρ^2) about Firm 1's objective type.

In this section, we will consider two groups of perfect Bayesian equilibria: separating and hybrid equilibria (Gibbons, 1992). In the separating equilibrium, each type of Firm 1 is willing to express its identity, so that in the second stage, Firm 2 will set an output level that best fits each type, instead of an output that is merely the best reply to a weighted sum of $q_1(m)$ and $q_1(l)$. In the hybrid equilibrium, one type of Firm 1 is not willing to express its identity, so that in the second stage, that particular type of Firm 1 can take advantage of both the impact on ρ^2, and the fact that Firm 2 will set an output that best replies to a weighted sum of $q_1(m)$ and $q_1(l)$. Different from the standard signaling game literature, the incentive constraints for the equilibrium will not be given exogenously here. They will be endogenously determined by the product market equilibrium of the second stage. In the following, we will first characterize the incentive constraints for both the separating and hybrid equilibrium and check if there exists any product market equilibrium in the second stage that satisfies these constraints.

First of all, given the second-stage equilibrium ($q_1(l)$, $q_1(m)$, q_2) as characterized above, the profits for each firm are given as follows. The profit-maximizing Firm 1 needs to find $x_1(m)$ to solve the following problem:

$$\max_{x_1} \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}} \left\{ \pi_1\left(x_1(l),\ x_2, \varepsilon, \rho^2, q_1(m), q_1(l), q_2\right) - \tfrac{(x_1)^2}{2} \right\} \tfrac{1}{2\bar{\varepsilon}}\, d\varepsilon \tag{8}$$

On the other hand, the target-meeting type of Firm 1 finds $x_1(l)$ such that $E(\Pi_1) \geq \bar{\Pi}$, that is:

$$x_1(l) \in \left\{ x_1 \middle| \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}} \left\{ \pi_1\left(x_1(m),\ x_2, \varepsilon, \rho^2, q_1(m), q_1(l), q_2\right) - \tfrac{(x_1)^2}{2} \right\} \tfrac{1}{2\bar{\varepsilon}}\, d\varepsilon \geq \bar{\Pi} \right\} \tag{9}$$

If $\bar{\Pi}$ is not reached, then the target-meeting type of Firm 1's payoff is $\prod_1 - k$. Firm 2 chooses x_2 to solve the following problem given the prior belief ρ^1:

$$\max_{x_2} \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}} \left\{ \pi_2\left(\rho^1, x_1(m),\ x_1(l), x_2, \varepsilon, \rho^2 q_1(m),\ q_1(l),\ q_2\right) - \tfrac{(x_2)^2}{2} \right\} \tfrac{1}{2\bar{\varepsilon}}\, d\varepsilon \tag{10}$$

Let $\varepsilon(x_1(m), x_1(l), x_2)$ denote the threshold value of ε such that $c_1 = c_1^*$. If $x_i > x_i^*$, i = 1, 2, then c_i, i = 1, 2, decreases with x_i and hence $\varepsilon(x_1(m), x_1(l), x_2)$ increases with x_i. We will examine the situations in which the profit-maximizing Firm 1 will overinvest in R&D to dampen the effect of common cost shock on its profit.

3.2.1 Separating equilibrium. In the separating equilibrium, each type of Firm 1 is willing to reveal its identity, so that in the second stage, Firm 2 will set an output that best fits each type, instead of an output that is the best reply to a weighted sum of $q_1(m)$ and $q_1(l)$. The first-stage equilibrium affects the continuation payoff in three aspects:

(1) It determines the Bayesian updating for ρ^2.

(2) The equilibrium at the first stage affects the level of $\hat{\pi}$, which in turn affects the setting of $q_1(l)$ for the target-meeting type of Firm 1 at the second stage.

(3) It affects the possibility that in the second stage, the target-meeting Firm 1 could set an output higher than q_1^*.

Let ($x_1(m)$, $x_1(l)$) with $x_1(l) > x_1(m) \geq x_1^*$ denote the equilibrium R&D investment level at t = 1. Note that x_2 is determined by Equation (10). On the basis of this, we consider the following beliefs for the second stage:

$$\rho^2 = \begin{cases} 0, & \textit{for } x_1 \geq x_1(l) \\ 1, & \textit{otherwise} \end{cases}$$

Note that the on-equilibrium path belief calculated by Bayes' rule is included in this setting. This setting of off-equilibrium path belief follows Gibbons (1992). After replacing ρ^2 with the above setting, we rewrite the total profit for the profit-maximizing type of Firm 1 as:

$$\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)} \left\{\pi_1\left(1,\hat{\pi}(x_1(m),(x_1(l),x_2,\varepsilon),q_1(m),\underline{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}\,d\varepsilon$$

$$+\int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \left\{\pi_1\left(1,\hat{\pi}(x_1(m),(x_1(l),x_2,\varepsilon),q_1(m),\bar{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}\,d\varepsilon \tag{11}$$

Henceforth, we denote $\underline{q}_1(l)$ as the output of the target-meeting type where ε lies between $-\bar{\varepsilon}$ and $\varepsilon(x_1(m), x_1(l), x_2)$ and $\bar{q}_1(l)$ as the output of the target-meeting type where ε lies be $\varepsilon(x_1(m), x_1(l), x_2)$ and $\bar{\varepsilon}$.

Next, the total profit for the target-meeting type of Firm 1, Φ, is given by:

$$\Phi \equiv \int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)} \pi_1\left(0,\hat{\pi}(x_1(m),x_1(l),x_2,\varepsilon),q_1(m),\underline{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}$$

$$+\int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \left\{\pi_1\left(0,\hat{\pi}(x_1(m),x_1(l),x_2,\varepsilon),q_1(m),\bar{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}\,d\varepsilon$$

The Profit-maximizing Firm 1 For (x_1(m), x_1(l)) being a separating equilibrium, it is required that for the profit-maximizing Firm 1, (i) x_1(m) maximize the total profit in Equation 11, meaning that the equilibrium profit is higher than any x_1(m'), x_1(l)) with $x_1(m') \neq x_1(m)$ and $\rho^2 = 1$; and (ii) the equilibrium profit is at least greater than that of mimicking the target-meeting type, setting R&D investment level to be (x_1(l), x_1(l)) and $\rho^2 = \rho^1$. For the purpose of this analysis, the first condition is equivalent to the marginal condition to the extent that the partial derivation of Equation (11) with respect to x_1(m) is equal to zero. The second condition requires the profit in Equation (11) to be at least as great as the following term:

$$\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)} \left\{\pi_1\left(\rho^1,\hat{\pi}(x_1(m),(x_1(l),x_2,\varepsilon),q_1(m),\underline{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}\,d\varepsilon$$

$$+\int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \left\{\pi_1\left(\rho^1,\hat{\pi}(x_1(m),(x_1(l),x_2,\varepsilon),q_1(m),\bar{q}_1(l),q_2\right) - \frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}\,d\varepsilon \tag{12}$$

Note that $x_1(l) > x_1(m)$. If we let the above condition be binding, then we have:

$$\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)} \left\{ \pi_1\left(1, \underline{q}_1(l)\right) - \pi_1\left(\rho^1, \underline{q}_1(l)\right) - \left(\frac{(x_1(m))^2}{2} - \frac{(x_1(l))^2}{2}\right) \right\} \frac{1}{2\bar{\varepsilon}} d\varepsilon$$
$$+ \int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \left\{ \pi_1\left(1, \bar{q}_1(l)\right) - \pi_1\left(\rho^1, \bar{q}_1(l)\right) - \left(\frac{(x_1(m))^2}{2} - \frac{(x_1(l))^2}{2}\right) \right\} \frac{1}{2\bar{\varepsilon}} d\varepsilon = 0 \tag{13}$$

For simplification, we have abbreviated the continuation payoff $\pi_1(\rho^2, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$. The same abbreviation will further apply to Equation (16).

The Target-meeting Firm 1. As for the target-meeting Firm 1, the equilibrium R&D investment, $x_1(m)$, will be chosen to satisfy the target $\Phi = \bar{\Pi}$, or else this type of Firm 1 will miss the earnings target and then take a loss. Hence, different from the conventional incentive constraint, for $x_1(l)$ to be the separating equilibrium, it is required that:

$$x_1(l) \in \{x_1 | \Phi = \bar{\Pi} \text{ or } \Phi < \bar{\Pi}\} \tag{14}$$

Hence, the separating equilibrium is determined by the marginal condition of Equations (11), (13) and (14). The following proposition describes the properties of separating equilibrium:

P1. In a separating equilibrium, for the target-meeting Firm 1, the earnings target at t = 2, π_1^* could not be achieved.

Proof. See the Appendix.

This proposition states that the profit-maximizing Firm 1's R&D investment level could influence Firm 2's posterior belief, which in turn affects the success of MBT for the target-meeting Firm 1. In this proposition, when the profit-maximizing Firm 1 has no incentive to set a higher x_1 and further to mislead Firm 2 about Firm 1's objective type, the higher earnings target for the target-meeting Firm 1 cannot be obtained.

3.2.2 Hybrid equilibrium. In a hybrid equilibrium, the profit-maximizing Firm 1 chooses randomly between $x_1(l)$ and $x_1(m)$, so that in the second stage, it can take advantage of the impact on ρ^2 (which will be lower than ρ^1). Firm 2 does not perfectly learn the type of Firm 1 and sets an output that best replies to a weighted sum of $q_1(m)$ and $q_1(l)$. According to Lemma 1, given $\rho^2 < 1$, the target-meeting type needs to set an output high enough to meet the target ($\pi_1 > \pi_1^*$). This could happen once the cost shock exceeds the expectations, with the probability $\bar{\varepsilon} - \varepsilon(x_1(l), x_1(m), x_2)/2\bar{\varepsilon}$, and the profit-maximizing Firm 1 will partially act as the target-meeting Firm 1 to mask the effect of negative cost shock. Let $(\theta x_1(m) + (1-\theta) x_1(l), x_1(l))$ with $x_1(l) > x_1(m) = x_1^*$ denote the first stage's equilibrium R&D investment. Note that x_2 is determined by Equation (10). Then, we consider the following beliefs for the second stage:

$$\rho^2 = \begin{cases} \dfrac{\rho^1(1-\theta)}{\rho^1(1-\theta) + (1-\rho^1)}, & x_1 = x_1(l), \\ 1, & x_1 \neq x_1(l) \end{cases}$$

The Profit-maximizing Firm 1. After replacing ρ^2 with the above setting, we can rewrite the total profit for the profit-maximizing Firm 1. In this, the mixed strategy between $x_1(m)$ and

$x_1(l)$ indicates that the total profit for the two alternatives is the same. Thus, the profit in Equation (11) can be rewritten as:

$$\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)}\left\{\pi_1\left(\rho^2,\hat{\pi}(x_1(l),\ (x_1(l)\ ,\ x_2,\varepsilon),\ q_1(m),\ \underline{q}_1(l),\ q_2\right)-\frac{(x_1(1))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}d\varepsilon$$
$$+\int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}}\left\{\pi_1\left(\rho^2,\hat{\pi}(x_1(l),\ (x_1(l)\ ,\ x_2,\varepsilon),\ q_1(m),\ \bar{q}_1(l),\ q_2\right)-\frac{(x_1(l))^2}{2}\right\}\frac{1}{2\bar{\varepsilon}}d\varepsilon \quad (15)$$

Assuming Equations (11) and (15) to be binding, then we have:

$$\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),x_1(l),x_2)}\left\{\pi_1\left(1,\underline{q}_1(l)\right)-\pi_1\left(\rho^2,\underline{q}_1(l)\right)-\left(\frac{(x_1(m))^2}{2}-\frac{(x_1(l))^2}{2}\right)\right\}\frac{1}{2\bar{\varepsilon}}d\varepsilon$$
$$+\int_{\varepsilon(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}}\left\{\pi_1(1,\bar{q}_1(l))-\pi_1(\rho^2,\bar{q}_1(l))-\left(\frac{(x_1(m))^2}{2}-\frac{(x_1(l))^2}{2}\right)\right\}\frac{1}{2\bar{\varepsilon}}d\varepsilon=0 \quad (16)$$

Moreover, the partial derivation of Equation (11) with respect to $x_1(m)$ is equal to zero.

The Target-meeting Firm 1 For the target-meeting Firm 1, the total profit $\hat{\Phi}$ is given by:

$$\hat{\Phi}\equiv\int_{-\bar{\varepsilon}}^{\varepsilon(x_1(m),\ x_1(l),\ x_2)}\left\{\pi_1\left(\rho^2,\ \hat{\pi}(x_1(m),\ x_1(l),\ x_2,\ \varepsilon),\ q_1(m),\ \underline{q}_1(l),\ q_2\right)-\frac{(x_1(l))^2}{2}\right\}$$
$$+\int_{\varepsilon(x_1(m),\ x_1(l),\ x_2)}^{\bar{\varepsilon}}\left\{\pi_1\left(\rho^2,\ \hat{\pi}(x_1(m),\ x_1(l),\ x_2,\ \varepsilon),\ q_1(m),\ \bar{q}_1(l),\ q_2\right)-\frac{(x_1(l))^2}{2}\right\}$$

For the target-meeting Firm 1, it is only required that the equilibrium strategy satisfy the following:

$$x_1(l)\in\{x_1|\Phi=\bar{\Pi}\text{ or }\Phi<\bar{\Pi}\} \quad (17)$$

Thus, the hybrid equilibrium is determined by the marginal condition of Equations (11), (16) and (17). The following proposition describes the equilibrium properties:

P2. There exists a hybrid equilibrium where the profit-maximizing Firm 1 takes on a mixed strategy, and sets the first stage's R&D investment and the second stage's output higher than in the separating equilibrium.

Proof. See the Appendix.

This proposition addresses both the competitive and informational impact of MBT (where real earnings management is equal to $b_{REM}=x_1(l)-x_i^*>0$) for an R&D firm. To maintain the competitor's uncertainty about Firm 1's objective type, the profit-maximizing Firm 1 is motivated to conceal its identity by taking on a mixed strategy (so that Firm 2 cannot fully learn of its type) and sets the first stage's R&D investment higher than in the separating equilibrium such that Firm 1 can increase its profit as well. Here, R&D overinvestment creates some reserves and provides an opportunity for Firm 1 to gain more profits, thereby meeting or beating its later target. Our theoretical analyses show that the profit-maximizing Firm 1 partially acts as the target-meeting Firm 1 and has kinky earnings surrounding the first-stage earnings target.

This proposition implies that R&D investment can be used by a firm to signal private information to the market for future economic benefits. However, it can also be used for opportunistic earnings management, which may happen when the common cost shock is expected to be high.

4. Discussion

The study by Bagnoli and Watts (2010) and our own research show that biased earnings reporting could increase a firm's profit in product market competition. However, our study differs from Bagnoli and Watts (2010) in focusing on the strategic impacts of real earnings management rather than on accruals management. In our model, the rival's uncertainty about the signal firm's objective type is another explanation for withholding of information (preventing full disclosure in equilibrium). The manipulation of real activities will provide a noisy signal about the signaling firm's strategic and information incentives. Such complexity might reveal a better explanation as to why real earnings management has a greater subsequent impact. Moreover, the private information in our model relates to the signaling firm's "objective type" rather than production cost. The uncertainty about the objective type reflects doubts about the signaling firm's honesty in its action and the related strategic intentions. Kedia and Philippon (2009) examine the consequence of accounting fraud in a two-period signaling setting in which a fraudulent firm boosts its reporting earnings and mimics the efficient one's investment and employment to maintain consistency between reporting earnings and actions. They show that this behavior distorts the allocation of resources in the economy, and hiring and investment are lower after the misreporting period. Different from Kedia and Philippon (2009), our study examines the impact of (R&D-based) real activities manipulation in a two-stage Cournot competition setting. In particular, we will investigate how the real earnings management incentive distorts a firm's R&D investment level by taking advantage of rivals' uncertainty about its truthfulness (either profit-maximizing type or target-meeting type) for competitive advantage. Markarian and Santalo (2014) examine the effect of product market competition on a firm's incentive to engage in real (accrual) earnings management for capital market valuation. Different from Markarian and Santalo (2014), our study examines the trade-off between the signaling effect and opportunistic earnings management resulting from distorted R&D investment and the impact of this on product market competition.

5. Conclusion

This paper examines how firms use discretion around R&D to meet or beat their earnings targets and how this influences the sequential product market competition. This issue is important as R&D decisions are not only investment decisions but also involve accounting discretion. When competitors are confused as to the purpose of a firm's effort in R&D accounting, there may be further competitive and informational impact of the firm's R&D decisions. First, as for the competitive impact of MBT for an R&D firm, unilateral R&D investment reduction can increase a single firm's returns, helping it meet or beat its earnings target. However, if a firm initiates a reduction in its R&D investment to meeting the earnings target and if this strategy is fully anticipated, the situation can only worsen the sequential product market competition. Second, considering the informational impact of MBT for an R&D firm, a rival's suspicion about the purpose of a firm's effort in its R&D investment will create an additional uncertainty affecting the operation decisions in product market competition.

To address this issue, we consider a non-cooperative R&D competition with one-sided incomplete information setting in which the competing firm is uncertain about its rival's objective type (profit-maximizing type or target-meeting type). In our model, the informed firm's R&D investment in the first stage partially reveals its objective type. The one-sided incomplete information on the firm's objective type is assumed to make the competitor suspicious about the purpose of the firm's effort in R&D decisions. Our paper shows that in a separating equilibrium, the profit-maximizing Firm 1 has no incentive to set a higher R&D investment level and further to mislead Firm 2's about Firm 1's objective type. In this case, the earnings target for the target-meeting Firm 1 is not achievable. However, in hybrid equilibrium, the privately informed firm is motivated to conceal its identity by adopting a mixed strategy and thus maintain the competitor's uncertainty about its objective type. This could raise the informed firm's R&D investment in the first stage to levels higher than in the separating equilibrium and reach the earnings target.

Notes

1. Capitalizing R&D is not allowed in the US (except in the case of the software industry-SFAS #86), but it is an available alternative in which SSAP #13 in the U.K. and CAS #6 in China allow for the capitalization of development expenditures provided that they meet five conditions (which generally requires that management is satisfied that the expenditure goes towards creating a commercially viable product or service). In Germany, the switch to IFRS allowed numerous firms to capitalize development expenditures according to IAS 38 if six criteria are fulfilled (technical feasibility, intention to complete, ability to use or sell, future economic benefits, adequate resources, and ability to measure). For 1999-2004, Lin *et al.* (2014) find that firms listed under the Prime Standard on Germany's Frankfurt Stock Exchange have higher levels of R&D-based real earnings management for the IAS/IFRS firms relative to the US GAAP firms. In Australia, prior to adoption of IFRS in 2005, AASB 1011 allowed the capitalization of research and/or development expenditures if their future economic benefits were beyond any reasonable doubt.
2. Anagnostopoulou (2008) provides a survey on R&D expenses and firm valuation.
3. We use the definition of stylized extension of selective capitalization in Hughes and Kao (1991) in which the results of firms' R&D spending and the actual marginal cost are known to each other.
4. It is known there is a positive correlation between the amount spent on R&D and the probability that an R&D project will be successful (Stoneman, 1995). Economic literature also shows that the pressure to spend on R&D increases exponentially under competition because the projects need to be operating more intensely to try to beat competitors to market (Stalk and Hout, 1990; Wheelwright and Clark, 1992; Datar *et al.*, 1997).
5. Failure to meet or beat earnings targets results in adverse consequences for a firm. Several empirical studies document a market penalty for failing to meet or beat earnings targets (Bartov *et al.*, 2002; Lopez and Rees, 2002; Skinner and Sloan, 2002; Brown and Caylor, 2005). From survey-based evidence, Graham *et al.* (2005) report that missing earnings benchmarks leads to increased market scrutiny of the reported earnings number, increased possibility of lawsuits, additional time and effort required to justify failure, and a general perception among stakeholders about problems in the firm.
6. Alzoubi (2016) finds that ownership structure has a significant influence on (accrual) earnings management in Jordanian companies; Xu and Ji (2016) find that Chinese in some industries engaged in accrual earnings management or real (abnormal cash flows) earnings management in the 2007-2009 global financial crisis.

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Appendix

Proof of *P1*: The conditions for the separating equilibrium consist of the marginal condition of Equations (11), (13) and (14). Let $x_1(m)$ satisfy the marginal condition of Equation (11):

$$\frac{\partial E(\Pi_1)}{\partial x_1(l)} = \frac{\partial \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}(x_1(m),x_1(l),x_2)} \{\pi_1(\rho^1, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), \bar{q}_1(l), q_2) - \frac{(x_1(l))^2}{2}\}\frac{1}{2\bar{\varepsilon}} d\varepsilon + \int_{\bar{\varepsilon}(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \{\pi_1(\rho^2, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), \bar{q}_1(l), q_2) - \frac{(x_1(l))^2}{2}\}\frac{1}{2\bar{\varepsilon}} d\varepsilon}{\partial x_1(l)} = 0$$

$x_1(m)$ can be set equal to x_1^*

Suppose that $x_1(l) > x_1(m) = x_1^*$ is the equilibrium R&D investment. Then, the second term in Equation (12) should be positive. Thus, for the equality in Equation (13) to hold, the necessary condition is to have $\pi_1(\rho^1. \hat{\pi}(x_1(l), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$ higher than $\pi_1(1, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$, for which we need $c_1(m) - c_1 > c_2/2$ and $1/2q_1(l) - 3/2q_1(m)/q_1(m) - q_1(l) > \rho^1$. The first inequality is satisfied when Firms 1 and 2's R&D investments are technologically feasible. The second inequality is satisfied when $A > a \gg \rho^2$ given that $1 > \rho^2 > 0$. As for the target-meeting type (or target-beating type), as $(x_1(l))^2/2 > (x_1(m))^2/2$, the second-stage target π will be higher with $x_1(l)$. If the target-meeting Firm 1 needs to meet a $\pi_1(0, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$ higher than π_1^*, for which it requires $\pi_1(l) \geq \pi_1^*$, then $q_1(l) > q_1(m) \geq q_1^*$. However, by Lemma 1, this is not possible given the mentioned belief in the separating equilibrium.

Proof of P2: The conditions for the hybrid equilibrium consist of the marginal condition of Equations (11), (16) and (17).

Let $x_1(m)$ satisfy the marginal condition of Equation (11):

$$\frac{\partial E(\Pi_1)}{\partial x_1(l)} = \frac{\partial \int_{-\bar{\varepsilon}}^{\bar{\varepsilon}(x_1(m),x_1(l),x_2)} \{\pi_1(\rho^1, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), \bar{q}_1(l), q_2) - \frac{(x_1(l))^2}{2}\}\frac{1}{2\bar{\varepsilon}} d\varepsilon + \int_{\bar{\varepsilon}(x_1(m),x_1(l),x_2)}^{\bar{\varepsilon}} \{\pi_1(\rho^2, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), \bar{q}_1(l), q_2) - \frac{(x_1(l))^2}{2}\}\frac{1}{2\bar{\varepsilon}} d\varepsilon}{\partial x_1(l)} = 0$$

$x_1(m)$ can be set equal to x_1^* Suppose that $x_1(l) > x_1(m) = x_1^*$ is the equilibrium R&D investment. We have $(x_1(l))^2/2 > (x_1(m))^2/2$. This indicates that the second term in Equation (16) is positive. Thus, for the equality in Equation (16) to hold, the necessary condition is to have $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$ higher than $\pi_1(1, \hat{\pi}(x_1(m), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$ for which we need $c_1(m) - c_1 > c_2/2$ and $\frac{1}{2} q_1(l) - \frac{3}{2} q_1(m)/q_1(m) - q_1(l) > \rho^2$. The first inequality is satisfied when Firms 1 and 2's R&D investments are technologically feasible. The latter inequality is satisfied when $A > a \gg \rho^2$ given that $1 > \rho^2 > 0$. As for the target-meeting type (or target-beating type), as $(x_1(l))^2/2 > (x_1(m))^2/2$, the second-stage target will be higher with $q_1(l)$. To satisfy Equation (17), the target-meeting type (or target-beating type) needs to meet a $\pi_1(\rho^2, \hat{\pi}(x_1(l), x_1(l), x_2, \varepsilon), q_1(m), q_1(l), q_2)$ higher than π_1^*, for which it requires $\pi_1(l) \geq \pi_1^*$, then $q_1(l) > q_1(m)$. As the profit-maximizing Firm 1 takes a mixed strategy $\theta x_1(m) + (1 - \theta)x_1(l)$, at the first stage, $\forall \theta \in (0, 1)$, this could mislead Firm 2's conjecture about the objective of Firm 1 in which $0 < \rho^2 < 1$ and $\rho^2 \leq \rho^1$. Consequently, by Lemma 1, π_1^* is achievable for the target-meeting Firm 1.