Decisions of Duopoly Firms on Sharing Information on Their Delegation Contracts

By Kyung Hwan Baik and Dongryul Lee*

Revised June 2019

Abstract

We study duopolies in which each firm, consisting of an owner and a manager, has the option of releasing or not to the public its contract information between the owner and the manager. The owner of each firm seeks to maximize her firm's profits, and designs a compensation scheme for her manager in which the manager's compensation depends on his performance measured by a linear combination of the firm's profits and sales. After accepting contracts for them, the managers compete in quantities or in prices. As a main result, we show in both quantity-setting and price-setting models that the firms both release their contract information. Then, we compare the outcomes of the observable-contracts case with those of the unobservable-contracts case.

JEL classification: D43, L13, C72, D82

Keywords: Decision on information sharing; Delegation; Contract; Managerial incentives; Duopoly

*Baik: Department of Economics, Sungkyunkwan University, Seoul 03063, South Korea (e-mail: khbaik@skku.edu); Lee (corresponding author): Department of Economics, Sungshin University, Seoul 02844, South Korea (e-mail: drlee@sungshin.ac.kr). We are grateful to Chris Baik, Dong Gyum Kim, Amy Baik Lee, Jong Hwa Lee, Yossi Spiegel, Lawrence White, and two anonymous referees for their helpful comments and suggestions.
1. Introduction

In some countries, firms are obliged to disclose information about their CEO compensation contracts, while in others there are no disclosure requirements on it.\(^1\) Even under mandatory disclosure rules, firms still have substantial discretion on whether to disclose their true contract information. A natural and interesting question is, then, whether firms have incentives to disclose – and actually disclose – true information about their CEO compensation contracts. Another interesting question is whether such mandatory disclosure regulations benefit either consumers or firms, or both. Yet another interesting question is whether such mandatory disclosure regulations increase social welfare. To the best of our knowledge, however, these questions have not been addressed previously.

Accordingly, we consider situations in which firms, each consisting of an owner and a manager, have the option of releasing or not their contract information between the owner and the manager. The purpose of this paper is to address those questions, focusing on whether the firms release their contract information.\(^2\) We do this in two separate cases. One is the case of strategic substitutes in which the firms compete in quantities.\(^3\) The other is the case of strategic complements in which the firms compete in prices.

Formally, we study duopolies in which each firm has an owner and a manager. In the duopolies, each firm first announces whether it will release to the public its contract information between the owner and the manager. Next, the owner of each firm writes – and releases if her

---

\(^1\) In the United States, public firms must disclose information about their CEO compensation contracts, according to the laws issued by the Securities and Exchange Commission in 2006. In the United Kingdom, large and medium-sized public companies are required to disclose comparative information about the pay of chief executives and employees. In Germany, stock corporations are required to disclose the remuneration packages individually in the companies' annual reports. In Canada, firms should disclose the amount and composition of individual compensation of the five paid executives.

\(^2\) By saying that the firms release their contract information, we mean that the firms disclose their true contract information.

\(^3\) Bulow et al. (1985) define two terms: strategic substitutes and strategic complements. In the literature on oligopoly, outputs are usually regarded as strategic substitutes, while prices are usually regarded as strategic complements.
firm announced to do so—a contract with her manager in which the manager's compensation depends on his performance measured by a linear combination of the firm's profits and sales. Finally, the managers in both firms compete in quantities or in prices. What is a main motive of such delegation? It is that the owner of each firm wants to benefit by achieving strategic commitments through delegation. Indeed, she can change the rival firm's behavior in her favor, by using her manager whose objective function differs from hers.

We develop two (main) models: a model with quantity-setting firms and one with price-setting firms. These models differ only in that the first model assumes a quantity-setting duopoly with homogeneous products, while the second model assumes a price-setting duopoly with differentiated products. By considering the models, we can further our understanding of firms' behavior regarding contract information disclosure and its effects on contracts, managerial decisions, profits, etc. Also, we can figure out the benefits and costs—in terms of consumer surplus, profits, and welfare—of regulations which require firms to disclose their contract information. Furthermore, with this knowledge, we may be able to argue for or against such mandatory disclosure regulations.

As a main result of this paper, we show in both quantity-setting and price-setting models that both firms announce that they will release their contract information, and actually release it. Then, we compare the outcomes—consumer surplus, profits, welfare, etc.—of the observable-contracts case with those of the unobservable-contracts case. We show that the welfare resulting from the observable-contracts case is greater than that resulting from the unobservable-contracts case, in both quantity-setting and price-setting markets.

---

4There is a vast literature on strategic delegation. Examples include Schelling (1960), Vickers (1985), Fershtman and Judd (1987), and Sklivas (1987).
5Note that, unlike many results in the literature on oligopoly, this main result does not depend on whether the strategic variables are strategic substitutes or strategic complements.
6By the observable-contracts [unobservable-contracts] case, we mean the one where each firm's contract is exogenously assumed to be observable [unobservable] to the rival firm. This comparison is interesting because the two cases are commonly observed in the real world.
1.1. Related literature

This paper is closely related to Fershtman and Judd (1987), Sklivas (1987), and Theilen (2007). They study duopolies with strategic managerial delegation, assuming exogenously that each manager knows the rival firm's contract information when choosing his firm's output level or price. The current paper can be viewed as extending Fershtman and Judd (1987) and Sklivas (1987) by incorporating firms' decisions on releasing their contract information.

This paper is also related to Fershtman and Kalai (1997), Koçkesen and Ok (2004), and Koçkesen (2007). They study delegation with unobservable contracts, and show that such delegation may yield strategic advantage to the delegating player or players. Specifically, Fershtman and Kalai (1997) consider incentive-delegation with unobservable contracts and instructive-delegation with unobservable instructions, and demonstrate when commitment via delegation is beneficial. Koçkesen and Ok (2004) consider a one-sided delegation game in which only one of the two principals has the option of hiring a delegate and the delegation contract, if any, is unobservable to the opponent. They show that, if the cost of hiring a delegate is relatively low, then strategic delegation may arise in equilibrium.

This paper is broadly related to the literature on information sharing: See, for example, Vives (1984), Gal-Or (1985), Raith (1996), Gill (2008), Jansen (2010), Baik and Lee (2012), Cho and Jun (2013), and Kovenock et al. (2015). These papers examine, in different contexts, whether firms or, in general, players have incentives to share their private information with their rivals. For example, Vives (1984) considers a duopoly model in which each firm has private information about an uncertain linear demand, and shows that if the goods are substitutes, then not sharing information (sharing information) is a dominant strategy for each firm in Cournot (Bertrand) competition; if the goods are complements, then the result is reversed.

2. The model with quantity-setting firms

Consider a quantity-setting duopoly in which two firms, 1 and 2, produce and sell homogeneous products. Each firm has an owner and a manager. Each firm first announces
whether or not to release to the public the information about its contract between the owner and the manager. Then, the owner of each firm writes—and releases if her firm announced to do so—a contract with her manager that specifies how the manager will be rewarded. Finally, each manager chooses his firm's output level.

Let $x_i$, for $i = 1, 2$, represent firm $i$'s output level, where $x_i \in R_+$. Firm $i$'s cost function is given by $c(x_i) = cx_i$ for all $x_i \in R_+$, where $c(x_i)$ represents firm $i$'s cost of producing $x_i$ units of its product, and $c$ represents a constant marginal cost to firm $i$.

Both firms' products are sold at a single price, which is determined by the inverse market demand function together with the firms' output levels:

$$P = a - bX \quad \text{for } 0 \leq X \leq a/b$$
$$0 \quad \text{for } X > a/b,$$

where $P$ represents the market price, $a$ and $b$ are positive constants, and $X = x_1 + x_2$. We assume that $0 < c < a$.

Let $\pi_i$ represent firm $i$'s profits (without subtracting its manager's compensation), and let $S_i$ represent firm $i$'s sales, for $i = 1, 2$. Each owner uses a compensation scheme for her manager in which the manager's compensation depends on his performance measured by a linear combination of the firm's profits and sales. To put it differently, manager $i$ is given an incentive to maximize

$$O_i = \alpha_i \pi_i + (1 - \alpha_i)S_i,$$

where a value of $\alpha_i$ is chosen when owner $i$ writes a contract with her manager. We make no restrictions on $\alpha_i$. A larger value of $\alpha_i$ implies that more emphasis is placed on profits.

More specifically, we assume that owner $i$ uses a compensation scheme in which manager $i$ is paid $A_i + B_i O_i$, where $A_i$ and $B_i$ are constants with $A_i \geq 0$ and $B_i > 0$ (see Fershtman and Judd 1987). Under this compensation scheme, once values of $A_i$ and $B_i$ (as well as a value of $\alpha_i$) are chosen, manager $i$'s compensation is determined by $O_i$.

Manager $i$ has a reservation wage of $R_i$, where $R_i$ is positive. This implies that, if his equilibrium compensation will fall short of $R_i$, then manager $i$ prefers not to work for owner $i$ (or
firm $i$), and will accept alternative employment instead. On the other hand, it never happens that the contract designed by owner $i$ will provide manager $i$ with equilibrium compensation greater than $R_i$. With the compensation scheme, for any $O_i$, owner $i$ can pay manager $i$ exactly his reservation wage $R_i$ by choosing appropriate values of $A_i$ and $B_i$.

Given an incentive structure which is a linear combination of profits and sales, manager $i$, for $i=1,2$, seeks to maximize

$$O_i = \alpha_i \{(a - bX)x_i - cx_i\} + (1 - \alpha_i) \{(a - bX)x_i\}$$

$$= (a - bX)x_i - \alpha_i cx_i.$$  

On the other hand, we assume that each owner's objective is to maximize her firm's profits net of her manager's compensation. Mathematically, this amounts to assuming that owner $i$ seeks to maximize her firm's profits

$$\pi_i = (a - bX)x_i - cx_i,$$  

because any contract designed by owner $i$ provides manager $i$ with equilibrium compensation exactly equal to his reservation wage $R_i$.

Each firm has the option of releasing or not its contract information to the public. We assume that each firm announces, before choosing its contract, whether it will release its contract information. We assume also that each firm decides to release its contract information only if both the owner and the manager of the firm agree to do so. Note that this amounts to assuming that each firm's decision on releasing its contract information is made only by its owner, because its manager – who will be paid his reservation wage regardless of the decision outcome – is indifferent between releasing and not releasing the contract information.

We formally consider the following game. First, each firm decides independently whether it will release its contract information to the public. The firms simultaneously announce and commit to their decisions before writing their contracts. Next, the owner of each firm writes – and releases if her firm announced to do so – a contract with her manager. That is,
owner $i$, for $i = 1, 2$, chooses values of $\alpha_i$, $A_i$, and $B_i$.\(^7\) (We will be more specific about this stage – in particular, about the timing of the firms' contract decisions – in Section 3.) Finally, the managers in both firms choose their firms' output levels simultaneously and independently.

We assume that all of the above is common knowledge among the owners and managers.

3. The firms both release their contract information

To solve the game, we need to work backward. We first analyze the subgames starting after the firms announce whether they will release their contract information, and then consider the firms' decisions on releasing their contract information.

There are four subgames starting after the firms announce whether they will release their contract information: the $(R, R)$ subgame, the $(R, NR)$ subgame, the $(NR, R)$ subgame, and the $(NR, NR)$ subgame, where $R$ denotes the action of announcing that the firm will release its contract information, and $NR$ denotes the action of announcing that it will not release its contract information.

3.1. The $(R, R)$ subgame

This subgame has two stages. In the first stage, each firm chooses its contract independently, and then the firms release their contract information simultaneously. In the second stage, after observing the values of $\alpha_1$ and $\alpha_2$, the managers in both firms choose their firms' output levels simultaneously and independently.

To solve for a subgame-perfect equilibrium of the $(R, R)$ subgame, we work backward.\(^8\) Lemma 1 summarizes the outcomes of the $(R, R)$ subgame.

\(^7\)Once values of $\alpha_i$, $A_i$, and $B_i$ are chosen, manager $i$'s compensation is determined by $O_i$. Thus, for concise exposition, we will restrict attention only to the value of $\alpha_i$.

\(^8\)For concise exposition, we omit the detailed analysis of this standard two-stage game. It is available from the authors upon request. See also Fershtman and Judd (1987) and Sklivas (1987).
Lemma 1. (a) In the equilibrium of the \((R, R)\) subgame, owner \(i\), for \(i = 1, 2\), chooses 
\[ \alpha_i^R = (6c - a) / 5c, \] and manager \(i\) chooses \(x_i^R = 2(a - c) / 5b. \) (b) The firms' equilibrium profits are 
\[ \pi_1^R = \pi_2^R = (a - c)^2 / 25b. \]

3.2. The \((R, NR)\) subgame and the \((NR, R)\) subgame

Consider a subgame in which firm \(i\) releases its contract information, but firm \(j\) does not, for \(i, j = 1, 2\) with \(i \neq j\). Note that we are considering the \((R, NR)\) subgame if \(i = 1\), and the \((NR, R)\) subgame if \(i = 2\).

We assume that firm \(j\) chooses its contract after observing firm \(i\)'s contract. This subgame is then described as follows. First, owner \(i\) chooses and releases a value of \(\alpha_i\), and then, after observing the value of \(\alpha_i\), owner \(j\) chooses a value of \(\alpha_j\). Next, manager \(i\) observes only the value of \(\alpha_i\), but manager \(j\) observes the values of \(\alpha_1\) and \(\alpha_2\). Finally, managers 1 and 2 simultaneously choose their firms' output levels. Note that owner \(i\) is the strategical leader in this subgame.

We solve the subgame by viewing it as the following two-stage game. In the first stage, owner \(i\) chooses and releases a value of \(\alpha_i\). In the second stage, after observing the value

---

9Alternatively, we may assume that firm \(j\) chooses its contract without or before observing firm \(i\)'s contract. Given this assumption, we use the solution technique introduced in Baik and Lee (2018) to solve the subgame. With the alternative assumption, however, we obtain the same main results as those with the current assumption, both in the quantity-setting model and in the price-setting model.

10Baik and Lee (2012) come up with a solution technique for games between two parties in which each party has two sequential moves; the first action chosen by one party is observed by the rival party before the rival party chooses its first action, but the first action chosen by the other party is not observed by the rival party; and the parties choose their second actions simultaneously. We use their solution technique to solve the subgames in Sections 3.2 and 5.2. Note that the equilibrium actions obtained by using their solution technique are a sequential equilibrium outcome – that is, the actions specified in a sequential equilibrium – and also a perfect Bayesian equilibrium outcome (see, for example, Gibbons 1992; Osborne and Rubinstein 1994). Koçkesen and Ok (2004) characterize the set of sequential equilibrium outcomes of a one-sided delegation game. Koçkesen (2007) characterizes the set of sequential equilibrium outcomes of a two-sided delegation game.
of $\alpha_i$, manager $i$ and firm $j$ play a simultaneous-move game. Specifically, manager $i$ chooses his firm's output level, without observing the value of $\alpha_j$ or firm $j$'s output level; owner $j$ chooses a value of $\alpha_j$, and manager $j$ (after observing the value of $\alpha_j$) chooses his firm's output level, both without observing firm $i$'s output level.

To solve this two-stage game, we work backward. In the second stage, manager $i$ and firm $j$ know the value of $\alpha_i$. We begin by deriving the reaction function for manager $i$. After observing $\alpha_i$, manager $i$ seeks to maximize $O_i$ in (1) over his firm's output level $x_i$, taking firm $j$'s output level $x_j$ as given. From the first-order condition for maximizing $O_i$, we obtain manager $i$'s reaction function:\footnote{Because we focus on interior solutions or because symmetric equilibria occur, we omit, for concise exposition, complete and precise descriptions of reaction functions throughout the paper.}

$$x_i(x_j; \alpha_i) = \frac{(a - \alpha_i c)}{2b} - \frac{x_j}{2}. \tag{3}$$

It is straightforward to check that the second-order condition for maximizing $O_i$ is satisfied.\footnote{The second-order condition is satisfied for every maximization problem in the paper. For concise exposition, we do not state it explicitly in each case.}

Next, consider firm $j$. Owner $j$ chooses a value of $\alpha_j$, and then manager $j$ chooses his firm's output level, both without observing firm $i$'s output level. Working backward, we first consider manager $j$'s decision on his firm's output level. After observing the values of $\alpha_1$ and $\alpha_2$, manager $j$ seeks to maximize $O_j$ in (1) over his firm's output level $x_j$, taking firm $i$'s output level $x_i$ as given. From the first-order condition for maximizing $O_j$, we obtain manager $j$'s reaction function:

$$x_j(x_i; \alpha_1, \alpha_2) = \frac{(a - \alpha_j c)}{2b} - \frac{x_i}{2}. \tag{4}$$

Then, we consider owner $j$'s decision on the value of $\alpha_j$. Owner $j$ seeks to maximize

$$\pi_j(x_i, \alpha_j; \alpha_i) = \{a - bx_i - bx_j(x_i; \alpha_1, \alpha_2)\} x_j(x_i; \alpha_1, \alpha_2) - cx_j(x_i; \alpha_1, \alpha_2) \tag{5}$$

$$= (a - 2c + \alpha_j c - bx_i)(a - \alpha_j c - bx_i)/4b$$
with respect to $\alpha_j$, taking firm $i$'s output level $x_i$ as given. Note that we obtain (5) by substituting (4) into (2). From the first-order condition for maximizing (5), we obtain another reaction function of firm $j$, or owner $j$'s reaction function:

$$\alpha_j(x_i; \alpha_i) = 1.$$  \hspace{1cm} (6)

By solving the system of three simultaneous equations, (3), (4), and (6), we obtain

$$x_i(\alpha_i) = \frac{(a - 2\alpha_i c + c)}{3b},$$

$$x_j(\alpha_i) = \frac{(a + \alpha_i c - 2c)}{3b},$$

and

$$\alpha_j(\alpha_i) = 1.$$  \hspace{1cm} (7)

These are the equilibrium output level of firm $i$, that of firm $j$, and the equilibrium value of $\alpha_j$, respectively, in the second stage.

Next, consider the first stage in which owner $i$ chooses a value of $\alpha_i$. Having perfect foresight about $\pi_i(\alpha_i)$ for any values of $\alpha_i$, owner $i$ chooses a value of $\alpha_i$ which maximizes

$$\pi_i(\alpha_i) = \frac{(a + \alpha_i c - 2c)}{9b}.$$

Note that we obtain (8) by substituting $x_i(\alpha_i)$ and $x_j(\alpha_i)$ in (7) into (2). From the first-order condition for maximizing (8) with respect to $\alpha_i$, we obtain the equilibrium value of $\alpha_i$ in the subgame:

$$\alpha_i^{IR} = \frac{(5c - a)}{4c}.$$  \hspace{1cm} (8)

Note that, henceforth, the superscript $iR$ indicates the outcomes of the subgame in which firm $i$ releases its contract information, but firm $j$ does not, for $i, j = 1, 2$ with $i \neq j$.

Now, substituting $\alpha_i^{IR}$ into $x_i(\alpha_i)$, $x_j(\alpha_i)$, and $\alpha_j(\alpha_i)$ in (7), we obtain the firms' equilibrium output levels, $x_i^{IR}$ and $x_j^{IR}$, and the equilibrium value of $\alpha_j$, denoted by $\alpha_j^{IR}$, in the subgame. Next, using these equilibrium actions, we obtain the firms' equilibrium profits, $\pi_1^{IR}$ and $\pi_2^{IR}$, in the subgame.
Lemma 2 summarizes the outcomes of the \((R, NR)\) subgame if \(i = 1\), and those of the \((NR, R)\) subgame if \(i = 2\).

**Lemma 2.** (a) In the equilibrium of a subgame in which firm \(i\) releases its contract information, but firm \(j\) does not, for \(i, j = 1, 2\) with \(i \neq j\), owner \(i\) chooses \(\alpha_i^{R} = (5c - a)/4c\), and manager \(i\) chooses \(x_i^{R} = (a - c)/2b\). Owner \(j\) chooses \(\alpha_j^{R} = 1\), and manager \(j\) chooses \(x_j^{R} = (a - c)/4b\). (b) The equilibrium profits of firm \(i\) and those of firm \(j\) are \(\pi_i^{R} = (a - c)^2/8b\) and \(\pi_j^{R} = (a - c)^2/16b\), respectively.

3.3. The \((NR, NR)\) subgame

In this subgame, each firm chooses two *sequential* actions – specifically, its contract and then its output level – without observing those chosen by the other firm. That is, the two firms play a simultaneous-move game.\(^{13}\)

The equilibrium values of \(\alpha_1\) and \(\alpha_2\) and the equilibrium output levels of the firms in the subgame satisfy the following two requirements. First, firm \(i\)'s output level is optimal given the value of \(\alpha_i\) and given firm \(j\)'s output level, for \(i, j = 1, 2\) with \(i \neq j\). In other words, firm \(i\)'s output level is a best response both to the value of \(\alpha_i\) and to firm \(j\)'s output level. Second, the value of \(\alpha_i\) is optimal given firm \(j\)'s output level and given firm \(i\)'s own subsequent optimal behavior, or rather its optimal output level.

To obtain the equilibrium values of \(\alpha_1\) and \(\alpha_2\) and the equilibrium output levels of the firms, we begin by deriving the reaction functions for firm \(i\). Working backward, we first consider manager \(i\)'s decision on his firm's output level. After observing the value of \(\alpha_i\), manager \(i\) seeks to maximize \(O_i\) in (1) over his firm's output level \(x_i\), taking firm \(j\)'s output level

\(^{13}\)Baik and Lee (2007) come up with a solution technique for games between two parties in which each party has two sequential moves; the first action chosen by each party is not observed by the rival party; and the parties choose their second actions simultaneously. We use their solution technique to solve the subgames in Sections 3.3 and 5.3. Note that their solution technique is also used in Baik and Lee (2012), Baik and Kim (2014), and Baik (2016).
$x_i$ as given. From the first-order condition for maximizing $O_i$, we obtain manager $i$'s reaction function:

$$x_i(x_j; \alpha_i) = (a - \alpha_i c)/2b - x_j/2. \quad (9)$$

Then, we consider owner $i$'s decision on the value of $\alpha_i$. Owner $i$ seeks to maximize

$$\pi_i(x_i, \alpha_i) = (a - 2c + \alpha_i c - bx_j)(a - \alpha_i c - bx_j)/4b \quad (10)$$

with respect to $\alpha_i$, taking firm $j$'s output level $x_j$ as given. Note that we obtain (10) by substituting (9) into (2). From the first-order condition for maximizing (10), we obtain another reaction function of firm $i$, or owner $i$'s reaction function:

$$\alpha_i(x_j) = 1. \quad (11)$$

Now, we denote the firms' equilibrium actions by $(\alpha_1^{NR}, x_1^{NR}, \alpha_2^{NR}, x_2^{NR})$. We obtain them by solving the system of four simultaneous equations, which comes from (9) and (11). Substituting (11) into (9), we have

$$x_1(x_2) = (a - c)/2b - x_2/2$$

and

$$x_2(x_1) = (a - c)/2b - x_1/2.$$

By solving this pair of simultaneous equations, we obtain the firms' equilibrium output levels, $x_1^{NR}$ and $x_2^{NR}$. Next, substituting $x_2^{NR}$ into (11), and $x_1^{NR}$ into (11), we obtain $\alpha_1^{NR}$ and $\alpha_2^{NR}$, respectively. Finally, substituting these equilibrium actions into (10), we obtain the firms' equilibrium profits, $\pi_1^{NR}$ and $\pi_2^{NR}$, in the $(NR, NR)$ subgame.

Lemma 3 summarizes the outcomes of the $(NR, NR)$ subgame.

**Lemma 3.** (a) In the equilibrium of the $(NR, NR)$ subgame, owner $i$, for $i = 1, 2$, chooses $\alpha_i^{NR} = 1$, and manager $i$ chooses $x_i^{NR} = (a - c)/3b$. (b) The firms' equilibrium profits are $\pi_1^{NR} = \pi_2^{NR} = (a - c)^2/9b$. 
3.4. Firms' decisions on releasing their contract information

Now consider the firms' decisions on releasing their contract information at the beginning of the entire game. Each firm chooses and announces one of the following two actions: $R$ or $NR$. We have four possible combinations of the actions resulting from the firms' decisions: $(R, R)$, $(R, NR)$, $(NR, R)$, and $(NR, NR)$.

Figure 1 shows the profits of the firms which will be realized under the four possible combinations. $(R, R)$ leads to the $(R, R)$ subgame analyzed in Section 3.1, so that firm $i$'s profits at the end of the game will be $\pi_i^R$, for $i = 1, 2$, in Lemma 1. $(R, NR)$ ($(NR, R)$) leads to the $(R, NR)$ subgame [the $(NR, R)$ subgame] analyzed in Section 3.2, so that firm $i$'s profits at the end of the game will be $\pi_i^{1R}$ [$\pi_i^{2R}$] in Lemma 2. Finally, $(NR, NR)$ leads to the $(NR, NR)$ subgame analyzed in Section 3.3, so that firm $i$’s profits at the end of the game will be $\pi_i^{NR}$ in Lemma 3.

Which combination occurs in equilibrium? It is straightforward to obtain that $\pi_1^R > \pi_2^{2R}$, $\pi_2^R > \pi_1^{1R}$, and $\pi_i^{1R} > \pi_i^{2R}$ for $i = 1, 2$. This implies that $(R, R)$ occurs in equilibrium; furthermore, $R$ is each firm's dominant action – that is, $R$ leads to higher profits for each firm than $NR$, no matter what the other firm does.

**Proposition 1.** Only the combination $(R, R)$ occurs in equilibrium.

The result that firm $i$ chooses $R$ regardless of the action it expects firm $j$ to choose, for $i, j = 1, 2$ with $i \neq j$, can be explained as follows.

Consider first the case where firm $j$ chooses $R$. Firm $i$ has two options: either to choose $R$ or to choose $NR$. If it chooses $R$, both firms will release their contract information. Then, firm $i$ will compete with firm $j$ on equal footing in the subsequent stages. On the other hand, if firm $i$ chooses $NR$, only firm $j$ will release its contract information exercising strategic leadership. Then, firm $j$ as the leader will choose and release a small value of $\alpha_j$ to make its manager aggressive in output competition, whereas firm $i$ as the follower, sizing up firm $j$’s contract, will choose 1 as the value of $\alpha_i$ to avoid stiff output competition. As a result of this, firm $j$’s manager
will choose a large output level, and firm i's manager will choose a small output level, which will lead to lower profits for firm i, as compared to firm i's choosing R. Hence, given firm j's action R, firm i chooses R.

Next, consider the case where firm j chooses NR. In this case, too, firm i is better off by choosing R rather than NR. This is supported by the following explanation. With firm j's action NR and its own action R, firm i will enjoy a first-mover advantage by releasing its contract information before firm j chooses its contract.\(^{14}\) However, if firm i chooses NR instead of R, it will not have the strategic leadership and play a simultaneous-move game against firm j, choosing two sequential actions without observing those chosen by firm j, which will result in smaller profits to firm i.

It is straightforward to see that there is no commitment problem (see Baik and Lee 2012). Indeed, each firm has no incentive to renege on the decision to release its contract information. To show this, suppose that firm i keeps its "promise" by choosing and releasing \(\alpha_i = (6c - a)/5c\), as shown in Lemma 1, but firm j does not release its contract information. In this case, firm j chooses \(\alpha_j = 1\) (see (5) and (6)). Then, using (5) and (7), we obtain \(x_i = 7(a - c)/15b, x_j = 4(a - c)/15b,\) and \(\pi_j = 16(a - c)^2/225b\). Note, however, that if firm j keeps its promise by choosing and releasing \(\alpha_j = (6c - a)/5c\), then its profits are \(\pi_j = 2(a - c)^2/25b\), as shown in Lemma 1. This implies that firm j would be worse off by reneging on the decision to release its contract information.

Interestingly, Baik and Lee (2012) study a contest in which two groups compete to win a prize, and show that \((R, R)\) never occurs, where R denotes the action of announcing that the sharing-rule information will be released. In contrast, Yildirim (2005) studies a two-player

\(^{14}\)In this case, as shown in Lemma 2, firm i as the leader chooses \(\alpha_i = (5c - a)/4c\) and firm j as the follower chooses \(\alpha_j = 1\). (Note that the firms' output levels are the same as those in the corresponding Stackelberg's model of duopoly.) Clearly, firm i makes its manager aggressive in output competition, as compared to firm i's choosing NR. We may say that choosing R (or releasing contract information to the public) is an example of the top-dog strategy, which is defined by Fudenberg and Tirole (1984).
contest, and shows that the players announce that they will release the information about their period-1 effort levels.

3.5. The outcomes of the entire game

Using Proposition 1 and Lemma 1, we obtain the following outcomes of the game. (Let the superscript \( * \) indicate the equilibrium values of the variables.) First, both firms announce at the beginning of the game that they will release the information about their contracts. Second, firm \( i \), for \( i = 1, 2 \), chooses and releases its contract, \( \alpha_i^* = (6c - a)/5c \). Third, firm \( i \) chooses its output level, \( x_i^* = 2(a - c)/5b \). Finally, firm \( i \)'s profits (without subtracting its manager's compensation) are \( \pi_i^* = 2(a - c)^2/25b \).

The value of \( \alpha_i \) which firm \( i \) chooses is less than unity, which implies that firm \( i \) gives a positive weight to the sales component, \( S_i \), in manager \( i \)'s performance measure, \( O_i \). By doing so, firm \( i \) makes its manager more aggressive in the subsequent output competition, as compared with the case of profit maximization where \( \alpha_i = 1 \).

4. The model with price-setting firms

Consider a price-setting duopoly in which two firms, 1 and 2, produce and sell differentiated products. Each firm first announces whether or not to release to the public the information about its contract between the owner and the manager. Then, the owner of each firm writes – and releases if her firm announced to do so – a contract with her manager that specifies how the manager will be compensated. Finally, each manager chooses his firm's price.

The market demand function facing firm \( i \) is given by

\[
q_i = d - hp_i + kp_j,
\]

for \( i, j = 1, 2 \) with \( i \neq j \), where \( q_i \) represents the quantity of firm \( i \)'s product demanded, \( p_i \) represents firm \( i \)'s price, \( p_j \) represents firm \( j \)'s price, and \( d, h, \) and \( k \) are positive constants. We assume that \( h > k > 0 \). This assumption means that the effect of increasing \( p_i \) on \( q_i \) is greater than the effect of the same increase in \( p_j \) on \( q_i \) or, to put it differently, that the quantity of firm \( i \)'s
product demanded is more responsive to a change in firm $i$'s price than to the same change in firm $j$'s price.\(^{15}\)

The cost function of firm $i$ is given by $c(q_i) = cq_i$ for all $q_i \in R_+$, where $c(q_i)$ represents firm $i$'s cost of producing $q_i$ units of its product, and $c$ represents a constant marginal cost to firm $i$. We assume that $0 < c < d/(h-k)$.

As in Section 2, we assume that manager $i$, for $i = 1, 2$, is induced to maximize

$$ O_i = \alpha_i \pi_i + (1 - \alpha_i)S_i. $$

We assume also that owner $i$ uses a compensation scheme in which manager $i$ is paid $A_i + B_i O_i$, where $A_i$ and $B_i$ are constants with $A_i \geq 0$ and $B_i > 0$. Under this compensation scheme, as explained in Section 2, the contract designed by owner $i$ provides manager $i$ with equilibrium compensation exactly equal to his reservation wage $R_i$.

Given an incentive structure which is a linear combination of profits and sales, manager $i$, for $i = 1, 2$, seeks to maximize

$$ O_i = p_i (d - hp_i + kp_j) - \alpha_i c (d - hp_i + kp_j). \tag{12} $$

On the other hand, we assume that each owner's objective is to maximize her firm's profits net of her manager's compensation. Mathematically, this amounts to assuming that owner $i$ seeks to maximize her firm's profits

$$ \pi_i = (p_i - c) (d - hp_i + kp_j), \tag{13} $$

because any contract designed by owner $i$ provides manager $i$ with equilibrium compensation exactly equal to his reservation wage $R_i$.

\(^{15}\)With inverse market demand functions, this assumption is commonly stated as "the own-price effect dominates the cross-price effect" (see, for example, Shy 1995, pp. 135-136).
We formally consider the following game. First, each firm decides independently whether it will release its contract information to the public. The firms simultaneously announce and commit to their decisions before writing their contracts. Next, the owner of each firm writes — and releases if her firm announced to do so — a contract with her manager. (We will be more specific about this stage in Section 5.) Finally, the managers choose their firms' prices simultaneously and independently.

We assume that all of the above is common knowledge among the owners and managers.

5. The equilibrium decisions of the owners and managers

Working backward, we first analyze the four subgames starting after the firms announce whether they will release their contract information, and then consider the firms' decisions on releasing their contract information.

5.1. The \((R, R)\) subgame

To solve for a subgame-perfect equilibrium of this subgame, we work backward. Lemma 4 summarizes the outcomes of the \((R, R)\) subgame.

**Lemma 4.** (a) In the equilibrium of the \((R, R)\) subgame, owner \(i\), for \(i = 1, 2\), chooses \(\alpha_i^R = \{c(2h^2 - k^2)(2h - k) + dk^2\}/hc(4h^2 - 2hk - k^2)\), and manager \(i\) chooses \(p_i^R = \{c(2h^2 - k^2) + 2dh\}/(4h^2 - 2hk - k^2)\). (b) The firms' equilibrium profits are \(\pi_1^R = \pi_2^R = 2h(2h^2 - k^2)^2/(4h^2 - 2hk - k^2)^2\).

\(^{16}\)As in Section 2, we assume that each firm decides to release its contract information only if both the owner and the manager of the firm agree to do so. As explained in Section 2, this amounts to assuming that each firm's decision on releasing its contract information is made only by its owner.
5.2. The (R, NR) subgame and the (NR, R) subgame

Consider a subgame in which firm $i$ releases its contract information, but firm $j$ does not, for $i, j = 1, 2$ with $i \neq j$. Note that we are considering the (R, NR) subgame if $i = 1$, and the (NR, R) subgame if $i = 2$. We assume that firm $j$ chooses its contract after observing firm $i$'s contract.

We solve the subgame by viewing it as the following two-stage game. In the first stage, owner $i$ chooses and releases a value of $\alpha_i$. In the second stage, after observing the value of $\alpha_i$, manager $i$ and firm $j$ play a simultaneous-move game. Specifically, manager $i$ chooses his firm's price, without observing the value of $\alpha_j$ or firm $j$'s price; owner $j$ chooses a value of $\alpha_j$, and manager $j$ (after observing the value of $\alpha_j$) chooses his firm's price, both without observing firm $i$'s price.

To solve this two-stage game, we work backward. In the second stage, manager $i$ and firm $j$ know the value of $\alpha_i$. We begin by deriving the reaction function for manager $i$. After observing $\alpha_i$, manager $i$ seeks to maximize $O_i$ in (12) over his firm's price $p_i$, taking firm $j$'s price $p_j$ as given. From the first-order condition for maximizing $O_i$, we obtain manager $i$'s reaction function:

$$ p_i(p_j; \alpha_i) = (d + \alpha_i h c + kp_j)/2h. \tag{14} $$

Next, consider firm $j$. Owner $j$ chooses a value of $\alpha_j$, and then manager $j$ chooses his firm's price, both without observing firm $i$'s price. Working backward, we first consider manager $j$'s decision on his firm's price. After observing the values of $\alpha_1$ and $\alpha_2$, manager $j$ seeks to maximize $O_j$ in (12) over his firm's price $p_j$, taking firm $i$'s price $p_i$ as given. From the first-order condition for maximizing $O_j$, we obtain manager $j$'s reaction function:

$$ p_j(p_i; \alpha_1, \alpha_2) = (d + \alpha_j h c + kp_i)/2h. \tag{15} $$

Then, we consider owner $j$'s decision on the value of $\alpha_j$. Owner $j$ seeks to maximize

$$ \pi_j(p_i, \alpha_j; \alpha_i) = \{p_j(p_i; \alpha_1, \alpha_2) - c\} \{d - hp_j(p_i; \alpha_1, \alpha_2) + kp_i\} \tag{16} $$
with respect to $\alpha_j$, taking firm $i$’s price $p_i$ as given. Note that we obtain (16) by substituting (15) into (13). From the first-order condition for maximizing (16), we obtain another reaction function of firm $j$, or owner $j$’s reaction function:

$$\alpha_j(p_i; \alpha_i) = 1. \quad (17)$$

By solving the system of three simultaneous equations, (14), (15), and (17), we obtain

$$p_i(\alpha_i) = \{d (2 h + k) + h c (2 \alpha_i h + k)\}/(4h^2 - k^2),$$

$$p_j(\alpha_i) = \{d (2 h + k) + h c (2h + \alpha_i k)\}/(4h^2 - k^2), \quad (18)$$

and

$$\alpha_j(\alpha_i) = 1.$$

These are the equilibrium price of firm $i$, that of firm $j$, and the equilibrium value of $\alpha_j$, respectively, in the second stage.

Next, consider the first stage in which owner $i$ chooses a value of $\alpha_i$. Having perfect foresight about $\pi_i(\alpha_i)$ for any values of $\alpha_i$, owner $i$ chooses a value of $\alpha_i$ which maximizes

$$\pi_i(\alpha_i) = \{d (2h + k) + c (hk - 4h^2 + k^2) + 2\alpha_i h c\}$$

$$\times \{dh (2h + k) - \alpha_i h c (2h^2 - k^2) + h^2 kc\}/(4h^2 - k^2)^2. \quad (19)$$

Note that we obtain (19) by substituting $p_i(\alpha_i)$ and $p_j(\alpha_i)$ in (18) into (13). From the first-order condition for maximizing (19) with respect to $\alpha_i$, we obtain the equilibrium value of $\alpha_i$ in the subgame:

$$\alpha_i^{ER} = [dk^2 (2h + k) + c \{hk^3 + (4h^2 - k^2)(2h^2 - k^2)\}]/4h^2 c (2h^2 - k^2).$$

Now, substituting $\alpha_i^{ER}$ into $p_i(\alpha_i)$, $p_j(\alpha_i)$, and $\alpha_j(\alpha_i)$ in (18), we obtain the firms’ equilibrium prices, $p_i^{ER}$ and $p_j^{ER}$, and the equilibrium value of $\alpha_j$, denoted by $\alpha_j^{ER}$, in the subgame. Next, using these equilibrium actions, we obtain the firms’ equilibrium profits, $\pi_i^{ER}$ and $\pi_j^{ER}$, in the subgame.
Lemma 5 summarizes the outcomes of the \((R, NR)\) subgame if \(i = 1\), and those of the \((NR, R)\) subgame if \(i = 2\).

**Lemma 5.** (a) In the equilibrium of a subgame in which firm \(i\) releases its contract information, but firm \(j\) does not, for \(i, j = 1, 2\) with \(i \neq j\), owner \(i\) chooses \(\alpha_i^{R} = [dk^2(2h + k) + c\{hk^3 + (4h^2 - k^2)(2h^2 - k^2)\}] / 4h^2c(2h^2 - k^2)\), and manager \(i\) chooses \(p_i^{R} = \{d(2h + k) + c(2h^2 - k^2 + hk)\} / 2(2h^2 - k^2)\). Owner \(j\) chooses \(\alpha_j^{R} = 1\), and manager \(j\) chooses \(p_j^{R} = [d(4h^2 - k^2 + 2hk) + c\{h(4h^2 - k^2) + k(2h^2 - k^2)\}] / 4h(2h^2 - k^2)\).

(b) The equilibrium profits of firm \(i\) and those of firm \(j\) are \(\pi_i^{R} = (2h + k)^2\{d - c(h - k)\}^2 / 8h(2h^2 - k^2)\) and \(\pi_j^{R} = \{d(4h^2 - k^2 + 2hk) + hc(3k^2 - 4h^2) + kc(2h^2 - k^2)\}^2 / 16h(2h^2 - k^2)^2\), respectively.

5.3. The \((NR, NR)\) subgame

The equilibrium values of \(\alpha_1\) and \(\alpha_2\) and the equilibrium prices of the firms in the subgame satisfy the following two requirements. First, firm \(i\)'s price is optimal given the value of \(\alpha_i\) and given firm \(j\)'s price, for \(i, j = 1, 2\) with \(i \neq j\). Second, the value of \(\alpha_i\) is optimal given firm \(j\)'s price and given firm \(i\)'s own subsequent optimal behavior, or rather its optimal price.

To obtain the equilibrium values of \(\alpha_1\) and \(\alpha_2\) and the equilibrium prices of the firms, we begin by deriving the reaction functions for firm \(i\). Working backward, we first consider manager \(i\)'s decision on his firm's price. After observing the value of \(\alpha_i\), manager \(i\) seeks to maximize \(O_i\) in (12) over his firm's price \(p_i\), taking firm \(j\)'s price \(p_j\) as given. From the first-order condition for maximizing \(O_i\), we obtain manager \(i\)'s reaction function:

\[ p_i(p_j; \alpha_i) = (d + \alpha_ihc + kp_j) / 2h. \]  

Then, we consider owner \(i\)'s decision on the value of \(\alpha_i\). Owner \(i\) seeks to maximize

\[ \pi_i(p_j, \alpha_i) = (d - 2hc + kp_j + \alpha_ihc)(d + kp_j - \alpha_ihc) / 4h \]  

(21)
with respect to $\alpha_i$, taking firm $j$'s price $p_j$ as given. Note that we obtain (21) by substituting (20) into (13). From the first-order condition for maximizing (21), we obtain another reaction function of firm $i$, or owner $i$'s reaction function:

$$\alpha_i(p_i) = 1. \tag{22}$$

We are now ready to obtain the firms' equilibrium actions, denoted by $(\alpha_1^{NR}, p_1^{NR}, \alpha_2^{NR}, p_2^{NR})$, by solving the system of four simultaneous equations, which comes from (20) and (22). Substituting (22) into (20), we have

$$p_1(p_2) = (d + hc + kp_2)/2h$$

and

$$p_2(p_1) = (d + hc + kp_1)/2h.$$ 

By solving this pair of simultaneous equations, we obtain the firms' equilibrium prices, $p_1^{NR}$ and $p_2^{NR}$. Next, substituting $p_2^{NR}$ into (22), and $p_1^{NR}$ into (22), we obtain $\alpha_1^{NR}$ and $\alpha_2^{NR}$, respectively. Finally, substituting these equilibrium actions into (21), we obtain the firms' equilibrium profits, $\pi_1^{NR}$ and $\pi_2^{NR}$, in the (NR, NR) subgame.

Lemma 6 summarizes the outcomes of the (NR, NR) subgame.

Lemma 6. (a) In the equilibrium of the (NR, NR) subgame, owner $i$, for $i = 1, 2$, chooses $\alpha_i^{NR} = 1$, and manager $i$ chooses $p_i^{NR} = (d + hc)/(2h - k)$. (b) The firms' equilibrium profits are $\pi_1^{NR} = \pi_2^{NR} = h\{d - c(h - k)\}^2/(2h - k)^2$.

5.4. Firms' decisions on releasing their contract information

At the beginning of the entire game, each firm chooses and announces one of the following two actions: $R$ or $NR$. We have four possible combinations of the actions resulting from the firms' choices: ($R$, $R$), ($R$, $NR$), ($NR$, $R$), and ($NR$, $NR$). Figure 2 shows the profits of the firms which will be realized under these four possible combinations (see Lemmas 4 through 6).
After some algebra, we obtain that $\pi_1^R > \pi_1^{2R}$, $\pi_2^R > \pi_2^{1R}$, and $\pi_i^{1R} > \pi_i^{NR}$ for $i = 1, 2$. These comparison results can be explained graphically in terms of the managers' reaction functions. For example, consider the comparison result that $\pi_1^{1R} > \pi_1^{NR}$. First, recall from Lemma 6 that $\alpha_i^{NR} = 1$, for $i = 1, 2$, in the $(NR, NR)$ subgame. In this case, the upward-sloping reaction functions of the managers intersect at $(p_1^{NR}, p_2^{NR})$ in the $p_1p_2$-space, where $p_1^{NR} = p_2^{NR}$ (see Sklivas 1987, p. 456), and firm 1 earns the profits, $\pi_1^{NR}$. Next, recall from Lemma 5 that $\alpha_1^{1R} > 1$ and $\alpha_2^{1R} = 1$ in the $(R, NR)$ subgame. In this case, the upward-sloping reaction function of manager 1 shifts outward in the $p_1p_2$-space, while the upward-sloping reaction function of manager 2 stays put, as compared with the $(NR, NR)$ subgame. This entails that the managers choose higher prices, compared to the $(NR, NR)$ subgame, at the intersection of these new reaction functions: $p_1^{1R} > p_1^{NR}$ and $p_2^{1R} > p_2^{NR}$. Finally, these higher prices of both firms result in higher profits to firm 1 in the $(R, NR)$ subgame: $\pi_1^{1R} > \pi_1^{NR}$.

The comparison results obtained in the preceding paragraph imply that $(R, R)$ occurs in equilibrium; furthermore, $R$ is each firm's dominant action.

**Proposition 2.** Only the combination $(R, R)$ occurs in equilibrium.

Proposition 2 says, as Proposition 1 does, that both firms announce at the beginning of the entire game that they will release their contract information. The explanations for Proposition 2 may be made similarly to those for Proposition 1, and therefore are omitted.

5.5. The outcomes of the entire game

Using Proposition 2 and Lemma 4, we obtain the following outcomes of the game. (Let the superscript ** indicate the equilibrium values of the variables.) First, both firms announce at the beginning of the game that they will release the information about their contracts. Second, firm $i$, for $i = 1, 2$, chooses and releases its contract, $\alpha_i^{**} = \{c(2h^2 - k^2)(2h - k) + dk^2\} / hc(4h^2 - 2hk - k^2)$. Third, firm $i$ chooses its price, $p_i^{**} = \{c(2h^2 - k^2) + 2dh\} /
\((4h^2 - 2hk - k^2)\). Finally, firm \(i\)'s profits (without subtracting its manager's compensation) are
\[\pi_i^{**} = 2h(2h^2 - k^2)(d - c(h - k))^2 / (4h^2 - 2hk - k^2)^2.\]

The value of \(\alpha_i\) which firm \(i\) chooses is greater than unity, which implies that firm \(i\) gives a negative weight to the sales component, \(S_i\), in manager \(i\)'s performance measure, \(O_i\). By doing so, firm \(i\) makes its manager less aggressive in the subsequent price competition, as compared with the case of profit maximization where \(\alpha_i = 1\). To understand this result, note first that the managers' reaction functions are upward-sloping in the \(p_1p_2\)-space (see Sklivas 1987, p. 456). Then, note that, if the firms motivate their managers to be less aggressive — so that the managers' reaction functions shift outward or upward — as compared with the case of profit maximization, then both managers choose higher prices, and thus both firms earn higher profits.

6. A comparison: observable versus unobservable contracts

Let the superscripts \(oc\) and \(uc\) indicate the outcomes of the observable-contracts case and those of the unobservable-contracts case, respectively.\(^{17}\) Several outcomes of the observable-contracts case are provided in Lemma 1 for the quantity-setting firms, and in Lemma 4 for the price-setting firms. On the other hand, the corresponding outcomes of the unobservable-contracts case are provided in Lemma 3 for the quantity-setting firms, and in Lemma 6 for the price-setting firms. Let \(CS\) represent the consumer surplus, and let \(W\) represent welfare, defined as the simple sum of the consumer surplus and the firms' profits.

**Lemma 7.** (a) For the quantity-setting firms, we obtain: \(CS^{oc} = 8(a - c)^2 / 25b,\)
\(CS^{uc} = 2(a - c)^2 / 9b,\) \(W^{oc} = 12(a - c)^2 / 25b,\) and \(W^{uc} = 4(a - c)^2 / 9b.\) (b) For the price-setting firms, we obtain: \(CS^{oc} = (2h^2 - k^2)^2 (d - c(h - k))^2 / h (4h^2 - 2hk - k^2)^2,\) \(CS^{uc} = \)

\(^{17}\)Recall from Section 1 that the observable-contracts [unobservable-contracts] case is the one where each firm's contract is *exogenously* assumed to be observable [unobservable] to the rival firm. In the two models we have so far considered, we have established that both firms release their contract information. This implies that the outcomes of each of the two models are exactly the same as those of the corresponding observable-contracts case.
\[ h \{d - c(h - k)\}^2/(2h - k)^2, \quad W^{oc} = (2h^2 - k^2)(6h^2 - k^2)\{d - c(h - k)\}^2/h(4h^2 - 2hk - k^2)^2, \]
\[ and \quad W^{uc} = 3h \{d - c(h - k)\}^2/(2h - k)^2. \]

We compare the outcomes of the observable-contracts case with those of the unobservable-contracts case. The comparison results are reported in Proposition 3.

**Proposition 3.** (a) For the quantity-setting firms, we obtain for \( i = 1, 2 \): \( \alpha_i^{oc} < \alpha_i^{uc}, \quad x_i^{oc} > x_i^{uc}, \)
\( \pi_i^{oc} < \pi_i^{uc}, \quad CS^{oc} > CS^{uc}, \) and \( W^{oc} > W^{uc}. \) (b) For the price-setting firms, we obtain for \( i = 1, 2 \): \( \alpha_i^{oc} > \alpha_i^{uc}, \quad p_i^{oc} > p_i^{uc}, \quad \pi_i^{oc} > \pi_i^{uc}, \) and \( CS^{oc} < CS^{uc}. \) We also obtain that \( W^{oc} > W^{uc} \) if \( k < h < \min\{1.9297k, k + d/c\}. \)\(^{18}\)

The following complements part (b) in the case where \( k + d/c \geq 1.9297k \): \( W^{oc} < W^{uc} \) if
\[ 1.9297k \leq h < k + d/c. \]

Each quantity-setting firm makes its manager more aggressive in the observable-contracts case than in the unobservable-contracts case. This results in greater output levels, lower profits of the firms, and greater consumer surplus in the observable-contracts case. By contrast, each price-setting firm makes its manager less aggressive in the observable-contracts case than in the unobservable-contracts case. This results in higher prices, higher profits of the firms, and lower consumer surplus in the observable-contracts case.

The welfare resulting from the observable-contracts case is always greater than that resulting from the unobservable-contracts case, in the quantity-setting market. Similarly, in the price-setting market, \( W^{oc} \) is greater than \( W^{uc} \) unless the ratio of \( h \) to \( k \) is significantly large. This welfare comparison result in the price-setting market can be explained as follows. First, due to the definitions, \( W^{oc} = 2\pi_i^{oc} + CS^{oc} \) and \( W^{uc} = 2\pi_i^{uc} + CS^{uc}, \) and the comparison results that \( \pi_i^{oc} > \pi_i^{uc} \) and \( CS^{oc} < CS^{uc}, \) it implies that two times the profits gap between the two cases,

\(^{18}\)Note that \( W^{oc} > W^{uc} \) if \( -8\theta^4 + 20\theta^3 - 7\theta^2 - 4\theta + 1 > 0, \) where \( \theta = h/k. \) Note also that \( 0 < k < h < k + d/c \) under the assumptions in Section 4.
2(\pi_i^{oc} - \pi_i^{uc}), outweighs the consumer surplus gap between the two cases, (CS^{uc} - CS^{oc}), unless the ratio of h to k is significantly large. Second, it may occur that \( W^{oc} \) is less than \( W^{uc} \). In fact, if \( k + d/c \geq 1.9297k \), then \( W^{oc} < W^{uc} \) if \( 1.9297k \leq h < k + d/c \). In this case, the consumer surplus gap between the two cases, (\( CS^{uc} - CS^{oc} \)), outweighs two times the profits gap between the two cases, \( 2(\pi_i^{oc} - \pi_i^{uc}) \). Indeed, given that \( k + d/c \geq 1.9297k \), if the ratio of h to k is significantly large, so that the own-price effect is, in relative terms, significantly greater than the cross-price effect, then \( (CS^{uc} - CS^{oc}) \) is greater than \( 2(\pi_i^{oc} - \pi_i^{uc}) \) (see footnote 15).

7. A modification: more than two firms

We briefly consider a modified model in which there are \( n \) quantity-setting firms, and also one in which there are \( n \) price-setting firms, where \( n \geq 3 \). The first modified model is the same as the model in Section 2 with the exception that the number of firms is now larger. The second modified model is the same as the model in Section 4 with the exception that the number of firms is now larger, and the market demand function facing firm \( i \), for \( i = 1, \ldots, n \), is now replaced with

\[
q_i = d - hp_i + k\sum_{j \neq i} p_j.\tag{19}
\]

Because of computational complexities involved, we may not complete the full analyses of these two modified models. However, we find in both modified models that there exists an equilibrium in which every firm announces at the beginning of the game that it will release its contract information, and actually releases the information.

\[
^{19}\text{For demand systems with product differentiation, see Vives (1999, pp. 144-148).}
\]
8. Conclusions

We have studied duopolies in which each firm, consisting of an owner and a manager, has the option of releasing or not the information on its contract between the owner and the manager. Formally, we have considered the following game. First, each firm decides and announces whether it will release its contract information to the public. Next, the owner of each firm writes – and releases if her firm announced to do so – a contract with her manager. Finally, the managers in both firms choose values of the strategic variable, quantity or price, simultaneously and independently.

As a main result, we have shown that each firm announces that it will release its contract information, regardless of the action it expects the rival firm to take, and actually release it. Then, comparing the outcomes of the observable-contracts case with those of the unobservable-contracts case, we have shown that the welfare resulting from the observable-contracts case is greater than that resulting from the unobservable-contracts case.

In the models we have considered in this paper, we have assumed that the firms have the same marginal cost of production. Instead, we could assume that they have different marginal costs. With this modification, we obtain exactly the same main results.

In the models of this paper, each firm's decision on releasing its contract information is, in effect, made by its owner because its manager is indifferent between releasing and not releasing the contract information. One may obtain different results if he or she develops a model in which each firm's decision on releasing its contract information is, in effect, made by both its owner and its manager or only by its manager. Another possible modification of this paper would be to consider quantity-setting and price-setting models in both of which there is asymmetric information between each firm's owner and its manager. We leave these modifications for future research.
References


Figure 1. The Profits of the Quantity-Setting Firms

<table>
<thead>
<tr>
<th></th>
<th>Firm 1</th>
<th>Firm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>R</strong></td>
<td><strong>NR</strong></td>
</tr>
<tr>
<td><strong>R</strong></td>
<td>$\pi_1^R = \frac{2(a - c)^2}{25b}$</td>
<td>$\pi_2^R = \frac{(a - c)^2}{16b}$</td>
</tr>
<tr>
<td><strong>NR</strong></td>
<td>$\pi_1^{NR} = \frac{(a - c)^2}{16b}$</td>
<td>$\pi_2^{NR} = \frac{(a - c)^2}{9b}$</td>
</tr>
</tbody>
</table>

$\pi_1 = \frac{2(a - c)^2}{25b}$ 

$\pi_2 = \frac{(a - c)^2}{8b}$
Figure 2. The Profits of the Price-Setting Firms

<table>
<thead>
<tr>
<th></th>
<th>Firm 1</th>
<th>Firm 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>( \pi_1^R ) = \frac{2h(2h^2 - k^2)(d - c(h - k))^2}{(4h^2 - 2hk - k^2)^2}</td>
<td>( \pi_2^R ) = \frac{(d(4h^2 - k^2 + 2hk) + hc(3k^2 - 4h^2) + kc(2h^2 - k^2))^2}{16h(2h^2 - k^2)^2}</td>
</tr>
<tr>
<td></td>
<td>( \pi_1^N ) = \frac{2h(2h^2 - k^2)(d - c(h - k))^2}{(4h^2 - 2hk - k^2)^2}</td>
<td>( \pi_2^N ) = \frac{(2h + k)(d - c(h - k))^2}{8h(2h^2 - k^2)}</td>
</tr>
<tr>
<td></td>
<td>( \pi_1^{NR} ) = \frac{b(d - c(h - k))^2}{(2h - k)^2}</td>
<td>( \pi_2^{NR} ) = \frac{b(d - c(h - k))^2}{(2h - k)^2}</td>
</tr>
</tbody>
</table>