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**Decentralization and the Management of
Competition**

Diego Rodríguez
Universitat Pompeu Fabra
and

Dimitri Vayanos
Stanford Business School

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Abstract

This paper studies the costs and the benefits of decentralizing decision-making authority to competing divisions of a firm. We argue that when a division is given the right to market its product to customers of the other division, its manager has an incentive to increase product quality. At the same time divisions locate their products too close together. We find that top management may or may not want to restrict competition among divisions and show that even if competition is desirable, it may not be credible due to top management's temptation to intervene "ex-post".

2.1 Introduction.

Almost any large firm is a multiproduct firm. Some of its products are, in addition, horizontally or vertically differentiated i.e. are targeted to different customers but are at the same time close substitutes for some of these customers. The design and pricing of these products require thus considerable coordination among the firm's units.

Lack of coordination in product design was a major concern of top management at GM, before the radical reform of the company in the early 20's.¹ According to Sloan [8], GM was extremely decentralized and was offering, as a result, too many competing products.

In the middle [segment of the market], where we were concentrated with duplication, we did not know what we were trying to do, except to sell cars which, in a sense, took volume from each other.^{2 3}

At the same time large firms may seek to promote competition among their units. For instance, in the last decade IBM drastically decentralized its internal structure allowing units to bargain on transfer prices and to trade with outside partners.⁴ In addition, under decentralization:

[Units] are free to compete with each other for business, even if this means cannibalizing the sales of other IBM units.⁵

As the above examples suggest, the existence of units offering substitute products within a firm raises a number of questions for organizational design. When should

¹See Sloan [8] chapter 4.

²Sloan [8] p.60

³Another example of a firm centralizing decision-making to reduce competition among units is described in Smith [9] (see section 2 below). A major commercial bank in California centralized its operations, removing branch managers' autonomy to sell loans to customers. Branch managers had, instead, to refer customers to a center that coordinated trade.

⁴See Ferguson [1] for a detailed description of the evolution of IBM.

⁵Ferguson p.61 and 62.

top management control the design and pricing of these products, thus centralizing decision-making, and when is it better to allow the units decide which products to make and how to sell them? In the case where it is optimal to let the units decide (and eventually compete) what prevents top management from intervening and restricting competition when the latter threatens to dissipate too many of the firm's profits?

In this paper we develop a simple model to address the above questions. We consider a firm which is composed by top management and two divisions. Divisions design horizontally differentiated products, characterized by their "location" and their "quality", and sell them to customers. For simplicity, we focus on the allocation of decision rights at the price setting stage. More precisely, top management can restrict the set of customers with whom a division can deal, thus prohibiting competition for customers, or can alternatively allow both divisions to approach all customers.

We argue that when a division is given the right to deal with all customers, it offers a higher quality product. Indeed, by increasing the quality of its product it not only can charge its own customers higher prices, but it also becomes a better competitor of the other division. Using competition as a threat, it can extract concessions from the other division, such as dealing with some of its customers.⁶ However, higher quality comes at a cost. A division aiming also at attracting the customers of the other division, will opportunistically locate its product too close to the product of the other division.

Top management will allow divisions to compete, i.e. will *decentralize* decision making, when the benefits due to higher product quality outweigh the costs of inefficient locations. We argue that top management's information about customers' characteristics (i.e. their locations) crucially determines the credibility of its commitment to competition among divisions. If it knows customers' locations it can efficiently allocate them to divisions (since in equilibrium it also knows the characteristics of both products) without letting the divisions engage in bargaining and

⁶In the model we assume, for simplicity, that divisions can make side-transfers so that concessions can simply be these transfers.

eventually compete.⁷

We show that centralization of decision-making may or may not be optimal. If divisional managers are very risk-averse, centralization dominates decentralization since the benefit of increased incentives is small compared to the cost of inefficient locations. Interestingly, the same conclusion holds when divisional managers' risk-aversion is low. Indeed, high-powered incentive schemes for improving product quality can be provided at a small cost under centralization. Decentralization thus brings small additional benefits and inefficient locations. Decentralization is a better solution if the set of customers who desire both products is small so that divisional incentives to locate products closer are small and locations are close to their first-best values. Costs due to inefficient locations are in the second order, while product quality increases in the first-order.

As we argued above, when a division is given the right to deal with all customers it will offer a higher quality product. Indeed, by becoming a better competitor of the other division, it can extract some concessions from it. Taking surplus away from the other division does not have any social value and if divisional managers receive very high-powered incentive schemes so that they become residual claimants, they will overprovide quality. The idea that competing agents may overinvest in some activities is familiar in industrial organization; firms may offer too many products because they are only "stealing" each other's business and may spend too much on R&D (Tirole [10] Chs. 7 and 10). In our model competition is valuable because agents' incentives are initially *too low*.

The channel through which competition affects incentives in this paper is different than the one studied in the principal-agent literature, namely that competition improves the information available for contracting. Papers in that literature have shown that the performance of an agent can better be assessed if performance measures of competing agents are available and that, as a result, this agent can be given

⁷In our model bargaining is costless, for simplicity. However, top management prefers to intervene even for a very small cost of bargaining (which can easily be introduced in the model).

a higher-powered incentive scheme.⁸ Even if the principal does not have access to performance measures of competing agents, competition may still improve the information available for contracting by making the agent's profits less variable (Hart [2], Scharfstein [6]).

Rey and Tirole [5] also address the question of whether a principal (in their model a manufacturer) prefers to restrict competition among agents (retailers). A monopoly retailer will charge a price which is too high from the manufacturer's viewpoint, as long as he does not buy from the manufacturer at marginal cost. Competition allows the manufacturer to resolve this moral-hazard problem (since retailers will charge the price at which they are buying from the manufacturer) and at the same time provides insurance to retailers making their profits less variable, as in Hart [2]. When retailers compete they will thus charge lower prices (keeping the price at which they are buying from the manufacturer constant) and will on average supply the same quality. By contrast in our paper, when divisions are allowed to compete, they offer higher quality products and charge higher prices as a result. A second difference with Rey and Tirole [5] is that the cost of competition in their model is the inability of retailers to price-discriminate, while in our model is the choice of inefficient locations by the divisions.

Our paper is also related to a recent paper by Holmstrom and Tirole [4] studying transfer pricing within firms. They compare a regime of "exchange autonomy" where top management allows divisions to trade with outside partners to a regime where divisions can only trade internally (but can refuse to trade).⁹ They show that if divisions are allowed to trade with outside partners, they offer higher quality products but they may choose a product design which is general purpose and not specific to the needs of the other division. Although studying different issues, both papers share the feature that if divisions have more decision rights they will have more incentives but they may also take decisions which are not optimal from the firm's viewpoint.

⁸For summaries of the literature on relative performance evaluation see, for instance, Holmstrom and Tirole [3] and Tirole [10], Ch. "The Theory of the Firm".

⁹They also study the case where one division can order the other division to trade.

The remainder of the paper is organized as follows: In section 2 we describe the model and in section 3 we derive the first-best. In sections 4 and 5 we study the outcomes under decentralization and centralization. Section 6 compares the two organizational forms. All proofs are in the appendix.

2.2 The Model.

2.2.1 Supply and Demand.

We consider a firm which is composed by top management and two divisions. Each division makes one product. The potential buyers of these products (the “customers”) are uniformly distributed in the interval $[0, 1]$. The product of division i ($i = 1, 2$) (referred to as product i) is characterized by its location, l_i , and its “quality”, v_i . We assume that “transportation” costs are linear, so that the valuation of a customer located at x for product i is

$$v_i(x) = v_i - t|x - l_i| \quad (2.1)$$

We also assume that the location of each customer is known to the divisions and that the divisions can charge customer-specific prices.¹⁰

Product 1 can be located anywhere in $[0, 1/2]$ and product 2 can be located anywhere in $[1/2, 1]$. The manager of division i can improve the quality of product i by exerting effort e_i at a non-monetary cost $C(e_i)$. We will assume that:

$$v_i = v_0 + e_i, \quad v_0 > 0, \quad (2.2)$$

and:

$$C(e_i) = \frac{1}{2}C e_i^2 \quad (2.3)$$

¹⁰We plan to study the case where customers’ locations are not known and divisions cannot price-discriminate in a later version of this paper.

The marginal cost of each of the two products is zero.

For simplicity, we will restrict the parameter space assuming that only one product cannot cover the whole market even if the manager of the corresponding division exerts first best effort. Since the optimal effort level when the whole market is covered by one product is $\frac{1}{c}$ and the optimal location in order to cover the market is $\frac{1}{2}$, our assumption (“assumption A”) is equivalent to:

$$\frac{v_0}{t} + \frac{1}{Ct} \leq \frac{1}{2}$$

In words, product quality when effort is zero, v_0 , has to be small compared to transportation costs, t , and the cost of exerting effort and improving quality, C , has to be large.

2.2.2 Information Structure and Contracts.

We assume that a divisional manager’s effort as well as the actions that he undertakes to determine the location of his product are observed by the other divisional manager. However, neither of these actions is verifiable, i.e. divisional managers cannot write short-term contracts with each other that bind them to exert a given effort level or to choose a particular location for their product. This will naturally be the case if, as we will assume, top management does not perfectly understand product design (quality and location) and cannot enforce such contracts. The non-verifiability of actions will imply in particular that divisions may not be able to coordinate on an efficient choice of product locations. Finally, divisions are assumed to know the location of all customers.

Top management is assumed to be less informed about both divisions’ environments than each divisional manager. In particular by not perfectly understanding product design, top management does not observe effort levels (product quality) and product location. We however assume that it knows the location of customers. Since

in equilibrium it also knows product quality and product location, it can infer which product is better for a given customer. We briefly consider the case where top management does not know customers' locations in section 6.

Divisional profits are partly generated by the revenues from dealing with customers. We assume that they contain an additional component which is random, normally distributed and independent across divisions,¹¹ and are thus a noisy signal of the actions taken by divisional managers. Profits are the only variables in our model which are verifiable by outside parties (such as courts).

We assume that divisional managers are given incentive schemes which depend only the profits of their own division (and not on the profits of the other division) (This assumption is more innocuous than it may seem. See the analysis of the centralized firm in Section 5.) are linear and have the same slope which is between 0 and 1. Denoting by π_i the profits of division i , the manager of division i thus receives:

$$A\pi_i + B_i \tag{2.4}$$

We assume that both managers are risk-averse and have a negative exponential VNM utility function with coefficient of absolute risk-aversion equal to α . Their reservation levels are normalized to zero.

We consider two organizational forms, the decentralized firm and the centralized firm. Top management allows divisions to compete for a given customer in the decentralized firm while it allocates customers to divisions in the centralized firm. We assume that under decentralization divisions bargain efficiently so that competition only defines the status quo in the bargaining game, and that bargaining power is equal. Since the incentive schemes given to divisional managers have the same slope, customers are allocated to divisions efficiently from the firm's viewpoint.

The timing is thus:

¹¹It can be due, for example to other divisional operations.

Decentralized Firm:

Centralized Firm:

To illustrate our model, we consider the example of commercial banks in a large city. There is demand for bank loans but different individuals are interested in loans with different characteristics (business are interested in short-term lending, entrepreneurs in funding a start-up venture, consumers need cash for acquiring durable goods).¹²

Managers sell loans to customers and can undertake two kinds of investments in order to become more efficient:

- **“Supply” Effort:** They can acquire a skill that is not specific to any kind of loan, but rather improves the chances of striking deals in good terms (like learning state of the art software to gather information in a timely fashion, or information technology that improves readiness of on-line help to customers, whatever the kind of loan they want to purchase). (The supply effort corresponds to the investment e above.)
- **“Demand” Effort:** They can become specialized in being particularly efficient in customizing loans to a particular segment of the market (by learning detailed information on a particular sector of the population or following more closely the trends of an industry. (This corresponds to the location choice, l , above.)

¹²Heterogeneity is *large* and it is therefore difficult to segment the market in non-arbitrary intervals of potential customers.

The bank has two divisions in the city, that deal directly with customers. Each division is run by one manager. Each manager has expertise in the business and is able to assess the investment levels of the other manager. Top management is however unable to measure those investment levels.¹³

Top management can centralize or decentralize the firm's operations. gathering more or less precise information about customers.

Under decentralization, divisional managers are not required to obtain approval from top management to strike deals with customers. Under centralization divisional managers transmit information on a potential deal with a customer to top management, who either approves the deal or allocates the customer to the other division.¹⁴

Smith [9] provides a case study of the reorganization of several divisions in a major investment bank in California. She examines in particular¹⁵ the transition from relative autonomy to a regime of centralization in a division of the bank. The manager of the division (referred to as L.) is being deprived of authority over some actions that she previously controlled. The control is being recovered by the next superior level in the hierarchy, the area management group (referred to as AMG.)

Branch top management centralized lending into specialized divisions, reflecting the bank's commitment to targeting and profiting from stratified market segments. The differentiation of the lending function into specialized units removed a significant source of L.'s authority. She no longer had authority to make loans, nor did she manage loan personnel. [...] L. forwarded [loan application] to the appropriate consumer, real state or commercial loan center.[...] Her role was [now] strictly one of referral.¹⁶

¹³A manager can infer the ability (investment) of the other manager because customers transmit information from one office to another.

¹⁴The center is unable to separate the market geographically if, for instance, business have multiple locations.

¹⁵See Smith [9], pp.95-101.

¹⁶In addition, it becomes clear that the transfer of authority required a redefinition of the information flowing from lower level (L.) to upper level (the AMG). The information flow is defined in a

Even when *L.* did tabulate statistical information, the role she once played in evaluating and acting on that information had changed. Whereas formerly *L.* would have tracked branch information and used it to develop an integrated picture of branch performance, the job of tracking various kinds of information had been transferred into specialized sections in the *AMG*.¹⁷

The new *PPCE* and the extensive documentation it contained provided the area manager with the information required for indirect management: in other words, it gave area managers more control over individual branches.

2.3 The First Best.

In this section we derive the effort levels and product locations that maximize total welfare. Total welfare (which is equal to top management's payoff since the reservation levels of the divisional managers are normalized to zero) is:

$$\begin{aligned} & \int_0^1 \max(v_1(x), v_2(x), 0) dx - \frac{1}{2}C(e_1^2 + e_2^2) \\ &= \int_0^1 \max(v_1 - t|x - l_1|, v_2 - t|x - l_2|, 0) dx - \frac{1}{2}C(e_1^2 + e_2^2) \end{aligned} \quad (2.1)$$

Proposition 3.1, proven in Appendix A, gives us the first best effort levels, e_1^* and e_2^* , and locations l_1^* and l_2^* .

Proposition 3.1. *The maximum of expression 2.1 is achieved by choosing:*

$$l_1^* = \frac{1}{4} \qquad l_2^* = \frac{3}{4}.$$

If $2v_0/t + 1/Ct < 1/2$, e_1^ and e_2^* are given by:*

document of the corporation, the Performance Evaluation Plan (*PPCE* in the text).

¹⁷Smith [9] p.97

$$e_1^* = e_2^* = v_0 / \left(\frac{Ct}{2} - 1 \right)$$

and the firm does not sell to all customers (i.e. the market is not "covered").

If $2v_0/t + 1/Ct \geq 1/2$, e_1^* and e_2^* are given by:

$$e_1^* = e_2^* = \frac{1}{2C}.$$

and the market is covered.

Assumption A makes the problem sufficiently concave so that it is not optimal to require different effort levels (and product locations) from the two managers.

If the market is not covered (i.e. if product quality is low compared to transportation costs and the cost of improving it is large), total welfare is maximum for any locations which imply non-overlapping sets of customers willing to buy a given product and which are not too close to the extremes, 0 and 1. (So that each product is located in the middle of its market segment - the set of customers who are buying the product.) $1/4$ and $3/4$ always belong to the set of optimal locations. If the market is covered, $1/4$ and $3/4$ are the unique optimal locations and each product is located in the middle of its market segment. ($[0, 1/2]$ for product 1 and $[1/2, 1]$ for product 2.) In addition, since more customers buy the products if the market is covered, the optimal effort levels are higher than if the market is not covered.

2.4 The Decentralized Firm.

We now come to the analysis of the decentralized firm. In section 2 we assumed that top management allows divisions to compete for a given customer. We then assumed that divisions bargain efficiently so that competition only defines the status quo of

the bargaining game, and that bargaining power is equal.

Considering a customer located at x and assuming, for example, that $v_1(x) > v_2(x) \geq 0$, it is easy to see that division 1 deals with the customer and receives $v_1(x) - v_2(x)/2$ while division 2 receives $v_2(x)/2$.¹⁸

Aggregating over customers, division 1's profits are given by:

$$\begin{aligned} & \int_{S_1} \left(\max(v_1(x), 0) - \frac{1}{2} \max(v_2(x), 0) \right) dx + \int_{[0,1] \setminus S_1} \frac{1}{2} \max(v_1(x), 0) dx = \\ & \int_{S_1} \left(\max(v_1 - t|x - l_1|, 0) - \frac{1}{2} \max(v_2 - t|x - l_2|, 0) \right) dx \\ & \quad + \int_{[0,1] \setminus S_1} \frac{1}{2} \max(v_1 - t|x - l_1|, 0) dx \end{aligned} \quad (2.1)$$

where the set S_1 is defined by:

$$S_1 = \{x \in [0, 1] : v_1(x) > v_2(x)\} = \{x \in [0, 1] : v_1 - t|x - l_1| > v_2 - t|x - l_2|\} \quad (2.2)$$

and division 2's profits are given by the symmetric expression.

Using equation 2.4 which gives managers' incentive schemes, we get for the payoff of the manager of division 1:

$$\begin{aligned} & A \left(\int_{S_1} \left(\max(v_1 - t|x - l_1|, 0) - \frac{1}{2} \max(v_2 - t|x - l_2|, 0) \right) dx \right. \\ & \quad \left. + \int_{[0,1] \setminus S_1} \frac{1}{2} \max(v_1 - t|x - l_1|, 0) dx \right) + B_1 - \frac{1}{2} C e_1^2 \end{aligned} \quad (2.3)$$

To determine the outcome under decentralization we proceed in two steps. In Proposition 4.1, proven in appendix B, we characterize pure-strategy equilibria of the

¹⁸If there is competition, division 1 serves the customer charging the price $v_1(x) - v_2(x)$. Its payoff is thus $v_1(x) - v_2(x)$ while the payoff of division 2 is 0. Since bargaining power is equal, i.e. each divisional manager makes a take-it-or-leave-it offer to the other divisional manager with probability 1/2, it is clear that the payoffs of the two divisions are given by the previous expressions.

effort and location game taking incentive schemes as given. We then determine the optimal value of A , the slope of the incentive schemes.

Proposition 4.1. *There exists a pure-strategy equilibrium in which locations and effort levels are given by:*

case I: $2v_0/t + A/Ct < 1/2$

$$l_1 = \frac{1}{4} \qquad l_2 = \frac{3}{4},$$

$$e_1 = e_2 = v_0 / \left(\frac{Ct}{2A} - 1 \right)$$

and the market is not covered. In any other pure-strategy equilibrium effort levels and payoffs are the same.

case II: $2v_0/t + A/Ct \geq 1/2$

$$l_1 = 1 - l_2 = \left(\frac{1}{4} + \frac{v_0}{2t} \right) / \left(\frac{3}{2} - \frac{A}{Ct} \right) \geq \frac{1}{4},$$

$$e_1 = e_2 = (2A/C)l_1 = \left(\frac{t}{2} + v_0 \right) / \left(\frac{3Ct}{2A} - 1 \right)$$

and the market is covered. This is the unique pure-strategy equilibrium.

In case I product quality, v_0 , is low compared to transportation costs, t , the cost of improving it, C , is high and the benefit, A , that divisional managers get is small. The market is not fully covered and the divisions do not have incentives to offer products that appeal to overlapping sets of customers.

By contrast, in case II divisions offer products which appeal to overlapping sets of customers and whose distance is too small compared to the first best ($l_1 \geq 1/4$, $l_2 \leq 3/4$). The private gain of each division to locate its product closer to the product

of the other division is larger than the social gain. Indeed, by locating its product closer, the division better “penetrates” the market of the other division and becomes a more serious potential competitor.¹⁹ The incentive to locate closer and becoming a more serious potential competitor is clearly larger if there is a significant overlap already (v_0 high, C small, A large).

Effort levels are higher in case II than in case I. Indeed, the manager of one division by exerting more effort supplies a product which is valued more by the customers of his division (who now have a larger mass) as well as by the customers of the other division (so that this product can better compete with the product of the other division).

It is straightforward to show that the top management’s payoff is given by:

$$\int_0^1 \max(v_1 - t|x - l_1|, v_2 - t|x - l_2|, 0)dx - \frac{1}{2}C(e_1^2 + e_2^2) - A^2\alpha\sigma_u^2 \quad (2.4)$$

for the values of e_1 , e_2 , l_1 , l_2 determined in proposition 4.1. Expression 2.4 is derived from expression 2.1 by subtracting the costs of having the divisional managers bearing risk. The slope of the incentive scheme, $A \in [0, 1]$, is determined by the maximization of expression 2.4. Expression 2.4 is not generally concave in A since the responsiveness of effort to A increases with A .²⁰ Although the characterization of the optimal A is involved, it is easy to show (see appendix B) that A decreases with managers’ risk aversion, α , and the variance of the noise, σ_u^2 . Comparative statics w.r.t. v_0 , t and C are ambiguous.

2.5 The Centralized Firm.

In this section we study the centralized firm in which the general office allocates customers to divisions. Each division charges its customers their valuations.

¹⁹Of course, (price) competition does not take place in equilibrium.

²⁰If A is higher, increasing A will induce the managers to exert more extra effort since they will receive the benefit of selling a better product to a larger market.

Since the sets:

$$S_1 = \{x \in [0, 1] : v_1 - t|x - l_1| > v_2 - t|x - l_2|\}$$

$$S_2 = \{x \in [0, 1] : v_1 - t|x - l_1| = v_2 - t|x - l_2|\}$$

and:

$$S_3 = \{x \in [0, 1] : v_1 - t|x - l_1| < v_2 - t|x - l_2|\}$$

are ordered, in the sense that $\forall (x_1, x_2, x_3) \in S_1 \times S_2 \times S_3$ $x_1 < x_2 < x_3$ ²¹, top management can achieve its maximum payoff by choosing a dividing point $\bar{x} \in [0, 1]$ such that customers with locations $< \bar{x}$ deal with division 1 and customers with locations $\geq \bar{x}$ deal with division 2. For simplicity we will consider only these strategies for top management.

We will rule out a class of equilibria that exhibit an extreme lack of coordination. In these equilibria top management allocates all customers to one division, say division 1, “shutting” division 2. The manager of division 1 is then very motivated while the manager of division 2 does not exert any effort and may locate his product close enough to product 1 so that all customers prefer product 1 to product 2.

In proposition 5.1, proven in appendix C, we characterize the remaining pure-strategy equilibria.

Proposition 5.1. *There exists a pure-strategy equilibrium in which locations and effort levels are given by:*

case I: $2v_0/t + A/Ct < 1/2$

$$l_1 = \frac{1}{4}$$

$$l_2 = \frac{3}{4},$$

²¹This is easy to check, using $l_1 \leq l_2$.

$$e_1 = e_2 = v_0 / \left(\frac{Ct}{2A} - 1 \right)$$

and the market is not covered. In any other pure-strategy equilibrium, effort levels and payoffs are the same.

case II: $2v_0/t + A/Ct \geq 1/2$

$$l_1 = \frac{1}{4} \qquad l_2 = \frac{3}{4},$$

$$e_1 = e_2 = \frac{A}{2C}$$

and the market is covered. This is the unique pure-strategy equilibrium.

The outcome in case I is exactly the same as in proposition 4.1. In case II where divisional products appeal to overlapping sets of customers, divisions choose first best locations for their products. By being unable to deal with the customers of the other division their private gain to locate their product closer to the product to the other division coincides with the social gain. At the same time effort levels in case II are lower than in proposition 4.1. When deciding to exert more effort or not, the manager of a division considers only the increase in valuation of the customers of his own division and not of the customers of the other division.

Top management' payoff is again given by expression 2.4 for the values of e_1 , e_2 , l_1 , l_2 determined in proposition 5.1. In appendix C we determine A and show, as before, that it decreases with α and σ_v^2 .

Before leaving this section we discuss our assumption that divisional managers' incentive schemes depend only on the profits of their own division and not on profits of the other division. Consider the extreme case where each manager's incentive scheme depended only on the *sum* of the profits of the two divisions. In this case, a manager

would not attribute any value to his division becoming a more serious competitor of the other division and to profits being transferred from that division to his division. Locations and effort levels in both the decentralized and the centralized firm would then be given by proposition 5.1. Since managers would have to be compensated for bearing more risk, giving incentive schemes that depend on joint profits is dominated by centralizing and giving incentive schemes that depend on individual profits.

2.6 Comparison of Organizational Forms.

In this section we compare the decentralized and the centralized firm. As the analysis of the previous sections showed, decentralization brings more incentives and higher quality products together with inefficient locations for these products. Due to the non-concavity of expression 2.4 w.r.t A in both the decentralized and the centralized case, the analysis of top management's welfare for general values of the parameters v_0 , t , C , α and σ_u^2 is somewhat involved. However, the following intuitive results hold:

- If divisional managers are very risk-averse (or the variance of the noise is large) so that the slope of the incentive schemes is small, centralization improves welfare. Indeed, the benefit of increased incentives is small compared to the cost of inefficient locations (provided that even if divisional managers exert zero effort, products, when optimally located, appeal to overlapping sets of customers).²²
- If divisional managers' risk-aversion is small (or the variance of the noise is small) centralization improves welfare. Indeed, high-powered incentives for improving product quality can be provided at a small cost in the centralized firm. Decentralization thus brings small additional benefits (there may even be over-investment compared to the first best if incentives remain high-powered) at the cost of inefficient locations.

²²This result holds because divisional managers can choose any location for their products at the same cost. If, instead, some locations are costlier to choose than others and incentive schemes have a small slope, equilibrium locations may not differ much in the two organizational forms.

- If for the optimal incentive scheme in the centralized case, the set of customers who desire both products is small, decentralization improves welfare. Indeed, decentralization will induce (slightly) more effort while locations will deviate little from their first best values so that the costs induced by inefficient locations are very small (in the second order).

These intuitive results are made precise and proven in appendix D.

We finally discuss the feasibility of the two organizational forms. Until now we have assumed that top management knows customers' locations. Since in equilibrium it also knows product quality and product location it can infer which product is better for a given customer. If bargaining between the divisions is costly,²³ top management would strictly prefer to allocate customers to divisions without letting them bargain. We thus see that decentralization may not be feasible.

Decentralization may become feasible if top management faces a cost to intervene, for instance if it does not know customers' locations. Bargaining among divisions may then be a more attractive option than mandating a suboptimal allocation of customers to divisions. We plan to study the feasibility of decentralization when top management is less informed, in a later version of this paper.

²³We can easily introduce a small cost of bargaining in the model.

2.7 Appendix

2.7.1 Proof of Proposition 3.1.

Writing that the left-derivative of expression 2.1 w.r.t e_1 is ≥ 0 at e_1^* we get:

$$\text{measure}(S'_1) - C e_1^* \geq 0 \Rightarrow e_1^* \leq \frac{1}{C} \min\left(1, \frac{v_0 + e_1^*}{t}\right) \leq \frac{1}{C}$$

where:

$$S'_1 = S_1 \cap \{x \in [0, 1] : v_1^* - t|x - l_1^*| \geq 0\}$$

and S_1 is the set defined in section 4 (for $e_1^*, e_2^*, l_1^*, l_2^*$).

Therefore:

$$v_1^* = v_0 + e_1^* \leq v_0 + \frac{1}{C} < \frac{t}{2}$$

(and similarly for v_2^*) by assumption A, and one product even if located at $1/2$ cannot cover the whole market. It is thus not optimal to offer two products such that all customers (weakly) prefer one to the other.

We will now fix v_1 and v_2 (smaller than $t/2$) and determine the optimal locations, l_1 and l_2 .²⁴ We will then determine the optimal effort levels. Our previous analysis implies that l_1 and l_2 are such that each product is strictly better than the other for some set of customers

Suppose that products do not overlap i.e.

$$l_1 + \frac{v_1}{t} \leq l_2 - \frac{v_2}{t}. \quad (2.1)$$

Suppose then that $l_1 - v_1/t < 0$. It is then easy to show that the right-derivative

²⁴These optimal locations exist since we maximize a continuous function over the compact set $[0, 1/2] \times [1/2, 1]$.

of expression 2.1 w.r.t l_1 ($l_1 < 1/2$ since $l_1 - v_1/t < 0$) is $-tl_1 + v_1 > 0$.²⁵ Therefore:

$$l_1 - \frac{v_1}{t} \geq 0 \quad (2.2)$$

and similarly:

$$l_2 + \frac{v_2}{t} \leq 1. \quad (2.3)$$

Inequalities 2.1, 2.2 and 2.3 imply that $(v_1 + v_2)/t \leq 1/2$. Expression 2.1 is then equal to:

$$\frac{v_1^2}{t} + \frac{v_2^2}{t} - \frac{1}{2}C(e_1^2 + e_2^2). \quad (2.4)$$

Defining $l_1 = 1/4 + (v_1 - v_2)/2t$ and $l_2 = 1/2 + l_1$ ²⁶ and using $(v_1 + v_2)/t \leq 1/2$, inequalities 2.1, 2.2 and 2.3 are satisfied and payoff is the same as when locating products at l_1 and l_2 .

Suppose now that products overlap i.e.

$$l_1 + \frac{v_1}{t} > l_2 - \frac{v_2}{t}. \quad (2.5)$$

We denote by x_* the location of the customer who is indifferent between the two products i.e. $x_* \equiv (l_1 + l_2)/2 + (v_1 - v_2)/2t$. ($l_1 < x_* < l_2$)

Suppose then that $l_1 - v_1/t \geq 0$. It is then easy to show that the left-derivative of expression 2.1 w.r.t l_1 ($l_1 > 0$ since $l_1 - v_1/t \geq 0$) is $-v_1 + (x_* - l_1) > 0$.²⁷ Therefore:

$$l_1 - \frac{v_1}{t} < 0 \quad (2.6)$$

and similarly:

²⁵We have to distinguish two cases: $l_1 + v_1/t < l_2 - v_2/t$ and $l_1 + v_1/t = l_2 - v_2/t$.

²⁶ $l_1 \in [0, 1/2]$ since $|v_1 - v_2|/t < 1/2$.

²⁷We again have to distinguish two cases: $l_1 - v_1/t > 0$ and $l_1 - v_1/t = 0$.

$$l_2 + \frac{v_2}{t} > 1. \quad (2.7)$$

Inequalities 2.5, 2.6 and 2.7 imply that $(v_1 + v_2)/t > 1/2$.

The derivative of expression 2.1 w.r.t l_1 is $-tl_1 + t(x_s - l_1)$ (therefore $l_1 > 0$ and $l_1 < 1/2$ and this derivation is meaningful). Similarly the derivative w.r.t l_2 is $-t(l_2 - x_s) + t(1 - l_2)$. Setting these derivatives equal to zero we find $l_1 = 1/4 + (v_1 - v_2)/2t$ ($l_1 \in [0, 1/2]$) and $l_2 = 1/2 + l_1$.

Expression 2.1 is then equal to:

$$\frac{v_1 + v_2}{2} - \frac{t}{8} + \frac{(v_1 - v_2)^2}{2t} - \frac{1}{2}C(e_1^2 + e_2^2). \quad (2.8)$$

To summarize, our above analysis implies that $l_1 = 1/4 + (v_1 - v_2)/2t$ and $l_2 = 1/2 + l_1$ are always optimal locations. In addition if $(v_1 + v_2)/t \leq 1/2$ payoff is given by expression 2.4 while if $(v_1 + v_2)/t > 1/2$ payoff is given by expression 2.8.

Assumption A implies $1/Ct < 1/2$ which in turn implies the concavity of expressions 2.4 and 2.8 w.r.t e_1 and e_2 . Since these expressions are symmetric in these variables, the optimal e_1 and e_2 are equal and straightforward maximization gives us proposition 3.1.

2.7.2 Proof of Proposition 4.1.

We will first characterize pure-strategy equilibria and then show that they exist.

Characterization.

Taking the left-derivative of expression 2.3 w.r.t e_1 and writing that the derivative is ≥ 0 for the equilibrium value of e_1 we get:

$$A(\text{measure}(S'_1) + \frac{1}{2}\text{measure}(S'_2 \cup S'_3)) - Ce_1 \geq 0$$

$$\Rightarrow e_1 \leq \frac{A}{C} \min\left(1, \frac{v_0 + e_1}{t}\right) \leq \frac{A}{C} \quad (2.1)$$

where:

$$S'_k = S_k \cap \{x \in [0, 1] : v_1 - t|x - l_1| \geq 0\}$$

and the S_k 's are the sets defined in sections 4 and 5 (for the equilibrium values of e_1 , e_2 , l_1 , l_2).

Therefore one product even if located at $1/2$ cannot cover the whole market and it is easy to check that no equilibrium in which all customers (weakly) prefer one product to the other, exists. (Otherwise the manager of the inferior product would change its location so that customers strictly prefer his product.)

Suppose that in equilibrium products do not overlap i.e. inequality 2.1 holds. A similar argument to that given in the proof of proposition 3.1. implies that inequalities 2.2 and 2.3 hold.

The derivative w.r.t e_1 is $A(v_0 + e_1)/t - Ce_1 = 0$.²⁸ Therefore e_1 is given by its expression in proposition 4.1, case I (as well as e_2). Moreover, combining inequalities 2.1, 2.2 and 2.3 and using the expressions for e_1 and e_2 , we find that an equilibrium with non-overlapping products exists only if:

$$\frac{2v_0}{t} + \frac{A}{Ct} \leq 1/2 \quad (2.2)$$

Suppose now that products overlap i.e. inequality 2.5 holds. Defining x_s as before we can show that inequalities 2.6 and 2.7 hold.

The derivative of expression 2.3 w.r.t l_1 is $-tl_1 + t(x_s - l_1) + 1/2(tl_1 + v_1 - tx_s)$ (therefore $l_1 > 0$ and $l_1 < 1/2$ and this derivation is meaningful). Similarly the derivative w.r.t l_2 is $-1/2(tx_s - (tl_2 - v_2)) - t(l_2 - x_s) + t(1 - l_2)$. The derivatives w.r.t e_1 and e_2 are $x_s + 1/2(l_1 + v_1/t - x_s)$ and $1/2(x_s - (l_2 - v_2/t)) + (1 - x_s)$. Setting

²⁸We again have to distinguish two cases according to whether $l_1 + v_1/t < l_2 - v_2/t$ or $l_1 + v_1/t = l_2 - v_2/t$.

these derivatives equal to zero we get the expressions in proposition 4.1 (case II).

Inequalities 2.5, 2.6 and 2.7 together with the expressions for e_1 and e_2 imply that an equilibrium with overlapping products exists only if:

$$\frac{2v_0}{t} + \frac{A}{Ct} > 1/2 \quad (2.3)$$

Existence.

Suppose that inequality 2.2 holds so that the only possible equilibria involve non-overlapping products located in the middle of their market segments. We first note that if we choose $l_1 = 1/4$ and $l_2 = 3/4$, inequalities 2.1, 2.2 and 2.3 are satisfied. We now show that a manager, say manager 1, does not get anything by deviating. Consider a deviation (\bar{e}_1, \bar{l}_1) . Equation 2.1 implies that \bar{e}_1 is always smaller than its equilibrium value. Since a manager always prefers to offer a product which does not overlap with the other product (provided that the product is always located in the middle of its market segment and that product quality is kept constant) the choice (\bar{e}_1, \bar{l}_1) is dominated by $(\bar{e}_1, 1/4)$ which is obviously dominated by $(e_1, 1/4)$.

Suppose now that inequality 2.3 holds so that the only possible equilibrium is the one described in proposition 4.1 (case II). Let us consider a deviation (\bar{e}_1, \bar{l}_1) by manager 1. If products do not overlap, using inequalities 2.1, 2.2 and 2.3 we find that $\bar{v}_1/t \leq 1/4$. This last inequality is not compatible with the first-order condition for e_1 and inequality 2.3. Moreover, it is clearly not optimal for manager 1 to offer a product which all customers prefer to product 2 (since it would then have to cover the whole market), nor to offer a product which all customers find inferior to product 2. Finally, it is easy to check that manager 1's payoff is concave in (e_1, l_1) in the domain of overlap, so that the first-order conditions are sufficient for optimality.

Incentive Schemes.

If inequality 2.2 holds, the derivative of expression 2.1 (where e_1, e_2, l_1, l_2 are given by proposition 4.1, case I), w.r.t A is

$$4(1 - A) \frac{\frac{v_0^2}{t} \left(\frac{Ct}{2}\right)^2}{\left(\frac{Ct}{2} - A\right)^3} - 2\alpha\sigma_u^2 A \quad (2.4)$$

By contrast if inequality 2.3 holds the derivative is:

$$2 \frac{\left(\frac{t}{2} + v_0\right) \left(\frac{Ct}{2}\right)^2}{\left(\frac{3Ct}{2} - A\right)^3} \left[3 \left(\frac{3}{2}(1 - A) - A \left(\frac{2v_0}{t} + \frac{1}{Ct} - \frac{1}{2} \right) \right) - \left(\frac{2v_0}{t} + \frac{A}{Ct} - \frac{1}{2} \right) \right] - 2\alpha\sigma_u^2 A \quad (2.5)$$

The derivative is not always decreasing in A . (It is easy to see that a sufficient condition for the derivative to be decreasing in A is that $1/Ct < 1/6$.) However, the derivative is decreasing in $\alpha\sigma_u^2$ and Topkis's [11] monotonicity theorem implies that the optimal A is decreasing in $\alpha\sigma_u^2$.

2.7.3 Proof of Proposition 5.1.

Equilibrium.

Suppose that in equilibrium all customers (weakly) prefer the product of one division, say division 1, to the product of the other division. Suppose first that the two products are not the same. Then $\bar{x} \geq l_2$. If $\bar{x} < 1$, and since product 1 does not cover the whole market (by assumption A), the manager of division 2 would have an incentive to increase l_2 . Therefore $\bar{x} = 1$. If both products are the same, we can assume that $\bar{x} \geq 1/2$ and the same conclusion holds. Ruling out these equilibria where top management allocates all customers to one division, consider an equilibrium where products do not overlap. We then have:

$$l_1 + \frac{v_1}{t} \leq \bar{x} \leq l_2 - \frac{v_2}{t}. \quad (2.1)$$

Following similar steps as in the proof of proposition 4.1, we can show that equations 2.2 and 2.3 hold and that e_1 and e_2 are given by their expressions in proposition 4.1

(case I). Combining inequalities 2.1, 2.2 and 2.3 and using the expressions for e_1 and e_2 , we find that an equilibrium with non-overlapping products exists only if inequality 2.2 holds. Clearly, any values l_1 , l_2 and \bar{x} that satisfy inequalities 2.1, 2.2 and

2.3 are equilibrium values, and it is easy to check that setting $l_1 = 1/4$, $l_2 = 3/4$ and $\bar{x} = 1/2$ inequalities 2.1, 2.2 and 2.3 hold.

Suppose now that products overlap i.e. inequality 2.5 holds. Defining x_* as before, we have $x_* = \bar{x}$ and we can show that inequalities 2.6 and 2.7 hold. The derivatives of agents' payoffs w.r.t l_1 and l_2 are $-tl_1 + t(x_* - l_1)$ and $-t(l_2 - x_*) + t(1 - l_2)$ and w.r.t e_1 and e_2 are $Ax_*/t - Ce_1$ and $A(1 - x_*)/t - Ce_2$. Setting these derivatives equal to zero we get the expressions in proposition 5.1 (case II). As before, inequalities 2.5, 2.6 and 2.7 together with the expressions for e_1 and e_2 imply that an equilibrium with overlapping products exists only if inequality 2.3 holds. It is clear that managers cannot do better by deviating from equilibrium.

Incentive schemes.

If inequality 2.2 holds, the derivative of expression 2.1 (where e_1 , e_2 , l_1 , l_2 are given by proposition 5.1, case I), w.r.t A is the same as in expression 2.4.

By contrast if inequality 2.3 holds the derivative is:

$$\frac{1}{2C}(1 - A) - 2\alpha\sigma_u^2 A \quad (2.2)$$

As before, the derivative is decreasing in A if $1/Ct < 1/6$, and the optimal A is always decreasing in $\alpha\sigma_u^2$.

2.7.4 Comparison of Organizational Forms.

We will prove the following proposition:

Proposition 6.1.

Part 1: Suppose that $v_0/t > 1/4$. Then if $\alpha\sigma_u^2$ is sufficiently large, welfare is higher under centralization.

Part 2: Suppose that $2v_0/t + 1/Ct > 1/2$. Then if $\alpha\sigma_u^2$ is sufficiently small, welfare is higher under centralization.

Part 3: Suppose that the optimal A under centralization verifies $2v_0/t + A/Ct = 1/2$. Then, welfare is higher under decentralization and under some cases is strictly higher.

Proof:

Part 1.

Since $v_0/t > 1/4$, inequality 2.3 holds for any value of A . Expression 2.5 shows then that the optimal A can be made arbitrarily small if $\alpha\sigma_u^2$ is sufficiently large. Proposition 4.1 implies then that e_1 and e_2 can be made arbitrarily close to zero and l_1 and $1 - l_2$ arbitrarily close to $1/6 + v_0/3t$ (which is strictly larger than $1/4$ since $v_0/t > 1/4$). Since in the centralized firm effort levels are positive, welfare is higher under centralization for $\alpha\sigma_u^2$ sufficiently large.

Part 2.

Welfare under centralization is larger than its value for $A = 1$, which in turn can be made arbitrarily close to welfare under the first best for $\alpha\sigma_u^2$ sufficiently small. By contrast, welfare under decentralization cannot be made arbitrarily close to welfare under the first best for $\alpha\sigma_u^2$ sufficiently small. Indeed, since $2v_0/t + 1/Ct > 1/2$, effort levels are strictly smaller than first best effort levels for A such that $2v_0/t + A/Ct \leq 1/2$, and by continuity for A slightly larger. For A even larger, effort levels may approach first best effort levels but the welfare loss due to inefficient locations is bounded away from zero.

Part 3.

If the optimal A under centralization, say A_c , verifies $2v_0/t + A_c/Ct = 1/2$, decentralization can only improve welfare since welfare under decentralization for A_c is

equal to the maximum welfare under centralization. To provide parameter values such that welfare is strictly higher in the decentralized firm assume that $1/Ct < 1/6$ so that welfare in the centralized firm is concave in A and assume that the right-derivative of welfare in the centralized firm w.r.t A , i.e. expression 2.2, is zero for A_c .²⁹ Simple algebra shows that expression 2.5 is always strictly larger than expression 2.2 for values of A such that $2v_0/t + A/Ct = 1/2$ (and for A_c in particular). Therefore for A slightly higher than A_c welfare under decentralization is strictly higher than the maximum welfare under centralization. (Obviously this result is not “knife-edge” and holds even if the optimal A is close to an A that verifies $2v_0/t + A/Ct = 1/2$.)

²⁹Welfare in both the centralized and the decentralized firm is not differentiable for values of A such that $2v_0/t + A/Ct = 1/2$ so if such a value is optimal, the right-derivative is not necessarily zero.

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