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Asymmetry in Cournot Duopoly*

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Résumé / Abstract

Nous analysons les cause d'asymétrie entre les firmes et entre les marchés d'une même industrie. Nous nous interrogeons sur le cas où une légère asymétrie technologique présente *ex ante* se répercute *ex post*, de manière amplifiée, sur les coûts, les parts de marché, les prix et les profits. Notre modèle, un duopole de Cournot avec deux marchés, met en lumière les rôles respectifs des conditions du marché, en l'occurence celui de l'élasticité de la demande, et des caractéristiques des organisations, plus précisément le rôle de l'inertie organisationnelle. Il est démontré que ces deux types de facteurs ont un impact similaire, voire sont substituts, en ce qui concerne l'asymétrie dans les coûts. L'inertie organisationnelle semble cependant jouer un rôle plus important que les conditions du marché pour l'asymétrie dans les parts de marché et les profits. Enfin, nous montrons que l'asymétrie dans les coûts qui survient à l'équilibre du duopole n'est pas socialement optimale : les firmes devraient se spécialiser davantage là où elles ont un avantage technologique *ex ante*.

We analyze the sources of persistent asymmetry between firms and between markets in a given industry. We focus on the case where some exogenous ex ante cost asymmetry can be magnified ex post in terms of cost (capabilities), market shares, prices and profit. Our model - a two-product Cournot duopoly - emphasizes the respective role of market conditions (demand elasticities) and organizational characteristics (organizational inertia). We find that both factors act as substitutes in creating asymmetries in cost; however, organizational factors seem to play a greater role than market ones in explaining asymmetries in market shares and profit. We also show that, from a benevolent social planner's viewpoint, the equilibrium asymmetry in cost that results in the duopoly is not enough : each firm should specialize further in the market where it has an ex ante cost advantage.

Mots Clés : Duopole multi-produits, Inertie organisationnelle, Capabilités

Keywords : Multi-Product Duopoly, Organizational Inertia, Capabilities

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INTRODUCTION

Diversity is a prevalent characteristic of human societies. People differ in their personality, values, tastes and features; countries in their landscape, history, languages and cultures. Although economists do not deny the ubiquity of diversity in social life - they actually see it as an important reason for establishing a market system (Friedrich von Hayek, 1945), they have often predicted that such diversity may not permeate most relevant dimensions of economic life, at least in the long run. This is indeed a logical outcome of perfect competition. Take, for example, the behavior of two key economic magnitudes - profits and prices - in this context: clearly, the former would settle at zero for every firm and the latter would take a single value for each product. Empirical research suggests, however, that convergence on economic dimensions may not occur always, as significant discrepancies in firms' conduct and performance have been found to persist over time (Kenneth J. Hatten and Dan E. Schendel, 1977; John Cubbin and Paul Geroski, 1987; Dennis C. Mueller, 1986, 1990; Ariel Pakes, 1987; and Richard Schmalensee, 1987). In this note, we study why this might be so. Specifically, we investigate which characteristics of an economic environment tend to magnify, instead of smoothing out, some socially given (exogenous) asymmetry.

There is an expanding literature that seeks to explain heterogeneity within industries. Some papers (for example Peter Zemsky [1993]) build on the previous literature on spatial competition (for a survey of this literature, see Jean Tirole [1988], chapter 7). Another stream - mainly a theoretical one - attributes this phenomenon to the lack of convexity inherent in organizational design (Rabah Amir, 1995; Benjamin E. Hermalin, 1994) or technology choice (Davis E. Mills and William Smith, 1996). In the absence of convexity, optimizing firms necessarily select corner-solution strategies, and these strategies may lie at different corners of their choice set. These works address an issue that differs from ours in one important respect: they deal with endogenous *ex post* asymmetry and do not relate it to *ex ante* exogenous differences between firms.

A third branch of literature bases industry heterogeneity on the persistent effects of random shocks. The possibility that contingent events affecting a given firm make a lasting impact on its relative position (and that of others) within the industry was pointed out early on by many economists (see e.g., Frank H. Knight [1921]). Such marking events could include unpredictable changes in the firm's business environment (Armen A. Alchian, 1950), as well as successful bets and creative insights by the firm's management (Jay B. Barney, 1986). For the effects of those events to persist over time, however, there has to be some resistance in the business environment that prevents firms' conduct and performance to converge rapidly. There is an ongoing debate between industrial organization and management strategy scholars concerning the causes of this resistance (see Daniel

F. Spulber [1995]). The former would usually look for entry and mobility barriers (Richard E. Caves and Michael E. Porter, 1977), which includes search and learning costs (Boyan Jovanovic, 1982; Steve A. Lippman and Richard P. Rumelt, 1982; Arthur Fishman and Rafael Rob, 1995), whilst the latter would rather focus on the firm's organization (see the survey in Röller and Sinclair-Desgagné [1996]).

This note provides a unifying view on the problem of industry heterogeneity. Within some range of our model's parameters, this phenomenon can readily be linked to the absence of convexity. In the opposite range, on which we concentrate, we show that, under specific organizational and market conditions slight exogenous differences in the firms' respective endowment can lead to large *ex post* discrepancies in technology, profits, prices and market share. We actually find that market and organizational conditions are substitutes in producing technology differences. We also identify two kinds of asymmetry: *firm* asymmetry, which refers to heterogeneity amongst firms competing in an industry - the standard meaning of industry heterogeneity, and *supply* asymmetry, which refers to differences between supply functions in the various markets of a multi-product industry. We find that there would be less divergence between firms *ex post* - their respective profit would be the same, for instance - if only one kind of asymmetry is present *ex ante*.

Our model brings together several notions of the industrial organization and management strategy literatures, yet it remains rather simple and intuitive. We consider a two-market duopoly. Demand functions on each market are independent and identical.[1] Firms are identical *ex ante*, except for a parameter of their cost function which determines their respective marginal cost on each market. This parameter can be seen as capturing a particular kind of what many authors (see Alfred D. Chandler [1992]; and Richard E. Nelson [1994]) call "organizational capabilities", i.e. the efficiency with which a firm can deliver goods on several markets at the same time. If firms are bidivisional, for instance, it may indicate the contribution of their central headquarters' supporting activities.[2] Firms interact within a two-stage game. In the second stage, they compete à la Cournot on each market. In the first stage, they set their actual capabilities, incurring a cost that increases as departure from the *ex ante* situation becomes more drastic. In our interpretation of the model, the curvature of the latter cost function measures the

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[1] The similarity and independence of demand functions seems to fit the situation of an industry such as pharmaceuticals. Consider, for instance, two important markets of this industry: that for cardiovascular drugs and that for cancer drugs. Those markets are about the same size and drugs in different markets are clearly neither substitutes nor complements.

[2] Implicit here is a strict budget constraint, so that a lower marginal cost on one market implies a higher marginal cost on the other market. The presence of this constraint differentiates our set-up from a standard R&D investment game (see e.g., Morton Kamien et al. [1992]).

degree of "organizational inertia" in each firm, i.e. the amount of resistance to change by their respective organization. Organizational inertia is a well-known and acknowledged phenomenon (Rumelt, 1995; and David J. Teece, 1980); its role together with that of *ex ante* capabilities and the slope of market demands in enhancing *ex post* firm and supply asymmetries is clarified below.[3]

The paper runs as follows. Section I presents the model. Section II analyzes how *ex ante* asymmetries can be magnified *ex post* under specific market and organizational conditions. Section III takes up welfare issues associated with firm and supply asymmetries. An important question in competition policy is whether enduring profits of firms in a given industry are due to monopoly power or production efficiency (see e.g., Harold Demsetz [1973]). We demonstrate in this section that firms' profits do not increase at the expense of consumer surplus in the absence of supply asymmetry. We also investigate the optimal levels of firm and supply asymmetries. Section IV concludes the paper.

I. THE MODEL

We consider an industry with two markets A and B and two firms i and j. Markets are characterized by identical and independent inverse demand functions $p^A = a - bQ^A$ and $p^B = a - bQ^B$, where p^A and p^B are the prices associated with respective total quantities Q^A and Q^B, and the parameters a and b are positive.[4] Each firm *k* (= i, j) incurs total cost $c(t_k q_k^A + (1-t_k)q_k^B)$ for producing quantities q_k^A and q_k^B of goods A and B, where $0 \leq t_k \leq 1$. For simplicity, the function $c(\cdot)$ is assumed to be linear with slope equal to 1. Hence, the parameter t_k (resp. $1-t_k$) is firm *k*'s marginal cost for producing on market A (resp. B). Given the constraint on t_k, we interpret this parameter as an index of firm *k*'s organizational capabilities. More precisely, assuming that firm *k* has adopted a bidivisional structure, then t_k indicates the amount of some scarce resource (e.g., the attention of highly competent people) that the central corporate headquarters contributes to each division.

We now analyze a two-stage game between firms i and j. In the second stage, firms compete à la Cournot on markets A and B. That is, each firm sets its quantities q_k^A and q_k^B in order to solve

$$(1) \qquad \max_{q_k^A, q_k^B} \; p^A(\bullet)q_k^A + p^B(\bullet)q_k^B - (q_k^A t_k + q_k^B(1-t_k)) \; ,$$

[3] Note that the management strategy literature sometimes views the dual of organizational inertia - i.e. organizational flexibility - as part of the firm's organizational capabilities, which might create confusion.

[4] With this specification, industry effects due to variations in consumers' preferences are ruled out, so the impact of firms' conduct is emphasized.

taking the other firm's production as given. Standard Cournot calculations yield the equilibrium quantities for each firm:[5]

$$(2)\qquad q_i^A = \frac{a + (t_j - 2t_i)}{3b} \qquad q_i^B = \frac{a + (2t_i - t_j - 1)}{3b}$$

$$q_j^A = \frac{a + (t_i - 2t_j)}{3b} \qquad q_j^B = \frac{a + (2t_j - t_i - 1)}{3b}$$

At stage 1, firms set their respective capabilities t_i and t_j. They do not start from scratch, however, but from some *ex ante* (i.e., socially given or "natural") endowments which we denote by t_i° and t_j° respectively. The presence of organizational resistance or inertia entails that firm *k* incurs a cost $\epsilon(t_k - t_k^\circ)^2$, $\epsilon > 0$, if it chooses to modify its initial capabilities. The problem that each firm solves at stage 1 is then given by

$$(3)\qquad \max_{t_k}\; p^A(\bullet)q_k^A + p^B(\bullet)q_k^B - \epsilon(t_k - t_k^\circ)^2 - (q_k^A t_k + q_k^B(1 - t_k))$$

An interior solution to this problem for firm i must satisfy the following first-order condition:

$$(4)\qquad -bq_i^A[\frac{dq_i^A}{dt_i} + \frac{dq_j^A}{dt_i}] + (a - b(q_i^A + q_j^A))\frac{dq_i^A}{dt_i} - bq_i^B[\frac{dq_i^B}{dt_i} + \frac{dq_j^B}{dt_i}] + $$

$$+ (a - b(q_i^B + q_j^B))\frac{dq_i^B}{dt_i} - \frac{d(\epsilon(t_i - t_i^\circ)^2)}{dt_i} - (q_i^A - q_i^B + t_i\frac{dq_i^A}{dt_i} + (1 - t_i)\frac{dq_i^B}{dt_i}) = 0$$

A similar condition holds for firm j. The second-order condition for an interior maximum to problem (3) is $b\epsilon > 8/9$, and an equilibrium exists in this case provided $b\epsilon \neq 4/3$.

After substituting the derivatives in equation (4) and some manipulations, we obtain the following reaction functions:

$$(5)\qquad t_i = \frac{2 + 4t_j - 9b\epsilon t_i^\circ}{8 - 9b\epsilon} \quad , \quad t_j = \frac{2 + 4t_i - 9b\epsilon t_j^\circ}{8 - 9b\epsilon} \quad .$$

[5] a is assumed large enough so that these quantities are positive.

Note that, when $b\epsilon > 8/9$, these functions are downward sloping. In this case, therefore, firms' capabilities are strategic substitutes in the sense that, if one firm increments its capabilities towards market A, then the other firm increases its capabilities to serve market B.

II. ASYMMETRIES

In this section we study the economic conditions that tend to magnify some initial heterogeneity in the endowments t_i° and t_j°. Therefore, we concentrate on the case where $b\epsilon > 8/9$ (but $\neq 4/3$), $t_i^\circ \neq t_j^\circ$, and the equilibrium values of t_i and t_j satisfy equation (4).[6] Organizational conditions will be given by the inertia parameter ϵ, and market conditions by the demand parameter *b*. It will be useful to distinguish between two meanings of asymmetry, that is

(i) *firm asymmetry*, which occurs when $t_i - t_j \neq 0$; and

(ii) *supply asymmetry*, which occurs when $t_i + t_j \neq 1$.

The sum $t_i + t_j$ can be interpreted as measuring *industry* (as opposed to firm-specific) capabilities. Let us first deal with those capabilities.

A. *Supply Asymmetry*

Adding up the two reaction functions in (5) and rearranging yields

$$(6) \qquad t_i + t_j = \frac{9b\epsilon\,(t_i^\circ + t_j^\circ) - 4}{9b\epsilon - 4} \quad .$$

The next result is a trivial consequence of this equation.

PROPOSITION 1: *There is ex post supply asymmetry, i.e.* $t_i + t_j \neq 1$, *if and only if a similar asymmetry existed ex ante, i.e.* $t_i^\circ + t_i^\circ \neq 1$. *Moreover, if there is an "efficiency bias" ex ante towards market A (resp. market B) so that* $t_i^\circ + t_i^\circ < 1$ *(resp.* > 1*), then supply asymmetry is magnified ex post and we have* $t_i + t_i < t_i^\circ +$

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[6] The case where $b\epsilon < 8/9$ corresponds to a situation already analyzed by Mills and Smith (1996). In this case the objective functions at stage 1 are convex and there are two possible types of pure-strategy equilibria: one with maximum *ex post* differentiation, i.e. t_i-t_j = 1 (even if $t_i^\circ = t_j^\circ$), and one with no differentiation, i.e. t_i-t_j = 0.

t_i° *(resp.* $t_i + t_i > t_i^\circ + t_i^\circ$*).*[7]

It also appears that the magnitude of *ex post* supply asymmetry depends on the product of market and organizational factors $b\epsilon$. The derivative of (6) with respect to this product is given by

$$\frac{d\,(t_i + t_j)}{d\,(b\epsilon)} = \frac{36\,(1 - (t_i^\circ + t_j^\circ))}{(9b\epsilon - 4)^2} \quad . \tag{7}$$

If $t_i^\circ + t_i^\circ < 1$, this derivative is positive; if $t_i^\circ + t_i^\circ > 1$, it is negative. From this and using the above proposition, we can make the additional statement:

PROPOSITION 2. *A smaller product $b\epsilon$ will further enhance ex post supply asymmetry.*

Note that $b\epsilon$ will get smaller due to the joint occurrence of a more elastic demand and a lower organizational inertia, a situation which can be viewed as being relatively close to that of a competitive environment.

B. *Firm Asymmetry*

Let us first analyze asymmetry in firm-specific capabilities. Substracting the two reactions functions in (5) and rearranging, we get

$$t_i - t_j = \rho(t_i^\circ - t_j^\circ) \quad , \quad where \quad \rho = \frac{3b\epsilon}{3b\epsilon - 4} \quad . \tag{8}$$

This yields the following result.

PROPOSITION 3. *Firms diverge in their respective ex post capabilities*, i.e. $t_i - t_j \neq 0$, *if and only if some difference in their initial endowments exists*, i.e. $t_i^\circ - t_j^\circ \neq 0$. *Moreover, since* $|\rho| > 1$, *firm asymmetry in capabilities is magnified.*

Note that, when $b\epsilon > 4/3$, then $\rho > 1$ and the initial biases of firms are reinforced;

[7] We are of course modelling a one-shot situation as opposed to a repeated one. The simplest way to perform the latter would be to replace t_i° and t_j° by t_i and t_j, and make another iteration (this amounts to focusing on Markov strategies). Equation (6) then implies that supply symmetry, i.e. $t_i + t_j = 1$, would always be maintained through time.

on the other hand, if $b\epsilon < 4/3$, then $\rho < -1$ so the firms' respective *ex post* capabilities would permute with respect to their *ex ante* position.

The derivative of ρ with respect to $b\epsilon$ is negative. Interpreting the size of $b\epsilon$ as indicating the amount of departure from a competitive environment, we get the following assertion.

PROPOSITION 4. *A more competitive environment brings an larger increase in firm asymmetry if* $b\epsilon > 4/3$, *but a smaller increase if* $b\epsilon < 4/3$.

Two remarks are relevant at this point. First, supply asymmetry has no impact on firm asymmetry in capabilities, and vice-versa. In that sense the two kinds of asymmetries are mutually exclusive and they deserve separate treatments. Second, the *ex post* magnitude of both sorts of asymmetry depends on the combination of market and organizational factors, but these factors are substitutes: that is, more organizational inertia together with greater product market competition, or greater organizational flexibility jointly with lower product market competition, entail the same effect on industry asymmetry and firm asymmetry in capabilities.

Let us now turn to firm asymmetry in supplied quantities and market shares. The equilibrium quantities calculated in (2) can be rewritten in terms of the asymmetry indices $t_i + t_j$ and $t_i - t_j$. We have that

$$(9)\qquad \begin{aligned} q_i^A &= \frac{1}{6b}(2a - (t_i + t_j) - 3(t_i - t_j)) & \qquad q_j^A &= \frac{1}{6b}(2a - (t_i + t_j) + 3(t_i - t_j)) \\ q_i^B &= \frac{1}{6b}(2a - 2 + (t_i + t_j) + 3(t_i - t_j)) & \qquad q_j^B &= \frac{1}{6b}(2a - 2 + (t_i + t_j) - 3(t_i - t_j)) \end{aligned}$$

Without losing generality let us suppose that $t_i^\circ > t_j^\circ$. By the previous results, this entails that we should have $q_i^A < q_j^A$ but $q_i^B > q_j^B$. The exact size of the asymmetry in supplied quantities can be measured by substracting the right hand equations in (9) from the left-hand ones. This gives

$$(10)\quad q_j^A - q_i^A = q_i^B - q_j^A = \frac{1}{2b}(t_i - t_j) = \Psi(t_i^\circ - t_j^\circ)\ , \ where\ \Psi = \frac{3\epsilon}{6b\epsilon - 8}$$

using (8). On the other hand, adding up the two columns in (9) yields the total equilibrium quantities:

$$(11)\qquad Q^A = \frac{1}{3b}(2a - (t_i + t_j)) \qquad\qquad Q^B = \frac{1}{3b}(2a - 2 + (t_i + t_j))$$

The next proposition summarizes our new observations based upon the latter computations.

PROPOSITION 5. *The quantities delivered by each firm on markets A and B are affected by both supply asymmetry and firm asymmetry in capabilities. However, only firm asymmetry influences the firms' relative position on each market, whilst only supply asymmetry influences total quantities. If there is no supply asymmetry, then total quantities delivered on each market are the same.*

The last term in expression (10) seems to suggest that market and organizational conditions play a different role with respect to supplied quantities, as opposed to what happens in the case of *ex post* capabilities. This assertion can easily be qualified.

PROPOSITION 6. *Market and organizational factors have the same qualitative effect on the firms' relative market shares: that is, a more flexible organization (lower ϵ) or a more elastic demand (lower b) will tend to increase firm asymmetry in supplied quantities. However, ex ante firm asymmetry in capabilities is further magnified in terms of relative market shares (ψ is large) if and only if b is low compared to ϵ.*

Finally, let us analyze asymmetry in firm profits. Starting with the above computations, profit differences, noted π_i-π_j, can be expressed in terms of *ex ante* firm and industry asymmetries. After substitution in the profit functions of the expressions for the endogenous variables and some algebra, we get

$$(12) \qquad \pi_i - \pi_j = \varphi(t_i^\circ - t_j^\circ)((t_i^\circ + t_j^\circ) - 1) \text{ , } where\ \varphi = \frac{2\epsilon(9b\epsilon - 8)}{(3b\epsilon - 4)(9b\epsilon - 4)} \quad .$$

Interestingly, both kinds of asymmetry are found to matter for the existence of differences in profits.

PROPOSITION 7. *Ex ante firm asymmetry and industry asymmetry are each separately necessary conditions for asymmetry in profits, and together they are sufficient. Moreover, the larger these asymmetries, the larger the profit differential.*

Expression (12) also provides insights on who gets higher profits. Without losing generality let us assume again that $t_i^\circ > t_j^\circ$. Whether π_i-π_j is positive or negative depends on whether $b\epsilon$ is smaller or bigger than 4/3 and the industry is biased towards market A or market B. The next proposition summarizes the findings.

PROPOSITION 8. *Firm i makes more profit than firm j if either one of the following conditions hold:* (*i*) $b\epsilon < 4/3$ *and* $t_i^\circ + t_j^\circ < 1$; *or* (*ii*) $b\epsilon > 4/3$ *and* $t_i^\circ + t_j^\circ > 1$. *The reverse is true under the following conditions:* (*iii*) $b\epsilon < 4/3$ *and* $t_i^\circ + t_j^\circ > 1$; *or* (*iv*) $b\epsilon > 4/3$ *and* $t_i^\circ + t_j^\circ < 1$.

This proposition has an intuitive rationale. Recall that, by assumption, firm i is relatively more efficient *ex ante* than firm j to produce for market B, whilst firm j is *ex ante* relatively more efficient on market A. If $b\epsilon > 4/3$, this situation is maintained and magnified *ex post* by proposition 3. Therefore, if the industry as a whole is *ex ante* more efficient serving market B - i.e. $t_i^\circ + t_j^\circ > 1$, then firm i who is the most efficient of the two firms on this market makes higher profits; and conversely, if $t_i^\circ + t_j^\circ < 1$, then firm j who is the most efficient one on market A gets a larger profit. If $b\epsilon < 4/3$, on the other hand, the situation is reversed *ex post*, and firm i (resp. firm j) becomes relatively more efficient serving market A (resp. market B) - i.e. $t_i < t_j$. By proposition 1, however, $t_i^\circ + t_j^\circ < 1$ (resp. < 1) entails that $t_i + t_j < 1$ (resp. > 1). Again, the most efficient firm on the larger market (in terms of supplied quantities) makes higher profits.

Regarding the impact of market and organizational characteristics on the profit differential, let us consider the term φ in (12). Clearly, this term gets closer to 0 as the product $b\epsilon$ decreases and approaches 8/9. The contribution of the two factors b and ϵ is asymmetric, however, and the latter has a stronger influence on the difference π_i-π_j. The next statement highlights these facts.

PROPOSITION 9. *A more competitive environment decreases the asymmetry in profits. However, profit differences are greater if the organizational inertia parameter* ϵ *contributes relatively more to the product* $b\epsilon$ *than the demand parameter* b.

III. WELFARE AND POLICY CONSIDERATIONS

The previous section contains predictions on how *ex ante* asymmetries will be magnified *ex post*. We will now study the consequences of *ex post* asymmetries on consumer welfare and derive the optimal amount of such asymmetries that should prevail. These are matters of interest for at least two important chapters of public policy - competition policy and industrial policy. The present model allows a convenient distinction to be made between these. Competition policy seeks to prevent monopoly practices that can be detrimental to consumers; it can be viewed as regulating firm asymmetries. Industrial policy, on the other hand, focuses on a nation's industrial capabilities; it seems to be concerned, rather, with supply asymmetries.

A. Prices and Welfare

From (11) and proposition (5), it can be predicted that the equilibrium price on each market will not depend on firm asymmetry but only on supply asymmetry. Indeed, after substitution in the inverse demand functions of the expressions for total quantities in (11), we get

$$(13) \qquad p^A = \frac{1}{3}(a + (t_i + t_j)) \qquad p^B = \frac{1}{3}(a + 2 - (t_i + t_j))$$

Note in particular that, according to proposition 1, $t_i^\circ + t_j^\circ = 1$ implies that $t_i + t_j = 1$, so $p^A = p^B = (a+1)/3$. This result is stated as a proposition.

PROPOSITION 10. *If there is no supply asymmetry ex ante, then prices remain equal and constant.*

The result that prices are affected only by supply asymmetry bears interesting conclusions for competition policy. The usual relationship between concentration and consumer welfare does not hold here: since increased asymmetry between firms does not affect prices, consumer surplus may not be affected even though market shares shift and concentration in each market increases. The intuition for this result goes as follows. As firm asymmetry increases, more market share is taken by a given firm on a given market, which increases each firm's market power on the market it dominates. But total industry costs are also reduced, for it is the most efficient firm serving a market who gets to dominate this market. In the present model, cost reduction compensates for greater market concentration to leave prices and consumer surplus unchanged.

B. Optimal Supply Asymmetry

We will now investigate which level of industry capabilities $t_i + t_j$ would be chosen by a benevolent social planner. The social planner's objective in the actual context would be to maximize the sum of the consumer surplus and firm i and j's profits, that is:

(14)
$$W = \frac{a(Q^A + Q^B) + p^A Q^A + p^B Q^B}{2} -$$
$$(q_i^A t_i + q_j^A t_j + q_i^B(1-t_i) + q_j^B(1-t_j)) - \epsilon((t_i - t_i^\circ)^2 + (t_j - t_j^\circ)^2) .$$

For simplicity, let's assume that the planner can control supply asymmetry without affecting firm asymmetry. After some algebra the first-order necessary condition reduces to[8]

(15)
$$\frac{dW}{d(t_i + t_j)}\bigg|_{t_i - t_j \; constant} = (2 - 2(t_i + t_j)) -$$
$$3(2 - 2(t_i + t_j)) - 9b\epsilon((t_i + t_j) - (t_i^\circ + t_j^\circ)) = 0 \quad .$$

This gives the socially desirable level of supply asymmetry in relation with the exogenous parameters:

(16)
$$(t_i + t_j)^* = \frac{9b\epsilon(t_i^\circ + t_j^\circ) - 4}{9b\epsilon - 4} \quad .$$

This level is similar to the one that is predicted in equation (6) and proposition 1. Hence, we have:

PROPOSITION 11. *For a given index of firm asymmetry* $t_i - t_j$, *the level of supply asymmetry that emerges ex post is socially optimal.*

If one accepts the definition of industrial policy proposed above - i.e. public policy that regulates the sum $t_i + t_j$, this result can be seen as yet another argument against setting up such a policy. This interpretation needs to be qualified, of course, because the present model assumes a peculiar industry structure - a duopoly with two markets - and does not incorporate international trade. Proposition 11 shows nevertheless that an industrial policy that intervenes on industry capabilities may not contribute to enhance social welfare.

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[8] Note that this condition is also sufficient by the initial assumption that $b\epsilon > 8/9$.

C. Optimal Firm Asymmetry

We now consider optimal firm asymmetry in capabilities, assuming that supply asymmetry remains constant throughout. Propositions 5 and 10 above state that total quantities and market prices are unaffected by firm asymmetry. Hence, welfare maximization with respect to firm asymmetry reduces to minimizing total costs given by the last two terms of (14). The first-order conditions for this problem can then be written as

$$(17) \qquad \frac{dW}{d(t_i - t_j)}\bigg|_{t_i + t_j \, constant} = 2(t_i - t_j) - b\epsilon((t_i - t_j) - (t_i^\circ - t_j^\circ)) = 0$$

after some algebra. Note that the second-order derivative is positive, so the total cost function to be minimized is concave, when $b\epsilon < 2$. In this case the social planner's preferred level of firm asymmetry is then a corner solution where $t_i - t_j = \pm 1$, which means maximum firm asymmetry. However, when $b\epsilon > 8/9$, the duopolistic outcome could be an interior solution. This entails that *ex post* firm asymmetry may not be optimal when $8/9 < b\epsilon < 2$. On the other hand, if $b\epsilon > 2$, the social planner's problem can have an interior solution that is determined by equation (17) and is given by

$$(18) \qquad (t_i - t_j)^* = \rho^* (t_i^\circ - t_j^\circ) \,, \quad where \quad \rho^* = \frac{b\epsilon}{b\epsilon - 2} \,.$$

Note that the coefficient ρ^* is larger that the coefficient ρ defined in (8), so that the social planner would again prefer more firm asymmetry than what naturally emerges. We therefore have the following proposition.

PROPOSITION 12. *For a given index of supply asymmetry, ex post firm asymmetry is not optimal when capability indices are strictly between 0 and 1. Qualitatively, however, the social planner's choice of capabilities is similar to that of the duopoly.*

This proposition finally implies that it would be in the firms' collective interest to increase firm asymmetry by more than the duopoly outcome: that is, a monopoly would choose more asymmetry.

IV. CONCLUDING REMARKS

We have studied the causes of industry heterogeneity with the help of an integrative yet simple model. We thereby tried to shed some light on the current debate between industrial organization and management strategy scholars as to which type of factors - market or organizational respectively - are most important for explaining heterogeneity. Our model is a first step in this direction. One valuable extension would be to include some of the causes of organizational inertia (e.g., long-term contracts, influence costs, etc.) and endogenize partly in the analysis the extent to which an organization can resist to change. Such an exercise might lead to a finer description of organizational capabilities that would fit some of the peculiar facts provided by industry studies and case studies. Another interesting extension would also be to study a repeated version of the present game and consider some of the dynamic issues raised in evolutionary economics (Nelson and Sidney G. Winter, 1982; Nelson, 1994). In this context, one would need a more detailed description of organizational capabilities that is consistent with the notion of routines; it would also be necessary, and valuable, to make the number of firms in the industry endogenous.

We also tried in this paper to derive results that have empirical content. Recent industry studies, such as those by Karel O. Cool and Schendel (1987) and Catherine Matraves (1996) on the pharmaceutical industry, reveal that different firms lead in different markets, and that concentration in a specific product market can be high. *Ex ante* asymmetry in the firms' respective capabilities is often invoked to explain this outcome: firms have specialized in delivering products for which they had an initial cost advantage. This fact seems consistent with our propositions 3 and 5. Furthermore, overall industry shares and profits of the leading firms in the pharmaceutical industry seem not to have differed much in recent years, whilst overall industry capabilities appear not to have evolve significantly during the same period. This observation also seems consistent with some of our results (namely proposition 7). This is, however, casual empiricism. To rigorously confront the theoretical findings of this paper with the data is an immediate and important challenge for future research.

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