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Market Size and Substitutability in Imperfect Competition: A Bertrand–Edgeworth– Chamberlin Model

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Competition is often associated with the idea that there are many traders in the market or that each price maker is small as compared to the market. This paper introduces this notion of market size in a model of price competition with imperfect substitutes by constructing a model which creates a bridge between the Chamberlin and Bertrand–Edgeworth lines of work on price competition. We investigate the role of two fundamental parameters in the existence of an equilibrium: the market size, given by the number n of competitors, and the degree of substitutability. We prove that: (a) For a given number of $n \geq 2$ of competitors, a sufficiently large but finite degree of substitutability entails nonexistence. This thus generalizes the Bertrand–Edgeworth nonexistence result, which applies only to perfect substitutes. (b) Conversely for a given upper bound on the degree of substitutability, a sufficiently large number of competitors ensures existence, which thus introduces a significant role for market size in models of imperfect competition. We finally investigate the proximity of an equilibrium (when it exists) to a “competitive outcome”, and we find that both high substitutability and large market size are a condition for competitiveness.

1. INTRODUCTION

Though competition is often associated with the ideas that there are many traders in the market or that each price maker is small as compared to overall market size, there has been surprisingly little work formalizing these ideas in a true model of price competition. The two main approaches to this problem were indeed that of the core with a large number of traders¹ and that of Cournot–Nash equilibrium with many firms,² neither of which actually describes the agents as price makers.

Turning now to models where agents truly act as price makers, we essentially find in the literature two main, and hitherto disjoint, lines of work, depending on whether goods are assumed differentiated or perfect substitutes. On one hand, for differentiated products, there is the “imperfect competition” line of work, starting with Chamberlin (1933), and notably developed into a general equilibrium framework by Negishi (1961). As we shall see below, in such models competitiveness is closely associated with the degree of substitutability between goods, obviously a fundamental parameter, but not with market size. On the other hand, in the perfect substitutes case, for which one would

1. Debreu and Scarf (1963), Aumann (1964), Hildenbrand (1974).

2. Gabszewicz and Vial (1972), and many references thereafter. See Mas-Colell (1982) for a survey.

thus expect a competitive outcome, the standard model with price making agents is the so-called "Bertrand" model of competition (Bertrand (1883)). But it has been known since Edgeworth (1897) (see also Shubik (1959), Dixon (1987)), that this model generally has no Nash equilibrium in pure price strategies.³ In particular there is no Nash equilibrium under the standard assumption of decreasing returns to scale.

This brief comparison of these two lines of work shows two problems: first there seems to be some inconsistency between the two modes of formalization, as the perfect substitutes case is not the limit of the imperfect substitutes case when substitutability becomes infinite. Secondly none of these approaches seems to leave much role to market size in explaining competitiveness. The aim of this paper is to remedy these problems by constructing a "Bertrand-Edgeworth-Chamberlin" model of competition which will bridge the gap between the two lines of work and establish a role for market size in competition in models with actual price makers.

We should note that a few attempts have been made to give a role for market size in the perfect substitutes case by amending the traditionally used notion of Nash equilibrium in prices: Shubik (1959), Allen-Hellwig (1985) (1986*a, b*), Vives (1986) showed that, in some sense, mixed stochastic strategies solutions to the Bertrand-Edgeworth games "converged" in probability towards a competitive equilibrium when the number of competitors became large. Dixon (1987) considered some approximate equilibria and showed that for some particular rationing schemes these equilibria did converge towards the competitive outcome when the number of firms became large. In the imperfect substitutes cases, an early contribution by Shapley and Shubik (1969) studied an example with an L-shaped cost curve and a specific linear demand schedule. They showed that the Edgeworth non-existence problem could arise there too, and gave existence conditions which depended on the number of competitors.

Since one of our purposes is to bridge the gap between the Bertrand-Edgeworth and Chamberlinian lines, we shall focus in this paper on the imperfect substitutes case which has been very little studied in the Bertrand-Edgeworth literature. Our contribution will thus be closest in spirit to the Shapley-Shubik (1969) article, but we shall consider a more general model in terms of cost functions and demand structure. This will allow us to give a general formulation of the Bertrand-Edgeworth-Chamberlin model. Moreover the general demand structure will make it possible to clearly disentangle and specify the roles of two fundamental parameters: the "size" of the market, represented here by the number of competitors, and the "degree of substitutability" between the goods, represented by their elasticity of substitution (this will be defined more precisely below). We shall indeed show that the existence and competitiveness of "Bertrand-Edgeworth-Chamberlin" equilibria crucially depends upon these two parameters. More precisely we shall prove that (i) for a limited degree of substitutability a sufficient number of competitors will ensure existence of an equilibrium (ii) reciprocally for any number of competitors there is some degree of substitutability beyond which an equilibrium does not exist, which thus generalizes and explains the Edgeworth nonexistence result, which only dealt with perfect substitutes.

We shall then be able to characterize the proximity of the equilibrium (when it exists) to a competitive outcome. In view of the results above it is clear that the number of competitors will play a crucial role, whereas in traditional models of imperfect competition it is mostly the degree of substitutability between goods that matters.

3. Further formal studies of the Bertrand-Edgeworth model are found, *inter alia*, in Allen and Hellwig (1985) (1986), Beckmann (1965), D'Aspremont and Gabszewicz (1985), Dixon (1987), Kreps and Scheinkman (1983), Levitan and Shubik (1972), Shapley and Shubik (1969), Shubik (1959), Vives (1986).

2. THE BASIC SETTING AND TRADITIONAL EQUILIBRIUM

We shall consider here n competing firms indexed by $i=1, \dots, n$. Firm i produces a quantity q_i of a single good, also indexed by i , which it sells at a price p_i . Firm i has a cost function $C_i(q_i)$ assumed twice continuously differentiable and strictly convex, with $C'_i(0) > 0$. We assume moreover that the second derivative is bounded above and bounded away from zero.

The “demand side” is represented as an aggregate consumer⁴ with a utility function $U(x, m)$ where $x \in \mathbb{R}_+^n$ is the vector of purchases of the goods $1, \dots, n$ and m is the quantity of “money”, taken as the numéraire (in this model, which has, of course, a partial equilibrium flavour, money must be thought of as a convenient shorthand for “the rest of the goods in the economy”). This aggregate consumer has an initial income y . The utility function is assumed to be continuously differentiable and *strictly* quasi-concave in x , in order to reflect the differentiation of the n products.

Walrasian demand

The Walrasian demand of the consumer is obtained as the solution of the following programme:

$$\begin{aligned} &\text{Maximize } U(x, m) \text{ s.t.} \\ &px + m = y. \end{aligned}$$

There is a unique solution because of the strict quasi-concavity of U . This solution is denoted functionally as:

$$\begin{aligned} x &= D(p) = D(p_1, \dots, p_n) \\ m &= M(p) = M(p_1, \dots, p_n) \end{aligned}$$

In what follows it will sometimes be convenient to write the Walrasian demand for good i as $D_i(p_i, p_{-i})$ with $p_{-i} = \langle p_j | j \neq i \rangle$. We shall assume in all that follows that all goods (including money) are normal and gross substitutes. We shall also always assume that money has a limited degree of substitutability with the goods $i = 1, \dots, n$. Some of the goods $i = 1, \dots, n$, however, may become very close substitutes, in a sense which we shall now make more precise.

Elasticities of substitution and the elasticity of the demand curve

As indicated above, we shall take as an index of substitutability between goods their elasticity of substitution or, more specifically, the Allen–Hicks elasticity of substitution.⁵ The elasticity of substitution between goods i and j , $i \neq j$, which we shall denote by σ_{ij} , is related to the term s_{ij} of the Slutsky matrix by:

$$\sigma_{ij} = \frac{y}{x_i x_j} s_{ij}$$

4. Alternatively the demand side can be represented by many consumers but then a specific rationing scheme has to be assumed to derive contingent demand. The aggregate consumer allows us to dispense with the arbitrariness of the rationing scheme while retaining a rigorous choice-theoretic framework for contingent demand. A very thorough discussion of the determination of contingent demand for a given rationing scheme is given in Dixon (1986) for the perfect substitutes case.

5. See Allen and Hicks (1934), Allen (1938).

so that σ_{ij} is positive for substitute goods (in the Hicksian sense). The cross-elasticities of the demand functions are easily computed as:

$$\frac{\partial \text{Log } D_i}{\partial \text{Log } p_j} = \frac{p_j x_j}{y} (\sigma_{ij} - e_{iy}) \quad (1)$$

where e_{iy} is the income elasticity of the demand function D_i with respect to y . Note that since we assumed gross substitutability, we have:

$$\sigma_{ij} - e_{iy} \geq 0 \quad \forall i \neq j.$$

Our assumption of a limited degree of substitutability between money and non-monetary goods will be expressed by the assumption that σ_{im} is bounded above for all i . In what follows we shall often use the own-price elasticity of the demand function D_i with respect to p_i , which we shall denote by η_i in absolute value:

$$\eta_i = -\frac{p_i}{D_i} \frac{\partial D_i}{\partial p_i}.$$

By differentiating the budget constraint with respect to p_i and using formula (1), one easily computes η_i as:

$$\eta_i = 1 + \sum_{j \neq i} \frac{p_j x_j}{y} (\sigma_{ij} - e_{iy}) + \frac{m}{y} (\sigma_{im} - e_{my}). \quad (2)$$

Note that the gross substitutability assumption implies that η_i is higher than 1. We should also note that a high degree of substitutability between goods (i.e. high σ_{ij} 's) implies a high own-price elasticity of the demand function D_i . We should finally note that in view of the identity:

$$\frac{p_i x_i}{y} e_{iy} + \sum_{j \neq i} \frac{p_j x_j}{y} e_{jy} + \frac{m}{y} e_{my} = 1, \quad (3)$$

the above formula giving η_i can be rewritten as:

$$\eta_i = \sum_{j \neq i} \frac{p_j x_j}{y} \sigma_{ij} + \frac{m}{y} \sigma_{im} + \frac{p_i x_i}{y} e_{iy}. \quad (4)$$

A traditional imperfectly competitive equilibrium

We shall start by describing in this model the notion of imperfectly competitive equilibrium most commonly found in the literature.⁶ As we shall see this notion does not relate competitiveness to the size of the market, but only to the degree of substitutability.

In the traditional model, each firm chooses its price in order to maximize profits under the *assumption* that demand is served by all firms under all circumstances, i.e. each firm solves the following programme in p_i :

$$\text{Maximize } p_i q_i - C_i(q_i) \text{ s.t.}$$

$$q_i = D_i(p_i, p_{-i}).$$

6. For a lucid account see, for example, the survey by Friedman (1982). Note that we use here the "objective demand curve" approach, notably developed in a general equilibrium framework for such price making models by Marschak and Selten (1972), Nikaido (1975), Benassy (1988).

Definition. A traditional imperfectly competitive equilibrium is characterized by a set of p_i^* , $i = 1, \dots, n$ such that

$$p_i^* \in \beta_i(p_{-i}^*), \quad i = 1, \dots, n.$$

It is easy to see that the two following traditional assumptions are sufficient for existence:

Assumption A1. The profit function $p_i D_i(p_i, p_{-i}) - C_i[D_i(p_i, p_{-i})]$ is strictly quasi-concave in p_i .

This ensures that $\beta_i(p_{-i})$ is a continuous function of p_{-i} .

Assumption A2 (Boundedness). There exists \bar{p}_i such that:

$$\forall p_{-i}, \forall p_i \in \beta_i(p_{-i}), \quad p_i \leq \bar{p}_i.$$

Clearly A1 and A2 are sufficient for existence of a traditional imperfectly competitive equilibrium. It is also easy to see that the optimal price and production of firm i , p_i^* and q_i^* , are related by:

$$C'_i(q_i^*) = p_i^* \left(1 - \frac{1}{\eta_i} \right)$$

where η_i is evaluated at the point p^* . The equilibrium will thus be close to a competitive one (i.e. one where price equals marginal cost) if η_i is large. But for this it is enough (see formulas 2 or 4 above giving η_i) that only one of the other goods be perfect or very close substitute to good i . In this traditional model thus, “two is enough for competition”, provided there is enough substitutability.

A critique

As was pointed out in Benassy (1986a), there is a logical inconsistency in this traditional formulation of the imperfectly competitive price game in that each competitor takes the price of the others as given (the usual “Nash” assumption applied to a price game), but *also* assumes that the others will satisfy any demand at that price. This clearly violates traditional principles of profit maximization, as no firm with a price p_j and a cost function $C_j(q_j)$ would want to produce more than $C'_j{}^{-1}(p_j)$, which is its profit maximizing production. It is also intuitively clear that omitting this problem of profitable capacities does not leave much chance for market size to play a role, since competitors are assumed to be able to serve any demand forthcoming at any price, however big or small they are. We shall now construct a “Bertrand-Edgeworth-Chamberlin” model which integrates this problem of profitable capacities into the price making mechanism in an imperfectly competitive framework.

3. A BERTRAND-EDGEWORTH-CHAMBERLIN MODEL AND THE PROBLEM OF EXISTENCE

In order to formalize the ideas outlined in the previous section, namely that agents compete by prices but also take into account the potential quantity decisions of their competitors, we shall use a model adapted from one in Benassy (1986a) which captures in the simplest manner the ideas above. In the spirit of Bertrand-Edgeworth we shall thus model a Nash equilibrium with prices as strategic variables, but where each firm has a correct perception of the others’ production possibilities.

Consider thus a firm that has set a price p_i . As we indicated above, under voluntary exchange it will not serve demand beyond its profitable capacity, which will be denoted from now on as $k_i(p_i)$:

$$k_i(p_i) = C_i'^{-1}(p_i).$$

Under the Nash assumption, each firm i knows that other firms $j \neq i$ will not serve demand beyond $k_j(p_j)$. Taking into account these limitations, the demand of the consumer to firm i itself, its contingent demand, is determined as the solution in x_i of the following programme:

Maximize $u(x, m)$ s.t.

$$\begin{cases} px + m = y, \\ x_j \leq k_j, \quad j \neq i. \end{cases}$$

Note that we do not include the capacity of firm i in this programme as we want to determine the largest demand forthcoming to firm i , in the case this firm does not ration its customers. We recognize the solution of the above programme as the effective demand of non-Walrasian theory,⁷ and we shall denote it as $\tilde{D}_i(p_i, p_{-i}, k_{-i})$ where $k_{-i} = \{k_j | j \neq i\}$.

Now firm i chooses its price p_i so as to maximize profits, knowing that sales and production are limited by the above demand function. Thus p_i is solution of the following programme:

Maximize $p_i q_i - C_i(q_i)$ s.t.

$$q_i \leq \tilde{D}_i(p_i, p_{-i}, k_{-i}),$$

which yields the optimal price correspondence $\psi_i(p_{-i})$. Note that only p_{-i} is an argument, since k_{-i} is itself a function of p_{-i} . Now we can define the relevant equilibrium concept:

Definition. A Bertrand-Edgeworth-Chamberlin imperfectly competitive equilibrium is characterized by a set of prices p_i^* such that:

$$p_i^* \in \psi_i(p_{-i}^*) \quad \forall i.$$

What we shall do is to characterize under which conditions such a Bertrand-Edgeworth-Chamberlin equilibrium exists. For this the following theorem, proved in the appendix, will be very useful:

Theorem 1. *Assume A1, A2 and twice continuously differentiable and strictly convex cost functions. Then the traditional imperfectly competitive equilibria are the only possible pure strategies equilibria of the game. A traditional equilibrium is moreover locally Nash.*

Note that this theorem somehow generalizes the traditional Bertrand-Edgeworth result according to which a pure strategies equilibrium, if it existed, would be competitive. Here, in addition, the traditional equilibrium is locally Nash, due to the imperfect substitutability between goods.

7. See Benassy (1975) (1982) for definition and general properties and Benassy (1986a) and Dixon (1986, 1987) for its use in Bertrand-Edgeworth type models.

The problem of existence

In what follows we shall always assume that A1 and A2 hold and thus that a traditional imperfectly competitive equilibrium exists, characterized by prices and quantities p_i^* and q_i^* . In view of Theorem 1, the problem of existence can be posed in the following terms: all we need is to check whether or not the prices p_i^* in a “traditional” equilibrium are actually optimal strategies in the “true” Bertrand-Edgeworth-Chamberlin game. The problem is well-summarized in Figure 1.

The quasi-concave function, maximum in p_i^* , represents the “traditional” profit function, i.e.:

$$\pi_i(p_i) = p_i D_i(p_i, p_{-i}^*) - C_i[D_i(p_i, p_{-i}^*)]$$

The function $\tilde{\pi}_i(p_i)$ represents the true profit function of the Bertrand-Edgeworth-Chamberlin game.

$$\tilde{\pi}_i(p_i) = p_i \tilde{D}_i(p_i, p_{-i}^*, k_{-i}^*) - C_i[\tilde{D}_i(p_i, p_{-i}^*, k_{-i}^*)]$$

We note that this profit function can have discontinuous derivatives for some prices higher than p_i^* , whenever the demand function \tilde{D}_i itself has discontinuous derivatives. Indeed, because the goods are gross substitutes, any increase in p_i increases the demand for the goods of the competitors $j \neq i$. At some point the demand addressed to one of them, say j_1 , reaches his profitable capacity k_{j_1} , and he will then ration the consumer. At the corresponding price \hat{p}_{j_1} , the demand for good i becomes more inelastic and as a result there is a change in the slope of the profit function. This discontinuity may occur again at prices $\hat{p}_{j_2}, \hat{p}_{j_3}, \dots$, when competitors j_2, j_3, \dots reach their capacities. As a result, the

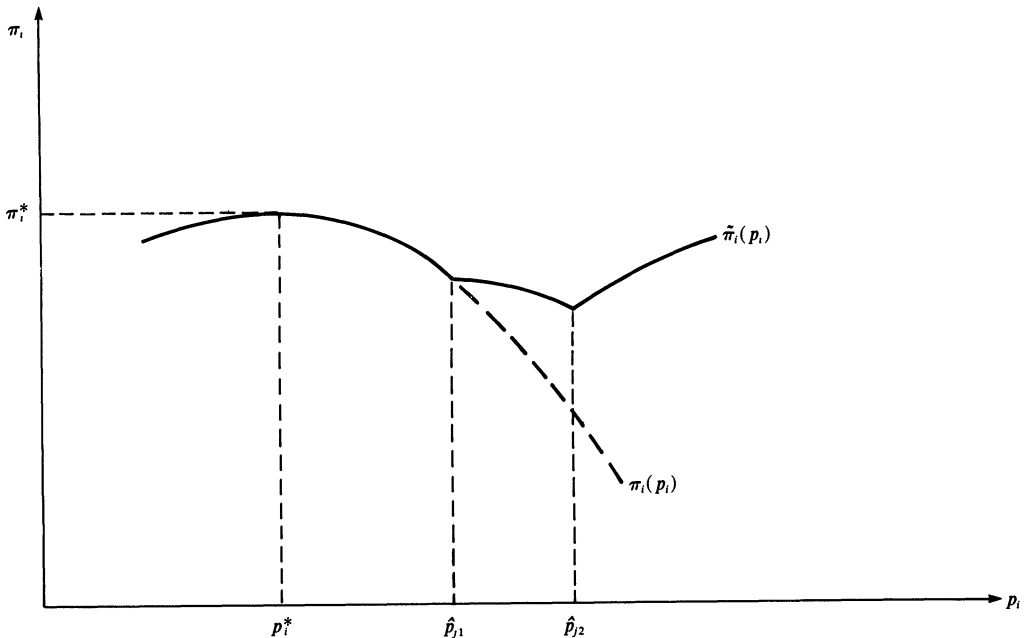


FIGURE 1

profit function $\tilde{\pi}_i$ may become positively sloped, and even reach a maximum above π_i^* , in which case an equilibrium does not exist in view of Theorem 1.

4. A SYMMETRIC MODEL

Of course investigating existence in a general model as above would be quite a formidable task, as no less than n different functional forms of the contingent demand function for each of the n firms would have to be considered. We shall thus consider in what follows a *symmetric* model. In particular, all firms have the same cost function

$$C_i(q_i) = C(q_i) \quad \forall i.$$

This cost function will be a datum in what follows. As indicated above, the second derivative of C is bounded above and below, so that:

$$0 < \gamma_2 \leq C'' \leq \gamma_1.$$

Furthermore, the utility function $U(x, m)$ is symmetrical in all x_i 's.

The first consequence of these symmetry assumptions is that the set of equilibria is symmetric. We shall actually assume a unique equilibrium,⁸ so that:

$$p_i^* = p^*, \quad q_i^* = q^*, \quad \pi_i^* = \pi^* \quad \forall i.$$

Since we shall be dealing in all that follows with economies of very different sizes as the number of firms, n , varies, we now want to make a simple "normalization" assumption which ensures that the "consumption side" and the "production side" are of comparable size. Specifically we shall assume that, whatever n , the Walrasian production per firm is the same and equal to q_0 .⁹ Consequently, the Walrasian price is also the same and equal to $p_0 = C'(q_0)$. We can now represent both the Walrasian equilibrium and the traditional imperfectly competitive equilibrium on the same diagram (Figure 2). Indeed let $\Delta(p) = D(p, \dots, p)$. Note that $\Delta(p)$ corresponds to the traditional *DD* curve in Chamberlinian analysis. The values (p_0, q_0) and (p^*, q^*) are characterized respectively by:

$$\begin{aligned} \Delta(p_0) &= q_0 & C'(q_0) &= p_0 \\ \Delta(p^*) &= q^* & C'(q^*) &= p^* \left(1 - \frac{1}{\eta^*}\right) \end{aligned}$$

where η^* is η_i computed at the symmetric equilibrium point p^* . We see immediately from Figure 2 that:

$$q^* \leq q_0 \quad p_0 \leq p^* \leq p_0 \frac{\eta^*}{\eta^* - 1}. \quad (5)$$

Now the second and perhaps most important effect of this symmetrization is that the profitable capacities will be reached at the same time for all competitors, for a value of the price p_i which we shall denote as $\hat{p}_i = \hat{p}$ (it is of course the same for all firms because of the full symmetry). We shall accordingly have only *two* different demand functions to deal with for each firm (they are moreover the same for all firms): the

8. See for example J. Friedman (1982), for simple sufficient conditions.

9. Actually it would be sufficient that the Walrasian production per firm be bounded above and below, but this would make the exposition more cumbersome.

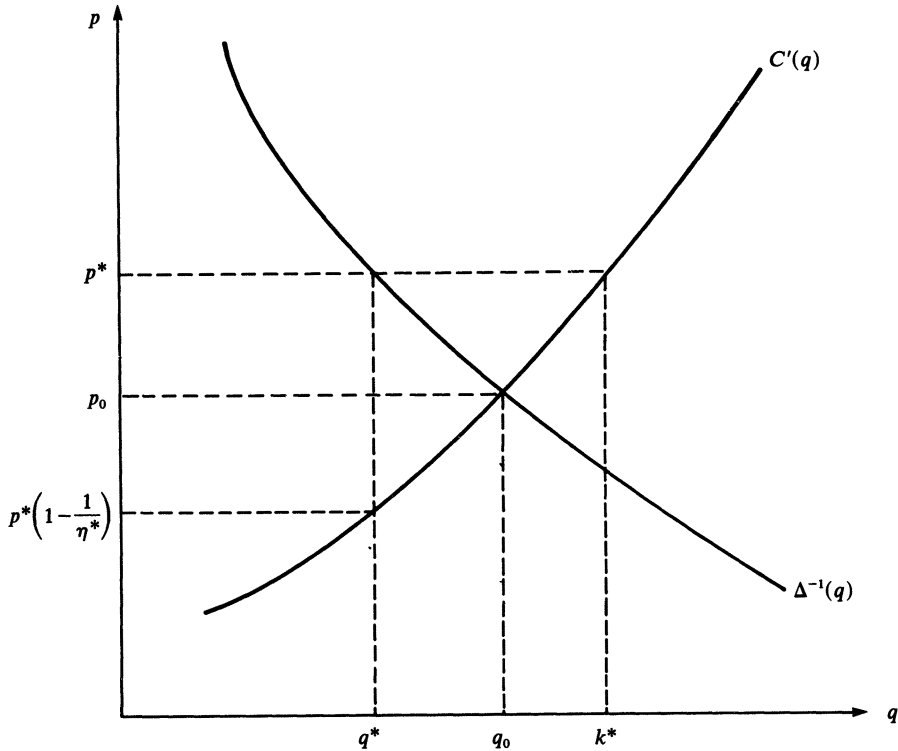


FIGURE 2

unconstrained “traditional” demand function $D_i(p_i, p_{-i})$ and a constrained demand function $\hat{D}_i(p_i, p_{-i}, k_{-i})$ which is the solution in x_i of the following programme:

Maximize $U(x, m)$, s.t.

$$\begin{cases} px + m = y, \\ x_j = k_j, \quad \forall j \neq i. \end{cases}$$

Note that all constraints hold with equality as we know that for $p_i > \hat{p}$, all will be simultaneously satisfied. Taking into account that all prices other than p_i are equal to p^* , the contingent demand is thus

$$\tilde{D}_i = \begin{cases} D_i(p_i, p_{-i}^*) & \text{for } p_i \leq \hat{p} \\ \hat{D}_i(p_i, p_{-i}^*, k_{-i}^*) & \text{for } p_i \geq \hat{p} \end{cases}$$

and the profit function looks as shown in Figure 3. Figure 3 actually depicts the case where the global maximum of the profit function is above π^* and thus there is no pure strategies Nash equilibrium. In the alternative case π^* is the global maximum, and the Nash equilibrium exists.

The problem posed

In dealing with the problem of existence, two parameters will be singled out: the “size” of the market, given by the number, n , of competitors, and the degree of substitutability between the goods, given by the Allen-Hicks elasticity of substitution in a neighbourhood

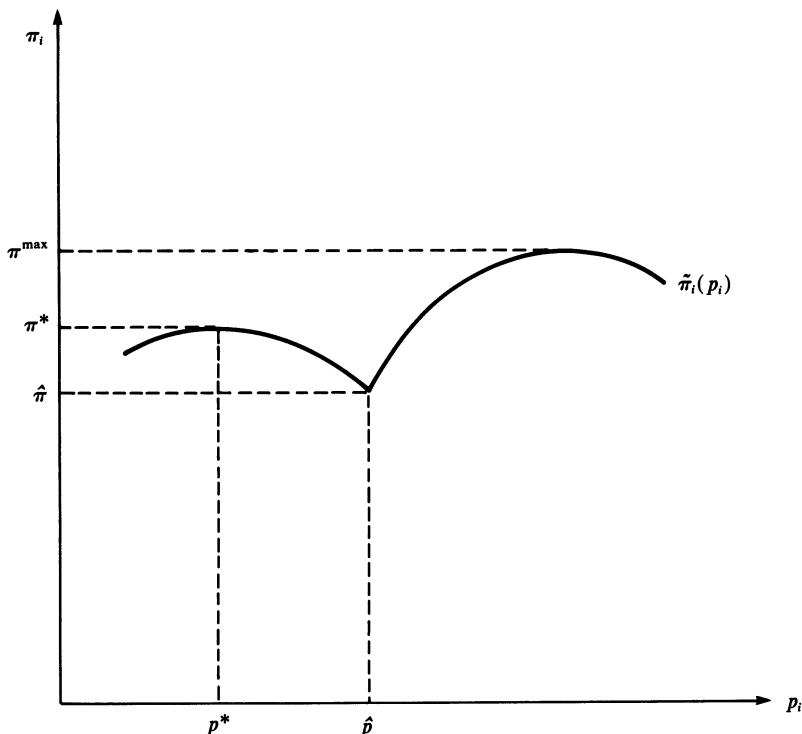


FIGURE 3

of p^* . In what follows, we shall be interested in characterizing which combinations of these two parameters are likely to lead to existence (or non-existence) of equilibrium.¹⁰ As we shall see in the following sections: (1) For a limited elasticity of substitution between all goods, a sufficiently high number of competitors implies existence (Theorem 2). (2) For a given number of competitors, a sufficiently high (but finite) elasticity of substitution between non-monetary goods implies non-existence (Theorem 3).¹¹

5. LARGE NUMBERS IMPLY EXISTENCE

We shall now show that for a limited degree of substitutability, a sufficiently high number of competitors implies existence. For this let us call σ^* the elasticity of substitution between all non-monetary goods at the (symmetric) traditional imperfectly competitive equilibrium. We can now prove:

Theorem 2. *There exists a function $N(\sigma^*)$ taking finite values for finite σ^* such that $n \geq N(\sigma^*)$ implies existence of a Bertrand-Edgeworth-Chamberlin equilibrium.*

10. We should note that a priori any combination of these two parameters is possible as the consideration of simple utility functions such as C.E.S. easily shows.

11. At this stage it may be useful to point out that the "thought experiment" to which these theorems might refer does not consist in increasing the number of firms for given elasticity or increasing the elasticity for given number of firms. It rather consists in considering an economy with given characteristics (notably the number of goods and their elasticity of substitution, as derived from the utility function), and trying to find out whether the corresponding combination is likely to lead to existence or inexistence of equilibrium. It turns out that the corresponding characterizations have the nice and simple form (made more precise in Theorems 2 and 3) according to which somehow "large numbers imply existence, high substitutability implies non-existence".

Proof. The argument of the proof will consist of two basic steps. The first one is to show that an equilibrium exists if the sum of excess profitable capacities of its competitors is greater than the production of each firm at the potential equilibrium. The intuitive argument is that however high each firm raises its price, the demand that spills over to its competitors will never saturate their capacities, and thus he has no interest in deviating. The second step consists in showing that, with a given finite σ^* , this condition can be met with a finite number of competitors. Before going to the more formal steps of the proof, let us recall, and make a few definitions: $k^* = C'^{-1}(p^*)$ is the profitable capacity at the price p^* . Now consider a firm i raising its price above p^* . The price \hat{p} is the one at which the demand of his competitors $j \neq i$ reaches k^* :

$$D_j(\hat{p}, p_{-i}^*) = k^*$$

and call $\hat{q} = D(\hat{p}, p_{-i}^*)$ the demand to firm i at that price.

Lemma 1. *Assume that*

$$(n - 1)(k^* - q^*) \geq q^*$$

then an equilibrium exists.

Proof. Let us write the budget constraint of the aggregate consumer, assuming the competitors of firm i all set $p_j = p^*$:

$$M(p_i, p_{-i}^*) + p_i D_i(p_i, p_{-i}^*) + p^* \sum_{j \neq i} D_j(p_i, p_{-i}^*) = y,$$

and consider an increase in p_i from p^* to \hat{p} . Because all goods are gross substitutes, $M(\hat{p}, p_{-i}^*) \geq M(p^*, p_{-i}^*)$ and therefore:

$$p^* D_i(p^*, p_{-i}^*) + p^* \sum_{j \neq i} D_j(p^*, p_{-i}^*) \geq \hat{p} D_i(\hat{p}, p_{-i}^*) + p^* \sum_{j \neq i} D_j(\hat{p}, p_{-i}^*),$$

which can also be written, with the notation seen above and using the symmetry of the problem:

$$p^* q^* + (n - 1) p^* q^* \geq \hat{p} \hat{q} + (n - 1) p^* k^*$$

or

$$\hat{p} \hat{q} \leq p^* q^* - (n - 1)(k^* - q^*) p^*.$$

This immediately shows that if:

$$(n - 1)(k^* - q^*) \geq q^*,$$

then \hat{q} should be negative, which is impossible. This means that \hat{p} is actually infinite. The relevant profit function is thus $\pi_i(p_i)$ on the whole range, which implies trivially existence. ||

The second step of the proof consists in showing that the condition in Lemma 1 can actually be attained for a finite number of competitors. Indeed k^* and q^* are characterized by:

$$C'(k^*) = p^*, \quad C'(q^*) = p^* \left(1 - \frac{1}{\eta^*} \right).$$

Recall that the second derivative of the cost function is bounded above by γ_1 . In particular, this implies:

$$C'(k^*) - C'(q^*) \leq \gamma_1(k^* - q^*)$$

$$k^* - q^* \geq \frac{C'(k^*) - C'(q^*)}{\gamma_1} = \frac{p^*}{\gamma_1 \eta^*}.$$

The sufficient condition for existence in Lemma 1, i.e. $(n-1)(k^* - q^*) \geq q^*$, will thus be satisfied if:

$$n-1 \geq \frac{\gamma_1 q^* \eta^*}{p^*}. \quad (6)$$

We thus need to evaluate η^* at the symmetrical traditional equilibrium. Recall that by formula (4):

$$\eta_i = \frac{m}{y} \sigma_{im} + \sum_{j \neq i} \frac{p_j x_j}{y} \sigma_{ij} + \frac{p_i x_i}{y} e_{iy}.$$

Call $\mu = m/y$. At the symmetrical equilibrium point:

$$\frac{p_i x_i}{y} = \frac{p_j x_j}{y} = \frac{1}{n} (1 - \mu^*),$$

and thus:

$$\eta^* = \mu^* \sigma_{im} + \frac{(n-1)}{n} (1 - \mu^*) \sigma^* + \frac{(1 - \mu^*)}{n} e_{iy}. \quad (7)$$

To make condition (6) valid in all circumstances, we need an upper bound on η^* which is independent of n . Because all goods are normal, the last term in (7) is smaller than 1 (see formula 3), and thus:

$$\forall n, \quad \eta^* \leq \mu^* \sigma_{im} + (1 - \mu^*) \sigma^* + 1 \leq \sigma_{im} + \sigma^* + 1. \quad (8)$$

We also know that $q^*/p^* \leq q_0/p_0$. Therefore condition (6), which is a sufficient condition for existence, will always be satisfied if:

$$n \geq \frac{\gamma_1 q_0}{p_0} [\sigma_{im} + \sigma^* + 1] + 1 = N(\sigma^*).$$

$N(\sigma^*)$ is bounded for finite σ^* since σ_{im} has been assumed to be bounded above. \parallel

As it turns out, it is fairly easy to prove, using the same method of proof, that Theorem 2 can be extended to any finite number of symmetrical households indexed by $h \in H$. The number N is then equal to:

$$1 + \frac{\gamma_1 q_0}{p_0} \max \{ \sigma_{imh} + \sigma_h^* + 1 \},$$

where the σ_{imh} and σ_h^* are the relevant elasticities of substitution for each household. This is left as an exercise to the reader. We shall now move to the "converse" result, namely that for any number of competitors sufficient substitutability implies non-existence.

6. HIGH SUBSTITUTABILITY IMPLIES NON-EXISTENCE FOR A FINITE MARKET

We shall now show that for any finite number of competitors, one can find a high enough (but finite) degree of substitutability between the non-monetary goods such that no equilibrium exists. This is thus a generalization of the traditional “Edgeworth” non-existence result, which applies only to perfect substitutes.

Theorem 3. *For any number $n \geq 2$ of competitors there is a finite number $\alpha(n)$ such that if the elasticity of substitution $\sigma_{ij} \geq \alpha(n)$ in a neighbourhood of p^* , then no Nash equilibrium in pure strategies exists.*

Proof. The main argument of the proof will be in some ways the reverse of that of Theorem 1: the elasticity of demand will be chosen sufficiently high so that excess capacities of its competitors are small as compared to the production level of each firm. Then we will show that as a consequence the loss in demand between p^* and \hat{p} , and the corresponding loss of profit can be made “small” or negligible, whereas the gain in profit beyond \hat{p} reaches a finite (and bounded below) value, due notably to a positive right hand derivative of the “true” profit function at \hat{p} (cf. Figure 3).

The first step consists thus in characterizing an upper bound on competitors’ excess capacities. Recall that the second derivative of the cost function is bounded below by $\gamma_2 > 0$. Therefore:

$$\begin{aligned}
 C'(k^*) - C'(q^*) &\geq \gamma_2(k^* - q^*), \\
 k^* - q^* &\leq \frac{1}{\gamma_2} [C'(k^*) - C'(q^*)] = \frac{p^*}{\gamma_2 \eta^*}, \\
 (n-1)(k^* - q^*) &\leq \frac{(n-1)p^*}{\gamma_2 \eta^*} \leq \frac{(n-1)p_0}{\gamma_2(\eta^* - 1)}.
 \end{aligned}
 \tag{9}$$

We see that by choosing σ^* (and thus η^* by formula 7) high enough these excess capacities of the competitors can be made as small as wanted. We now want to show that the quantity loss between p^* and \hat{p} , i.e. $q^* - \hat{q}$, can be made as small as wanted provided the elasticity of substitution σ_{ij} is high enough in a small neighbourhood of p^* . The intuitive argument of the proof is to show that what is lost by firm i , $q^* - \hat{q}$, is of the same order of magnitude as what is gained by its competitors, i.e. their total excess capacities $(n-1)(k^* - q^*)$, a quantity which by formula (9) can be made as small as wanted. Indeed it can be proved rigorously (see Benassy (1986b), available on request, for a full proof which is too long to be included here):

Lemma 2. *Whatever ε such that $0 < \varepsilon \leq 1/3$, it is possible to find a number $\chi(\varepsilon, n)$ such that $q^* - \hat{q} \leq \varepsilon q_0$ if $\sigma_{ij} \geq \chi(\varepsilon, n)$ in a neighbourhood of p^* .*

More precisely:

$$\chi(\varepsilon, n) = \frac{1}{\lambda^*} \left[2 + \frac{(n-1)p_0}{\varepsilon \gamma_2 q_0} \right],
 \tag{10}$$

where $\lambda = \sum_{j \neq i} p_j x_j / y$ evaluated at p^*, q^* . Furthermore the condition $\sigma_{ij} \geq \chi(\varepsilon, n)$ must be satisfied in a segment $[p^*, \hat{p}]$ where \hat{p} is bounded above by:

$$\hat{p} - p^* \leq \frac{3\varepsilon^2 \gamma_2 q_0}{(n-1)},
 \tag{11}$$

which defines the neighbourhood of p^* in which σ_{ij} must be greater than $\chi(\varepsilon, n)$.

In the next step of the proof we shall show that a small enough ε implies non-existence, which will occur if $\pi^{\max} - \pi^*$ is positive where π^{\max} is the maximum of profit beyond \hat{p} (Figure 3).

Lemma 3. *There exists a value $\bar{\varepsilon}(n) > 0$ such that for $\varepsilon < \bar{\varepsilon}$ and $\sigma_{ij} > \chi(n, \bar{\varepsilon})$, $\pi^{\max} - \pi^* > 0$ and thus an equilibrium in pure strategies does not exist.*

Proof. We actually only outline the proof, which can be found in full in Benassy (1986b). In order to show that $\pi^{\max} - \pi^* > 0$, we want to make a majoration of $\pi^* - \hat{\pi}$ and a minoration of $\pi^{\max} - \hat{\pi}$. It can first be shown that under the conditions of Lemma 2:

$$\pi^* - \hat{\pi} \leq (\gamma_1 + \gamma_2)\varepsilon^2 q_0^2. \quad (12)$$

We now want to compute a lower bound for $\pi^{\max} - \hat{\pi}$, and for this first find a minorant for $\partial \hat{\pi}_i / \partial p_i$. Recall that beyond point \hat{p} the contingent demand to firm i is given by the constrained demand $\hat{D}_i(p_i, p_{-i}^*, k_{-i}^*)$. The derivative of the profit function is thus:

$$\frac{\partial \hat{\pi}_i}{\partial p_i} = \hat{D}_i + [p_i - C'(\hat{D}_i)] \frac{\partial \hat{D}_i}{\partial p_i}$$

Because money and goods have a limited degree of substitutability, $\partial \hat{D}_i / \partial p_i$ can be shown¹² to be bounded in absolute value, whatever the degree of substitutability between goods, by $\delta(n)$, where:

$$\delta(n) = \frac{q_0}{p_0} [2 + \sigma_{im} + n\sigma_{jm}]. \quad (13)$$

This is bounded for finite n since σ_{im} and σ_{jm} are bounded above. It can further be shown, still under the conditions of Lemma 2, that beyond \hat{p} :

$$\frac{\partial \hat{\pi}_i}{\partial p_i} \geq A - B(p_i - \hat{p}),$$

$$B = \delta(2 + \delta\gamma_1),$$

$$A \geq q_0(1 - \rho\varepsilon) \quad \text{with } \rho = 2 + \delta(\gamma_1 + 2\gamma_2).$$

We thus know that $\pi_i - \hat{\pi}_i$ is greater (beyond \hat{p}) than a quadratic function in $p_i - \hat{p}$, which has, provided $A \geq 0$, its maximum for $p_i - \hat{p} = A/B$. Therefore:

$$\begin{aligned} \pi^{\max} - \hat{\pi} &\geq \int_0^{A/B} [A - B(p_i - \hat{p})] d(p_i - \hat{p}) = \frac{A^2}{2B} \\ \pi^{\max} - \hat{\pi} &\geq \frac{q_0^2(1 - \rho\varepsilon)^2}{2\delta(2 + \gamma_1\delta)}. \end{aligned} \quad (14)$$

Putting together equations (12) and (14) we obtain:

$$\pi^{\max} - \pi^* \geq \frac{q_0^2(1 - \rho\varepsilon)^2}{2\delta(2 + \delta\gamma_1)} - (\gamma_1 + \gamma_2)\varepsilon^2 q_0^2.$$

12. See Benassy (1986b), appendix, where the method used is similar to those already used in Tobin and Houthakker (1950), Neary and Roberts (1980) and Guesnerie and Roberts (1984).

The equation $(1 - \rho\varepsilon)^2 = 2\delta(2 + \delta\gamma_1)(\gamma_1 + \gamma_2)\varepsilon^2$ has a unique solution $\hat{\varepsilon}$ such that $0 < \hat{\varepsilon} < 1/\rho$. Remember we assumed ε to be smaller than $1/3$ and take $\bar{\varepsilon} = \min(\hat{\varepsilon}, 1/3)$. Since δ is a function of n (formula 13), $\bar{\varepsilon}$ is also a function of n , $\bar{\varepsilon}(n)$. Clearly for $\varepsilon < \bar{\varepsilon}(n)$, $\pi^{\max} - \pi^* > 0$, π^* is not an absolute maximum and thus no Nash equilibrium exists. ||

The end of Theorem 3 is now trivial from Lemmas 2 and 3; take:

$$\alpha(n) = \chi[n, \bar{\varepsilon}(n)]$$

where $\bar{\varepsilon}$ has just been defined and $\chi(n, \varepsilon)$ is that given by equation (10) above. Secondly, from equation (11), the condition $\sigma_{ij} \geq \alpha(n)$ needs to be satisfied in a neighbourhood of p^* defined as:

$$\hat{p} - p^* \leq \frac{3\bar{\varepsilon}^2\gamma_2q_0}{n-1}$$

The proof of the theorem is now complete. ||

7. PROXIMITY TO A COMPETITIVE EQUILIBRIUM

We shall now study with the help of Theorems 1, 2 and 3, the problem of the proximity of a Bertrand–Edgeworth–Chamberlin equilibrium to a Walrasian equilibrium. The two basic parameters in our discussion will be, as before, σ^* and n representing respectively the degree of substitutability and market size.

It is actually convenient to start the discussion with the examination of the traditional imperfectly competitive equilibrium. As noted above, under the standard assumptions A1 and A2 a traditional competitive equilibrium exists and is characterized by:

$$C'(q^*) = p^* \left(1 - \frac{1}{\eta^*}\right). \tag{15}$$

For the traditional equilibrium to be close to a competitive one where $C'(q^*)$ is equal to p^* , it is enough that η^* be large. Let us recall the expression of η^* found above (equation (7)):

$$\eta^* = \mu^* \sigma_{im} + \frac{(n-1)}{n} (1 - \mu^*) \sigma^* + \frac{(1 - \mu^*)}{n} e_{iy}. \tag{7}$$

In this we see first that, for a limited degree of substitutability between goods, the economy cannot be competitive, however large the number of competitors. Indeed, as we saw at the end of Section 6 (equation (8)):

$$\forall n, \eta^* \leq \sigma_{im} + \sigma^* + 1$$

and therefore, if σ^* is bounded above, η^* will itself be bounded above irrespective of n and the economy will not be competitive. But if we now take σ^* as the main variable, we see that provided there are at least two competitors, a large σ^* will bring about a large η^* , and thus a competitive outcome. The degree of substitution appears thus as the main determinant of competitiveness, *not* the number of competitors, as the economy will become competitive when products become close substitutes.¹³

13. Of course there may be an indirect link from the number of competitors to competitiveness if raising the number of competitors raises the degree of substitutability between the goods, which may occur for some particular parameterizations. But even in such a case our formula shows that it is not the number of competitors per se but the implied degree of substitutability which generates competitiveness.

If we now consider the Bertrand–Edgeworth–Chamberlin framework defined in this paper, we see that the above “proximity” result does not hold anymore. Indeed Theorem 3 shows that for any finite number of competitors there is some degree of substitution beyond which an equilibrium in pure strategies does not exist, and thus the above result which bases competitiveness on high substitutability only is jeopardized.¹⁴

Our results then point out that market size will become an important factor, together with the degree of substitutability. Indeed Theorem 2 shows that we will have proximity to a competitive equilibrium provided that not only the degree of substitutability, but also market size, are large in a suitable manner. More precisely, take as an index of distance from a competitive equilibrium the number $[p^* - C'(q^*)]/p^*$, which is of course the traditional “degree of monopoly”. We have the following proposition:

Proposition. *Assume $n \geq N(\sigma^*)$ where $N(\sigma^*)$ was defined in Theorem 2. Then an equilibrium in pure strategies exists and the degree of monopoly is bounded above by a quantity of the order of $1/\sigma^*$.*

Proof. Existence follows trivially from $n \geq N(\sigma^*)$ by Theorem 2. By formula (15), the degree of monopoly is equal to $1/\eta^*$. But by formula (7):

$$\eta^* \geq \frac{(n-1)}{n} (1-\mu^*)\sigma^*$$

$$\frac{1}{\eta^*} \leq \frac{n}{n-1} \frac{1}{(1-\mu^*)\sigma^*} \leq \frac{2}{(1-\mu^*)\sigma^*} \quad \parallel$$

This shows that if both σ^* and n go to infinity while satisfying $n \geq N(\sigma^*)$, the equilibrium can be made as close as wanted to a competitive equilibrium. High substitutability and large market size *together* yield competitiveness.

8. CONCLUSIONS

Implicitly or explicitly, traditional models of imperfect competition using prices as strategic variables emphasized mainly the degree of substitution between goods as the main determinant of proximity to a competitive equilibrium. This paper reintroduces the role of market size in such models by making a synthesis between the Bertrand–Edgeworth and Chamberlinian types of price competition.

Our model first extends the Bertrand–Edgeworth type by showing that the traditional Edgeworth non-existence result does not hold only for perfect substitutes, but carries over to differentiated products, a problem largely ignored in the imperfect competition literature.

On the other hand, our model extends the Chamberlinian type in the imperfect competition literature by introducing an explicit role for market size in the modelling and existence of imperfectly competitive equilibria.

Finally our results allow us to characterize the existence and proximity to a competitive equilibrium in terms of *both* parameters of substitutability and market size, whereas traditional models in the literature on imperfect competition (Cournot, Bertrand–Edgeworth, Chamberlin) emphasize only one of these parameters at a time.

14. Of course non-existence here concerns pure strategies equilibria, and it would be interesting to investigate whether mixed strategies equilibria exist, and to characterize them. We know already from the above quoted work of Shubik, Allen and Hellwig and Vives on such mixed strategies equilibria in the pure substitutes case that infinite substitutability without large numbers is not enough for competitiveness.

APPENDIX

Proof of Theorem 1. The proof will proceed in several steps. First we will show that at equilibrium the firms always serve demand. Indeed assume, on the contrary, that we would have:

$$q_i < \tilde{D}_i(p_i, p_{-i}, k_{-i}).$$

Then, because \tilde{D}_i is continuous, the firm could slightly increase its price without changing q_i , thereby increasing profits. We thus know that production and demand are lower than or equal to profitable capacity:

$$q_i = \tilde{D}_i(p_i, p_{-i}, k_{-i}) \leq k_i(p_i).$$

We want to show now that demand is actually strictly less than profitable capacity. Imagine, on the contrary that both were equal, and consider a small increase in p_i . The variation in profit is equal to:

$$\left(\frac{\partial \pi_i}{\partial p_i}\right)^+ = \tilde{D}_i + [p_i - C'_i(\tilde{D}_i)] \left(\frac{\partial \tilde{D}_i}{\partial p_i}\right)^+.$$

If $\tilde{D}_i = k_i(p_i)$, then $C'_i(\tilde{D}_i) = p_i$ and thus $(\partial \pi_i / \partial p_i)^+ > 0$, which would not correspond to a maximum of profits. We thus know that at equilibrium:

$$q_i = \tilde{D}_i(p_i, p_{-i}, k_{-i}) < k_i(p_i) \quad \forall i.$$

The constraints k_i are thus strictly non-binding at the potential Nash equilibrium. They must therefore also be non-binding in a neighbourhood. Consider the set of prices:

$$\Omega = \{p_i, i = 1, \dots, n \mid D_i(p_i, p_{-i}) \leq k_i(p_i) \quad i = 1, \dots, n\}.$$

For prices in Ω none of the constraints k_i is binding, and thus:

$$\tilde{D}_i(p_i, p_{-i}, k_{-i}) = D_i(p_i, p_{-i}), \quad i = 1, \dots, n.$$

From the above result Ω contains potential Nash equilibria in its interior. Now consider such a potential Nash equilibrium p_i^* . The strategy p_i^* must be a local maximum of the programme:

$$\text{Maximize } p_i q_i - C_i(q_i) \text{ s.t.}$$

$$q_i = D_i(p_i, p_{-i}^*).$$

More precisely p_i^* must dominate every strategy p_i such that $(p_i, p_{-i}^*) \in \Omega$. Under Assumption A1, a local maximum of this programme is also a global maximum, and thus using the notation of Section 3:

$$p_i^* \in \beta_i(p_{-i}^*), \quad i = 1, \dots, n,$$

which shows that the potential Nash equilibrium must be a traditional imperfectly competitive equilibrium. We furthermore saw that p_i^* is preferred to any p_i such that $(p_i, p_{-i}^*) \in \Omega$. Since the corresponding set of p_i^* contains p_i^* in its interior, the traditional equilibrium is locally Nash. \parallel

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