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OF DEMAND CHARACTERISTICS ON
THE SUSTAINABILITY OF COLLUSION**

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ABSTRACT

The Neglected Effects of Demand Characteristics on the Sustainability of Collusion*

According to standard IO models, the characteristics of market demand (intercept, slope, elasticity) and of the technology (level of symmetric marginal costs) do not play any role in defining the sustainability of collusive behaviors in Bertrand oligopolies. The paper modifies this counterintuitive result by showing that all the above mentioned factors do affect the sustainability of collusion when prices are assumed to be discrete rather than continuous. The sign of these effects is unambiguous. Their magnitude varies greatly: in some cases it is totally negligible, in others it becomes extremely relevant.

JEL Classification: L13 and L41
Keywords: Bertrand supergames, collusion and market demand

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1 Introduction

Collusion is profitable for participating firms but pernicious for the economy as a whole. It is well known in fact that collusive behaviors increase prices, undermine the incentives to innovate and reduce the quality and the variety of the products. Because of the importance of these negative effects the analysis of collusion always stimulated a lot of research with important links between theory (a vast IO literature) and practice (the daily activity of antitrust authorities).

One of the key aspects in the study of collusion lies in identifying the factors that can facilitate or hinder the sustainability over time of non-competitive behaviors. From a theoretical point of view, it is common to analyze such an issue in the context of Bertrand supergames (introduced in Friedman, 1971), i.e., situations where firms repeatedly compete, and potentially collude, on prices. In these models collusion appears to be sustainable whenever firms prefer the stream of collusive profits rather than the short terms gains that would follow a deviation from the cartel. In other words collusive agreements hold if firms are patient enough and discount the future at a rate that is not lower than a certain threshold. Existing results (for a review see Ivaldi et al., 2003, or Motta, 2004) show that many are the factors that can modify this threshold and thus facilitate or hinder the sustainability of collusive behaviors. Some of these factors have to do with the supply side of the market. For instance a high level of concentration in the industry, the presence of large entry barriers, symmetry of the firms and cross ownership are all factors that facilitate the survival of a cartel. Other factors are instead related with the demand side. As an example, a positive demand shock hinders collusion as it increases the incentives to deviate and conquer the entire market (Rotemberg and Saloner, 1986). Vice versa, collusion is more easily sustainable if the growth in demand is prolonged as lower are the incentives to start a price war when collusive profits increase over time (Haltiwanger and Harrington, 1991). Still these evolutions of market demand are usually modelled in an exogenous way, i.e., by assuming that a certain change would take place and not by modifying the actual parameters of the demand function.

In fact a standard result of traditional analysis is that the parameters that define the shape of market demand (the slope, the intercept, the elasticity), as well as the level of symmetric marginal costs, while obviously affecting the profitability of collusion, do not play any role in defining its sustainability. Therefore, collusive behaviors appear to be equally sustainable in two hypothetical markets where, everything else being equal, the demand function in market A is k times steeper than the demand function in market B or the marginal costs in market A are, say, 5% of the costs that firms in market B face.

This counterintuitive result is driven by the assumption of continuous prices. With such an assumption, all the above mentioned parameters affect in the same way both the long term collusive profits and the short term gains from undercutting the rivals. As a consequence, they cancel out from the constraint that defines the incentives that sustain collusion. In this paper we show that this result does not hold any more (such that demand characteristics and the level of symmetric costs do have an effect on the sustainability of collusion) if one is willing to assume that prices are discrete rather than continuous.

The possibility of discrete prices is often mentioned in the discussion of Bertrand models but the implications of such an assumption are usually studied for what concerns the prediction of perfect competition, i.e., as prices approach the lower bound of the admissible prices interval. For instance, a typical textbook exercise may ask to study how the standard Bertrand equilibrium (prices equal marginal cost and zero profits) changes when prices are discrete and setting $p = c$ is not feasible.[1] On the other hand, nothing has been said about the implications that discrete prices may have in a non-competitive environment, i.e., when prices stabilize at a much

[1] The solution is that firms set the lowest possible price above marginal cost, profits are positive and deviations are strictly costly. This same logic applies to the theoretical end experimental studies about "price floors" (see for instance Dufwenberg and Gneezy, 2000 and Dufwenberg et al., 2007).

higher level with respect to marginal cost. In this paper we start investigating this issue.

Still, before moving to the proper analysis, we briefly discuss the assumption of discrete prices. Is such an assumption plausible? We believe it is or at least we believe it to be much more plausible than the standard hypothesis of continuous prices. Indeed, as it is common in many contexts, also in the Bertrand framework continuity is derived as the limiting case of a discrete distribution as the size of the "tick" vanishes. Continuity simplifies the analysis but often remains a theoretical case which, talking about prices, is not truly met in reality. First of all, prices are discrete as there is a minimum unit of measurement (one cent for goods priced in dollars or euros). But the actual price grid is often much wider than that. In some markets (for instance in the financial sector, in regulated markets or in some auctions) a larger tick can be legally enforced. In others it can be the result of social conventions and habits possibly aiming to reduce transaction costs: therefore, houses are traded in thousands of dollars, cars in hundreds, hotel nights in dollars. Moreover, price competition appears to work through considerable price jumps even in markets where search costs should be negligible. For instance, Baye et al. (2004) show that the price difference between the two lowest prices for homogeneous electronic products sold over the internet through a price comparison site ranges between 3.5% and 22%. Finally, a last hint that points in the direction of discrete prices is implicitly rooted in the Bertrand model itself. The model is built on the assumption that a firm that undercuts the rivals conquers all the market. But for this to be true the price charged by the deviating firm must indeed be different from the price set by the rivals. And in line with the economic and psychological literature about finite sensibility, just perceptible differences and the numerous biases that agents display, this difference has to be large enough to be noticed and appreciated by the consumers.

To summarize, we study a Bertrand supergame of price competition and we show that the characteristics of market demand and the level of symmetric marginal costs do affect the sustainability of collusion when prices are assumed to be discrete rather than continuous. We find that the direction of these effects is unambiguous while their importance varies greatly: in some situations it is totally negligible, in others it can be as relevant as to radically modify the incentives that sustain collusive behaviors. The remaining of the paper is organized as follows: Section 2 introduces the general framework. A more specific analysis is then undertaken for two different settings: the case of a market characterized by linear demand (Section 3) and the case of a market characterized by constant elasticity demand (Section 4). Section 5 concludes.

2 The framework

We consider an oligopoly where N firms produce and sell an homogeneous good. Firms are perfectly symmetric with marginal cost $c \geq 0$, discount rate $\delta \in [0,1]$, no fixed costs and no capacity constraints. Market demand is given by $Q(p)$ with $\frac{\partial Q}{\partial p} < 0$. Firms compete on prices (Bertrand competition) such that the individual demand for firm $i \in N$ is given by:

$$q_i(p) = \begin{cases} \frac{Q(p)}{1+\sum\limits_j \left(1_{\{p_j = p_i\}}\right)} & \text{if } p_i \leq p_j \quad \text{for any } j \neq i \\ 0 & \text{otherwise} \end{cases}$$

In a one shot interaction collusion cannot arise as the incentives to undercut the rivals drive prices down to marginal cost. Still, in an infinite repetition of the one shot game, firms may find it profitable to set and maintain a common price that is higher than marginal cost. In what follows we assume that firms are able, through tacit or explicit agreements, to coordinate on the price that maximizes industry profits, namely the monopoly price p_m.[2] This price solves $\max_p \Pi = (p-c)Q(p)$

[2] More in general it is well known from the so called Folk theorem (see for instance Friedman, 1971) that collusion can take place at any price $p \in (c, p_m]$.

and leads to total profits Π_m. Because of symmetry, the per-period collusive profits for each firm are then given by $\pi_m = \frac{1}{N}\Pi_m$.

Collusion is sustainable if no firm has any incentive to unilaterally deviate from p_m. For this to be true the stream of profits that follows a deviation must be smaller than the stream of collusive profits. Such a condition is formally captured by the following constraint:

$$\pi_m(1 + \delta + \delta^2 ...) \geq \pi_d + \pi_p(\delta + \delta^2 ...) \tag{1}$$

The term π_d (where d stands for deviation) indicates the one off profits of a deviating firm while π_p (where p stands for punishment) refers to the firm's profits once that competitors react to the initial deviation.

A deviating firm slightly undercuts the collusive price p_m. In the standard analysis with continuous prices, the size of this undercut is assumed to be negligible ($\epsilon \simeq 0$) such that the deviator is basically able to fully realize the monopoly profits ($\pi_d = \Pi_m$). In this paper, because of the reasons mentioned in the introduction, we assume that the minimal price undercut, still being very small, is nevertheless strictly positive ($\Delta > 0$). This implies $\pi_d < \Pi_m$. For what concerns π_p, we stick to traditional models (see for instance Porter, 1983) and let firms adopt trigger strategies that punish deviations in the harshest possible way. More precisely, firms react to a deviation by reverting to the one shot Nash equilibrium such that $p = c$ and $\pi_p = 0$ in any future period. Using this result and the fact that $\sum_{t=0}^{\infty} \delta^t = \frac{1}{1-\delta}$, the constraint (1) can be solved for δ such as to get:

$$\delta \geq \delta^* = 1 - \frac{\pi_m}{\pi_d} = 1 - \frac{1}{N}\frac{\Pi_m}{\pi_d} \tag{2}$$

According to this expression, collusion is sustainable if firms' discount rate is not smaller than a certain threshold defined by δ^*. In other words, firms must be patient enough and put sufficient weight on future collusive profits rather than on short term gains that stem from breaking the cartel.

3 Discrete prices with linear demand

Assume that market demand is captured by the linear function $Q(p) = a - bp$ with both a and b positive. Individual demand for firm i is given by:

$$q_i(p) = \begin{cases} \frac{(a-bp_i)}{1+\sum\limits_j \left(1_{\{p_j=p_i\}}\right)} & \text{if } p_i \leq p_j \quad \text{for any } j \neq i \\ 0 & \text{otherwise} \end{cases}$$

The collusive price and quantity are $p_m = \frac{a+bc}{2b}$ and $Q_m = \frac{a-bc}{2}$ such that each firm realizes per-period profits of $\pi_m = \frac{1}{N}\frac{(a-bc)^2}{4b}$. If prices are discrete, a firm that deviates from the cartel sets $p_d = \frac{a+bc}{2b} - \Delta$ which leads to quantity $q_d = \frac{a-b(c-2\Delta)}{2}$ and profits $\pi_d = \frac{(a-bc)^2-4b^2\Delta^2}{4b}$.

By substituting these values in the incentive constraint (2) we obtain that collusion is sustainable if:

$$\delta \geq \delta^* = 1 - \frac{1}{N}\frac{(a-bc)^2}{(a-bc)^2 - 4b^2\Delta^2} \tag{3}$$

This expression nicely shows two related things. First, if $\Delta = 0$ (continuous prices), the constraint simplifies to the standard one $\left(\delta \geq \delta^* = 1 - \frac{1}{N}\right)$ and the characteristics of market demand (the parameters a and b) and of technology (c) do not influence the sustainability of collusion. Second, with $\Delta > 0$, there is a mismatch between the numerator and the denominator of the ratio: collusive profits and short term gains from deviating differ and do not cancel out any more. This implies that changes in a, b or c have an impact on the sustainability of the cartel as they change δ^*, the critical discount rate below which collusion breaks. It is easy to see that there may be cases in which this impact can be huge. In fact a positive Δ implies that the function that defines δ^* presents discontinuities. This happens whenever the condition $a - bc = 2b\Delta$ is met. More in general, notice that the mismatch between numerator and denominator is increasing in Δ: the higher is Δ the lower is δ^* and non-competitive agreements are more easily sustainable. The intuition behind this result is straightforward. A large Δ moves the price set by a deviating firm away from the monopoly price. This implies that profits of a deviator are substantially lower than the stream of collusive profits. Therefore, firms are willing to break the cartel only if they are very impatient (low δ). Nevertheless our main interest lies in studying how the condition (3) is affected by changes in the values of a, b or c when the price tick is discrete but still small: in what follows we assume a Δ which is in the range of 1-2% of the monopoly price.

3.1 Marginal effects and their magnitude

Starting from the constraint defined by (3), it is easy to compute the marginal effects that the parameters a (the vertical intercept of the demand function), b (the slope of the demand function) and c (the level of symmetric marginal costs) have on δ^*. These are:

$$\frac{\partial \delta^*}{\partial a} = \frac{1}{N} \frac{8b^2\Delta^2 (a - bc)}{\left((a - bc)^2 - 4b^2\Delta^2\right)^2} > 0 \tag{4}$$

$$\frac{\partial \delta^*}{\partial b} = -\frac{1}{N} \frac{8ab\Delta^2 (a - bc)}{\left((a - bc)^2 - 4b^2\Delta^2\right)^2} < 0 \tag{5}$$

$$\frac{\partial \delta^*}{\partial c} = -\frac{1}{N} \frac{8b^3\Delta^2 (a - bc)}{\left((a - bc)^2 - 4b^2\Delta^2\right)^2} < 0 \tag{6}$$

The signs of these marginal effects are unambiguous given that all the terms of the ratios are positive. In particular $(a - bc) > 0$ given that $p > c$ and thus $(a - bc) > (a - bp) = D(p) > 0$.

Therefore an increase in a (i.e., a market expansion) increases δ^* and makes collusion more difficult to sustain.[3] Alternatively, one could say that, everything else being equal, collusion is marginally less sustainable in larger markets. On the other side, positive shocks to b or c decrease δ^* and facilitate collusion.

For what concerns the parameter b, notice that, in the equation for the inverse demand curve ($P(q) = \alpha - \beta q$ with $\alpha = \frac{a}{b}$ and $\beta = \frac{1}{b}$), b influences both the vertical intercept and the slope: in a standard (q, p) diagram, an increase in b not only lowers the vertical intercept but also makes the demand curve flatter. In order to disentangle the possibly conflicting contributions of these two effects, we plug the parameters of the inverse demand ($b = \frac{1}{\beta}$ and $a = \alpha b = \frac{\alpha}{\beta}$) in (3) and we study how changes in β affect the new constraint:

$$\delta \geq \delta^* = 1 - \frac{1}{N} \frac{\left(\frac{\alpha}{\beta} - \frac{c}{\beta}\right)^2}{\left(\frac{\alpha}{\beta} - \frac{c}{\beta}\right)^2 - \frac{4\Delta^2}{\beta^2}} = 1 - \frac{1}{N} \frac{(\alpha - c)^2}{(\alpha - c)^2 - 4\Delta^2} \tag{7}$$

The parameter β cancels out and does not appear in (7). In other words the effects of b on δ^* work through the changes that b causes in the intercept α and not on the slope β. In a (q, p) diagram, a lower b implies a higher vertical intercept, i.e., a larger demand for any given price. As in the case of the parameter a, an unexpected and permanent market expansion makes collusion less sustainable.

The magnitude of the effects of variations in a, b and c on the degree of sustainability of collusion varies greatly. A common pattern is that these effects are small, and possibly negligible, for a vast range of the domain. But there are configurations of the parameters for which they can be huge. This is due to the fact that the three marginal effects (4), (5) and (6) are discontinuous as they display a vertical asymptote implicitly defined by the condition $a - bc = 2b\Delta$. In the neighborhood of this discontinuity, small variations in the parameters can have a major impact on

[3] Thinking in terms of the inverse demand function (standard quantity-price diagram) we have that $P(q) = \alpha + \beta q$ with $\alpha = \frac{a}{b}$ and $\beta = \frac{1}{b}$. Obviously an increase in a implies a positive demand shock also under this formulation.

the sustainability of a cartel.

Consider for instance the following examples that focus on the effects of b on δ^*.[4] Figure 1.a depicts δ^* (as defined in (3)) as a function of $b \in (0, 10)$ when $N = 2$, $a = 1$, $c = 0$ and $\Delta = 0.01$. Figure 1.b refers instead to the case with $N = 2$, $a = 1$, $c = 0.3$ and $\Delta = 0.01$. Therefore, the only difference between the two duopolies is that in the second one marginal costs are positive. As a consequence, in Figure 1.b the domain of b is restricted to $b \in (0, 3.3\bar{3})$. These are the positive values of b that fulfill the condition $(a - bc) > 0$ which ensures that profits are positive and production takes place.

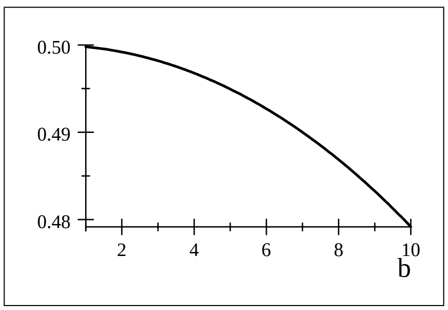

Fig. 1.a: The effects of b on $\delta^*$for $c = 0$.

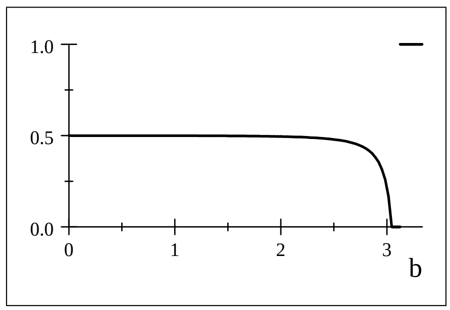

Fig. 1.b: The effects of b on $\delta^*$for $c = 0.3$.

In the first scenario we are far from the discontinuity that arises at $b = \frac{a}{2\Delta + c} = 50$. It follows that the effects of b on δ^* are limited. In the second situation the discontinuity arises at $b = 3.125$ and small variations of b in the neighborhood of this asymptote can have a dramatic impact on δ^*. Consider for instance three hypothetical markets that are characterized by $N = 2$, $a = 1$, $c = 0.3$ and $\Delta = 0.01$ (i.e., the situation depicted in Fig. 1.b) and that only differ in the level of the parameter b. In particular, $b = 1$ in market A, $b = 3$ in market B and $b = 3.2$ in market C. With continuous prices these differences in the demand curve would not influence the incentives to maintain a cartel: in all the three markets, collusion

[4] Analogous examples can be easily constructed for what concerns the effects of a or c.

would be sustainable for any $\delta \geq 0.5$. Our analysis shows instead that the situation is radically different when prices are assumed to be discrete. More precisely, by plugging the actual parameters in (3), we obtain that collusion is much more easily sustainable in market B ($\delta \geq 0.219$) rather than in market A ($\delta \geq 0.4996$). Finally, collusion cannot be sustained at all in market C: in this case the constraint is given by $\delta \geq 1.32$ which cannot happen given that $\delta \in [0, 1]$.

4 Discrete prices with constant elasticity demand

The elasticity of market demand is often mentioned as a factor that may affect the sustainability of collusion. Nevertheless, the formal analysis of its effects remains a bit vague, at least for what concerns the framework of Bertrand competition.[5] It is well known (see Ivaldi et al., 2003, or Motta, 2004) that there is an inverse relationship between elasticity and the profitability of collusion.[6] Through this channel, elasticity surely has an indirect effect on cartel stability: low elasticity makes collusion more profitable such that it is more likely that firms will try to implement and maintain non-competitive behaviors. On the other hand, standard analysis does not find any direct effect of elasticity on the sustainability of collusion. The reason lies again in the fact that, under the assumption of continuous prices, the characteristics of the demand function do not affect the critical discount factor above which collusive agreements become sustainable.

In this section we study the role of demand elasticity when prices are discrete. An ideal framework for analyzing such an issue is provided by demand functions characterized by a constant elasticity. The general form for such a function is given by $Q(p) = ap^{-\eta}$ where η is the parameter that captures elasticity. For the sake of tractability, in what follows we set $a = 1$. As before, firms are assumed to be

[5] For the case of Cournot oligopolies, Collie (2004) relies on numerical simulations to show that high elasticity makes collusion more easily sustainable.

[6] In fact, as it is made explicit by the formulation of the Lerner index, the optimal collusive price (i.e., the monopoly price) is negatively related with the elasticity of market demand.

perfectly symmetric with marginal cost $c > 0$, discount rate δ, no fixed costs and no capacity constraints. Competition is on prices such that generic firm i faces the following demand function:

$$q_i(p) = \begin{cases} \frac{p^{-\eta}}{1+\sum\limits_j \left(1_{\{p_j = p_i\}}\right)} & \text{if } p_i \leq p_j \quad \text{for any } j \neq i \\ 0 & \text{otherwise} \end{cases}$$

The collusive monopoly price is given by $p_m = \frac{\eta c}{\eta - 1}$ which implies total quantity $Q_m = \left(\frac{\eta-1}{\eta c}\right)^{\eta}$. It follows that each colluding firm realizes per period profits of $\pi_m = \frac{1}{N\eta}\left(\frac{\eta-1}{\eta c}\right)^{\eta-1}$. At the opposite, a deviating firm sets the price $p_d = \frac{\eta c}{\eta-1} - \Delta$ that leads to quantity $q_d = \left(\frac{\eta c}{\eta-1} - \Delta\right)^{-\eta}$ and one-off profits $\pi_d = \frac{(c+\Delta-\eta\Delta)}{(\eta-1)} \frac{1}{\left(\frac{1}{\eta-1}(\Delta+\eta c-\eta\Delta)\right)^{\eta}}$. According to the incentive constraint (2), collusion is then sustainable if the following condition holds:

$$\delta \geq \delta^* = 1 - \frac{1}{N\eta}(\eta - 1) \frac{\left(\frac{1}{\eta-1}(\Delta + \eta c - \eta\Delta)\right)^{\eta}}{c + \Delta - \eta\Delta} \left(\frac{1}{\eta c}(\eta - 1)\right)^{\eta-1} \tag{8}$$

This is quite a complicated function (notice the discontinuity at $\eta = \frac{c+\Delta}{\Delta}$) and its first derivative with respect to η is too cumbersome to be discussed. In order to have a feeling for the sign and the magnitude of the effects of η on δ^* we thus rely on a numerical example. Figure 2 reports the case with $N = 2$, $c = 0.1$, $\Delta = 0.01$ and $\eta \in (1, 12)$.

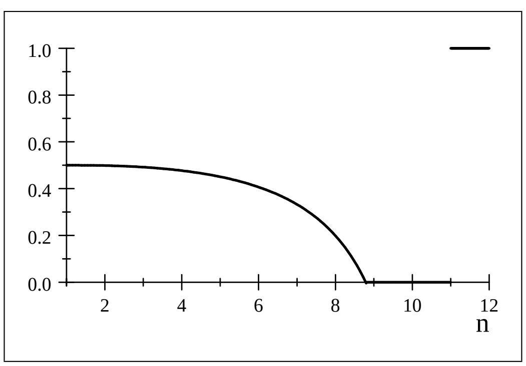

Fig. 2: The effects of η on δ^*.

The graph shows that there is an initial area in which δ^* is a decreasing function of η such that collusion becomes more easily sustainable as elasticity increases (in absolute value). Then there is an area in which the actual δ would be negative such that it is constrained to $\delta = 0$ and collusion is always sustainable. Finally, the function presents a vertical asymptote (in this case at $\eta = 11$) on the right of which δ is constrained to $\delta = 1$ and collusion cannot be sustained at all. As it was the case in the previous section, small variations of η around this critical point may have major effects on the solidity of non-competitive behaviors.

5 Summary and future research

The paper analyzed the issue of the sustainability of collusion in Bertrand supergames under the assumption of prices being discrete rather than continuous. In particular, the analysis highlighted the role that previously neglected factors, like the characteristics of market demand and the level of technology, may have in shaping the incentives that sustain a cartel. The paper can be extended in a number of ways. On the theoretical side, it would be interesting to investigate a similar setting in the context of partially differentiated products and/or Cournot oligopolies. On the empirical side, some of the results of the paper could be tested against the data. For instance, the model implies that the degree of sustainability of collusive behaviors is an increasing function of the price tick Δ. For what concerns European countries, an important exogenous variation of Δ was caused by the introduction of the Euro in January 2002. For example, Δ increased by a factor of around 6.5 for goods previously priced in French Francs while it increased by a factor of almost 20 for goods priced in Italian Liras. In markets characterized by high volumes and low unitary price (for instance some raw materials), these variations may have had an actual effect on the sustainability of non competitive behaviors.

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