

CENTRALIZATION VERSUS DECENTRALIZATION: AN APPLICATION TO PRICE SETTING BY A MULTI-MARKET FIRM

Ricardo Alonso

University of Southern California

Wouter Dessein

University of Chicago, Toulouse School
of Economics

Niko Matouschek

Northwestern University, University of
Texas at Austin

Abstract

This paper compares centralized and decentralized price setting by a firm that sells a single product in two markets, but is constrained to set one price (e.g., due to arbitrage). Each market is characterized by a different linear demand function, and demand conditions are privately observed by a local manager. This manager only cares about profits in his own market and, as a result, communicates his information strategically. Our main results link organizational design to market demand. First, if pricing is decentralized, it is always delegated to the manager who faces the flattest inverse demand function, regardless of the size of market demand. Second, even when pricing can be allocated to an unbiased headquarters, decentralization is optimal when markets differ sufficiently in how flat the inverse demand functions are. Finally, decentralization is more likely when, in expectations, local managers disagree more about prices. (JEL: D23, D83, L23)

1. Introduction

When discussing issues such as pricing by a monopolist or oligopolistic firm, economic textbooks typically assume that firms act as profit maximizers. In contrast, much recent economic research has focused on agency problems that may push the managers of a firm away from profit maximization and on how organizations are optimally designed to mitigate these problems. Perhaps surprisingly, at least given the historic importance of price theory, price elasticities or product market competition do not play a role in most of these theories. The aim of this paper is to link one of the most basic questions in organizational economics—*Should decision-making be centralized or delegated?*—with one of the most basic questions in price theory—*How is pricing affected by demand conditions?*

Acknowledgments:

E-mail addresses: Alonso: ricardo.alonso@marshall.usc.edu; Dessein: wouter.dessein@chicagosb.edu; Matouschek: n-matouschek@kellogg.northwestern.edu

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Ever since Hayek (1945), economists have invoked “local knowledge” as a reason to decentralize decision-making. In a world in which technological advances have all but eliminated communication costs, one may wonder whether local knowledge still matters. In response to this, Dessein (2002) and Alonso, Dessein, and Matouschek (forthcoming) have proposed an informational rationale for decentralization that does not rely on physical communication constraints. As they show, if a principal cannot commit to a formal mechanism to elicit information, decentralization to biased but better-informed agents is often optimal because this avoids agents distorting their information in order to influence decision-making. This paper builds on these insights to analyze whether pricing decisions are optimally made by an unbiased headquarters that bases its decision on information communicated by local division managers, or whether pricing should be delegated. In particular, we are interested in how the shape of the demand function faced by each division may affect whether or not pricing decisions are decentralized.

In our model, a firm sells a product in two markets but can only charge one price because of arbitrage by retailers or consumers, legal constraints on price discrimination, or a “most favored customer” clause. The two markets differ in their (linear) demand, and demand conditions are privately observed by a local manager who cares only about profits in his market (e.g., as a result of career concerns). Finally, the firm can commit only to an *ex ante* allocation of the pricing decision. Our results then link organization design with the shape of the demand function:

Fn 1

- (i) Conditional on decentralization, the pricing decision is always delegated to the manager who faces the market with the flattest demand curve, even if that market is much smaller (i.e., the intercept is smaller).¹
- (ii) If both (inverse) demand functions have the same slope, then pricing is always centralized.
- (iii) If the difference between the slopes of the demand function is beyond a threshold, then it is always optimal to decentralize pricing to the division with the flattest demand function.
- (iv) When division managers differ more in their preferred price, decentralization is more likely.

2. The Model

A firm produces one good at zero costs and sells it in two markets. In each market the firm faces uncertainty about the demand conditions. In particular, the inverse demand function in market $j = 1, 2$ is given by $p_j = a_j - b_j q_j$, where a_j is

1. The only restriction is that it must be optimal to sell in both markets.

independently drawn from a uniform distribution with support $[\mu_j - s, \mu_j + s]$, with $\mu_j - s > 0$ and $(\mu_1 - \mu_2)^2 < s^2$.² The slopes of the inverse demand functions satisfy $b_2 \geq b_1 > 0$. As a result of arbitrage, legal restrictions on price discrimination or contractual commitments to customers (such as most favored customer clauses), the firm needs to set the same price in both markets: $p_1 = p_2 = p$. The profits in market $j = 1, 2$ are then given by $\pi_j = pq_j$. **Fn 2**

The firm consists of two operating divisions and, potentially, one headquarter division. Each division is run by one manager. Manager 1 is in charge of the first market and privately observes the realization of a_1 ; manager 2 is in charge of the second market and privately observes the realization of a_2 . Manager HQ is in charge of headquarters and observes neither a_1 nor a_2 . Manager $j = 1, 2$ cares only about the profits π_j of division j , for example, owing to (unmodelled) career concerns.³ Manager HQ, in contrast, cares equally about both divisions and thus maximizes $\pi_1 + \pi_2$. **Fn 3**

We follow the property rights literature (Grossman and Hart 1986) in assuming that contracts are highly incomplete. In particular, the organization commits only to an ex ante allocation of the right to make the pricing decision.⁴ There are three possible allocations of the decision right: Under centralization, manager HQ has the right to make the decision; under decentralization- j , for $j = 1, 2$, manager j has the right to make the decision. Once the decision right has been allocated, it cannot be transferred before the decision is made. **Fn 4**

The lack of commitment implies that the decision makers are not able to commit to paying transfers that depend on the information they receive or to make their decisions depend on such information in different ways. Communication therefore takes the form of an informal mechanism: cheap talk. For simplicity we assume that this informal communication occurs in one round of communication. In particular, under centralization, managers 1 and 2 simultaneously send messages $m_1 \in M_1$ and $m_2 \in M_2$ to headquarters. Because division managers do not care about each other's profits—nor thus about each other's private information—communication plays no role under decentralization- j , for $j = 1, 2$.

2. The latter assumption ensures that the variance of the intercepts $\sigma^2 = s^3/3$ is sufficiently large relative to the average differences in the intercepts and facilitates analysis of the communication game that we shall describe.

3. Our results can be extended to the case where manager j ($j = 1, 2$) maximizes $\lambda\pi_j + (1-\lambda)\pi_i$, with $i \neq j$ and $\lambda \in (1/2, 1]$. The parameter λ then captures how biased each division manager is towards his own division's profits. Although a smaller bias favors decentralization, results are qualitatively similar as long as $\lambda > 1/2$.

4. Internal contracting on pricing may be difficult as courts are often unwilling to interfere with internal firm matters. Negotiating a mechanism with division managers may also result in costly bargaining or influence activities. As an empirical matter, Marin and Verdier (2007, Tables A1, A2) report that product pricing and price increases are among the most decentralized decisions in their sample of firms: only 4 out of 16 decisions (German firms) and 2 out of 13 decisions (Austrian firms) are more decentralized.

The timing of the game is as follows. First, the right to make the pricing decision is allocated so as to maximize the total expected profits $E[\pi_1 + \pi_2]$. Second, the division managers become informed about demand conditions in their markets; that is, they learn a_1 and a_2 , respectively. Third, if pricing is centralized, the division managers communicate with the decision maker. Finally, the pricing decision is made.

3. Decision-Making

We start by analyzing the decisions that headquarters would make if it were perfectly informed about the demand conditions in both markets. If manager HQ could observe a_1 and a_2 herself, then she would set the price that maximizes total firm profits:

$$\pi_1 + \pi_2 = \sum_{j=1,2} \left[\frac{a_j^2}{4b_j} - \frac{1}{b_j} \left(p - \frac{a_j}{2} \right)^2 \right]. \quad (1)$$

Observe that $a_j^2/4b_j$ are the maximum profits that can be earned in market $j = 1, 2$. In order to realize these profits, the price must be set equal to $a_j/2$, which is the optimal price for market j . If the firm sets a different price, then profits in market j are reduced by an amount equal to the second term on the right-hand side. In this sense the second term represents the cost of setting $p \neq a_j/2$. The price that maximizes (1) is given by

$$p^{FB} = \frac{1}{1 + b_1/b_2} \frac{a_1}{2} + \frac{b_1/b_2}{1 + b_1/b_2} \frac{a_2}{2},$$

where $b_1/b_2 \leq 1$. The first-best price is therefore a convex combination of the prices that maximize the respective profits in market 1 and market 2. Note that the weights that are put on the two prices depend on the slopes of the inverse demand functions b_1 and b_2 but not on the intercepts a_1 and a_2 . This feature, which will play an important role in what follows, is due to the fact that the cost of setting a price $p \neq a_j/2$ that is suboptimal for market j is decreasing in b_j but is independent of a_j . In particular, (1) shows that the smaller is b_j , the bigger is the cost of setting $p \neq a_j/2$.

Suppose now that manager HQ does not observe the demand conditions but retains the right to set prices. In this case manager HQ first receives messages m_1 and m_2 from the division managers and then sets the price that maximizes $E[\pi_1 + \pi_2 | m]$, where $m = (m_1, m_2)$. This price is given by

$$p^C = E[p^{FB} | m] = \frac{1}{1 + b_1/b_2} \frac{E[a_1 | m]}{2} + \frac{b_1/b_2}{1 + b_1/b_2} \frac{E[a_2 | m]}{2}. \quad (2)$$

Suppose next that the pricing decision is delegated to manager 1; then the chosen price maximizes π_1 and will thus be given by $p^{D_1} = a_1/2$. The discrepancy in the preferences between manager HQ and manager 1 is decreasing in $b_1/b_2 \leq 1$. Thus, the smaller is b_1/b_2 , the less biased is manager 1's decision-making. The analysis of decision making under decentralization 2 is analogous. In particular, $p^{D_2} = a_2/2$.

4. Strategic Communication

To understand strategic communication under centralization, we first analyze the division managers' incentives to misrepresent information under this organizational structure.

4.1. Incentives to Misrepresent

Consider the incentives of manager 1 to misrepresent his information under centralization. When setting the price, manager HQ puts less weight on setting it equal to $E[a_1 | m]/2$ and more weight on setting it equal to $E[a_2 | m]/2$ than manager 2 would like her to. Because $E[a_2] = \mu_2$, this implies that if manager 1 truthfully communicated his state then he would expect headquarters to set a price that is too close to $\mu_2/2$. In order to induce headquarters to set a price that is farther away from $\mu_2/2$, manager 1 therefore exaggerates the difference between his state and μ_2 —that is, he reports $m_1 > a_1$ if $a_1 > \mu_2$ and $m_1 < a_1$ if $a_1 < \mu_2$. Only if $a_1 = \mu_2$ does manager 1 report his state truthfully.

To see this more formally, let $v_1 = E[a_1 | m_1]$ be manager HQ's posterior belief about a_1 and suppose that manager 1 can simply choose any v_1 . Ideally, manager 1 would like manager HQ to have the posterior that maximizes his expected payoff, which is given by

$$v_1^* = \arg \max_{v_1} E[p^H q_1(p^H) | a_1], \quad (3)$$

where p^H depends on v_1 as defined in equation (2). In equilibrium, the expected value of the posterior of a_2 is equal to μ_2 . Assuming that this relationship holds, we can use equation (3) to obtain

$$v_1^* = a_1 + \frac{b_1}{b_2}(a_1 - \mu_2). \quad (4)$$

Because $b_1/b_2 \geq 0$, this confirms our intuition that manager 2 exaggerates the difference between his state a_1 and μ_2 . Only when $a_1 = \mu_2$ does he have an incentive to communicate truthfully. Moreover, it can be seen that his incentives

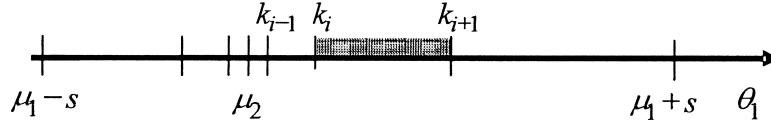


FIGURE 1. Communication equilibria under centralization.

to exaggerate are increasing in $|a_1 - \mu_2|$ and in b_1/b_2 . Essentially, the smaller is b_1/b_2 , the more responsive is price setting by headquarters to the information it receives about the demand conditions in the first market. Thus, the smaller is b_1/b_2 , the less manager 1 needs to exaggerate in order to influence decision making in his favor. The analysis of communication for manager 2 is analogous.

4.2. Communication Equilibria

We can now build on our understanding of the managers' incentives to misrepresent their information to characterize the communication equilibria. We provide an informal description of these equilibria in this section and relegate the formal characterization to the Appendix.

As in Crawford and Sobel (1982), all communication equilibria are interval equilibria in which the state spaces are partitioned into intervals and the division managers reveal only the interval to which their local conditions a_1 and a_2 belong. In this sense the managers' communication is noisy and information is lost. Consider manager 1's communication strategies, as illustrated in Figure 1. The states space $[\mu_1 - s, \mu_1 + s]$ is then partitioned into $N \geq 1$ intervals that are small close to $a_1 = \mu_2$ and grow larger as $|a_1 - \mu_2|$ increases. Moreover, the stronger the incentives to misrepresent information, as characterized by equation (4), the faster the intervals grow as $|a_1 - \mu_2|$ increases and hence the more noisy is communication. To see this, let k_i and k_{i+1} denote the endpoints of $(i + 1)$'s interval and suppose that this interval lies to the right of μ_2 . It can be shown that the size of this interval ($k_{i+1} - k_i$) is equal to the length of the preceding interval ($k_i - k_{i-1}$) plus $4(b_1/b_2)(k_i - \mu_2)$.

There are many equilibria of the communication game. Indeed, any number of partitions can be sustained in equilibrium. For the remainder of this paper we focus on the equilibrium for which the number of partitions approaches infinity.

LEMMA 1. *The most efficient communication equilibrium under centralization is the one in which the number of partitions goes to infinity. For this equilibrium, the residual variances are given by*

$$V_j^C \equiv E[(a_j - E[a_j|m_j])^2] = (\sigma^2 + (\mu_1 - \mu_2)^2) \frac{b_j/b_i}{3 + 4b_j/b_i},$$

where $i, j = 1, 2$ and $i \neq j$.

Proof. The proof of this proposition is analogous to those of Lemma 1 and Proposition 2 in Alonso, Dessein, and Matouschek (forthcoming). Details are available from the authors upon request. \square

The residual variance is therefore directly related to the division managers' incentives to misrepresent information as defined by equation (4). In particular, as b_1/b_2 increases, less information is communicated in equilibrium by manager 1 to headquarters and the residual variance regarding a_1 under centralization increases. At the same time, as b_1/b_2 increases, more information is communicated by manager 2. Because no informative communication takes place under decentralization, the residual variances are given by $V_1^{D1} = 0$ and $V_2^{D1} = \sigma^2$ under decentralization-1 and $V_1^{D2} = \sigma^2$ and $V_2^{D2} = 0$ under decentralization-2.

5. Organizational Performance

5.1. Overview

Now that we have analyzed decision-making and communication, we can work out the expected profits for each organizational structure.

LEMMA 2. *Let Π^* denote first-best expected profits. Then expected profits are given by*

$$\Pi^l = \Pi^* - A^l V_1^l - B^l V_2^l - C^l ((\mu_1 - \mu_2)^2 + 2\sigma^2) \quad (5)$$

for $l = C, D_1, D_2$, where A^l , B^l , and C^l are functions of b_1 , b_2 and λ only and are as defined in the proof.

We can use this proposition to compare the relative performance of the different organizational structures. For this purpose, it is useful to decompose the benefit $\Pi^{D1} - \Pi^C$ of delegating the pricing decision to manager 1.⁵ The first component is the gain in local information, which captures the increase in expected profits that is due to the pricing decision being based on better information about the demand conditions in market 1. Formally, the gain in local information is given by $A^C V_1^C \geq 0$. The second component is the loss of non local information. This component captures the reduction in expected profits that is due to the pricing decision being based on worse information about the demand conditions in market 2. Formally, the loss in non-local information is given by $B^C (\sigma^2 - V_2^C) \geq 0$. The third and final component is the loss of control, which is due to biased decision making by manager 1 and is given by $2C^{D1}\sigma^2 - (B^C - B^{D1})\sigma^2 \geq 0$. With this

Fn 5

5. The analysis for manager 2 is analogous.

decomposition in hand, we now turn to a pairwise comparison of the different organizational structures.

5.2. Decentralization-1 versus Decentralization-2

Suppose first that the slopes of the inverse demand functions are the same in both markets; that is, let $b_1/b_2 = 1$. In this case, headquarters is indifferent between delegating to manager 1 and delegating to manager 2. Observe that this is true even if one market is on average much larger than the other—that is, even if there are large differences between μ_1 and μ_2 . To understand this, recall from our discussion of the profit function (1) that the reduction in profits in market $j = 1, 2$ from setting the price different from the price that maximizes profits in market j is independent of a_j and depends only on b_j . Therefore, when $b_1 = b_2$, it is just as important to adapt the price to the conditions in a small market as to those in a larger market.

Although the two decentralized structures perform equally well when $b_1/b_2 = 1$, headquarters is better off delegating to manager 1 than to manager 2 whenever $b_1/b_2 < 1$, that is, whenever the inverse demand function in market 1 is flatter than that in market 2. This, too, can be understood by recalling our discussion of the profit function (1), which showed that the cost of not adapting prices to the demand conditions in market $j = 1, 2$ is decreasing in b_j . Thus, when $b_1/b_2 < 1$, it is more important to adapt the pricing decisions to the conditions in market 1 than to those in market 2.

PROPOSITION 1. *Delegating pricing to manager 1 is strictly preferred over delegating pricing to manager 2 if and only if $b_1 < b_2$, regardless of the value of μ_1 or μ_2 .*⁶

Fn 6

5.3. Centralization versus Decentralization-1

Before comparing the centralized with the decentralized structure, it is useful to define

$$R \equiv \frac{(\mu_1 - \mu_2)^2 + \sigma^2}{(\mu_1 - \mu_2)^2 + 2\sigma^2}.$$

Inspection of equation (5) shows that the relative performance of the different organizational structures depend on μ_1 , μ_2 , and σ^2 only through R .

6. Recall that we assume $\mu_i - s \geq 0$ and $(\mu_i - \mu_j)^2 \leq s^2$, which puts restrictions how small each market can be and on differences in demand. Proposition 1 further assumes that it is always optimal to sell in both markets.

Suppose first that $\mu_1 = \mu_2$, in which case $R = 1/2$. In this case, the relative performance of the different organizational structures depends only on the relative slopes b_1/b_2 and not on the variance σ^2 . In particular, decentralization-1 is then optimal whenever b_1/b_2 is sufficiently small. In contrast, centralization is optimal if the flatness in demand is fairly similar in both markets. Intuitively, delegating control to manager 1 results in a gain of local information (regarding market 1) but in a loss in non local information (regarding market 2) and a loss of control (because manager 1 is biased). For $b_1/b_2 = 1$, the gain in local information equals the loss in non local information. The additional loss of control under delegation then implies that centralization is optimal. When b_1/b_2 becomes smaller, however, this loss of control decreases because there is less discrepancy between the price preferred by headquarters and that by manager 1. Similarly, as b_1/b_2 becomes smaller, the gain in local information increases relative to the loss in non local information. Whenever b_1/b_2 is sufficiently small, decentralization is then optimal.

Suppose next that $\mu_1 \neq \mu_2$. The term $(\mu_1 - \mu_2)^2$ can then be seen as a *measure of conflict* between division managers regarding the preferred price p . From LEMMA 1 it follows that increased conflict between division managers reduces the quality of communication under centralization. As such, it both increases the gain of local information and reduces the loss in non local information associated with delegating to manager 1, two factors favoring delegation. On the downside, increased conflict also leads to more biased decision making by manager 1, which leads to an increase in the loss of control. As the next proposition shows, the increase in the gain of local information and the reduction in the loss of non local information dominates, so that more conflict always makes it weakly more attractive to delegate to manager 1.

PROPOSITION 2. *Delegating pricing to manager 1 is strictly preferred over centralized price setting if and only if $b_1/b_2 < \beta$, where $\beta \in (0, 1)$ is increasing in R and thus also in $(\mu_1 - \mu_2)^2$.*

6. Conclusion

This paper links organizational design to market demand. When markets are characterized by a flatter demand curve, getting the price “right” is more important. When local managers are better informed about local demand conditions, delegating pricing to the manager who faces the flattest demand may then be optimal, even if his market promises less in expected sales. Increased conflict between managers also makes decentralized pricing more likely. Intuitively, more conflict makes communication with headquarters more noisy and hence central decision making less effective. In our set up, the need for coordination is absolute: Only

one price can be charged. In future work, we aim to relax this assumption by analyzing price coordination between substitute or complement products.

Appendix

A communication equilibrium under centralization is characterized by (a) communication rules for the division managers and (b) by a decision rule and belief functions for manager HQ. The communication rule for manager $j = 1, 2$ specifies the probability of sending message $m_j \in M_j$ conditional on observing state a_j , and we denote this by $\mu_j(m_j | a_j)$. The decision rules map messages $m_1 \in M_1$ and $m_2 \in M_2$ into prices, and we denote it by $p(m)$. Finally, the belief functions are denoted by $g_j(a_j | m_j)$ for $j = 1, 2$ and give the probability of state a_j conditional on observing message m_j . We focus on perfect Bayesian equilibria of the communication subgame, which requires that: (i) communication rules are optimal for the division managers given the decision rule; (ii) the decision rule is optimal for manager HQ given the belief functions; and (iii) the belief functions are derived from the communication rules using Bayes' rule whenever possible.

PROPOSITION A.1. (Communication Equilibria). *For every positive integer \underline{N}_j and \bar{N}_j , for $j = 1, 2$, there exists at least one equilibrium $(\mu_1(\cdot), \mu_2(\cdot), p(\cdot), g_1(\cdot), g_2(\cdot))$, where*

1. $\mu_j(m_j | a_j)$ is uniform and supported on $[k_{j,i-1}, k_{j,i}]$ if $a_j \in (k_{j,i-1}, k_{j,i})$;
2. $g_j(a_j | m_j)$ is uniform and supported on $[k_{j,i-1}, k_{j,i}]$ if $m_j \in (k_{j,i-1}, k_{j,i})$;
- 3a. $k_{1,i+1} - k_{1,i} = k_{1,i} - k_{1,i-1} + 4b_1/b_2(k_{1,i} - \mu_2)$ for $i = 1, \dots, \bar{N}_1 - 1$, $k_{1,-i} - k_{1,-(i+1)} = k_{1,-(i-1)} - k_{1,-i} + 4b_1/b_2(\mu_2 - k_{1,i})$ for $i = 1, \dots, \underline{N}_1 - 1$;
- 3b. $k_{2,i+1} - k_{2,i} = k_{2,i} - k_{2,i-1} + 4b_2/b_1(k_{2,i} - \mu_1)$ for $i = 1, \dots, \bar{N}_2 - 1$, $k_{2,-i} - k_{2,-(i+1)} = k_{2,-(i-1)} - k_{2,-i} + 4b_2/b_1(\mu_1 - k_{2,i})$ for $i = 1, \dots, \underline{N}_2 - 1$,
- 3c. $k_{1,-\underline{N}_1} = k_{2,-\underline{N}_2} = \mu - s$, $k_{1,\bar{N}_1} = k_{2,\bar{N}_2} = \mu + s$, $k_{1,0} = \mu_2$ and $k_{2,0} = \mu_1$;
4. $p(m) = p^H$, where p^H is given by equation (2).

Moreover, all other finite equilibria have relationships between a_1 and a_2 as well as manager HQ's choice of p that are the same as those in this class for some value of \underline{N}_1 , \underline{N}_2 , \bar{N}_1 , and \bar{N}_2 ; they are therefore economically equivalent.

Proof. The proof of this proposition is analogous to that of Proposition 1 in Alonso, Dessein, and Matouschek (forthcoming). Details are available from the authors upon request. \square

Proof of Lemma 2. Substituting $p = p^{Dj}$ ($j = 1, 2$) into equation (1) and taking expectations yields

$$\Pi^{Dj} = \Pi^* - \frac{b_j}{4b_i(b_1 + b_2)}((\mu_1 - \mu_2)^2 + 2\sigma^2) \quad \text{for } i = 1, 2, i \neq j.$$

Therefore, $A^{Dj} = B^{Dj} = 0$ and $C^{Dj} = b_j/(4b_i(b_1 + b_2))$.

Similarly, substituting $p = p^H$ into (1) and taking expectations gives, after some cumbersome manipulations,

$$\Pi^H = \Pi^* - \frac{b_2}{4b_1(b_1 + b_2)}V_1^C - \frac{b_1}{4b_2(b_1 + b_2)}V_2^C.$$

Thus $A^C = b_2/[4b_1(b_1 + b_2)]$, $B^C = b_1/(4b_2(b_1 + b_2))$, and $C^C = 0$. \square

Proof of Proposition 1. From Lemma 2 it follows that

$$\Pi^{D1} - \Pi^{D2} = \frac{b_2 - b_1}{4b_1b_2}((\mu_1 - \mu_2)^2 + 2\sigma^2).$$

\square

Proof of Proposition 2. From Lemma 2 it follows that

$$\Pi^H - \Pi^{D1} = \frac{(\mu_1 - \mu_2)^2 + 2\sigma^2}{4(b_1 + b_2)} \left[(b_1/b_2) - 2R \frac{3(b_1/b_2) + 2(b_1/b_2)^2 + 2}{(3(b_1/b_2) + 4)(4(b_1/b_2) + 3)} \right].$$

The term in brackets is negative at $b_1/b_2 = 0$, positive at $b_1/b_2 = 1$, and strictly increasing in b_1/b_2 . Hence there exists a unique $\beta \in (0, 1)$ such that $\Pi^H - \Pi^{D1} < 0$ if $b_1/b_2 < \beta$, $\Pi^H - \Pi^{D1} = 0$ if $b_1/b_2 = \beta$, and $\Pi^H - \Pi^{D1} > 0$ if $b_1/b_2 > \beta$. Moreover, it is easily shown that β is increasing in R . \square

References

- Alonso, Ricardo, Wouter Dessein, and Niko Matouschek (2008). "When Does Coordination Require Centralization?" *American Economic Review*.
- Crawford, Vincent, and Joel Sobel (1982). "Strategic Information Transmission." *Econometrica*, 50, 1431–1445.
- Dessein, Wouter (2002). "Authority and Communication in Organizations." *Review of Economic Studies*, 69, 811–838.
- Grossman, Sanford, and Oliver Hart (1986). "The Costs and Benefits of Ownership: A Theory of Vertical and Lateral Integration." *Journal of Political Economy*, 94, 691–719.
- Hayek, Friedrich (1945). "The Use of Knowledge in Society." *American Economic Review*, 35(4), 519–530.
- Marin, Dalia, and Thierry Verdier (2007). "Corporate Hierarchies and the Size of Nations: Theory and Evidence." Working paper, University of Munich.