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Abstract

I characterize microfounded endogenous market structures with Bertrand and Cournot competition and perform welfare analysis generalizing the Mankiw-Whinston condition for excess entry. The impact of market leaders on welfare is reconsidered, with a number of policy implications about strategic investments, vertical contracts, bundling, mergers and more. The neutrality of consumer surplus holds only when utility is homothetic. Under quantity competition, aggressive (accommodating) leaders increase consumer surplus if the elasticity of utility is decreasing (increasing) in consumption. This provides general rules to evaluate mergers and abuse of dominance issues in antitrust policy.

Keywords

Endogenous entry, oligopoly, welfare

JEL Codes L1

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Endogenous Market Structures and Welfare¹

This article characterizes microfounded endogenous market structures with Bertrand and Cournot competition and performs welfare analysis generalizing the Mankiw and Whinston (1986) case for excess entry to product differentiation. I found the analysis on the non-homothetic utility introduced by Dixit and Stiglitz (1977) and recently re-examined by Zhelobodko *et al.* (2012) to study monopolistic competition. In case of oligopolistic competition, I find that there are too many firms selling too little at an excessive price if the elasticities of utility and marginal utility for each good are non-increasing, which includes the Mankiw-Whinston case of homogeneous goods and the Dixit-Stiglitz case of CES preferences. Moreover, I reconsider the welfare analysis presented in Etro (2011) of the role of leaders in these markets, with a number of implications for the impact of R&D and other strategic investments, vertical contracts, bundling, mergers and other commitments on consumer surplus.

Recent research on endogenous market structures (as in Etro, 2006) has characterized the optimal commitments that firms can adopt to gain a competitive advantage. The general principle is that only commitments leading to an aggressive behavior in the market (larger production and lower prices) are profitable. Moreover, in a number of examples presented by Davidson and Mukherjee (2007), Etro (2008, 2011), Erkal and Piccinin (2010), Ino and Matsumura (2012) and others, these commitments do not affect the utility of the consumers, therefore leading to an unambiguous increase in welfare, with crucial implications for industrial and antitrust policy.

Analyzing the impact of strategic commitments by leaders in the microfounded model adopted here, Etro (2011) stated a neutrality result for the strategies of the entrants and for consumer surplus. However, this neutrality holds only when preferences are homothetic, that is with CES utility or any monotonic transformation of it. I show that, under competition in quantities, the strategic commitment of the leaders may lead to either an increase or a decrease in consumer surplus depending on whether the elasticity of the utility is decreasing or increasing in consumption. In the first case we have beneficial concentration associated with the leadership, in the second case we have detrimental concentration. This delivers simple decision rules for antitrust policy: for instance, a merger decreases consumer surplus if the elasticity of utility with respect to consumption is increasing, while a strategic commitment by a market leader (for instance an optimal vertical contract with a retailer, or the decision to bundle two goods) increases welfare when the same elasticity is decreasing.

The analysis is also related to the growing literature on aggregative games: Anderson *et al.* (2012) derive similar neutrality results for a general class of aggregative games which includes CES preferences as a particular case. Here I

 $^{^1\}mathrm{I}$ am thankfull to Paolo Bertoletti for enlight ening comments, and to Jacques Thisse for further discussion.

generalize that analysis beyond the CES case, complementing the work of Bertoletti *et al.* (2008) and Zhelobodko *et al.* (2012) on monopolistic competition.

The article is organized as follows. In Section 1 I derive the main results for both Bertrand and Cournot competition. In Section 2 I discuss the welfare implications for a number of examples and an extension to endogenous sunk costs in the tradition of Sutton. In Section 3 I conclude.

1 Microfounded Market Structures

Consider a representative agent with preferences depending on the consumption of n goods according to the following separable utility:

$$U = \Psi\left(\sum_{j=1}^{n} u\left(x_{j}\right)\right) \tag{1}$$

where x_j is consumption of good j, $\Psi(\cdot)$ is an increasing function, u(x) > 0, u'(x) > 0 and $u''(x) \le 0$. The budget constraint is $\sum_{j=1}^{n} p_j x_j = E$, where p_j is the price of good j and E is the exogenous endowment of the representative agent. The problem of utility maximization under the budget constraint implies:

$$u'(x_i) = \lambda p_i \tag{2}$$

with λ Lagrange multiplier of the budget constraint. For simplicity, we assume that each firm produces one of the goods at the constant marginal cost c. Entry requires a fixed cost of production F. Bertoletti *et al.* (2008) and Zhelobodko *et al.* (2012) have independently characterized the equilibrium with an infinity of firms, that is with monopolistic competition. Here we will focus on the case in which a limited and endogenous number of firms compete in prices or in quantities.

1.1 Bertrand competition

The direct demand can be derived as $x_i = D(\lambda p_i)$ with $D'(\lambda p) = 1/u''(x) < 0$. Given the general demand function, gross profits for each firm are:

$$\Pi^{i} = (p_{i} - c) D(\lambda p_{i})$$
(3)

where the prices of the competitors affect demand through the impact on the Lagrange multiplier. As well known, only a homothetic utility provides a demand which is multiplicatively separable, such that $x_i = d(\lambda)d(p_i)$ for some decreasing function $d(\cdot)$. In particular this is the case under CES preferences, when $d(\cdot)$ is isoelastic and the elasticity of the utility $\rho(x) = xu'(x)/u(x)$ is a constant (then we have $xu'(x) \propto u(x)$).

The budget constraint $\sum_{j} p_{j} D(\lambda p_{j}) = E$ determines implicitly the multiplier λ , which depends on each price. In particular, total differentiation provides:

$$\frac{d\lambda}{dp_i} = -\frac{D(\lambda p_i) + \lambda p_i D'(\lambda p_i)}{\sum_j p_j^2 D'(\lambda p_j)} = -\frac{x_i \left[1 - r(x_i)\right]\lambda}{r(x_i) \sum_j \frac{p_j x_j}{r(x_j)}} < 0$$
(4)

where we defined the elasticity of the marginal utility or relative love for variety (Zhelobodko *et al.*, 2012) as $r(x) \equiv -xu''(x)/u'(x)$ and we assumed r(x) < 1 to guarantee that goods are substitutes. We remark that the relative love for variety is constant only with homothetic utility, in which case $\rho'(x) = \rho(x)[1 - \rho(x) - r(x)]/x = 0$.

The general framework induces a complex interaction between the firms under price competition. Nevertheless, we can characterize in a simple way the symmetric Bertrand equilibrium, which we assume to be unique. In the short run (that is for given n), the equilibrium price can be derived (see the Appendix) as:

$$p = \frac{n-1+r(x)}{(n-1)\left[1-r(x)\right]}c$$
(5)

where x = E/np by symmetry. Notice that the markup disappears when goods become homogenous $(r(x) \to 0)$. An increase in the number of firms exerts two effects: a direct competitive effect to reduce prices and an indirect and ambiguous effect through the impact on the relative love for variety. As long as $r'(x) \ge 0$ the price is always decreasing in n, but not necessarily otherwise. In the long run, the endogenous market structure (indexed with b for Bertrand equilibrium) is characterized by the price:

$$p^{b} = \frac{sc}{(s-1)\left[1 - r(x^{b})\right]}$$
(6)

where s = E/F is defined as the relative market size, and the production of each firm satisfies:

$$x^{b} = \frac{\left[1 - r(x^{b})\right](s-1)F}{c\left[1 + r(x^{b})(s-1)\right]}$$
(7)

1.1.1 Welfare analysis

From a welfare point of view, it is interesting to compare this outcome with the constrained second best \dot{a} la Mankiw and Whinston (1986) in which strategic (Bertrand) behavior is taken as given but the number of firms can be chosen to maximize welfare (in the Appendix we show that this corresponds to the constrained optimum derived by Dixit and Stiglitz, 1977). Besides market power, two classic externalities bias the equilibrium: a business stealing effect leads to excess entry because firms do not take into account the impact of entry on the profitability of the rivals, and a consumer surplus effect leads to too few firms because these do not internalize the impact of the provision of a new variety of good on consumer surplus. Since the externalities work in opposite directions, the final outcome is ambiguous and depends on the shape of the utility function. However, we can derive a simple sufficient condition for excess entry focusing on the elasticities of utility and marginal utility. In the Appendix we prove the following proposition:

Proposition 1. Under separable utility, the endogenous market structure with Bertrand competition is characterized by the endogenous number of firms:

$$n^{b} = 1 + r(x^{b})(s-1) \tag{8}$$

which is above the constrained optimal number if $\rho'(x) \le 0$ and $r'(x) \le 0$.

In the standard case of isoelastic utility, with $\rho'(x) = r'(x) = 0$, the number of firms is (weakly) above the optimal one, the price is above the optimal level and individual production is below its optimal level.² The same happens whenever the elasticity of the utility and the relative love for variety are decreasing in consumption. An example emerges with $u(x) = (x-a)^{\rho}$ with $\rho < 1$, in which case both elasticities are decreasing whenever $a \in (0, x)$. In all these cases, the business stealing effect is prevailing.

It is important to remark that the proposition states only sufficient conditions for excess entry: the latter can emerge also when $\rho(x)$ is weakly increasing, namely if $0 < \rho'(x) < \rho(x)^2/(s-1)x$ for any x (see the Appendix). Therefore, loosely speaking, the chances that excess entry occurs are actually larger under Bertrand competition as opposed to monopolistic competition. This is not surprising because strategic interactions lead to higher markups (compared to monopolistic competition) and therefore attract more entry.

1.1.2 The role of leaders

Let us now look at the impact of strategic commitments adopted by a firm (a leader) on the structure of the market and on consumer surplus following the analysis started in Etro (2006, 2011).³ The focus is on a class of demand functions $D(p_i, P_{-i})$ where $P_{-i} = \sum_{j=1, j \neq i}^{n} g(p_j)$ and $D_1 < 0$, $D_2 < 0$ for some function g(p) > 0 with g'(p) < 0. For this class of demand functions, the price adopted by the entrants p, the aggregate statistic of their rivals' prices P and the individual demand D(p, P) are all independent from the strategy of the leader (Etro, 2006). If possible, a leader commits to a lower price than the others (Etro, 2008) or undertakes a strategic contract which will induce a subsequent aggressive pricing rule (Etro, 2011), but this will not affect the strategies of the entrants: only the number of entrants will change. The question is what does this imply for consumer surplus.

In the Appendix we prove that the microufounded demand $D(\lambda p_i)$ is nested in the class of demand functions above only if utility is homothetic, that is if $\rho'(x) = 0$. More importantly, we show that also the neutrality of consumer surplus with respect to any commitment of the leader holds only in this case:

Proposition 2. Under endogenous entry with Bertrand competition, the consumer surplus is independent from any strategic contract signed by a firm when utility is homothetic.

 $^{^{2}}$ However, taking the integer constraint (on the number of firms) into account, there can be at most one more firm than optimal under homothetic utility.

³See also Anderson *et al.* (2012) and Žigić (2012).

This is consistent with the examples presented in Etro (2011), which were based on CES utility. However, beyond the case of homothetic preferences, there is not much we can say. The commitment of the leader affects the price of the entrants, the number of entrants and the Lagrange multiplier, and consumer surplus can increase or decrease as a consequence of this.⁴ Further progress in the welfare analysis can be obtained in case of competition in quantities, to which we now turn.

1.2 Cournot competition

The inverse demand for each firm derives immediately from the utility maximizing condition $p_i = u'(x_i)/\lambda$, where the Lagrange multiplier can be obtained from the budget constraint as $\lambda = \sum_j x_j u'(x_j)/E$.⁵ Consequently, the profit function for firm *i* becomes:

$$\Pi^{i} = \frac{x_{i}u'(x_{i})E}{\sum_{j=1}^{n} x_{j}u'(x_{j})} - cx_{i}$$
(9)

Under Cournot competition, the symmetric equilibrium for given n generates the output per firm:

$$x = \frac{(n-1)\left[1 - r(x)\right]E}{n^2c}$$
(10)

Budget balance requires x = E/np, which provides the price:

$$p = \frac{nc}{(n-1)\left[1 - r\left(x\right)\right]}$$
(11)

Totally differentiating, one can verify that when $r'(x) \ge 0$ the price is always decreasing in the number of firms and when r'(x) < 0 the price follows a U-curve in the number of firms, a result first emerging in Bertoletti *et al.* (2008).⁶

The equilibrium profits become:

$$\Pi = \frac{[1 + (n-1)r(x)]E}{n^2}$$

which is always decreasing in the number of firms and allows one to solve for the endogenous market structure in the long run. For instance, in the CES case

⁶Totally differentiating and using repeatedly the equilibrium pricing, we obtain:

$$\frac{n}{p}\frac{dp}{dn} = -\left[\frac{\frac{1-r(x)}{n-1} + r'(x)x}{1-r(x) + r'(x)x}\right]$$
(12)

⁴Nevertheless, neutrality holds not only with isoelastic demand functions, but also with other demand functions characterized by constant expenditure, such as the Logit demand functions and others analyzed by Anderson *et al.* (2012).

⁵Only with homothetic utility we have $xu'(x) \propto u(x)$ and the inverse demand can be written as $p_i = p[x_i, \sum u(x_j)]$ as assumed in Etro (2011).

whose denominator is positive by the second order condition. Notice that, with r'(x) < 0, the price is always increasing in the number of firms when there is an infinity of firms (Zhelobodko *et al.*, 2012).

with r'(x) = 0 the price is always decreasing in the market size, the individual production is increasing and the number of firms is always increasing less than proportionally. In the particular case of homogenous goods, r(x) = 0 and the number of firms becomes $n = \sqrt{s}$ with a price $p = c/(1 - 1/\sqrt{s})$.

1.2.1 Welfare analysis

The general case with non-homothetic utilty can be solved and compared with the constrained optimal organization. Define x^c as the production level satisfying (10) for a given number of firms, where the index c stands for Cournot competition. In the Appendix we prove the following proposition:

Proposition 3. Under separable utility, the endogenous market structure with Cournot competition is characterized by the endogenous number of firms:

$$n^{c} = \sqrt{s\left(1 - r(x^{c})\right) + \frac{1}{4}r(x^{c})^{2}s^{2}} + \frac{1}{2}r(x^{c})s$$
(13)

which is above the constrained optimal number if $\rho'(x) \le 0$ and $r'(x) \le 0$.

Again, the proposition only states sufficient conditions, because the excess entry result can actually occur also with increasing elasticities. However, Propositions 1 an 3 provide sufficient conditions for excess entry that do not depend on the form of competition, and include the isoelastic case, which in turn includes the Mankiw-Whinston case of homogenous goods. Once again, loosely speaking, the case for excess entry appears to be expanded.

1.2.2 The role of leaders

Finally, let us consider asymmetric competition in which a leader adopts a preliminary commitment that changes the incentives to select its strategy x_L . We know that it is always in the interest of the leader to induce an aggressive behavior $x_L > x$ (Etro, 2006). The equilibrium must satisfy the conditions for profit maximization and endogenous entry of the followers which can be expressed as follows:

$$\frac{\left[u'(x) + xu''(x)\right]E}{\Delta} - \frac{\left[u'(x) + xu''(x)\right]xu'(x)E}{\Delta^2} = c \text{ and } \frac{xE}{\Delta} = cx + F$$

where $\Delta = x_L u'(x_L) + (n-1)xu'(x)$. Notice that the strategies of the entrants are always independent from any strategic commitment, since x and Δ solve the system above independently from x_L . What changes with the output of the leader is the number of firms, which is decreasing in x_L :

$$n = 1 + \frac{\Delta - x_L u'(x_L)}{x u'(x)} \tag{14}$$

Nevertheless, neutrality does not always hold in this case. To verify this, let us evaluate consumer surplus as a function of the strategy chosen by the leader:

$$U(x_L) = \Psi(u(x_L) + (n-1)u(x)) = = \Psi\left(u(x_L) + \frac{\Delta - x_L u'(x_L)}{x u'(x)}u(x)\right)$$
(15)

Clearly $U(x) = \Psi (Du(x)/xu'(x))$, and the comparison between this utility and the one with a leader implies:

$$U(x_L) \stackrel{\geq}{\equiv} U(x) \quad \text{iff} \quad u(x_L) + \frac{\Delta - x_L u'(x_L)}{x u'(x)} u(x) \stackrel{\geq}{\equiv} \frac{\Delta u(x)}{x u'(x)}$$

$$\iff u(x_L) \stackrel{\geq}{\equiv} \frac{x_L u'(x_L) u(x)}{x u'(x)}$$

$$\iff \frac{u(x_L)}{x_L u'(x_L)} \stackrel{\geq}{\equiv} \frac{u(x)}{x u'(x)}$$

$$\iff \rho(x_L) \stackrel{\leq}{\equiv} \rho(x) \tag{16}$$

where the first step derives from simplification, the second step from rearranging terms, and the third step derives from the definition of $\rho(x)$. The consequences are summarized below:

Proposition 4. Under endogenous entry with Cournot competition, the consumer surplus is independent from any strategic contract signed by a firm if and only if utility is homothetic, while consumer surplus is increased (decreased) by the presence of an aggressive leader if the elasticity of the utility is decreasing (increasing).

We now have a necessary and sufficient condition for the impact on consumer surplus which depends only on a basic parameter of preferences. The intuition relies on the fact that a leader facing endogenous entry takes as given the aggregate statistic of the production level of all the firms Δ , and substantially behaves as a monopolistically competitive firm. From Dixit and Stiglitz (1977) we know that such a firm produces too little (leading to excess entry) if and only if $\rho'(x) < 0$, that is if profits xu'(x) increase less than utility u(x) with the production level x - remember that $\rho(x) = xu'(x)/u(x)$. Exactly in this case, the increase in the production of a single firm with endogenous entry increases consumer surplus. The opposite happens when $\rho'(x) > 0$.

2 Implications

The previous results contain two kinds of general implications. The first one is about the conditions for excess entry in models of endogenous market structures. Since oligopolistic competition induces higher mark ups compared to monopolistic competition, which attracts more entrants, both the Bertrand and Cournot models tend to increase the likelyhood of excess entry compared to the Dixit-Stiglitz model. This form of inefficiency is going to emerge in similar frameworks extended with dynamic general equilibrium aspects or with endogenous technology.

For instance, Etro and Colciago (2010) find a tendency toward excess entry in a dynamic general equilibrium model where firms pay a fixed cost to enter in a market and compete à la Bertrand or à la Cournot for multiple periods before exiting the market for exogenous reasons. There, the problem of excess entry in steady state is even more pervasive, in the sense that it may induce dynamic inefficiency, with excessive investment in the creation of new firms that reduces consumption both in the short and in the long run.

The welfare analysis can be extended also to the case of endogenous sunk costs in the tradition of Sutton (1991, 1998). Dasgupta and Stiglitz (1980), Tandon (1984) and more recently Vives (2008) have assumed that firms choose simultaneously their market strategy and also an R&D investment which reduces the marginal cost of production. While the general characterization of this equilibrium under both price and quantity competition is provided by Vives (2008), we are not aware of a welfare analysis for this case. The endogeneity of the R&D investment creates an additional trade-off between the benefit from lower marginal costs in the production process and the cost from higher sunk costs, which makes it inefficient to have many firms. However, in the Appendix we show that the spirit of our previous welfare comparisons remains the same, and whenever the decentralized equilibrium involves excess entry, there is also suboptimal production by each firm and suboptimal investment in R&D, and *vice versa*.

The second set of implications of our results is about the welfare impact of the strategies adopted by market leaders. To verify this, let us consider a generic strategic investment by a leader in R&D to reduce the marginal cost. or a contractual commitment able to reduce the effective marginal cost and expand production (Etro, 2006).⁷ Imagine first the case in which firms produce a homogenous good: since this can be derived from linear subutilities (that are trivially isoelastic), the consumer surplus is not affected by the investment or the contract signed by the leader. The intuition is that any increase in the production of the leader (induced by the strategic investment) perfectly crowds out the production of the entrants (by means of a reduction in their number) leaving the price unchanged. Clearly, the gains from the cost reduction are entirely translated into higher profits for the leader, which unambiguously increases total welfare. The same outcome emerges when we introduce product differentiation as long as consumers have a homothetic utility, and nothing changes if competition is in prices or in quantities. In this case the oligopolistic equilibrium is always characterized by too little consumption of each variety for too many varieties, and the impact of the leadership is neutral for the consumers: they are perfectly compensated of the reduction in the number of varieties consumed

 $^{^7{\}rm Etro}~(2011)$ has provided a number of examples, including incentive contracts for managers and financial contracts.

by the increase in the consumption of the variety of the leader, whose price goes down.

Neutrality disappears, however, when we depart from homothetic utilities. Neat results emerge only with competition in quantities. When the elasticity of utility is not constant but decreasing, the larger consumption of a variety more than compensates for the smaller number of varieties consumed. The opposite is true when the elasticity of utility is increasing: the increase in the consumption of the good produced by the leader is not enough to compensate for the reduction in the number of varieties. It is important to remark that our results generalize to the case of multiple leaders acting independently and of increasing marginal costs of production. Of course, also the opposite situation can be analyzed: if a firm adopts an accommodating strategy like a price increase or a reduction in production compared to the rivals, new entry is attracted but consumer surplus goes up or down depending on whether the elasticity of the utility is respectively increasing or decreasing.

As a second more concrete application, consider *mergers* in market with endogenous structures, as in Davidson and Mukherjee (2007) and Erkal and Piccinin (2010). For simplicitly, suppose that the merger does not affect the marginal cost of production of each variety produced by two merged firms. After the merger, these two firms tend to be more accommodating: they internalize the impact of the price choice on each other and increase the prices of their varieties, or they internalize the impact of their production level on each other and reduce the production of each variety. If the utility is homothetic, there is no impact on consumer surplus, but the number of entrants increases: the merged entity makes more profits only if there are sinergies that reduce the fixed cost of production. A similar result has been derived by Davidson and Mukherjee (2007) in case of homogenous goods and quantity competition, and by Anderson et al. (2012) for an alternative class of aggregative models including those based on CES preferences. However, our results go beyond their analysis and the CES case and provide an unambiguous guide for the normative evaluation of a merger under competition in quantities: consumer surplus tends to increase after the merger if and only if $\rho'(x) > 0$. The policy implications for antitrust analysis are then immediate if one is mainly concerned on the impact of mergers on consumers.

Now, consider vertical contracts with retailers, as analyzed in Etro (2011) for general franchising contracts and Etro (2012) for contracts between a leader in a multisided market and downstream firms. We know that an upstream firm would gaing from adopting a vertical contract toward the downstream retailer with a wholesale price below the marginal cost or with large sales: this would induce an aggressive behavior of the downstream unit, but it will not affect consumers surplus if and only if the utility of the final consumers is homothetic. Otherwise, consumer surplus changes. In the case of competition in quantities, our result implies that the optimal contracts leave consumer surplus unchanged under homothetic preferences, increases it if $\rho'(x) < 0$ and decreases it if $\rho'(x) > 0$. Therefore it is perfectly possible that the vertical contract between a dominant firm and a downstream firm is anticompetitive both under exogenous

entry, typically because it softens competition, and under endogenous entry, now because it reduces entry hurting consumers via a reduction in the number of varieties produced. In Etro (2012) we have analyzed the case of Google in online advertising, where vertical contracts with downstream firms and other manipulative strategies may represent anti-competitive strategies leading to a reduction in consumer surplus.

The same applies for *bundling* of a primary good sold by a monopolist jointly with a secondary good sold in price competition with others. In the example of Etro (2011, p. 474-5) neutrality did hold because of the assumption of CES preferences, and the bundling strategy did not affect consumer surplus: it only increased producer surplus and therefore welfare. When utility is not homothetic, however, consumer surplus may be affected in an ambiguous way.

Finally, our results generalize some of the recent findings of the literature on *beneficial concentration*. Ino and Matsumura (2012) have recently shown that the presence of a leader is neutral for consumer surplus and increases welfare in case of homogenous goods and endogenous entry. We extended their result to the case of differentiated goods as long as demand derives from CES preferences. However, we have also emphasized that consumer surplus may increase or decrease under more general conditions. If antitrust policy is mainly concerned with consumer surplus (rather than total welfare), the consequences of concentration are generally ambiguous.

3 Conclusion

In this article we have fully characterized microfounded endogenous market structures and analyzed their welfare properties. The impact of market leaders on welfare is reconsidered, with a number of policy implications about strategic investments, vertical contracts, bundling, mergers and more. This provides general rules to evaluate mergers and abuse of dominance issues in antitrust policy. Further theoretical research should try to extend this kind of analysis to more general models of price competition and more general preferences than separable preferences. Finally, it would be useful to introduce this class of models in general equilibrium frameworks to study trade and business cycle issues.

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Technical Appendix

Bertrand Competition. *The decentralized equilibrium*. The first order condition for the maximization of profits (3) is:

$$D(\lambda p_i) + (p_i - c) \left[\lambda D'(\lambda p_i) + p_i D'(\lambda p_i) \frac{d\lambda}{dp_i} \right] = 0$$

where $d\lambda/dp_i$ is given by (4). Under symmetry, the latter becomes $d\lambda/dp_i = -[1 - r(x)]\lambda/np$. Using this, $x = D(\lambda p)$ and $D(\lambda p) = 1/u''(x)$, the equilibrium condition becomes:

$$x + (p-c)\left[\frac{\lambda}{u''(x)} - \frac{[1-r(x)]\lambda}{nu''(x)}\right] = 0$$

which can be solved for the price (5). Gross profits are then:

$$\Pi = \frac{r(x)E}{n-1+r(x)}$$

and endogenous entry requires price and demand given by (6) and (7) with a number of firms given by (8).

The constrained optimum. Define the total expenditure as the sum of endowment and profits, $I = E + n(\Pi - F)$. In the symmetric Bertrand equilibrium between n firms, the price remains the same as in (5), but the demand for each variety is now x = I/pn. Then, gross profits for each firm in this symmetric equilibrium are:

$$\Pi = \frac{r(x)I}{n-1+r(x)} = \frac{r(x)\left[E+n(\Pi-F)\right]}{n-1+r(x)} = \frac{r(x)\left(E-nF\right)}{(n-1)\left[1-r(x)\right]}$$

which generates the following total expenditure:

$$I = E + n \left[\frac{r(x) (E - nF)}{(n-1) [1 - r(x)]} - F \right] = \frac{[n-1+r(x)] (E - nF)}{(n-1) [1 - r(x)]}$$

Using this and the price (5) we obtain the consumption of each variety as:

$$x = \frac{I}{np} = \frac{E - nF}{nc}$$

which corresponds to the resource constraint of the economy. However, this does not imply zero profits, because a number n of firms generates profis $\Pi = I/n - cx - F > E/n - cx - F$ as long as I > E.

The problem of maximization of welfare $\Psi[nu(x)]$ for the number of firms is equivalent to the second best analyzed by Dixit and Stiglitz (1977), who imposed the resource constraint and zero profit constraint. This problem:

$$\max_{x,n} \Psi [nu(x)]$$

s.v. : $E = xnc + nF$

has the first order condition:

$$u'(x)\left(F+xc\right) = cu(x)$$

which can be arranged as follows for the optimal consumption of each variety:

$$x^* = \frac{F\rho(x^*)}{c(1 - \rho(x^*))}$$

This is associated with the optimal number of firms:

$$n^* = s \left[1 - \rho(x^*)\right]$$

corresponding to a price:

$$p^* = \frac{c}{\rho(x^*)}$$

The comparison. We want to establish a sufficient condition for $n^b > n^*$ and equivalently, from the resource constraint, $x^b < x^*$ and $p^b > p^*$. The equilibrium number of firms is above the optimal level if and only if:

$$1 + r(x^b)(s-1) > s(1 - \rho(x^*))$$

Calculating the derivative of the elasticity of the utility we have:

$$\rho'(x) = \frac{\rho(x)}{x} [1 - \rho(x) - r(x)]$$

Using this and rearranging, excess entry occurs if and only if:

$$1 - r(x^{b}) > \frac{\rho'(x^{b})sx^{b}}{\rho(x^{b})} + s\left[r(x^{*}) - r(x^{b})\right]$$

With $\rho'(x) = r'(x) = 0$ this is always satisfied. With $\rho'(x) < 0$ a sufficient condition is r'(x) < 0 since this implies $r(x^*) < r(x^b)$. This proves Proposition 1.

To verify that this is only a sufficient condition, let us rearrange the inequality needed for excess entry as:

$$\frac{\rho'(x^b)(s-1)x^b}{\rho(x^b)} < \rho(x^b) + s\left[\rho(x^*) - \rho(x^b)\right]$$

If $\rho'(x) > 0$ a sufficient condition for excess entry (which implies $\rho(x^*) > \rho(x^b)$)

$$\rho'(x) < \frac{\rho(x)^2}{(s-1)x}$$
 for any x

or $1 - r(x) < s\rho(x)/(s-1)$.

Neutrality result. The demand function $D(\lambda p_i)$ is nested in the class of demand functions $D(p_i, P_{-i})$ defined in the text and in Etro (2006, 2011) if the Lagrange multiplier λ depends on the prices only as a decreasing function of $\sum_{j=1}^{n} g(p_j)$ for some function g(p), that is if:

$$\frac{d\lambda/dp_i}{d\lambda/dp_j} = \frac{g'(p_i)}{g'(p_j)} \tag{17}$$

Inspection of (4) shows that this is possible only under homothetic utility. Indeed, this implies a constant relative love for variety r(x) = r for any x, so that $d\lambda/dp_i = -x_i (1-r) \lambda/E$, and also $x_i = d(\lambda)d(p_i)$. Therefore, homothetic utility generates the following impact of a price change on the Lagrange multiplier:

$$\frac{d\lambda}{dp_i} = -\frac{d(\lambda)d(p_i)\left(1-r\right)\lambda}{E}$$

and the condition (17) is immediately satisfied with $g'(p_i) = -d(p_i)$. Only in this case, as shown for instance in Etro (2008), the strategy of the leader p_L has no impact on the equilibrium price of the entrants p and on the equilibrium value of the Lagrange multiplier λ , which are jointly defined by a system of two equations (profit maximization and endogenous entry for the entrants) in two unknowns (again assumed with a unique solution):

$$D(\lambda p) + (p-c) \left[\lambda D'(\lambda p) + pD'(\lambda p) \frac{d\lambda}{dp} \right] = 0$$
$$(p-c) D(\lambda p) = F$$

Since the Lagrange multiplier satisfies $E = \sum_{j=1}^{n} p_j d(p_j) d(\lambda)$, we have:

$$E = p_L d(p_L) d(\lambda) + (n-1)p d(p) d(\lambda)$$

the number of firms is actually a function of the strategy of the leader:

$$n = 1 + \frac{E}{pd(p)d(\lambda)} - \frac{p_L d(p_L)}{pd(p)}$$
(18)

Moreover, welfare becomes:

$$U(p_L) = \Psi \left\{ u \left[D(\lambda p_L) \right] + (n-1)u \left[D(\lambda p) \right] \right\} =$$

$$= \Psi \left\{ u \left[D(\lambda p_L) \right] - \frac{p_L d(p_L)u \left[D(\lambda p) \right]}{p d(p)} + \frac{Eu \left[D(\lambda p) \right]}{p d(p) d(\lambda)} \right\} =$$

$$= \Psi \left[u'(x_L)x_L \left(\frac{u \left(x_L \right)}{u'(x_L)x_L} - \frac{u(x)}{u'(x)x} \right) + \frac{Eu(x)}{px} \right] =$$

$$= \Psi \left(\frac{Eu \left(x \right)}{px} \right) = U(p)$$

is:

where the first step derives from the equilibrium number of firms (18), the second step from the definition of the direct demand with homothetic utility $x_i = D(\lambda p_i) = d(\lambda)d(p_i)$, and the third step derives from the fact that $\rho(x_L) = \rho(x)$ under homothetic utility.

Cournot competition. *The decentralized equilibrium*. The equilibrium profits under competition in quantities are:

$$\Pi = \frac{[1 + (n-1)r(x)]E}{n^2}$$

Setting them equal to the fixed cost F, one can solve a quadratic equation for the endogenous number of firms (13).

The constrained optimum. Define the total expenditure as the sum of endowment and profits, $I = E + n(\Pi - F)$. In the symmetric Cournot equilibrium between n firms, the output remains the same as in (10), and the gross profits of each firm in this symmetric equilibrium are:

$$\Pi = \frac{\left[1 + (n-1)r(x)\right]I}{n^2} = \frac{\left[1 + (n-1)r(x)\right](E - nF)}{n(n-1)\left[1 - r(x)\right]}$$

which generates the following total expenditure:

$$I = \frac{[n-1+r(x)](E-nF)}{(n-1)[1-r(x)]}$$

Consumption of each variety is again x = (E - nF)/nc, which corresponds to the resource constraint of the economy. The problem of maximization of welfare is again equivalent to the second best analyzed by Dixit and Stiglitz (1977) even if profits are not zero in our context.

The comparison. We want to establish a sufficient condition for $n^c > n^*$ and equivalently, from the resource constraint, $x^e < x^*$. The equilibrium number of firms is above the optimal level if and only if:

$$\sqrt{s(1-r(x^c)) + \frac{1}{4}r(x^c)^2 s^2} + \frac{1}{2}r(x^c)s > s(1-\rho(x^*))$$

Rearranging, excess entry occurs if and only if:

$$1 - r(x^{c}) > s\left(1 - \rho(x^{*})\right) \left[\frac{\rho'(x^{*})x^{*}}{\rho(x^{*})} + r(x^{*}) - r(x^{c})\right]$$

With $\rho'(x) = r'(x) = 0$ this is always satisfied. With $\rho'(x) < 0$ a sufficient condition is again r'(x) < 0, which implies $r(x^*) < r(x^c)$. This proves Proposition 3.

Endogenous sunk costs. Following Vives (2008), let us imagine that the fixed cost can be chosen as an investment z which reduces the marginal cost at c(z) with c(z) > 0, c'(z) < 0 and c''(z) > 0 for all z. Let us define the elasticity

of the innovation function as $\gamma(z) \equiv -zc'(z)/c(z)$. The net profits of each firm are:

$$\pi^{i} = x_{i}p_{i} - c(z_{i})x_{i} - z_{i} \tag{19}$$

Each firm chooses the market strategy as before and the investment according to the following rule:

$$1 = -c'(z_i)x_i \tag{20}$$

which implies that the investment is increasing in the production level. Closed form solutions for the case of CES preferences and isoelastic innovation function are derived in Vives (2008).

Now, let us consider the welfare maximization problem. In general, this problem can be expressed as follows:

$$\max_{z,x,n} \Psi [nu(x)]$$

s.v. : $E = xnc(z) + nz$

First of all, notice that in the absence of additional restrictions on the innovation function, corner solutions may emerge. If R&D is cheap enough it may be optimal to invest as much as possible to reduce the marginal cost to its lower bound and to have a single firm producing its variety at a very low marginal cost. On the other side, if R&D is too costly, it may be always optimal to reduce the investment and the production of each firm while expanding the number of firms. In the case of CES preferences and isoelastic innovation a corner solution is what emerges always.

Let us focus on the case of interior optima. The welfare maximization problem above can be rearranged as:

$$\max_{z,x} \frac{Eu(x)}{z + xc(z)}$$

whose first order conditions are:

$$z : 1 = -c'(z^*)x^*$$

$$x : u'(x^*)[z^* + x^*c(z^*)] = c(z^*)u(x^*)$$

The first condition is the same as the one emerging in the symmetric decentralized equilibrium. Therefore, if the decentralized output per firm is the optimal one, also the decentralized investment in R&D is optimal and if $x \ge x^*$ then $z \ge z^*$. The resource constraint can be rearranged as z + xc(z) = E/n, whose left hand side is always increasing in x since its derivative is c(z) + [1 + xc'(z)] dx/dz = c(z) > 0. Therefore if $x \ge x^*$ then $n \le n^*$ as well. As a consequence, whenever the decentralized equilibrium involves excess entry, there is also suboptimal production by each firm and suboptimal investment in R&D, and the other way around.

The optimal allocation of resources balances the benefit from lower marginal costs and the cost from higher fixed costs, which make it inefficient to have many

firms. Combining the two conditions above we can derive a single condition for an interior optimum:

$$\rho(x^*) = \frac{1}{1 + \gamma(z^*)}$$

As noticed, with CES preferences and isoelastic innovation, this condition cannot be satisfied and corner solutions emerge. But this is also the case whenever the innovative activity is easy enough, that is when the elasticity $\gamma(z)$ is high enough: then it is always optimal to have a single firm investing as much as possible to reduce the marginal cost as much as possible.