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Werner Neus* and Manfred Stadler**

Abstract

We study quantity and price competition in heterogeneous triopoly markets where two firms are commonly owned by institutional shareholders, whereas the third firm is owned by independent shareholders. With such a mixed ownership structure, the common owners have an incentive to coordinate their firms' behavior. If direct coordination of the operational decisions is prevented by antitrust authorities, delegation to managers enables indirect coordination via the designs of the manager compensation contracts. Compared to direct owner collusion, this more sophisticated type of indirect collusion leads to a lower loss of social welfare in the mode of quantity competition, but to a higher loss of welfare in the mode of price competition. In general, owner coordination via the management compensation contracts is detrimental to welfare: the tragedy of common holdings.

Keywords: Manager compensation, common holdings, shareholder coordination

JEL Classification: G32, L22, M52

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1 Introduction

Owners of publicly traded firms usually have to delegate operational decisions to specialized managers. These managers, however, have their own objectives and aim to maximize their personal reward instead of the firm's profit. Therefore, the design of their compensation contracts is crucial for their decision behavior and hence the market outcome. In the theory of industrial organization, manager delegation is analyzed with two-stage games where the owners design irreversible compensation contracts in the first stage and managers decide on quantities or prices in the second stage (see, e.g., Lambertini 2017). In the basic models, the compensation contracts consist of a linear combination of fixed salaries and performance-dependent payments which, in turn, consist of a weighted linear combination of firm profits on the one hand and sales (i.e. quantities or revenues) on the other hand (see Vickers 1985; Sklivas 1987; Fershtman and Judd 1987, 2006). These compensation schemes induce an aggressive output behavior in the mode of quantity competition and an inoffensive price setting in the mode of price competition.

A complementary feature of publicly traded firms is their mixed ownership structure where some firms are commonly held by the same decisive group of owners whereas other firms are owned by independent shareholders. Investment firms such as BlackRock or Vanguard typically replicate the composition of major stock indices which often implies investment in different firms in a relevant market. This inevitably provides an incentive to coordinate their firms' activities and raises concerns about anti-competitive behavior of commonly owned firms (see, e.g., Schwalbe 2018).

In this paper, we aim to integrate these two strands of the literature, i.e. we are interested in firms' product market competition with manager delegation in the presence of common holdings. So far, only few models contribute to this interesting field of research up to now. The influence of common holdings on the managers' compensation schemes and hence on market conduct and performance has been studied by Neus and Stadler (2018). They considered a triopoly market with asymmetric marginal production cost of firms and a numerically specified system of demand functions, reflecting an exogenously given intermediate degree of product heterogeneity. Neus et al. (2020) have simplified the setting by assuming marginal production costs of equal size and a homogeneous market, but extended the model by allowing for a general oligopoly where m out of n firms in the market are held by common owners. Both of these papers exclusively deal with the mode of quantity competition. However, many markets are better characterized by the mode of price competition. Since these modes of competition usually lead to contrary implications for the adequate strategic behavior, a complementary analysis of price competition seems to be necessary in order to provide more general results.

Therefore, the present paper extends the existing approach in two further directions. First, we consider more flexible demand functions, allowing for different degrees of the products' substitutability and hence of the heterogeneity of the market. Second, we complement the analysis of quantity competition with a consistent analysis of price competition. This enables us to assess the influence of the degree of capacity precommitment, since quantity competition can be interpreted as a two-stage capacity-then-price-setting game with hard capacity constraints (see Kreps and Scheinkman 1983 for the case of homogeneous markets and Maggi 1996 for the generalized case heterogeneous markets). Given this framework, we identify a rather fundamental effect of common ownership which holds for both modes of competition: compared to direct owner coordination of the operational decisions, coordination via the design of the manager compensation contracts leads to higher firm profits whereas social welfare is reduced. This is what we call "the tragedy of the common holdings".[1]

The rest of the paper is organized as follows: Section 2 presents the basic framework and the benchmark model where owners themselves decide on quantities or prices, respectively. Section 3 studies direct quantity and price coordination of the common owners. In Section 4, we analyze the effect of strategic manager delegation in isolation. Section 5 studies the impact of common owner coordination with respect to the manager compensation contracts. Section 6 compares all scenarios in terms of a welfare analysis. Section 7 summarizes the results and concludes the paper.

[1]The pun between our title and the famous article "The tragedy of the commons", published by Hardin (1968), is intended. In the latter issue, the tragedy is that an open access to a common resource such as pasture land leads to an overuse and finally to a loss of social welfare. In our context, the tragedy is that common holdings are responsible for a loss of consumer surplus as well as welfare.

2 The Benchmark Triopoly Model

In order to study a mixed ownership structure with commonly owned and independent firms, we consider a product market with three firms $i = 1, 2, 3$, each producing a substitute good. The preferences of unit-mass consumers are represented by the quasi-linear quadratic utility function

$$U = q_0 + \alpha(q_1 + q_2 + q_3) - \beta(q_1^2 + q_2^2 + q_3^2)/2 - \gamma(q_1 q_2 + q_1 q_3 + q_2 q_3) \qquad (1)$$

with the preference parameters $\alpha > 0$ and $0 \leq \gamma \leq \beta$, where $q_i, i = 1, 2, 3$, are the consumed quantities of the differentiated products supplied by the firms $i = 1, 2, 3$, and $q_0 > 0$ is the quantity of the numéraire good. The limit case of a homogeneous market is characterized by $\gamma = \beta$, the opposite limit case of completely separated monopoly markets is captured by $\gamma = 0$. Substituting q_0 from the budget constraint $E = q_0 + p_1 q_1 + p_2 q_2 + p_3 q_3$ and maximizing the utility function (1) with respect to the quantities gives the inverse demand system

$$p_i = \begin{cases} \alpha - \beta q_1 - \gamma q_2 - \gamma q_3 & \text{for } \ i = 1 \\ \alpha - \beta q_2 - \gamma q_1 - \gamma q_3 & \text{for } \ i = 2 \\ \alpha - \beta q_3 - \gamma q_1 - \gamma q_2 & \text{for } \ i = 3\ . \end{cases} \qquad (2)$$

The firms' marginal production costs c are assumed to be quantity-invariant and of equal size. This leads to the firms' profits

$$\pi_i = \begin{cases} (\alpha - c - \beta q_1 - \gamma q_2 - \gamma q_3) q_1 & \text{for } \ i = 1 \\ (\alpha - c - \beta q_2 - \gamma q_1 - \gamma q_3) q_2 & \text{for } \ i = 2 \\ (\alpha - c - \beta q_3 - \gamma q_1 - \gamma q_2) q_3 & \text{for } \ i = 3\ . \end{cases} \qquad (3)$$

In the case of owner-controlled firms, one obtains the benchmark solutions for triopoly markets. The mode of quantity competition gives the equilibrium production levels

$$q^Q = \frac{\alpha - c}{2(\beta + \gamma)}\ ,$$

leading to the equilibrium prices

$$p^Q = c + \frac{\beta(\alpha - c)}{2(\beta + \gamma)}$$

and firm profits

$$\pi^Q = \frac{\beta(\alpha - c)^2}{4(\beta + \gamma)^2} \ .$$

Table 1 provides numerical results for quantity competition (Q) under different degrees of product substitutability.

Table 1: Standard Quantity Competition ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$p^Q - c$	0.5000	0.4000	0.3333	0.2857	0.2500
q^Q	0.2500	0.2000	0.1667	0.1429	0.1250
π^Q	0.1250	0.0800	0.0556	0.0408	0.0313

In order to study the mode of price competition, we use (2) to calculate the linear demand system

$$q_i = \begin{cases} a - bp_1 + dp_2 + dp_3 & \text{for} \quad i = 1 \\ a - bp_2 + dp_1 + dp_3 & \text{for} \quad i = 2 \\ a - bp_3 + dp_1 + dp_2 & \text{for} \quad i = 3 \ , \end{cases} \tag{4}$$

where $a \equiv \alpha/(\beta + 2\gamma) \ > 0$, $b \equiv (\beta + \gamma)/[(\beta - \gamma)(\beta + 2\gamma)] \ > 0$ and $d \equiv \gamma/[(\beta - \gamma)(\beta + 2\gamma)] \ \in [0, b/2]$. Maximizing the profits

$$\pi_i = \begin{cases} (p_1 - c)(a - bp_1 + dp_2 + dp_3) & \text{for} \quad i = 1 \\ (p_2 - c)(a - bp_2 + dp_1 + dp_3) & \text{for} \quad i = 2 \\ (p_3 - c)(a - bp_3 + dp_1 + dp_2) & \text{for} \quad i = 3 \end{cases} \tag{5}$$

leads to the equilibrium prices

$$p^P = c + \frac{(\beta - \gamma)(\alpha - c)}{2\beta}$$

and hence to the production quantities

$$q^P = \frac{(\beta + \gamma)(\alpha - c)}{2\beta(\beta + 2\gamma)}$$

and firm profits

$$\pi^P = \frac{(\beta - \gamma)(\beta + \gamma)(\alpha - c)^2}{4\beta^2(\beta + 2\gamma)} .$$

In comparison to Table 1, Table 2 provides the corresponding numerical results for price competition (P) under different degrees of product substitutability.

Table 2: Standard Price Competition ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$p^P - c$	0.5000	0.3750	0.2500	0.1250	0.0000
q^P	0.2500	0.2083	0.1875	0.1750	0.1667
π^P	0.1250	0.0781	0.0469	0.0219	0.0000

As is well-known, the mode of price competition leads to lower prices, higher quantities and lower profits. In order to explain the different results, we refer to the often used interpretation that quantity competition can be regarded as a reduced form of a two-stage capacity-price game where capacity constraints are strictly binding and the rule of efficient consumer rationing is applied in the out-of-equilibrium case of excess demand is assumed (see Maggi 1996 for our generalized case of heterogeneous markets). In the case of such a hard capacity constraint, the additional marginal cost of a subsequent expansion of capacity is prohibitively high. In the case of a soft capacity constraint, the additional cost is low and in the limit even zero. Then, the game converges to the standard game of price competition. In this interpretation, the relevance of the one or other mode of competition finally depends on the shape of the marginal cost function. Price competition indicates markets with fairly flat marginal production costs, whereas quantity competition reflects markets with sharply rising marginal costs.

Of course, for both modes of competition it holds that prices and profits are monotonically decreasing in the degree of product substitutability and increasing in the degree of heterogeneity, respectively.

3 Owner Coordination of the Operational Decisions

In order to study the consequences of a coordinated owner behavior, we now assume that firms 1 and 2 are commonly owned by the same institutional shareholders, while firm 3 is owned by independent shareholders. The common shareholders constitute a decisive group of owners who have an incentive to coordinate their output and price decisions. In contrast to the previous section, the common owners of firms 1 and 2 now simultaneously maximize their joint profits π_1 and π_2 in (3), whereas the independent owners of firm 3 maximize the profit π_3 as before.[2]

In the mode of quantity competition, profit maximization gives the equilibrium production levels

$$q_{1,2}^{CQ} = \frac{(2\beta - \gamma)(\alpha - c)}{4\beta^2 + 4\beta + \gamma - 2\gamma^2}$$
$$q_3^{CQ} = \frac{2\beta(\alpha - c)}{4\beta^2 + 4\beta + \gamma - 2\gamma^2} ,$$

leading to the prices

$$p_{1,2}^{CQ} = c + \frac{(2\beta^2 + \beta\gamma - \gamma^2)(\alpha - c)}{4\beta^2 + 4\beta\gamma - 2\gamma^2}$$
$$p_3^{CQ} = c + \frac{(2\beta^2)(\alpha - c)}{4\beta^2 + 4\beta\gamma - 2\gamma^2}$$

and the firm profits

$$\pi_{1,2}^{CQ} = \frac{(2\beta^2 + \beta\gamma - \gamma^2)(2\beta - \gamma)(\alpha - c)^2}{(4\beta^2 + 4\beta\gamma - 2\gamma^2)^2} ,$$
$$\pi_3^{CQ} = \frac{(4\beta^3)(\alpha - c)^2}{(4\beta^2 + 4\beta\gamma - 2\gamma^2)^2} ,$$

Table 3 provides numerical results for quantity competition when firms 1 and 2 are coordinated via the output decisions (CQ) .

[2]We do not consider tacit collusion of all firms as it would be possible in repeated games (see, e.g., the supergame models of Lambertini and Trombetta 2002 and Spagnolo 2003).

Table 3: Quantity Competition with Coordinated Firms ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$p_{1,2}^{CQ} - c$	0.5000	0.4487	0.4091	0.3723	0.3333
$p_3^{CQ} - c$	0.5000	0.4103	0.3636	0.3404	0.3333
$q_{1,2}^{CQ}$	0.2500	0.1795	0.1364	0.1064	0.0833
q_3^{CQ}	0.2500	0.2051	0.1818	0.1702	0.1667
$\pi_{1,2}^{CQ}$	0.1250	0.0805	0.0558	0.0396	0.0278
π_3^{CQ}	0.1250	0.0842	0.0661	0.0579	0.0556

A comparison with Table 1 shows that the coordinated firms 1 and 2 reduce the output levels, while the non-coordinated firm 3 increases its output level. The profit of the non-coordinated firm generally increases, while the profits of the coordinated firms only increase in rather heterogeneous markets. In a homogeneous market, the profits of the coordinated firms are reduced. This finding corresponds to the well-known result from the merger literature that at least 80 % of the number of firms in the market have to merge in order to raise their common profit (see Salant et al. 1983). The effect of coordinated quantity decisions decreases with the degree of heterogeneity. Of course, in the case of separated monopolies, nothing can be gained by coordination.

In the mode of price competition, the common owners of the firms 1 and 2 simultaneously maximize their joint profits π_1 and π_2 in (5) with respect to the prices, whereas the independent owners of firm 3 maximize the profit π_3. This gives the equilibrium prices

$$p_{1,2}^{CP} = c + \frac{(2\beta^2 + \beta\gamma - 3\gamma^2)(\alpha - c)}{4\beta^2 + 4\beta\gamma - 2\gamma^2}$$

$$p_3^{CP} = c + \frac{2(\beta^2 - \gamma^2)(\alpha - c)}{4\beta^2 + 4\beta\gamma - 2\gamma^2} \ ,$$

leading to the quantities

$$q_{1,2}^{CP} = \frac{\beta(2\beta + 3\gamma)(\alpha - c)}{(\beta + 2\gamma)(4\beta^2 + 4\beta\gamma - 2\gamma^2)}$$

$$q_3^{CP} = \frac{2(\beta + \gamma)^2(\alpha - c)}{(\beta + 2\gamma)(4\beta^2 + 4\beta\gamma - 2\gamma^2)}$$

and the firm profits

$$\pi_{1,2}^{CP} = \frac{\beta(2\beta+3\gamma)(2\beta^2+\beta\gamma-3\gamma^2)(\alpha-c)^2}{(\beta+2\gamma)(4\beta^2+4\beta\gamma-2\gamma^2)^2} \; ,$$

$$\pi_{3}^{CP} = \frac{4(\beta^2-\gamma^2)(\beta+\gamma)^2(\alpha-c)^2}{(\beta+2\gamma)(4\beta^2+4\beta\gamma-2\gamma^2)^2} \; .$$

Table 4 provides the corresponding numerical results for price competition when firms 1 and 2 are coordinated via the price decisions (CP).

Table 4: Price Competition with Coordinated Firms ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$p_{1,2}^{CP} - c$	0.5000	0.4231	0.3182	0.1809	0.0000
$p_3^{CP} - c$	0.5000	0.3846	0.2727	0.1489	0.0000
$q_{1,2}^{CP}$	0.2500	0.1880	0.1591	0.1447	0.1389
q_3^{CP}	0.2500	0.2137	0.2045	0.2085	0.2222
$\pi_{1,2}^{CP}$	0.1250	0.0796	0.0506	0.0262	0.0000
π_3^{CP}	0.1250	0.0822	0.0558	0.0311	0.0000

A comparison with Table 2 shows that for all degrees of product substitutability, coordination implies higher prices of all firms and lower quantities of the coordinated firms, but a higher output of the non-coordinated firm. All firms gain, however the coordinated ones less than the non-coordinated one. Remarkably, the profit gain of the non-coordinated firm even exceeds the joint profit gains of the coordinated firms. This resembles an important result from the merger literature: in the mode of price competition, the merging firms slightly increase their profits, while the non-merging firms experience an even higher increase of their profits (see Deneckere and Davidson 1985).

A comparison with Table 3 shows that all firms realize lower profits in the mode of price competition than in the mode of quantity competition. When approaching the limit case of homogeneous markets, all prices converge to the marginal production costs. As a remarkable difference to the standard Bertrand result, however, quantities do not converge to the same amount. Instead, market shares are shifted from the coordinated firms to the outside firm.

4 Manager Delegation

The owners of big and publicly traded firms usually cannot run their firms themselves. Instead, they have to hire specialized managers who make the operational production and price decisions. These managers, however, have their own interests and adjust their decisions to the incentive structure provided by the compensation contracts as offered by the firm owners. We follow Sklivas (1987) and Fershtman and Judd (1987, 2006) and assume irreversible and observable contracts implying the linear payments

$$s_i = f_i + g_i\psi_i \ , \quad i = 1, 2, 3 \ .$$

f_i denotes the fixed salary for the manager of firm i, $g_i > 0$ serves as a weight parameter which, in combination with f_i, guarantees that the total payment s_i for each manager is equal to the exogenously given market-specific amount $\bar{s}$. The managers' objective functions $\psi_i = (1 - \hat{\kappa}_i)\pi_i + \hat{\kappa}_i p_i q_i = \pi_i + \hat{\kappa}_i c q_i$ represent the performance-dependent payments consisting of the weighted sum of the performance measures profit π_i and revenue $p_i q_i$.[3] This setting is consistent with the empirically observed fact that manager compensation is related to both firm profits and revenues (see, e.g. Murphy 1985, Jensen and Murphy 1990 and Conyon 1997). The firm owners strategically decide on the contract parameters $\hat{\kappa}_i$. For convenience we follow Neus and Stadler (2018) and define the transformed strategic parameters $\kappa_i \equiv \hat{\kappa}_i c$ to obtain the performance-dependent manager payments

$$\psi_i = \begin{cases} (\alpha - c + \kappa_1 - \beta q_1 - \gamma q_2 - \gamma q_3)q_1 & \text{for} \;\; i = 1 \\ (\alpha - c + \kappa_2 - \beta q_2 - \gamma q_1 - \gamma q_3)q_2 & \text{for} \;\; i = 2 \\ (\alpha - c + \kappa_3 - \beta q_3 - \gamma q_1 - \gamma q_2)q_3 & \text{for} \;\; i = 3 \ . \end{cases} \tag{6}$$

In the theory of industrial organization, manager delegation is modeled as a strategic two-stage game, where owners simultaneously offer compensation contracts characterized by the strategic weight variables κ_i in the first stage and managers simultaneously decide on the production quantities q_i or prices p_i in the second stage. While owners aim to maximize the firm profits π_i, the managers aim to maximize their performance-dependent payments ψ_i.

In the first stage of the game, the firm owners strategically decide on the contract parameters κ_i of the compensation scheme. As derived in Appendix

[3] It becomes immediately clear that revenue evaluation is strategically equivalent to sales evaluation as long as the firms' marginal production costs are of equal size.

A for the mode of quantity competition, the subgame perfect equilibrium weights are

$$\kappa^{DQ} = \frac{(2\beta - \gamma)\gamma^2(\alpha - c)}{\beta[(2\beta + \gamma)^2 - 4\gamma^2]} \quad > \quad 0 \; .$$

The positive sign of the contract parameters indicates compensation schemes that induce managers to aggressively expand production, thereby increasing the intensity of competition. Given the owners' strategic decisions, the managers choose the equilibrium quantities

$$q^{DQ} = \frac{(2\beta + \gamma)[\beta(2\beta + \gamma) - \gamma^2](\alpha - c)}{2\beta(\beta + \gamma)[(2\beta + \gamma)^2 - 4\gamma^2]} \; ,$$

leading to the market-clearing prices

$$p^{DQ} = c + \frac{4\beta^4 + 4\beta^3\gamma - 5\beta^2\gamma^2 - 3\beta\gamma^3 + 2\gamma^4}{2\beta(\beta + \gamma)[(2\beta + \gamma)^2 - 4\gamma^2]} \, (\alpha - c)$$

and firm profits

$$\pi^{DQ} = \frac{(4\beta^4 + 4\beta^3\gamma - 5\beta^2\gamma^2 - 3\beta\gamma^3 + 2\gamma^4)(2\beta + \gamma)[\beta(2\beta + \gamma) - \gamma^2]}{[2\beta(\beta + \gamma)[(2\beta + \gamma)^2 - 4\gamma^2]]^2} \, (\alpha - c)^2 \; .$$

Table 5 provides numerical results for delegated quantity competition (DQ) under different degrees of product substitutability.

Table 5: Delegated Quantity Competition ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
κ^{DQ}	0.0000	0.0227	0.0714	0.1324	0.2000
$p^{DQ} - c$	0.5000	0.3864	0.2857	0.1912	0.1000
q^{DQ}	0.2500	0.2045	0.1786	0.1618	0.1500
π^{DQ}	0.1250	0.0790	0.0510	0.0309	0.0150

In homogeneous as well as heterogeneous product markets ($0 < \gamma \leq \beta$) firm owners set positive weight parameters inducing an aggressive output expansion which leads to decreasing prices and profits. The bias in the compensation scheme is increasing in the degree of product substitutability so that this effect reaches its maximum in the limit case of homogeneous markets. However, the positive output effect of a strategically high weight parameter is dominated by the negative output effect of a lower degree of heterogeneity. Therefore, regardless of the strategic effect, increasing substitutability of products goes along with lower quantities, prices and firm profits.

Compared to the case of owner-controlled firms, the delegation of quantity decisions to managers leads to more production and hence to lower firm profits.

As is well-known from strategic market games, the sign of the strategic effect typically switches when quantity competition is replaced by price competition. The reason is that, in the case of substitute products, quantities are strategic substitutes whereas prices are strategic complements. In the mode of price competition, the performance-dependent manager payments $\psi_i = \pi_i + \kappa_i q_i$ amount to

$$\psi_i = \begin{cases} (p_1 - c + \kappa_1)(a - bp_1 + dp_2 + dp_3) & \text{for} \quad i = 1 \\ (p_2 - c + \kappa_2)(a - bp_2 + dp_1 + dp_3) & \text{for} \quad i = 2 \\ (p_3 - c + \kappa_3)(a - bp_3 + dp_1 + dp_2) & \text{for} \quad i = 3 \; . \end{cases} \tag{7}$$

As derived in Appendix B for the mode of price competition, the subgame perfect weights are

$$\kappa^{DP} = -\,\frac{(2\beta + 3\gamma)\gamma^2(\beta - \gamma)(\alpha - c)}{(\beta + \gamma)^2(4\beta^2 + 4\beta\gamma - 3\gamma^2)} \quad \leq \quad 0 \; .$$

The negative sign of the weight parameters indicates compensation schemes that induce managers to inoffensively increase prices, thereby relaxing the intensity of competition. Given these compensation contracts, the managers charge the equilibrium prices

$$p^{DP} = c \; + \; \frac{(4\beta^3 + 8\beta^2\gamma + 3\beta\gamma^2)(\beta - \gamma)(\alpha - c)}{(4\beta^2 + 4\beta\gamma - 3\gamma^2)2\beta(\beta + \gamma)} \; ,$$

leading to the production quantities

$$q^{DP} = \frac{[(4\beta^2 + 4\beta\gamma - 3\gamma^2)(\beta + \gamma)^2 - (2\beta^2 + \beta\gamma - 3\gamma^2)\gamma^2](\alpha - c)}{(4\beta^2 + 4\beta\gamma - 3\gamma^2)2\beta(\beta + \gamma)(\beta + 2\gamma)}$$

and firm profits

$$\pi^{DP} = \left[\frac{(\beta - \gamma)(4\beta^2 + 8\beta^2\gamma + 3\beta\gamma^2)(\alpha - c)}{2\beta(\beta + \gamma)(4\beta^2 + 4\beta\gamma - 3\gamma^2)}\right]$$

$$\left[\frac{[(4\beta^2+4\beta\gamma-3\gamma^2)(\beta+\gamma)^2-(2\beta^2+\beta\gamma-3\gamma^2)\gamma^2](\alpha-c)}{2\beta(\beta+\gamma)(\beta+2\gamma)(4\beta^2+4\beta\gamma-3\gamma^2)}\right].$$

In comparison to Table 5, Table 6 presents the results of delegated price competition (DP) under different degrees of product substitutability.

Table 6: Delegated Price Competition ($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
κ^{DP}	0.0000	-0.0171	-0.0370	-0.0367	0.0000
$p^{DP} - c$	0.5000	0.3857	0.2778	0.1571	0.0000
q^{DP}	0.2500	0.2048	0.1806	0.1686	0.1667
π^{DP}	0.1250	0.0790	0.0502	0.0265	0.0000

Except for the extreme cases of homogeneous and separated monopoly markets, the owners set negative weight parameters, inducing an inoffensive increase in the prices. The bias in the compensation schemes reaches its maximum at an intermediate degree of heterogeneity. Regardless of this non-monotonic relationship, an increasing substitutability of products is accompanied with decreasing prices and firm profits.

Even if delegation leads to lower profits in quantity competition and to higher profits in price competition, profits are still higher when firms compete in quantities, i.e. the precommitment effect of capacity installation is still at work.

The different results, derived for manager delegation and common ownership in isolation, lead to the question about the effects of a combination of intra-firm manager delegation on the one hand and inter-firm coordination of common owners on the other hand, i.e. the scenario of coordinated manager compensation.

5 Common Holdings and Coordinated Manager Compensation

Let us now again assume that firms 1 and 2 are commonly owned by institutional shareholders, while firm 3 is owned by independent shareholders. The common shareholders together constitute a decisive group of owners who have the power to design the compensation contracts for their managers. Under this ownership structure, the common owners of firms 1 and 2 have an incentive to coordinate when specifying their manager compensation contracts. This incentive will certainly cause a serious problem for antitrust authorities because it opens the attractive possibility for firm owners to indirectly collude.

In contrast to the previous section, the common owners of firms 1 and 2 now simultaneously maximize their joint profits π_1 and π_2 with respect to the contract variables κ_1 and κ_2, whereas the independent owners of firm 3 maximize the profit π_3.

As derived in Appendix C for the mode of quantity competition, in the subgame perfect equilibrium, the strategic owner decisions are

$$\kappa_{1,2}^{CDQ} = - \frac{(2\beta-\gamma)(\beta-\gamma)\gamma(4\beta^5+8\beta^4\gamma-3\beta^3\gamma^2-10\beta^2\gamma^3+3\gamma^5)(\alpha-c)}{2(\beta^2+\beta\gamma-\gamma^2)(8\beta^6+16\beta^5\gamma-6\beta^4\gamma^2-18\beta^3\gamma^3+2\beta^2\gamma^4+5\beta\gamma^5-\gamma^6)}$$
$$\kappa_3^{CDQ} = \frac{(2\beta-\gamma)\gamma^2(2\beta^3+2\beta^2\gamma-\beta\gamma^2-\gamma^3)(\alpha-c)}{2\beta(2\beta+\gamma)(2\beta^2+\beta\gamma-2\gamma^2)(\beta^2+\beta\gamma-\gamma^2)+(\beta-\gamma)\gamma^5} ,$$

implying the managers' quantity decisions

$$q_{1,2}^{CDQ} = \frac{\beta(2\beta^2+\beta\gamma-\gamma^2)(4\beta^5+8\beta^4\gamma-3\beta^3\gamma^2-10\beta^2\gamma^3+3\gamma^5)(\alpha-c)}{2(\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)[2\beta(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)(2\beta^2+\beta\gamma-2\gamma^2)+(\beta-\gamma)\gamma^5]} ,$$
$$q_3^{CDQ} = \frac{(2\beta+\gamma)[(2\beta^2+\beta\gamma-2\gamma^2)(4\beta^3+4\beta^2\gamma-\gamma^3)+\beta\gamma^4](\alpha-c)}{4(\beta+\gamma)[2\beta(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)(2\beta^2+\beta\gamma-2\gamma^2)+(\beta-\gamma)\gamma^5]} .$$

and hence the prices

$$p_{1,2}^{CDQ} = \alpha - (\beta+\gamma)q_{1,2}^{CDQ} - \gamma q_3^{CDQ} ,$$
$$p_3^{CDQ} = \alpha - \beta q_3^{CDQ} - 2\gamma q_{1,2}^{CDQ} .$$

and firm profits $\pi_i^{CDQ} = (p_i^{CDQ} - c)q_i^{CDQ}$, $i = 1, 2, 3$.

In the limit case of a homogeneous market ($\beta = \gamma$) the solution simplifies to $\kappa_{1,2}^{CDQ} = 0$, $\kappa_3^{CDQ} = (\alpha - c)/3$, $q_{1,2}^{CDQ} = (\alpha - c)/(6\beta)$, $q_3^{CDQ} = (\alpha - c)/(2\beta)$, $p_{1,2,3}^{CDQ} = c + (\alpha - c)/6$, $\pi_{1,2}^{CDQ} = (\alpha - c)^2/(36\beta)$, $\pi_3^{CDQ} = (\alpha - c)^2/(12\beta)$.[4]

[4]The zero value of $\kappa_{1,2}^{CDQ}$ in a homogeneous market only holds in the special scenario of a triopoly. In an oligopoly where m out of n firms are coordinated, this weight parameter can take positive as well as negative values, depending on the ownership structure (see Neus et al. 2020).

Table 7 summarizes the results for delegated quantity competition when firms 1 and 2 are coordinated via the compensation schemes (CDQ).

Table 7: Delegated Quantity Competition with Coordinated Firms
($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$\kappa_{1,2}^{CDQ}$	0.0000	-0.0688	-0.0730	-0.0444	0.0000
κ_3^{CDQ}	0.0000	0.0233	0.0787	0.1657	0.3333
$p_{1,2}^{CDQ} - c$	0.5000	0.4361	0.3652	0.2814	0.1667
$p_3^{CDQ} - c$	0.5000	0.3966	0.3146	0.2394	0.1667
$q_{1,2}^{CDQ}$	0.2500	0.1836	0.1461	0.1185	0.0833
q_3^{CDQ}	0.2500	0.2099	0.1966	0.2026	0.2500
$\pi_{1,2}^{CDQ}$	0.1250	0.0800	0.0533	0.0333	0.0139
π_3^{CDQ}	0.1250	0.0832	0.0619	0.0485	0.0417

In sharp contrast to the quantity delegation model without owner coordination, the common owners now induce the managers of firms 1 and 2 to act inoffensively ($\kappa_1^{CDQ} = \kappa_2^{CDQ} < 0 < \kappa^{DQ}$), thereby inducing lower quantities, whereas the independent owners of firm 3 give their manager an incentive to act even more aggressively ($\kappa_3^{CDQ} > \kappa^{DQ}$) by a further extension of production. The coordinated firms slightly increase their profits while the outside firm experiences an even higher increase of its profit.

The coordination between the common shareholders leads to a less intensive competition between the firms because the strategic effects of manager compensation are mitigated when they are internalized by the coordinated firms.

As derived in Appendix D for the mode of price competition, in the subgame perfect equilibrium, the strategic owner decisions are

$$\kappa_{1,2}^{CDP} = -\frac{\beta[4(\beta+\gamma)^2 - 3\gamma^2](2\beta+3\gamma)(\beta+2\gamma)\gamma(\beta-\gamma)(\alpha-c)}{(\beta+\gamma)[[(\beta+\gamma)(2\beta+\gamma) - 2\gamma^2]4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2) - 2\gamma^5(\beta+2\gamma)]}$$

$$\kappa_3^{CDP} = -\frac{[2\gamma^2(\beta+2\gamma) + 4(\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)]\gamma^2(2\beta+3\gamma)(\beta-\gamma)(\alpha-c)}{(\beta+\gamma)[[(\beta+\gamma)(2\beta+\gamma) - 2\gamma^2]4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2) - 2\gamma^5(\beta+2\gamma)]}$$

implying the managers' price decisions

$$p_{1,2}^{CDP} = c + \frac{\beta(2\beta+3\gamma)(4\beta^2+8\beta\gamma+\gamma^2)(\beta+\gamma)(\beta-\gamma)(\alpha-c)}{4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)[(\beta+\gamma)(2\beta+\gamma)-2\gamma^2]-2\gamma^5(\beta+2\gamma)}\ ,$$

$$p_{3}^{CDP} = c + \frac{(2\beta+\gamma)(2\beta+3\gamma)[2(\beta+\gamma)^3-2\beta^2\gamma-5\beta\gamma^2-2\gamma^3](\beta-\gamma)(\alpha-c)}{4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)[(\beta+\gamma)(2\beta+\gamma)-2\gamma^2]-2\gamma^5(\beta+2\gamma)}\ .$$

Inserting the prices into the demand functions (4) gives the production levels[5]

$$q_{1,2}^{CDP} = \frac{(\beta-\gamma)(\alpha-c)-\beta(p_{1,2}^{CDP}-c)+\gamma(p_3^{CDP}-c)}{(\beta-\gamma)(\beta+2\gamma)}$$

$$q_{3}^{CDP} = \frac{(\beta-\gamma)(\alpha-c)-(\beta+\gamma)(p_3^{CDP}-c)+2\gamma(p_{1,2}^{CDP}-c)}{(\beta-\gamma)(\beta+2\gamma)}$$

and finally the firm profits $\pi_i^{CDP} = (p_i^{CDP}-c)q_i^{CDP}$, $i = 1, 2, 3$.

In comparison to Table 7, Table 8 summarizes the results for delegated price competition when firms 1 and 2 are coordinated via the compensation schemes (CDP).

[5] In the limit case of a homogeneous market, where $\gamma = \beta$ and $p_{1,2}^{CDP} = p_3^{CDP} = c$, these expressions for the quantity equations are obviously not defined. Therefore, we have to explicitly substitute for the prices in terms of the preference parameters only and then take limits for $\gamma \to \beta$. As can be derived after tedious calculations, the quantities approach $q_{1,2}^{CDP} = 13(\alpha-c)/(54\beta)$ and $q_3^{CDP} = 28(\alpha-c)/(54\beta)$, so that the total production $2q_{1,2}^{CDP} + q_3^{CDP} = (\alpha-c)/\beta$ indeed equals the market demand at competitive prices equal to the marginal cost c. But, as in Section 3, there is a quantity redistribution from the coordinated firms to the non-coordinated one.

Table 8: Delegated Price Competition with Coordinated Firms
($\alpha - c = 1$, $\beta = 2$)

γ	0	0.5	1	1.5	2
$\kappa_{1,2}^{CDP}$	0.0000	-0.1045	-0.1583	-0.1447	0.0000
κ_3^{CDP}	0.0000	-0.0176	-0.0477	-0.0457	0.0000
$p_{1,2}^{CDP} - c$	0.5000	0.4354	0.3561	0.2363	0.0000
$p_3^{CDP} - c$	0.5000	0.3959	0.3058	0.1956	0.0000
$q_{1,2}^{CDP}$	0.2500	0.1838	0.1484	0.1283	0.1204
q_3^{CDP}	0.2500	0.2102	0.1987	0.2098	0.2593
$\pi_{1,2}^{CDP}$	0.1250	0.0800	0.0528	0.0303	0.0000
π_3^{CDP}	0.1250	0.0832	0.0608	0.0410	0.0000

The modified incentive structure induces managers to change their price policy. The prices of the coordinated firms strongly increase from $p_{1,2}^{DP}$ to $p_{1,2}^{CDP}$, whereas the price of the outside firm 3 only slightly increases from p_3^{DP} to p_3^{CDP}. As in the mode of quantity competition, the coordination leads to a less intense competition and higher profits. Again the profits of the two coordinated firms only slightly increase from $\pi_{1,2}^{DP}$ to $\pi_{1,2}^{CDP}$, while the profit of the outside firm 3 increases up to π_3^{CDP}.

6 The Tragedy of the Common Holdings

We define the social welfare W in a market as the sum of the consumer surplus $CS = U - q_0 - p_1q_1 - p_2q_2 - p_3q_3$ and the producer surplus $\Pi = \sum_{i=1}^{3} \pi_i$, where the net profits $\Pi - 3\bar{s}$ are realized by the firm owners and the amount $3\bar{s}$ is the aggregate payment for the managers. Given the utility function (1) and the inverse demand functions (2), we obtain the consumer surplus $CS = q_1^2 + q_2^2 + q_3^2 + q_1q_2 + q_1q_3 + q_2q_3$, so that the social welfare adds up to $W = CS + \sum_{i=1}^{3} \pi_i$.

Table 9 summarizes the marker-performance results for the eight considered scenarios with an intermediate degree of heterogeneity where $\gamma = 1 < \beta = 2$. However, it is worth noting that the presented ranking pattern holds in general. a

Table 9: Welfare Measures in the Considered Scenarios
$(\alpha - c = 1, \beta = 2, \gamma = 1)$

	No Coordination		Common Owner Coordination	
	Owner Control	Delegation	Owner Control	Delegation
Quantity C.				
$\pi_{1,2}$	0.0556	0.0510	0.0558	0.0533
π_3	0.0556	0.0510	0.0661	0.0619
CS	0.1667	0.1913	0.1384	0.1601
W	0.3333	0.3444	0.3161	0.3287
Price C.				
$\pi_{1,2}$	0.0469	0.0502	0.0506	0.0528
π_3	0.0469	0.0502	0.0558	0.0608
CS	0.2109	0.1956	0.1829	0.1645
W	0.3516	0.3461	0.3399	0.3310

Coordination leads to higher firm profits but a lower consumer surplus and social welfare, no matter if there is quantity or price competition. While switching from direct to indirect coordination reduces the welfare loss associated with firm coordination in the mode of quantity competition, the welfare loss even increases by delegating operational decision to the management in mode of price competition. This is the tragedy of the common holdings.

7 Summary and Conclusion

Many product markets are characterized by firm ownership structure with several but not all firms commonly held by the same institutional investors. This gives the common owners an incentive to coordinate their decisions. This paper studied the consequences of common owner coordination by analyzing heterogeneous triopoly markets in which two out of three firms are owned by the same decisive group of common shareholders.

In order to derive rather general results, we analyzed markets with different basic conditions on the production and the demand side. On the production side, we referred to the interpretation that quantity competition is a reduced form of a two-stage capacity-price-setting game where capacity constraints are strictly binding. In contrast to such hard capacity constraints, negligible constraints do not allow for capacity precommitment and the game converges to a standard game of price competition. According to this interpretation, price competition indicates markets with fairly flat marginal production costs, whereas quantity competition reflects markets with sharply rising marginal costs.

On the demand side, we concentrated on the product substitutability from the consumers' perspective. We allowed for different degrees of market heterogeneity, including the extreme cases of homogeneous markets and completely separated monopoly markets. For the limit case of homogeneous markets, coordination leads to the remarkable result that even though firms charge identical prices, market shares are shifted from the coordinated firms to the outside firm, regardless of whether there is price or quantity competition and of whether there is direct or indirect coordination.

Coordination per se decreases social welfare. Externalities caused by competition are at least partly internalized by coordinated operational decisions or by coordinated designs of managerial compensation contracts. Even though investment firms compete for the investors' capital, They have no conflicting interests regarding the behavior of their portfolio firms. Therefore, they share the same incentives when designing the manager compensation contracts. The anti-competitive effects are substantial, as Azar et al. (2018) and Azar et al. (2021) have shown for the airline and the banking markets, respectively.

As it is well known, strategic delegation generally leads to a fiercer competition in product markets with quantity competition because managers are induced to act more aggressively in their output decisions. This result continues to hold when there is coordination between commonly owned firms, i.e., the welfare reducing effects of coordination are mitigated if firms are coordinated indirectly via manager compensation contracts instead of a direct coordination of the quantity decisions.

In the mode of price competition, delegation typically decreases social welfare because managers are incentivized to act less aggressively in setting prices than owners would. This effect transfers to the coordination scenario. While coordination is generally socially harmful, it is even more harmful if it is done indirectly via manager compensation contracts instead of a direct coordination of the price decisions: the tragedy of common holdings.

Antitrust authorities are certainly monitoring the market behavior of common holdings. Therefore, shareholders are interested in avoiding the strict supervision of collusive activities by indirectly coordinating via the less transparent strategy of management compensation. So far, this sophisticated and rather indirect form of collusion is hardly prevented by the antitrust authorities. Without doubt, the problem of common ownership should stay high on the agenda for competition law and policy.

Appendix

A Delegation and Quantity Competition

In the second stage of the quantity delegation game, the managers decide on quantities q_i, given the contract parameters κ_i. The maximization of the performance-dependent payments (6) with respect to the quantities leads to a system of three linear first-order conditions which can be solved in terms of the quantities

$$q_1 = \frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_1 - \gamma\kappa_2 - \gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)} ,$$

$$q_2 = \frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_2 - \gamma\kappa_1 - \gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)} ,$$

$$q_3 = \frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_3 - \gamma\kappa_1 - \gamma\kappa_2}{2(2\beta - \gamma)(\beta + \gamma)} .$$

Substitution into (3) gives the reduced-form gross profit functions

$$\pi_1 = \left[\frac{\beta(2\beta - \gamma)(\alpha - c) - [\beta(2\beta + \gamma) - 2\gamma^2]\kappa_1 - \beta\gamma\kappa_2 - \beta\gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)}\right] \cdot \left[\frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_1 - \gamma\kappa_2 - \gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)}\right] ,$$

$$\pi_2 = \left[\frac{\beta(2\beta - \gamma)(\alpha - c) - [\beta(2\beta + \gamma) - 2\gamma^2]\kappa_2 - \beta\gamma\kappa_1 - \beta\gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)}\right] \cdot \left[\frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_2 - \gamma\kappa_1 - \gamma\kappa_3}{2(2\beta - \gamma)(\beta + \gamma)}\right] ,$$

$$\pi_3 = \left[\frac{\beta(2\beta - \gamma)(\alpha - c) - [\beta(2\beta + \gamma) - 2\gamma^2]\kappa_3 - \beta\gamma\kappa_1 - \beta\gamma\kappa_2}{2(2\beta - \gamma)(\beta + \gamma)}\right] \cdot \left[\frac{(2\beta - \gamma)(\alpha - c) + (2\beta + \gamma)\kappa_3 - \gamma\kappa_1 - \gamma\kappa_2}{2(2\beta - \gamma)(\beta + \gamma)}\right] . \tag{A.1}$$

In the first stage of the game, since managers' total payment $s_i = \bar{s}$ is fixed, the firm owners maximize these reduced-form profit functions with respect to the contract parameters κ_i. In the subgame perfect Nash equilibrium, the first-order conditions consist of the system of linear reaction functions

$$\kappa_1 = \frac{[(2\beta-\gamma)(\alpha-c)-\gamma\kappa_2-\gamma\kappa_3]\gamma^2}{(2\beta+\gamma)[\beta(2\beta+\gamma)-2\gamma^2]} ,$$
$$\kappa_2 = \frac{[(2\beta-\gamma)(\alpha-c)-\gamma\kappa_1-\gamma\kappa_3]\gamma^2}{(2\beta+\gamma)[\beta(2\beta+\gamma)-2\gamma^2]} ,$$
$$\kappa_3 = \frac{[(2\beta-\gamma)(\alpha-c)-\gamma\kappa_1-\gamma\kappa_2]\gamma^2}{(2\beta+\gamma)[\beta(2\beta+\gamma)-2\gamma^2]} ,$$

that can be solved in terms of the strategic owner decisions

$$\kappa^{DQ} = \frac{(2\beta-\gamma)\gamma^2(\alpha-c)}{\beta[(2\beta+\gamma)^2-4\gamma^2]} .$$

B Delegation and Price Competition

In the second stage of the price delegation game, the managers decide on the prices p_i, given the compensation contract parameters κ_i. The maximization of the performance-dependent payments (7) with respect to the prices leads to a system of three linear first-order conditions which can be solved in terms of the prices

$$p_1 = c + \frac{(2b+d)[a-(b-2d)c]-b(2b-d)\kappa_1-bd\kappa_2-bd\kappa_3}{2(b-d)(2b+d)} ,$$

$$p_2 = c + \frac{(2b+d)[a-(b-2d)c]-b(2b-d)\kappa_2-bd\kappa_1-bd\kappa_3}{2(b-d)(2b+d)} ,$$

$$p_3 = c + \frac{(2b+d)[a-(b-2d)c]-b(2b-d)\kappa_3-bd\kappa_1-bd\kappa_2}{2(b-d)(2b+d)} .$$

Substitution into (5) gives the reduced-form gross profit functions

$$\pi_1 = \left[\frac{(2b+d)[a-(b-2d)c] - b(2b-d)\kappa_1 - bd\kappa_2 - bd\kappa_3}{2(b-d)(2b+d)}\right] \cdot \left[\frac{(2b+d)b[a-(b-2b)c] + b[(2b-d)b-2d^2]\kappa_1 - b^2d\kappa_2 - b^2d\kappa_3}{2(b-d)(2b+d)}\right] ,$$

$$\pi_2 = \left[\frac{(2b+d)[a-(b-2d)c] - b(2b-d)\kappa_2 - bd\kappa_1 - bd\kappa_3}{2(b-d)(2b+d)}\right] \cdot \left[\frac{(2b+d)b[a-(b-2b)c] + b[(2b-d)b-2d^2]\kappa_2 - b^2d\kappa_1 - b^2d\kappa_3}{2(b-d)(2b+d)}\right] ,$$

$$\pi_3 = \left[\frac{(2b+d)[a-(b-2d)c] - b(2b-d)\kappa_3 - bd\kappa_1 - bd\kappa_2}{2(b-d)(2b+d)}\right] \cdot \left[\frac{(2b+d)b[a-(b-2b)c] + b[(2b-d)b-2d^2]\kappa_3 - b^2d\kappa_1 - b^2d\kappa_2}{2(b-d)(2b+d)}\right] . \tag{B.1}$$

In the first stage of the game, the firm owners maximize these reduced-form profit functions with respect to the contract parameters κ_i. In the subgame perfect Nash equilibrium, the first-order conditions consist of the reaction functions

$$\kappa_1 = \frac{-(2b+d)d^2[a-(b-2d)c] + bd^3\kappa_2 + bd^3\kappa_3}{b(2b-d)[b(2b-d)-2d^2]} ,$$
$$\kappa_2 = \frac{-(2b+d)d^2[a-(b-2d)c] + bd^3\kappa_1 + bd^3\kappa_3}{b(2b-d)[b(2b-d)-2d^2]} ,$$
$$\kappa_3 = \frac{-(2b+d)d^2[a-(b-2d)c] + bd^3\kappa_1 + bd^3\kappa_2}{b(2b-d)[b(2b-d)-2d^2]} ,$$

which can be solved in terms of the strategic owner decisions

$$\kappa^{DP} = -\frac{(2b+d)d^2[a-(b-2d)c]}{b^2[4b(b-d)-3d^2]} = -\frac{(2\beta+3\gamma)\gamma^2(\beta-\gamma)(\alpha-c)}{(\beta+\gamma)^2(4\beta^2+4\beta\gamma-3\gamma^2)} .$$

C Coordinated Delegation and Quantity Competition

In this scenario, the common owners of firms 1 and 2 simultaneously maximize their joint reduced-form profits π_1 and π_2 in (A.1) with respect to the contract variables κ_1 and κ_2, whereas the independent owners of firm 3 maximize the profit π_3 as before. The corresponding first-order conditions consist of the system of reaction functions

$$\kappa_1 = \frac{-(2\beta-\gamma)(\beta-\gamma)\gamma(\alpha-c) - 2\gamma^3\kappa_2 + (\beta-\gamma)\gamma^2\kappa_3}{(2\beta+\gamma)(2\beta^2+\beta\gamma-2\gamma^2) - \beta\gamma^2} ,$$

$$\kappa_2 = \frac{-(2\beta-\gamma)(\beta-\gamma)\gamma(\alpha-c) - 2\gamma^3\kappa_1 + (\beta-\gamma)\gamma^2\kappa_3}{(2\beta+\gamma)(2\beta^2+\beta\gamma-2\gamma^2) - \beta\gamma^2} ,$$

$$\kappa_3 = \frac{[(2\beta-\gamma)(\alpha-c) - \gamma\kappa_1 - \gamma\kappa_2]\gamma^2}{(2\beta+\gamma)(2\beta^2+\beta\gamma-2\gamma^2)} ,$$

that are solved in terms of the subgame perfect contract variables

$$\kappa_{1,2}^{CDQ} = -\frac{(2\beta-\gamma)(\beta-\gamma)\gamma(4\beta^5+8\beta^4\gamma-3\beta^3\gamma^2-10\beta^2\gamma^3+3\gamma^5)(\alpha-c)}{2(\beta^2+\beta\gamma-\gamma^2)(8\beta^6+16\beta^5\gamma-6\beta^4\gamma^2-18\beta^3\gamma^3+2\beta^2\gamma^4+5\beta\gamma^5-\gamma^6)} ,$$

$$\kappa_3^{CDQ} = \frac{(2\beta-\gamma)\gamma^2(2\beta^3+2\beta^2\gamma-\beta\gamma^2-\gamma^3)(\alpha-c)}{2\beta(2\beta+\gamma)(2\beta^2+\beta\gamma-2\gamma^2)(\beta^2+\beta\gamma-\gamma^2)+(\beta-\gamma)\gamma^5} .$$

D Coordinated Delegation and Price Competition

In the case of price competition, the common shareholders of the firms 1 and 2 maximize their joint reduced-form profits π_1 and π_2 in (B.1) with respect to the contract variables κ_1 and κ_2 while the independent owners of firm 3 maximize the profit π_3 only. The corresponding first-order conditions consist of the system of reaction functions

$$\kappa_1 = \frac{-2d(2b+d)(b+d)[a-(b-2d)c] + 4bd^3\kappa_2 + 2bd^2(b+d)\kappa_3}{b[8b^2(b-d) - 4d^2(2b-d)]} ,$$

$$\kappa_2 = \frac{-2d(2b+d)(b+d)[a-(b-2d)c] + 4bd^3\kappa_1 + 2bd^2(b+d)\kappa_3}{b[8b^2(b-d) - 4d^2(2b-d)]} ,$$

$$\kappa_3 = \frac{-(2b+d)d^2[a-(b-2d)c] + bd^3\kappa_1 + bd^3\kappa_2}{b(2d-d)[b(2b-d) - 2d^2]} ,$$

that are solved in terms of the subgame perfect contract variables

$$\kappa_{1,2}^{CDP} = -\frac{(b-d)(4b^2-3d^2)(2b+d)(b+d)d[a-(b-2d)c]}{b[[b(2b-d)-2d^2]4b(2b-d)(b^2-d^2-bd)-2d^5(b+d)]}$$
$$= -\frac{\beta[4(\beta+\gamma)^2-3\gamma^2](2\beta+3\gamma)(\beta+2\gamma)\gamma(\beta-\gamma)(\alpha-c)}{(\beta+\gamma)[[(\beta+\gamma)(2\beta+\gamma)-2\gamma^2]4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)-2\gamma^5(\beta+2\gamma)]},$$

$$\kappa_{3}^{CDP} = -\frac{[2d^2(b+d)+4b(b^2-d^2-bd)]d^2(2b+d)[a-(b-2d)c]}{b[[b(2b-d)-2d^2]4b(2b-d)(b^2-bd-d^2)-2d^5(b+d)]}$$
$$= -\frac{[2\gamma^2(\beta+2\gamma)+4(\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)]\gamma^2(2\beta+3\gamma)(\beta-\gamma)(\alpha-c)}{(\beta+\gamma)[[(\beta+\gamma)(2\beta+\gamma)-2\gamma^2]4(\beta+\gamma)(2\beta+\gamma)(\beta^2+\beta\gamma-\gamma^2)-2\gamma^5(\beta+2\gamma)]}.$$

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