Decentralized Pricing and Multiproduct Firms

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Abstract

There are two multiproduct firms that compete in prices. Each firm can assume either a functional structure, thus committing to centralized pricing, or it can assume a divisional structure, thus committing to decentralized pricing. Decentralized pricing, while suboptimal per se, is shown to be profitable if every firm produces a range of complementary products and if the products of one firm are strong substitutes to the products of the other firm. Broadly speaking, product differentiation matters for organizational choices.

Key Words: multiproduct firms, competition, organizational structure, commitment, product differentiation.

JEL Classification: D23, D43, L22.

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1 Introduction

Back in 1962 Chandler coined the expression "strategy follows structure". This link implies that a firm can commit to a certain strategy by choosing an appropriate organizational structure. In this spirit, the present paper studies price competition between multiproduct firms together with their choices of organizational structures as means of committing to certain pricing strategies.

Two organizational choices are commonly available to a multiproduct firm. A multiproduct firm can assume a functional structure, which implies, from a marketing perspective, that all the prices are set centrally to maximize the total profits of the firm. Alternatively, a firm can assume a divisional structure, which implies that each product's price is set individually by its respective division to maximize the divisional profits.

Ceteris paribus, decentralized pricing is suboptimal, but when the responses of the competitors are taken into account, decentralized pricing changes the equilibrium and can potentially result in higher total profits for the firm. The focus of the present paper is on this strategic effect and on its implications for organizational choices and total welfare.

The idea that suboptimal response strategies, when they can be committed to, can provide higher profits for a competitive firm is well known. The classical example is Stackelberg competition (Stackelberg, 1952). A Stackelberg leader has higher profits than a Cournot duopolist. However, the quantity the leader chooses in the first period is not an optimal response in the second period (a Cournot response is). To be able to achieve higher profits a Stackelberg leader must be able to commit to that suboptimal response.

More recently, Fershtman et al. (1991) show that if some principles are engaged in a game, if they can contract agents to play this game for them (so, a general commitment device is available), and if these contracts can not be broken and are common knowledge, then any Pareto-efficient outcome can be delivered as a subgame perfect Nash equilibrium, where in the first period the contracts are signed and in the second period the game is played. In general these contracts do not prescribe an optimal response in the second period.

Which commitment devices are available to a firm in different situations, and which can be made common knowledge is a vast question and goes beyond the scope of this paper. In this paper the commitment device is the organizational structure of a firm: a firm can either choose a functional structure and commit to centralized pricing or choose a divisional one and commit to decentralized pricing. The motivation is twofold. Intuitively, changing organizational structures is costly, is known to be costly, and hence an organizational structure is and is known to be a strong commitment. Additionally to that, much of the industrial organization literature takes the same path and discusses strategic effects of committing to different organizational structures.[1] The literature overview section discusses the relevant papers, here I would like to mention but a few well known ones.

McGuire and Staelin (1983) consider having retailing business in-house versus contracting with outside retailers. While leaving retailing in-house delivers higher profits ceteris paribus, the authors show that outsourcing retailing can be profitable if the final good market is competitive enough. Baye et al. (1996b) consider competition in quantity over a uniform good, where each competing firm can further split into multiple divisions. While divisionalization results in competition between divisions, it also increases the market share of the firm. The authors show that in equilibrium the firms find it profitable to divisionalize.

The present paper focuses on a different setting: price competition between multiproduct firms, where each firm's product range is composed of either substitutes or complements, and where the product ranges of different firms are always substitutes to one another. The following examples argue such a setting abounds in practice.

If the goods within a firm's product range are substitutes, then computer manufacturers all offering choices from small notebooks to server stations is one example, and car manufacturers offering choices from family hatchbacks to business class saloons is another one. The examples when the goods within a range are complements include: cosmetic manufacturers making all kind of products from a foot cream to a hair shampoo, or sports equipment manufacturers offering tennis shoes, light clothing, rackets, et cetera. Other examples of complementary products are cases when competing firms split their products into several offers: software and software support, vacuum cleaners and vacuum bags, etc.

The main result of this paper is as follows. If the products within the product ranges are gross substitutes, then the firms prefer centralized pricing.

[1] Though commitment via organizational structure is certainly not the only commitment mechanism studied. For example, Fershtman and Judd (1987) study managerial compensation that is linear in profits and sales. They show that contracting on sales can be profit improving.

If the product ranges consist of complementary products, then either case is possible. In particular, when competition between the firms is stronger, they are more likely to opt for decentralized pricing. So, decentralized pricing, which is suboptimal ceteris paribus, has a strategic advantage over centralized pricing when it comes to more competitive markets with competitors producing ranges of complementary goods.

Broadly speaking, this paper shows that the product ranges of multiproduct firms—whether they consist of complements or substitutes—influence the organizational choices of those firms through market interactions.

From a welfare perspective, the case of complementary goods gives ambiguous results. However, the case of substitutes is unambiguous: the firms always choose functional structures, while divisional structures always deliver higher total welfare. So, on markets with competing multiproduct firms, each producing goods that are gross substitutes, a sufficiently high subsidy for divisionalization will be welfare improving.

There is also a novel but peculiar result that for certain parameters two equilibria coexist: in one equilibrium both competitors prefer centralized pricing and in the other equilibrium both competitors prefer decentralized pricing. As discussed in more detail at the end of section 4, this multiplicity of equilibria suggests there can be an industry-wide lag in the adjustment of organizational structures to the new market conditions.

While the focus of this paper is on the commitment role of organizational structures, whether a company prefers a more centralized or a more decentralized structure does depend upon a variety of other factors. An interested reader is referred to Williamson (1981) for a discussion of transaction costs; to Jennergren (1981) for a discussion of scale economies, specialization, adaptiveness, etc.; to Mookherjee (2006) for a discussion of incentives, communication and information processing costs within a firm; and to Chandler (1962) for a seminal case study.

The next section presents further overview of the literature. Section 3 sets up the model. For simplicity of exposition a basic model with two goods, two firms and a linear demand system is taken. Section 4 solves for subgame perfect Nash equilibria of the model and discusses the results. Welfare analysis are done separately in section 5. Section 6 concludes.

2 Literature Overview

Baye et al. (1996b) study divisionalization: in the first period firms choose how many divisions to form, in the second period all the division of all the firms produce a uniform good and engage in Cournot competition. The authors show that the firms divisionalize in equilibrium. In the model the costs are assumed to be linear, so the focus is solely on the strategic role of divisionalization. The problem of divisionalization is then similar to a setting, where the number of divisions is fixed and the firms decide whether to set quantities centrally or to delegate quantity setting to the divisions. In this respect Baye et al. (1996b) can be compared to my setting of centralized versus decentralized pricing. The main differences are: I consider price competition instead of quantity competition and I consider differentiated goods. This different perspective allows to judge how the trade-off between centralized and decentralized pricing depends upon the degree of differentiation between the goods. A priori this perspective can not be justified by anything except curiosity, however, a posteriori it is justified as I achieve novel predictions concerning the dependence of organizational structures on the degree of differentiation between the goods.

Baye et al. (1996a) complement their earlier analysis with integral restrictions (the number of divisions is naturally an integer). Ziss (1998) extends Baye et al. (1996b) by considering a case, where the products of different firms are partial substitutes. He shows that differentiation of goods between firms alters the resulting equilibrium, most importantly a competitive solution is not approached as costs of divisionalization go to zero (which is the case in Baye et al. (1996b)).

Zhou (2005) compares a functional organizational structure to a divisional one in a market setting, where the goods within a firm are partial substitutes (or complements) but all the firms produce the same two goods and compete in quantities. If a firm chooses a functional structure, then it sets its quantities centrally and the cross-price effects are taken into account, but there is double marginalization: a production department charges transfer prices to a marketing department. If the firm chooses a divisional structure, the activities are split by product and not by function, so there is no double marginalization but each division sets its own quantity to maximize its own profits. So, the cross-price effects are not accounted for. The author shows that a divisional form is preferred for substitute goods and a functional form is preferred when the goods are sufficiently complementary.

In my setting the results are the opposite: a firm prefers a functional structure for gross substitutes and it might prefer a divisional structure for complementary goods if the inter-firm competition is strong enough. Besides me considering price competition, the other main reason for a such a difference in results is that I associate no additional costs with a functional structure (like double marginalization). I focus exclusively on the strategic role of different pricing mechanisms and do not look into internal costs that might be associated with them.

Ju (2003) considers multiproduct firms that produce differentiated goods and compete in prices, which is also what I do. However, his paper has a different focus. He assumes the pricing mechanism to be given (centralized pricing in his case) and studies instead how many differentiated products a firm finds optimal to produce and compares that to the social optimal. In principle, both choices—for optimal pricing mechanisms and for optimal product variety—deserve equal attention. This is so, because an ultimate goal is combining those choices into a unified theory of the behaviour of oligopolistic multiproduct firms, a common arrangement on today's markets, and thus improving our understanding of how this arrangement influences our welfare.

3 Setup

3.1 Market Layout

There are two multiproduct firms and each firm $i \in \{1,2\}$ produces two goods, x_{i1} and x_{i2}, which are either gross substitutes or gross complements to one another. The corresponding goods produced by different firms are gross substitutes, namely x_{1k} is a substitute to x_{2k}, $k \in \{1,2\}$. Such a setup is a simple schematic representation for a typical situation, when firms cover similar product ranges. Fig. 1 illustrates the setup.

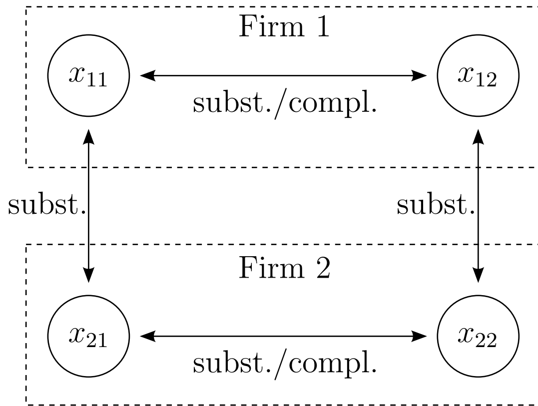
The following notation is used throughout the paper: $i \in \{1,2\}$ denotes one firm, while $j = 3-i$ denotes the other firm; $k \in \{1,2\}$ denotes one good, while $l = 3-k$ denotes the other good.

For simplicity, a symmetric linear demand system is assumed:

$$x_{ik}(p) = 1 - p_{ik} + ap_{jk} + bp_{il} \tag{1}$$

where $a > 0$ and $a + |b| < 1$. If $b > 0$ then the goods of the same firm are gross substitutes, if $b < 0$ then they are gross complements. The condition

Figure 1: Market Setup



that $a+|b| < 1$ guarantees that the demand system is rationalizable, i.e. that there exist preferences that generate it (the technical details are provided in the appendix).

3.2 Pricing

The profits of division k of firm i are

$$\pi_{ik} = p_{ik} \cdot x_{ik}(\boldsymbol{p})$$

where $\boldsymbol{p} = (p_{11}, p_{12}, p_{21}, p_{22})$. As the focus of this paper is not on the costs of production, they are omitted for simplicity.

The total profits of firm i are

$$\pi_i = \pi_{i1} + \pi_{i2}$$

In general, each firm might be able to commit to a variety of pricing mechanisms. The managerial compensation can be contracted upon the total profits, the divisional profits or the combination of both, yielding different response functions. It can even be contracted upon prices and quantities directly, however it is natural to assume the owners do not posses complete information about the demand, in which case such direct contracting is not optimal (see, for example, Fershtman and Judd, 1987).

At the same time, any commitment shall be credible and common knowledge, otherwise it can never change the market equilibrium in favour of the firm. Arguably, the strongest public commitment is when a firm chooses a certain organizational structure that is known to result in a certain pricing mechanism. In this paper I assume that every firm can adopt either a functional or a divisional organizational structure.

A functional structure slices the activities of a firm by function, so all the pricing decisions of the final goods fall within the same department (marketing, or sales). It is then natural to associate a functional structure with centralized pricing, under which the firm sets its prices so as to maximize the total profits:

$$(p_{i1}, p_{i2}) = \arg \max_{(p_{i1}, p_{i2})} \pi_i(\boldsymbol{p})$$

A divisional structure, on the other hand, slices the activities of a firm by product, and it is customary to organize divisions as profit centres (see Jennergren, 1981, page 43). A divisional structure is then associated with decentralized pricing, under which each division sets its own price so as to maximize its own profits:

$$p_{ik} = \arg \max_{p_{ik}} \pi_{ik}(\boldsymbol{p})$$

Under decentralized pricing the divisions within a firm compete with one another as well as with the rivalling firm.

3.3 Game Structure

Changing an organizational structure is more resource consuming than changing prices. Therefore, the prices have ample time to reach an equilibrium between the adjustments of the organizational structures (this is precisely the reason why an organizational structure is a credible commitment). Hence, when choosing an organizational structure, a firm is ought to compare the profits from the consequent price equilibria. The appropriate way to model this situation is to assume a sequential move game with perfect information: first the firms choose their organizational structures and second, after observing the organizational choices, they choose their prices.

It is additionally assumed no firm is a clear market leader, which means that no firm has a guaranteed first move when choosing an organizational structure or prices. So, organizational choices as well as price choices are modelled as simultaneous move games.

Overall, the game then is as follows. First the firms simultaneously choose their organizational structures, then they observe the organizational choices and simultaneously decide upon the prices. This is a standard way to model organizational choices of the firms that compete in prices or quantities (see, e.g., McGuire and Staelin, 1983; Baye et al., 1996b; Ziss, 1998; Zhou, 2005; González-Maestre, 2001).

4 Analysis

Consider the second stage of the game. If firm i has a functional structure, it chooses (p_{i1}, p_{i2}) so as to maximize

$$\pi_i(\boldsymbol{p}) = p_{i1}(1 - p_{i1} + ap_{j1} + bp_{i2}) + p_{i2}(1 - p_{i2} + ap_{j2} + bp_{i1})$$

Solving the maximization problem gives the following best response function:

$$p_{ik}^{f}(p_{jk}, p_{jl}) = \frac{(1+b) + a(p_{jk} + bp_{jl})}{2(1-b^2)} \tag{2}$$

If firm i opts for a divisional structure instead, then each division k chooses its price p_{ik} so as to maximize

$$\pi_{ik}(\boldsymbol{p}) = p_{ik}(1 - p_{ik} + ap_{jk} + bp_{il})$$

Solving the maximization problem gives the following best response function for division k:

$$p_{ik}^{d}(p_{il}, p_{jk}) = \frac{1 + ap_{jk} + bp_{il}}{2} \tag{3}$$

Given the best response functions we can solve for the equilibrium prices. Let p_{ik}^{fd} denote the equilibrium price for good k of firm i, when firm i has a functional structure, while firm j has a divisional structure. Similarly for p_{ik}^{df}, p_{ik}^{ff}, p_{ik}^{dd}.

Suppose firm i chooses a functional structure and its opponent j chooses a divisional one. Then from Equations (2) and (3) it follows that

$$p_{ik}^{fd} = \frac{(2 + a - b)}{2b^2 + 4 - 6b - a^2}$$

Similarly,

$$
\begin{aligned}
p_{ik}^{df} &= \frac{(2+a-2b)}{2b^2+4-6b-a^2} \\
p_{ik}^{ff} &= \frac{1}{2-a-2b} \\
p_{ik}^{dd} &= \frac{1}{2-a-b}
\end{aligned} \tag{4}
$$

These are the equilibrium prices in the respective subgames, i.e. the subgames defined by the organizational choices of the firms.

Now, let π_i^{fd} denote equilibrium total profits of firm i if it chooses a functional structure, and its opponent chooses a divisional structure. Similarly for π_i^{df}, π_i^{ff}, π_i^{dd}.

Then

$$
\begin{aligned}
\pi_i^{fd} = p_{i1}^{fd}(1-p_{i1}^{fd}+ap_{j1}^{df}+bp_{i2}^{fd}) + p_{i2}^{fd}(1-p_{i2}^{fd}+ap_{j2}^{df}+bp_{i1}^{fd}) = \\
\frac{2(1-b)(2+a-b)^2}{(4-a^2+2b^2-6b)^2}
\end{aligned} \tag{5}
$$

Similarly,

$$
\begin{aligned}
\pi_i^{df} &= \frac{2(2+a-2b)^2}{(4-a^2+2b^2-6b)^2} \\
\pi_i^{ff} &= \frac{2(1-b)}{(2-a-2b)^2} \\
\pi_i^{dd} &= \frac{2}{(2-a-b)^2}
\end{aligned} \tag{6}
$$

As the symmetry of the model has resulted in symmetric equilibrium prices and symmetric equilibrium profits, in the following discussion the subscripts for p^{fd}, etc and π^{fd}, etc are dropped.

Consider now the first stage of the game. We know that $a > 0$ and $a + |b| < 1$. From Equations (5) and (6) it then follows after some algebra that

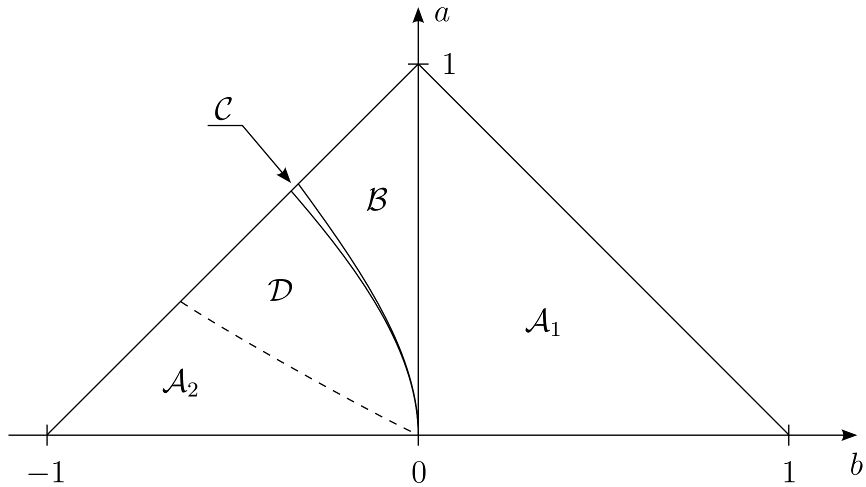
$$\pi^{ff} \gtreqless \pi^{df} \;\Leftrightarrow\; -b\left(a^4 - 4(b-1)^2a^2 + 4b(b-1)^2\right) \gtreqless 0 \tag{7}$$

$$\pi^{fd} \gtreqless \pi^{dd} \;\Leftrightarrow\; -b\left(a^4 - 2(b-1)(b-2)a^2 + b(b-1)(b-2)^2\right) \gtreqless 0 \tag{8}$$

$$\pi^{ff} \gtreqless \pi^{dd} \;\Leftrightarrow\; -b\left(a^2 + 2(b-1)a + b(b-1)\right) \gtreqless 0 \tag{9}$$

The expressions in (7) and (8) are quadratic equations in terms of a^2, the one in (9) is a quadratic equation in terms of a. Therefore for each $b \in (-1, 1)$

Figure 2: Parameters' Space



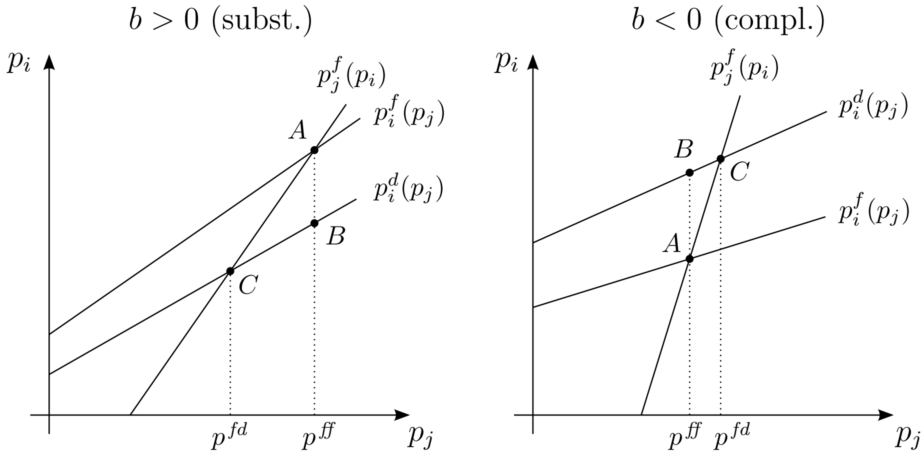
it is straightforward to determine the values of a for which those expressions become positive or negative. The results are plotted in Fig. 2, where

$$\mathcal{A}_1 \cup \mathcal{A}_2 = \{(a,b)\,|\,\pi^{ff} > \pi^{df},\ \pi^{fd} > \pi^{dd},\ \pi^{ff} > \pi^{dd}\}$$
$$\mathcal{B} = \{(a,b)\,|\,\pi^{ff} < \pi^{df},\ \pi^{fd} < \pi^{dd},\ \pi^{ff} < \pi^{dd}\}$$
$$\mathcal{C} = \{(a,b)\,|\,\pi^{ff} > \pi^{df},\ \pi^{fd} < \pi^{dd},\ \pi^{ff} < \pi^{dd}\}$$
$$\mathcal{D} = \{(a,b)\,|\,\pi^{ff} > \pi^{df},\ \pi^{fd} > \pi^{dd},\ \pi^{ff} < \pi^{dd}\}$$

If $(a,b) \in \mathcal{A}_1 \cup \mathcal{A}_2 \cup \mathcal{D}$, then it is a dominant strategy to choose a functional structure and centralized pricing. If $(a,b) \in \mathcal{B}$, then it is a dominant strategy to choose a divisional structure and decentralized pricing. Finally, if $(a,b) \in \mathcal{C}$, then there are two Nash equilibria: either both firms choose a functional structure, or they both choose a divisional structure.

Moreover, if $(a,b) \in \mathcal{A}_1 \cup \mathcal{A}_2 \cup \mathcal{B}$, then the resulting unique equilibrium is also Pareto-efficient from firms' perspective: in $\mathcal{A}_1 \cup \mathcal{A}_2$ the firms choose functional structures and at the same time we have that $\pi^{ff} > \pi^{dd}$, and in $\mathcal{B}$ the firms choose divisional structures and $\pi^{dd} > \pi^{ff}$. In contrast, if $(a,b) \in \mathcal{D}$, then the resulting unique equilibrium is not Pareto-efficient. In $\mathcal{D}$ the firms choose functional structures, whereas if they were to agree on divisional structures, then they would have been better off, because $\pi^{dd} > \pi^{ff}$ in $\mathcal{D}$. In $\mathcal{C}$ the divisional equilibrium is efficient, while the functional equilibrium is not.

Figure 3: Best Response Functions



Notably, there are no asymmetric equilibria, i.e. equilibria, where one firm chooses a functional structure while the other firm chooses a divisional structure.

To understand why it can be profitable for a firm to opt for suboptimal decentralized pricing, it is instructive to look at the best response functions in prices. To make a graphical exposition possible, let us restrict our attention to symmetric prices, i.e. let

$$p_i = p_{i1} = p_{i2}$$

Then the best response functions of a functionally or a divisionally organized firm (Equations 2 and 3 respectively) can be rewritten as follows:

$$p_i^f(p_j) = \frac{1 + ap_j}{2(1-b)}$$
$$p_i^d(p_j) = \frac{1 + ap_j}{2-b}$$

Suppose firm j has a functional structure and firm i considers whether to choose a divisional structure over a functional structure. Fig. 3 depicts this situation for a case of substitutes ($b < 0$) and for a case of complements ($b > 0$).

Consider first the case when $b > 0$. In this case $\frac{1}{2(1-b)} > \frac{1}{2-b}$ and the functional best response line lies above the divisional one. If firm i chooses a functional structure, the resulting equilibrium prices are in point A, if it opts for a divisional one, the equilibrium prices are in point C. Let us analyse a move from A to C as a move from A to B and then to C. Between A and B the prices of firm j are constant, a divisional structure provides a suboptimal price response by definition, therefore the profits of firm i are lower at B than at A. As the goods between the firms are gross substitutes, the profits of firm i are increasing with p_j along any of its best response functions. Consequently, the profits of firm i are lower at C than at B. Summing up: the profits of firm i are lower at C than at A, i.e. there is no incentive to choose a suboptimal divisional structure when one's product range consists of gross substitutes.

The above argument is a general one and while I do not spell it formally for a general demand system, it shall be intuitively clear the result extends beyond the linear demand case.

Consider next the case when $b < 0$. In this case $\frac{1}{2(1-b)} < \frac{1}{2-b}$ and the divisional best response line lies above the functional one. For the same reason as before, the profits of firm i are lower at B than at A. However, switching to a divisional structure and decentralized pricing yields higher equilibrium prices in this case and, consequently, the profits of firm i are higher at C than at B. This a positive strategic effect of decentralized pricing. So, there is an ambiguity between A and C. Which effect prevails depends upon the specification of the demand and a general statement is difficult to make. However, it was shown earlier that for a case of linear demand a decentralized pricing is profitable if the competition between the firms is strong enough and the product range consists of complementary goods, though the complementarity effect shall not be too strong, namely, it shall be that $(a, b) \in \mathcal{B}$.

Finally, consider region $\mathcal{C}$.[2] There are two possible Nash equilibria there: either both firms choose functional structures and centralized pricing or they both choose divisional structures and decentralized pricing. Both equilibria coexist for the same demand parameters. Additionally, the latter equilibrium Pareto dominates the former equilibrium.

In comparison with the literature this result that there are multiple equi-

[2] While it is small for a linear demand, it can be more pronounced for other demand specifications.

libria is uncommon: in the literature there is usually a unique Nash equilibrium (see McGuire and Staelin, 1983; Baye et al., 1996b; Ziss, 1998; Zhou, 2005; González-Maestre, 2001). This literature shows in various settings how an organizational choice depends upon the market parameters. Given the parameters the choice is unique. From the existence of region $\mathcal{C}$ it can be concluded that an organizational choice of a firm can depend not only on the market parameters, but also on the organizational choices of its competitors. Given the parameters, multiple outcomes can be possible.

What equilibrium the firms will coordinate upon will likely depend upon the history of their interaction as the history can provide a focal point here, see Schelling (1960) for a rich discussion on the topic. For example, if the firms are originally in region $\mathcal{B}$ and the competition starts to loosen to such an extent that the firms move to region $\mathcal{C}$, then they are likely to end up with a divisional equilibrium, inheriting it from $\mathcal{B}$. On the other hand, if the firms were to start in region $\mathcal{D}$ and then move to $\mathcal{C}$, then they are likely to end up with a functional equilibrium. In this latter case, a Pareto-inefficient equilibrium is carried into a setting, where a Pareto-efficient equilibrium is already an option. Broadly speaking, this story illustrates how an industry can be *slow* in adjusting its organizational choices to the new market conditions, not because of transaction costs, but because of strategic considerations.

5 Welfare Analysis

One of the results of the previous section is that only two types of equilibria occur: either both firms choose functional structures or they both choose divisional structures.[3] Consider the corresponding prices, p^{ff} and p^{dd}. From (4) it follows that $p^{ff} > p^{dd}$ for $b > 0$ and $p^{ff} < p^{dd}$ for $b < 0$. So, in case of substitutes functional prices are higher than divisional prices. In turn, divisional prices would be higher than perfectly competitive prices, if we were to compare the considered duopoly against a perfectly competitive situation. Intuitively then, the divisional equilibrium shall deliver higher total welfare than the functional equilibrium, because the divisional prices are closer to the perfectly competitive case. Conversely, in case of complements the functional equilibrium shall be the better one. The following formal analysis confirms this intuition.

[3] There are no asymmetric equilibria, i.e. equilibria, where one firm chooses a functional structure, while the other firm chooses a divisional one.

As before, $\boldsymbol{p} = (p_{11}, p_{12}, p_{21}, p_{22})$. Additionally, let $\boldsymbol{p}^{ff} = (p_{11}^{ff}, p_{12}^{ff}, p_{21}^{ff}, p_{22}^{ff})$, etc., and let $\boldsymbol{x} = (x_{11}, x_{12}, x_{21}, x_{22})$. Then

$$CS^{ff} - CS^{dd} = \int_{\boldsymbol{p}^{ff}}^{\boldsymbol{p}^{dd}} \boldsymbol{x}(\boldsymbol{p}) d\boldsymbol{p} = \int_0^1 \boldsymbol{x}\big(\boldsymbol{p}^{ff} + t(\boldsymbol{p}^{dd} - \boldsymbol{p}^{ff})\big) \cdot (\boldsymbol{p}^{dd} - \boldsymbol{p}^{ff}) dt = -\frac{2b\big((b-2)a + (b-1)(b-4)\big)}{(a+b-2)^2(a+2b-2)^2}$$

where CS stands for consumer surplus.

Producer surplus $PS = \pi_1 + \pi_2$, it can be computed from (6). Total welfare $W = CS + PS$. Straightforward computations give:

$$W^{ff} - W^{dd} = -\frac{2b(a+b-1)(2a+3b-4)}{(a+b-2)^2(a+2b-2)^2}$$

For any (a, b) such that $a > 0$ and $a + |b| < 1$ it then holds that $W^{dd} > W^{ff}$ if $b > 0$ and $W^{ff} > W^{dd}$ if $b < 0$.

So, only when the product ranges of firms consist of complementary goods with the complementarity effects strongly pronounced, and only when the competition is not too strong, namely regions $\mathcal{A}_2$ and $\mathcal{D}$, the resulting unique Nash equilibrium is also welfare optimal.

In general, in the case of complements the welfare implications are ambiguous (region $\mathcal{A}_2 \cup \mathcal{D}$ versus region $\mathcal{B}$). However, if the product ranges consist of gross substitutes, then divisionalization creates more welfare than functional structures, while the firms unambiguously choose functional structures. Therefore, a sufficiently high subsidy for creating divisional units will be welfare improving in the case of gross substitutes.

6 Conclusions

This paper studies commitment to different pricing strategies and the resulting price competition on a market with differentiated products and multi-product firms. It extends a well-known intuition that public commitment to suboptimal responses can be beneficial: the main result of the paper shows that choosing a divisional structure and decentralized pricing is more profitable than centralized pricing when firms' product ranges are composed of gross complements and when the market competition is strong.

In practice, different types of organizational structures have many different costs and benefits associated with them. These costs and benefits vary from a market to a market. Observing divisional structures for companies producing complementary goods and observing functional structures for companies producing substitutes does not alone support the proposed theory, because the comparison goes across different markets. Neither observing the opposite rejects the theory, for the same reason. However, there is a theoretical possibility to validate the theory. Obviously, a monopolist always chooses a functional structure. If this monopolist produces complementary goods and if a strong competitor enters the market, then the theory predicts that the monopolist will change his organizational structure to a divisional one. Correcting for other possible costs and benefits of different organizational forms, the prediction is as follows: a monopolist that produces complementary goods is likely to decentralize more once confronted with a strong competitor.

Broadly speaking, studying strategic effects of organizational choices helps us better understand the internal structures of firms as well as the resulting market equilibria. The field is still developing and larger questions, like making a link from team incentives to organizational structures to market equilibria to the resulting product variety, are still difficult to answer in a formal way. This paper is a modest step in that general direction.

Appendix

Here I show that if $a > 0$ and $a + |b| < 1$, then demand system (1) is rationalizable.

Suppose there are 5 goods: $x_1, \dots, x_5$, where x_5 is a numeraire good. Suppose there is a representative consumer, whose income is w and whose demand is as follows:

$$
\begin{aligned}
x_1 &= 1 - \frac{p_1}{p_5} + a\frac{p_3}{p_5} + b\frac{p_2}{p_5} \\
x_2 &= 1 - \frac{p_2}{p_5} + a\frac{p_4}{p_5} + b\frac{p_1}{p_5} \\
x_3 &= 1 - \frac{p_3}{p_5} + a\frac{p_1}{p_5} + b\frac{p_4}{p_5} \\
x_4 &= 1 - \frac{p_4}{p_5} + a\frac{p_2}{p_5} + b\frac{p_3}{p_5} \\
x_5 &= \frac{1}{p_5}\left(w - \sum_{i=1}^{4} p_i x_i\right)
\end{aligned} \tag{10}
$$

Let

$$
\begin{aligned}
x_{11} = x_1, \quad x_{12} = x_2, \quad x_{21} = x_3, \quad x_{22} = x_4 \\
p_{11} = p_1, \quad p_{12} = p_2, \quad p_{21} = p_3, \quad p_{22} = p_4
\end{aligned} \tag{11}
$$

Good x_5 is a numeraire good, hence $p_5 = 1$. Therefore, given definitions (11), demand system (10) implies demand system (1).

From (10) it immediately follows that 1) Walras' law is satisfied, and 2) demand x(p,w) is homogeneous of degree zero. We next check whether the Slutsky matrix is symmetric and negative semi-definite.

Let S be the Slutsky matrix. By definition, its elements s_{lk} are given by

$$
s_{lk} = \frac{\partial x_l}{\partial p_k} + \frac{\partial x_l}{\partial w} x_k
$$

Given (10) it is straightforward to check that $s_{lk} = s_{kl}$. As for the semi-definiteness, let Δ_k denote the k^{th} leading principal minor of matrix S (the determinant of the upper-left $k \times k$ submatrix of matrix S). Then we have

$$
\begin{aligned}
\Delta_1 &= -\frac{1}{p_5} \\
\Delta_2 &= \frac{1-b^2}{p_5^2} \\
\Delta_3 &= -\frac{1-(b^2+a^2)}{p_5^3} \\
\Delta_4 &= \frac{(1-(b+a)^2)(1-(b-a)^2)}{p_5^4} \\
\Delta_5 &= 0
\end{aligned}
$$

From $a > 0$ and $|b| + a < 1$ it follows that

$$\Delta_1 < 0, \quad \Delta_2 > 0, \quad \Delta_3 < 0, \quad \Delta_4 > 0$$

Therefore, by Sylvester's criterion, the Slutsky matrix S is negative semi-definite.

So, Walras' law is satisfied, the demand is homogeneous of degree zero and the Slutsky matrix is symmetric and negative semi-definite. Therefore, there exist preferences that rationalize demand system (10), which in turn implies demand system (1).

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