Vertical Differentiation, Trade and Endogenous Common Standards[1]

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Abstract

Different market settings are considered in a free trade environment, where firms can choose technology, quality, and price or quantity. The shape of competition in prices requires the intervention of governments, via a common antidumping policy, to make firms converge on the simultaneous equilibrium which is socially optimal. In the Cournot framework, the equilibria we obtain impinge upon the kind of precommitments undertaken by firms. The coincidence between firms' behaviour and social preference obtains either when competition is tough, since income is low, or when firms must compete in quantities in the market stage, since they cannot modify qualities. The spontaneous coordination over common standards has to be contrasted with both the case of affluent consumers and Bertrand competition.

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1 Introduction

When trade takes place among countries producing vertically differentiated goods, competition may assume various forms, namely, firms may alternatively set prices, quantities and qualities, according to the commitments inherited from either autarchy or a previous stage of infant development when the relevant market is limited and fairly sheltered, e.g. by the presence of some patented process or product whose protection is geographically confined to the home country.[1] The kind of competition under free trade may be conditional upon the technological menu to the avail of producers. We figure out two main possibilities according to previous literature in the field (Mussa and Rosen, 1978; Shaked and Sutton, 1982; 1983). The first is represented by a technology where quality improvements rely on a variable cost. For the second technology the provision of quality impinges upon a fixed cost that can be interpreted as an R&D effort. Then we enrich the menu by considering also different levels of efficiency associated with the same technologies.

The available contributions in the field are confined to the analysis of price competition (Shaked and Sutton, 1984; Lambertini, 1997; Motta, Thisse and Cabrales, 1997) and quantity competition (Motta, 1992), under both a short-run and a long-run perspective, according to whether qualities are the same as in autarchy, or are adjusted after trade liberalization. These contributions are mainly aimed at outlining the implications of liberalization on welfare and market structure when firms face similar production opportunities but countries differ in terms of income distribution or consumer density. None of the two takes into account the possible consequences of either firms' technological choices or efficiency, or the arising of quality competition when firms are supposed to be quantity-constrained.

The choice of a technology out of a menu or the availability of a certain technology inherited from the past shapes the nature of competition, in such a way that either a problem of coordination over trade policies arises for governments, or a problem of coordination over quality standards and the production process arises for firms.

The first case arises when firms compete à la Bertrand and operate with technologies characterized by different degrees of efficiency: market incentives never let firms coordinate spontaneously over simultaneous play, so that governments' intervention is needed in order to ensure the attainment of the unique welfare-maximizing equilibrium. To this purpose we imagine a sort of antidumping policy that follows a philosophy quite near to the one that inspires some of the intervention of the EU Commission, according to which there may be a case in point for

[1] There are many instances of commercial disputes among firms as to the geographic effectiveness of a patent. In some cases the result is a partial insulation of the home market for a firm that has introduced either a new product or a new process in the country in which it has its main establishment. In such cases a condition akin to autarchy arises.

an antidumping intervention, when the price of the imported good is much lower than the price of the corresponding domestically produced good.[2] Surprisingly enough, the antidumping has, in this case, a procompetitive effect and therefore does not bring about the deadweight loss usually associated with such policy. This means that the sort of antidumping policy we shall describe below can be undertaken by an antitrust agency to pursue a welfare maximization objective.

The second situation may emerge when firms behave à la Cournot after trade liberalization. Here, firms face a twin choice between using either quantity or quality as a control in the market stage. As a consequence different equilibria emerge, according to the affluence of the market. When the market has a sufficiently low reservation price, a spontaneous coordination obtains as far as quality standards and technology are concerned, while, as the market shows a higher willingness to pay, multiple equilibria are associated with multiple standards. The corresponding evaluation of welfare shows that it would be socially desirable to have firms converging to the same quality standard and the most efficient technology.

This has policy implications which are different according to the consumers' evaluation of quality in the countries engaging in trade. If such evaluation is relatively low there seems to be no point in supporting neither national nor common international standards, in that an efficient common standard arises out of the endogenous market interaction. The opposite happens when consumers exhibiting a high marginal evaluation of quality, since in that case the variance of standards becomes relevant and no endogenous coordination emerges. Again there may be a case in point for a government intervention that may take the form of a quality standard that corresponds to a Pareto-superior equilibrium. The time consistency of these interventions is analyzed in Jensen and Thursby (1996) who describe an uncertain R&D race between firms of different countries and show that a domestic (autarchic) simple standard is bound to be time inconsistent.[3] Our result shows that this time inconsistency never arises, because it is optimal for governments to fix the same standard regardless of the market regime.

The remainder of the paper is organized as follows. In section 2 we provide the autarchy model, while in section 3 we deal with Bertrand competition in free trade. Section 4 is dedicated to Cournot competition. Section 5 provides concluding comments.

2 The basic setting

We first consider a country with only one firm producing a differentiated good of quality q sold to a population of consumers whose income distribution is assumed

[2] On this topic see for instance Vandenbussche (1996), Bronkers (1996).

[3] There exists a wide literature (see Katz and Shapiro, 1985 and 1986; Farrell and Saloner, 1985; 1987; Matutes and Regibeau, 1988, inter alia), where the issue of standardization depends on compatibility among products, with or without network externalities.

uniform and the marginal willingness to pay for the differentiated good is given by $\theta \in [\underline{\theta}; \overline{\theta}]$ with $\underline{\theta} = \overline{\theta} - 1$ and $\underline{\theta} > 0$.[4] Moreover we normalize the population density to 1, for the sake of simplicity. Hence the total mass of consumers in the market is also 1.

Each consumer has unit demand and buys if and only if his net surplus is non-negative

$$U = \theta q - p \geq 0; \tag{1}$$

where p is the price charged by the monopolist.

We are then able to obtain the market demand function:

$$x = \overline{\theta} - \frac{p}{q}. \tag{2}$$

We can consider two alternative types of technology. The first is given by the following cost function:

$$C_v = tq^2x; \tag{3}$$

whereby total costs are convex in quality and linear in quantity, and no fixed cost is associated either to quality or to quantity. The parameter $t \in]0; 1]$ is an efficiency indicator of the firm's marginal cost.

The second technology looks as follows:

$$C_f = tq^2; \tag{4}$$

implying that production involves exclusively a fixed cost and marginal cost is zero.

We can now write the profit function

$$\pi_i = px - C_i \text{ for } i = f; v. \tag{5}$$

We start considering the case for $i = v$; defined as variable cost technology. The first order conditions (FOCs) for profit maximization are:

$$\frac{\partial \pi_v}{\partial p} = \overline{\theta} - \frac{2p}{q} + qt = 0; \tag{6}$$

$$\frac{\partial \pi_v}{\partial q} = tp + \frac{p^2}{q^2} - 2\overline{\theta}tq = 0; \tag{7}$$

[4] This formalization of consumers' preferences has been introduced by Mussa and Rosen (1978). Since θ can be seen as the reciprocal of the marginal utility of nominal income, we can interpret the reservation price as the closest proxy to consumers' affluency (see Tirole, 1988, p. 96).

which yield the following solutions:[5]

$$q_v = \frac{\bar{\theta}}{3t}; \qquad p_v = \frac{2\bar{\theta}^2}{9t}. \tag{8}$$

Using (2) and (5), we can establish that equilibrium quantity and profit are:

$$x_v = \frac{\bar{\theta}}{3}; \qquad \pi_v = \frac{\bar{\theta}^3}{27t}. \tag{9}$$

The corresponding social welfare level is $W_v = 3\bar{\theta}^3/(54t)$. When $i = f$, defined as fixed cost technology, the FOCs for profit maximization become

$$\frac{\partial \pi_f}{\partial p} = \bar{\theta} - \frac{p}{q}(1 - p) = 0; \tag{10}$$

$$\frac{\partial \pi_f}{\partial q} = \frac{p^2}{q^2} - 2tq = 0; \tag{11}$$

Solving (10) and (11) yields

$$q_f = \frac{\bar{\theta}^2}{8t}; \qquad p_f = \frac{\bar{\theta}^3}{16t}; \tag{12}$$

while profits and quantity sold are

$$x_f = \frac{\bar{\theta}}{2}; \qquad \pi_f = \frac{\bar{\theta}^4}{64t}. \tag{13}$$

Social welfare is $W_f = \bar{\theta}^4/(32t)$. Quick comparison between profits and social welfare with the two technologies suggests that, while firms always prefer technology v to f, social preferences switch from v to f when $\bar{\theta} > 48/27$. Consumers are partially served with both technologies if the highest marginal willingness to pay $\bar{\theta}$ is less than 2. We shall take into account this constraint on $\bar{\theta}$ in the remainder of the paper.

In the following sections we deal with different kinds of competition in the international market. A common feature of all settings will be the inheritance from autarchy, or from a period of market insulation due to trade barriers, of an inflexible choice relating alternatively either to capacity or to quality. Any departure from that can be thought of as entailing such a huge adjustment cost that no viable firm would undertake it. Quality may be stuck to the autarchy level due to patents protecting the acquired R&D knowledge. Quantity may be limited by capacity constraints driving marginal cost to infinity (Kreps and Scheinkman, 1983; Davidson and Deneckere, 1986).

[5] Observe that, independently of the technology adopted, the monopolist supplies the same quality as the social planner, since the demand function is linear (Spence, 1975, pp. 419-21).

3 Bertrand competition and free trade

We now focus on free trade settings. First, we consider the case where firms compete in prices, adopting different technologies and playing different roles in the market game. We assume that no barriers of any kind exist between countries.

The results we shall obtain may prompt for antidumping measures, triggered by price differentials between countries engaging in trade. The desirability of antidumping policies is then investigated according to the endogenous shape of competition on the international market.

3.1 Variable costs and free trade

We now consider free trade between two countries competing in an industry where each one has a single firm adopting the variable cost technology.

The two countries are equal in all respects but for the efficiency of their respective firms. In other words we assume that one firm has a cost function which is the same as (3), while the other firm has the same cost function with $t = 1$. As a consequence the quality of the good sold by the less efficient firm is lower than the one supplied by the more efficient firm. The former firm is labeled L while the latter is called H. The same identification code is used for the two countries.

Assuming that the quality standards are set in autarchy as an irreversible commitment due to an arbitrarily large adjustment cost, possibly due to the existence of a patent, we can determine the demand functions of the integrated market, whose density is twice as large as that of the autarchic market faced by each firm. To this purpose we have to define the positions of the consumers indifferent between buying either of the two goods, and between buying the low quality good or nothing:

$$k = \frac{p_L}{q_L}; \qquad h = \frac{p_H - p_L}{q_H - q_L}. \tag{14}$$

Then we can determine the market demand:

$$x_H = 2[\bar{\theta} - \frac{3t(p_H - p_L)}{\bar{\theta}(1 - t)}]; \tag{15}$$

$$x_L = \frac{6(tp_H - p_L)}{\bar{\theta}(1 - t)}. \tag{16}$$

Therefore, the profit functions look as follows:

$$\pi_H = 2(p_H - \frac{\bar{\theta}^2}{9t})(\bar{\theta} - \frac{3t(p_H - p_L)}{\bar{\theta}(1 - t)}); \tag{17}$$

$$\pi_L = \frac{2(\bar{\theta}^2 - 9p_L)(tp_H - p_L)}{3\bar{\theta}(t-1)}. \tag{18}$$

Firms noncooperatively and simultaneously optimize w.r.t. prices. The FOCs are:

$$\frac{\partial \pi_H}{\partial p_H} = \frac{6\bar{\theta}^2 t - 8\bar{\theta}^2 + 36tp_H - 18tp_L}{3\bar{\theta}(t-1)} = 0; \tag{19}$$

$$\frac{\partial \pi_L}{\partial p_L} = \frac{-2(\bar{\theta}^2 - 18p_L + 9tp_H)}{3\bar{\theta}(t-1)} = 0; \tag{20}$$

whose solution is

$$p_H = \frac{\bar{\theta}^2(8-5t)}{9t(4-t)}; \qquad p_L = \frac{\bar{\theta}^2(2-t)}{3(4-t)}; \tag{21}$$

so that the relative price $p_H/p_L > 1$ for all $t \in]0;1]$. Substituting (21) into (17-18) and rearranging, yields the Nash equilibrium profits

$$\pi_H^n = \frac{32\bar{\theta}^3(1-t)}{27t(t-4)^2}; \qquad \pi_L^n = \frac{8\bar{\theta}^3(1-t)}{27(t-4)^2}. \tag{22}$$

It is quickly established that $\pi_H^n > \pi_L^n$.

Welfare evaluations are straightforward since consumers in both countries enjoy the same level of surplus and the only difference between the two countries is due to the respective levels of producer's surplus, which is higher in country H.

3.2 Endogenous choice of roles

In the previous section we focussed on the Bertrand-Nash equilibrium emerging from simultaneous play, which appears as the natural way of playing when firms cannot choose the timing of their respective moves, before actual competition takes place. Now we may address the question whether firms may choose to play sequentially, when we introduce a preplay stage where they noncooperatively set the timing. Following Hamilton and Slutsky (1990), we analyze an extended game with observable delay, consisting of two stages. In the first, firms can choose between playing at the first available occasion (F) or delay as long as possible (S). If both select the same strategy, a simultaneous equilibrium obtains. Otherwise, a sequential equilibrium is observed out of the two possible. Then firms proceed to optimally set prices according to the timing of moves previously decided. The market equilibrium, emerging from such a process, is part of the two-stage subgame perfect equilibrium of the extended game with observable delay.

In case firm H takes the lead, her maximum problem consists in solving the following program:

$$\max_{p_H} \pi_H = 2\left(p_H - \frac{\bar{\theta}^2}{9t}\right)\left(\bar{\theta} - \frac{3t(p_H - p_L)}{\bar{\theta}(1-t)}\right) \tag{23}$$

$$\text{s.t.: } p_L = \frac{\bar{\theta}^2 + 9tp_H}{18}.$$

As a consequence, the leader's price is $p_H = \bar{\theta}^2(3t-4)/[9t(t-2)]$ and equilibrium profits amount to:

$$\pi_H^l = \frac{4\bar{\theta}^3(1-t)}{27t(2-t)}, \quad \pi_L^f = \frac{2\bar{\theta}^3(1-t)}{27(2-t)^2}, \tag{24}$$

where superscripts l and f stand for leader and follower, respectively.

The case where firm L moves first and firm H follows remains to be investigated. The leader's problem appears now as follows:

$$\max_{p_L} \pi_L = \frac{2(\bar{\theta}^2 - 9p_L)(tp_H - p_L)}{3\bar{\theta}(t-1)} \tag{25}$$

$$\text{s.t.: } p_H = \frac{8\bar{\theta}^2 - 6\bar{\theta}^2 t + 18tp_L}{36t},$$

whose solution gives $p_L = \bar{\theta}^2(3-2t)/[9(2-t)]$, and

$$\pi_L^l = \frac{\bar{\theta}^3(1-t)}{27(2-t)}, \quad \pi_H^f = \frac{\bar{\theta}^3(t-4)^2(1-t)}{54t(t-2)^2}. \tag{26}$$

We can thus establish the following sequence of inequalities:

$$\pi_i^f > \pi_i^l > \pi_i^n, \quad i = H, L. \tag{27}$$

This information allows for a quick solution of the first stage of the game, which is represented by Matrix 1.

		H: F	H: S
L	F	π_L^n, π_H^n	π_L^l, π_H^f
	S	π_L^f, π_H^l	π_L^n, π_H^n

Matrix 1

The game has two asymmetric subgame perfect equilibria involving sequential moves, $(F; S)$ and $(S; F)$: There exist no generally accepted criteria for selecting one of these equilibria which cannot be Pareto-ordered. However, aggregate industry pro¯ts can provide some hints as to the social desirability of one equilibrium vis µa vis the other. By comparing the aggregate payo®s associated with $(F; S)$ and $(S; F)$, we observe that $¼^f_L + ¼^l_H > ¼^f_H + ¼^l_L$ for all t 2]0; 1], i.e., industry pro¯ts are higher when the more e±cient ¯rm takes the lead in market competition.

It can be shown that the ¯rst best solution from a social standpoint could be reached if both countries simultaneously adopted an antidumping policy. To this purpose, we discuss policy-makers' preferences by considering a similar game of timing which is described in Matrix 2, where payo®s are represented by social welfare levels.

		H: F	H: S
L	F	$W^n_L; W^n_H$	$W^l_L; W^f_H$
	S	$W^f_L; W^l_H$	$W^n_L; W^n_H$

Matrix 2

Provided that $W^n_i > W^l_i > W^f_i$; i=H,L, the introduction of an antidumping policy, aimed at preventing the foreign ¯rm from playing the follower's role, will lead to the unique Nash equilibrium $(F; F)$; where ¯rms set prices simultaneously at the ¯rst available occasion. Then we see that the overall social desirability of simultaneous play triggers a spontaneous coordination of antidumping policies.

This result has an implication as far as the coordination of trade policies is concerned. If governments simultaneously adopt an antidumping policy, they end up bene¯ting consumers in both countries, since they induce ¯rms to play a non-cooperative Nash equilibrium in prices, as an antitrust agency would aim to. This result appears quite odd, since antidumping and antitrust policies usually do not pursue the same objective. Once we allow for spontaneous coordination, the consequence is that each country's antidumping policy against the foreign ¯rm is equivalent to an antitrust policy against the domestic ¯rm. The observational equivalence between antitrust and antidumping policies in this setting is due to the existence of multiple subgame perfect equilibria in the extended game played by ¯rms. If the equilibrium were unique, i.e. if there were only one-sided dumping, the antidumping policy would maintain its usual anticompetitive characterization.

3.3 Heterogeneous technologies with different degrees of flexibility

The choice between technologies associated with different cost functions, in the context of vertical differentiation, is going to lead to clear-cut results. When we compare the performances of the technologies v and f in autarchy, we reach the simple conclusion that, for a given t, the profit of the firm that adopts the f technology is always lower than the one of the firm opting for the more flexible technology. From the social point of view, the v technology is more desirable if $1 < \bar{\theta} < 48/27$, because when $\bar{\theta}$ is close to 2 the f technology allows for the market to be almost completely covered, while the v technology leaves unserved many consumers.

The comparison we are providing basically relies on two sorts of heterogeneities among firms belonging to different countries. Firms differ partly because of efficiency and partly because of flexibility. In the next subsection we investigate the case where the high quality is being produced with the less flexible technology.

3.3.1 High quality with fixed costs

Let us outline the structural technological features of the two countries. In one country both technologies exhibit the same degree of efficiency. As a consequence, the firm located in this country adopts the more flexible technology involving only variable costs, since it gives a higher profit. In the other country, the fixed cost technology enjoys a comparative advantage and is therefore adopted. Then we can write

$$C_f = tq^2; \quad C_v = q^2 x \qquad \text{with } t \in]0, 1]. \tag{28}$$

The two optimal qualities become:

$$q_f = q_H = \frac{\bar{\theta}^2}{8t} \text{ and } q_v = q_L = \frac{\bar{\theta}}{3} \tag{29}$$

and $q_f > q_v$ if $\frac{\bar{\theta}}{t} > \frac{8}{3}$. The latter inequality implies that $2 > \bar{\theta} > \frac{8}{3}t$ and $t < \frac{3}{4}$.

The duopoly demand functions are defined by (15) and (16). The profit functions are:

$$\pi_H = 2p_H\left[\bar{\theta} - \frac{24t(p_H - p_L)}{\bar{\theta}(3\bar{\theta} - 8t)}\right] - \frac{\bar{\theta}^4}{64t}, \tag{30}$$

$$\pi_L = \frac{2(\bar{\theta}^2 - 9p_L)(3\bar{\theta}p_L - 8p_H t)}{3\bar{\theta}(3\bar{\theta} - 8t)}. \tag{31}$$

We first consider simultaneous price competition. First and second order conditions are satisfied by the following pair of optimal prices

$$p_H = \frac{\bar{\theta}^3(9\bar{\theta} - 20t)}{48t(3\bar{\theta} - 2t)}; \quad p_L = \frac{\bar{\theta}^2(5\bar{\theta} - 8t)}{12(3\bar{\theta} - 2t)}; \tag{32}$$

which are both positive in the admissible range of parameters. The Nash equilibrium profits amount to:

$$\pi_H^n = \frac{\bar{\theta}^4(243\bar{\theta}^3 - 1116\bar{\theta}^2 t + 1276\bar{\theta}t^2 + 96t^3)}{192t(2t - 3\bar{\theta})^2(3\bar{\theta} - 8t)}; \tag{33}$$

$$\pi_L^n = \frac{\bar{\theta}^4(3\bar{\theta} - 16t)^2}{72(3\bar{\theta} - 8t)(3\bar{\theta} - 2t)^2}. \tag{34}$$

Equilibrium outputs are:

$$x_H = \frac{\bar{\theta}^2(9\bar{\theta} - 20t)}{(3\bar{\theta} - 8t)(3\bar{\theta} - 2t)}; \tag{35}$$

$$x_L = \frac{\bar{\theta}^2(3\bar{\theta} - 16t)}{2(9\bar{\theta}^2 - 30\bar{\theta}t + 16t^2)}. \tag{36}$$

From the latter expression, we derive a further restriction, whereby $\bar{\theta}/t > 16/3$ and $t < 3/8$, i.e., the comparative advantage enjoyed by the firm operating with the fixed cost technology and producing the high quality good must be large.

As a partial conclusion we can state that the more efficient country, which is the one that adopts the less flexible technology, produces the higher quality good, enjoys the superior producer surplus and hence welfare, since the demand structure is the same in both countries.

Notice that the condition that $\bar{\theta}/t \in]16/3; \infty)$ is reminiscent of the finiteness property (Shaked-Sutton, 1982, 1983, 1984) giving rise to natural oligopolies. As we go below the lower bound of the interval, there may not be enough room for two firms in the market because consumers' marginal willingness to pay is too low for the inefficient firm to survive. The efficiency parameter t can change the relative market shares of the two contending firms in a subtle way. As t decreases, the high quality increases and it leaves more room for the low quality firm. The opposite happens if t increases. In other words, a superior efficiency of the high quality firm is anti-competitive, since it enhances the degree of monopoly power enjoyed by both firms, by widening the quality gap between the two products. On the contrary, a lower efficiency of the high quality firm is pro-competitive as long as the low quality firm has a positive demand. When t is sufficiently high that the output of the inefficient firm is driven close to zero, the high quality firm is in a position to become a monopolist.[6] We confine our analysis to the region of parameters where both firms are active.

[6] The possibility for the low quality firm to be driven off would require the consideration

3.3.2 High quality with variable costs

In this case the more efficient firm chooses to adopt the variable cost technology, $C_v = tq^2x$, with $t \in]0,1[$. In order to attain $\pi_v > \pi_f$, it must be $\bar{\theta}t < 27/32$. This condition is also sufficient to ensure that $q_v > q_f$, so that $q_H = \bar{\theta}/(3t)$ and $q_L = \bar{\theta}^2/8$. Moreover it appears that the degree of differentiation is larger than in the previous case.

Duopoly profits can be written as

$$\pi_H = 2\left(\bar{\theta} - \frac{24t(p_H - p_L)}{\bar{\theta}(3 - 8\bar{\theta}t)}\right)\left(p_H - \frac{\bar{\theta}^2}{9t}\right), \tag{37}$$

$$\pi_L = 2p_L\left(\frac{24t(p_H - p_L)}{\bar{\theta}(3 - 8\bar{\theta}t)} - \frac{8p_L}{\bar{\theta}^2}\right) - \frac{\bar{\theta}^4}{64}, \tag{38}$$

First order conditions lead to the following equilibrium prices:

$$p_H = \frac{2\bar{\theta}^2(9\bar{\theta}t - 32)}{9t(3\bar{\theta}t - 32)}, \tag{39}$$

$$p_L = \frac{\bar{\theta}^3(9\bar{\theta}t - 32)}{24(3\bar{\theta}t - 32)}. \tag{40}$$

Substituting and rearranging, we obtain the Nash equilibrium profits:

$$\pi_H = \frac{16\bar{\theta}^3(15\bar{\theta}t - 32)^2}{27t(3\bar{\theta}t - 32)^2(8 - 3\bar{\theta}t)}, \tag{41}$$

$$\pi_L = \frac{\bar{\theta}^4(57344 - 32256\bar{\theta}t + 4536\bar{\theta}^2t^2 + 243\bar{\theta}^3t^3)}{576(3\bar{\theta}t - 32)^2(8 - 3\bar{\theta}t)}. \tag{42}$$

where $\pi_H > \pi_L$. Equilibrium outputs are:

$$x_H = \frac{2\bar{\theta}(256 - 120\bar{\theta}t)}{3(256 - 120\bar{\theta}t + 9\bar{\theta}^2t^2)}, \tag{43}$$

$$x_L = \frac{2\bar{\theta}(256 - 72\bar{\theta}t)}{3(256 - 120\bar{\theta}t + 9\bar{\theta}^2t^2)}. \tag{44}$$

where[7] $x_L > x_H$. The advantage given to the technology with variable costs, which is already the one that maximizes the producer surplus, has the effect of

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of two alternative routes for the industrial policy aiming at keeping competition as workable as possible: either the adoption of minimum quality standards (Ronnen, 1991; Crampes and Hollander, 1995; Ecchia and Lambertini, 1997) or the design of R&D incentives to reduce the comparative disadvantage.

[7] Both quantities are non negative in the viable range of parameters.

extending the number of consumers served in both countries, since the low quality produced with the fixed cost technology is now lower than the previous one and the high quality produced with the variable cost is higher than the previous one. The effect of that is a greater integration between the two economies.

3.4 Sequential play with heterogeneous technologies

We now proceed to describe the equilibria generated by sequential moves in both settings where firms resort to different technologies. First, we analyze the case in which the high quality good is supplied through a production process involving fixed costs.

3.4.1 High quality with fixed costs

When the price leadership is taken by the high quality firm, the leader's problem consists in

$$\max_{p_H} \pi_H = 2p_H\left[\bar{\theta} - \frac{24t(p_H - p_L)}{\bar{\theta}(3\bar{\theta} - 8t)}\right] - \frac{\bar{\theta}^4}{64t} \tag{45}$$

$$\text{s.t.: } \frac{\partial \pi_L}{\partial p_L} = 0; \tag{46}$$

whose solution yields the following equilibrium profits:

$$\pi_H^l = \frac{\bar{\theta}^4(243\bar{\theta}^2 - 1116\bar{\theta}t + 1312t^2)}{t(5184\bar{\theta}^2 - 2073\bar{\theta}t + 18432t^2)}; \tag{47}$$

$$\pi_L^f = \frac{\bar{\theta}^4(\bar{\theta} - 4t)^2}{8(3\bar{\theta} - 8t)(3\bar{\theta} - 4t)^2}. \tag{48}$$

In the opposite case, when the low quality firm takes the lead, she must solve the following program:

$$\max_{p_L} \pi_L = \frac{2(\bar{\theta}^2 - 9p_L)(3\bar{\theta}p_L - 8p_H t)}{3\bar{\theta}(3\bar{\theta} - 8t)} \tag{49}$$

$$\text{s.t.: } \frac{\partial \pi_H}{\partial p_H} = 0. \tag{50}$$

The profits associated with this equilibrium are:

$$\pi_H^f = \frac{\bar{\theta}^3(2187\bar{\theta}^4 - 12960\bar{\theta}^3 t + 24368\bar{\theta}^2 t^2 - 16512\bar{\theta}t^2 + 4096t^4)}{1728t(4t - 3\bar{\theta})^2(3\bar{\theta} - 8t)}; \tag{51}$$

$$\pi_L^l = \frac{\bar{\theta}^3(3\bar{\theta} - 16t)^2}{216(3\bar{\theta} - 8t)(3\bar{\theta} - 4t)}. \tag{52}$$

We have to compare these solutions with the simultaneous Nash equilibrium profits (33) and (34). For each firm we can write the sequence of profits:

$$\pi_L^f > \pi_L^l > \pi_L^n; \qquad \pi_H^l > \pi_H^f > \pi_H^n. \tag{53}$$

Provided the two firms can choose the timing in an extended game with observable delay, two subgame perfect equilibria arise, where firms move sequentially. The equilibrium where the more efficient firm providing the high quality good moves first, Pareto-dominates the other where the leadership is taken by the low-quality firm, i.e. $\pi_H^l + \pi_L^f > \pi_H^f + \pi_L^l$. The equilibrium in which the more efficient firm is leader can be considered as a focal point.

We may now consider the social desirability of a non-cooperative trade policy aimed at the maximization of social welfare. The outcomes can be ordered in the following way: $W_L^n > W_L^l > W_L^f$; and $W_H^n > W_H^f > W_H^l$. Hence, to reach the social optimum, governments move simultaneously and spontaneously coordinate over a common antidumping policy against the respective foreign firm. As in the previous section, these coordinated antidumping policies have a procompetitive effect.

3.4.2 High quality with variable costs

We now turn to the setting where the high quality good is produced by the firm operating with the variable costs technology. When she acts as the leader in prices, her objective is:

$$\max_{p_H} \pi_H = 2\left(\bar{\theta} - \frac{24t(p_H - p_L)}{\bar{\theta}(3 - 8\bar{\theta}t)}\right)\left(p_H - \frac{\bar{\theta}^2}{9t}\right) \tag{54}$$

$$\text{s.t.: } \frac{\partial \pi_L}{\partial p_L} = 0. \tag{55}$$

The equilibrium outcome is given by the following profits:

$$\pi_H^l = \frac{\bar{\theta}^3(15\bar{\theta}t - 32)^2}{108t(3\bar{\theta}t - 16)(3\bar{\theta}t - 8)}, \tag{56}$$

$$\pi_L^f = \frac{\bar{\theta}^4(14336 - 7680\bar{\theta}t + 288\bar{\theta}^2t^2 + 243\bar{\theta}^3t^3)}{576(3\bar{\theta}t - 16)^2(8 - 3\bar{\theta}t)}. \tag{57}$$

In the opposite case, the less efficient firm plays the leader's role and solves the program:

$$\max_{p_L} \pi_L = 2p_L\left(\frac{24t(p_H - p_L)}{\bar{\theta}(3 - 8\bar{\theta}t)} - \frac{8p_L}{\bar{\theta}^2}\right) - \frac{\bar{\theta}^4}{64} \tag{58}$$

$$\text{s.t.: } \frac{\partial \pi_L}{\partial p_L} = 0. \tag{59}$$

The equilibrium profits are:

$$\pi_L^l = \frac{\bar{\theta}^4(896 - 504\bar{\theta}t + 81\bar{\theta}^2t^2)}{73728 - 41472\bar{\theta}t + 5184\bar{\theta}^2t^2}; \tag{60}$$

$$\pi_H^f = \frac{\bar{\theta}^3(512 - 288\bar{\theta}t + 27\bar{\theta}^2t^2)^2}{1728t(3\bar{\theta}t - 16)^2(8 - 3\bar{\theta}t)}. \tag{61}$$

If we evaluate the profits associated with either simultaneous or sequential moves, we find that the following sequence of inequalities holds for both firms:

$$\pi_i^f > \pi_i^l > \pi_i^n; \quad i = H, L. \tag{62}$$

This entails that the extended game with observable delay has two subgame perfect equilibria, where firms play sequentially. Moreover, since both firms strictly prefer the follower's role, such equilibria cannot be Pareto-ordered. A case largely similar to the one previously seen, when the high quality was provided through technology f, arises for trade policy. Again, a coordinated antidumping policy by both governments pushes firms to play a simultaneous Bertrand equilibrium. The kind of intervention we figure out is quite similar in spirit to some of those undertaken by the EU Commission, mainly against Eastern countries. These antidumping measures are triggered simply by relevant differences in prices of goods belonging to the same industry, but usually lead to greater distortions and additional welfare losses. In our case an antidumping measure may be triggered by the same facts but has a definite procompetitive effect, provided it is bilateral.

To sum up the results obtained in the section, we may formulate the following:

Proposition 1 When firms operate with either homogeneous or heterogeneous technologies and compete à la Bertrand, they prefer sequential play. If governments maximize welfare, they might independently implement an antidumping policy that ends up having a reciprocal pro-competitive effect.

4 Cournot competition and free trade

Now we conduct our analysis within a framework where the relevant market variable is no longer price. Once Cournot competition is considered, several possible scenarios may arise. Firms can fix their outputs under autarchy and then adjust qualities under free trade, or vice versa, according to the different degree of flexibility characterizing their technology and their capacity. If firms operate with a technology that involves fixed costs of quality production, they can only adjust output. If instead they adopt a variable cost technology, they have the option to fix either the output or the quality at the autarchy level. The efficiency level is the same for both technologies, i.e., $t = 1$.

4.1 Symmetric choices

(a) Quality competition under capacity constraints. A situation can be envisaged, where the existence of capacity constraints obliges firms to maintain the output level adopted in autarchy, while being flexible in terms of quality supplied in duopoly because of the flexibility associated with a variable cost technology. This assumption may be consistent with those models of intraindustry trade where the opening of trade has only a variety effect, leaving the total number of firms as well as their activity level unaffected (Krugman, 1979).

We still consider two countries which are equivalent in all respects. Both firms operate with a variable cost technology, as in (3). The inverse demand functions are:

$$p_H = \frac{2\overline{\theta}q_H - q_H x_H - q_L x_L}{2}; \tag{63}$$

$$p_L = \frac{q_L(2\overline{\theta} - x_H - x_L)}{2}. \tag{64}$$

The profit functions are:

$$\pi_H = \frac{x_H}{2}(2\overline{\theta}q_H - q_H x_H - q_L x_L - 2tq_H^2); \tag{65}$$

$$\pi_L = \frac{q_L x_L}{2}(2\overline{\theta} - x_H - x_L - 2tq_L). \tag{66}$$

Provided both quantities are fixed at the autarchy level, i.e., $x_i = \overline{\theta}/3$, we can derive the optimal qualities by differentiating the profit functions w.r.t. their controls:

$$q_H = \frac{5\overline{\theta}}{12}; \; q_L = \frac{\overline{\theta}}{3}. \tag{67}$$

It is worth noting that q_L is the same as in autarchy, due to the absence of strategic interaction emerging in this case. As a consequence, the low-quality good is sold at the autarchic price (8), while $p_H = 7\overline{\theta}^2/24$. Equilibrium profits are:

$$\pi_H^{vv}(x_A) = \frac{17\overline{\theta}^3}{432}; \; \pi_L^{vv}(x_A) = \frac{\overline{\theta}^3}{27}; \tag{68}$$

where superscript vv indicates that both firms operate with a variable cost technology, while x_A means that quantity is fixed under autarchy.

The consumer surplus is the same for each country, $CS_i = 17\overline{\theta}^3/864$. This obviously entails that social welfare is higher in the country where the high-quality firm is located.

(b) Quantity competition under quality constraints. Here we consider the opposite case where qualities are fixed in autarchy and firms compete in quantities after liberalization. A first intuitive result is that both goods are sold at the same price, since their qualities coincide: $p_H = p_L = \bar{\theta}(2\bar{\theta} - x_H - x_L)/6$. Optimal quantities are $x_H = x_L = 4\bar{\theta}/9$, while profits are:

$$\pi_H^{vv}(q_A) = \pi_L^{vv}(q_A) = \frac{8\bar{\theta}^3}{243}, \tag{69}$$

where q_A means that quality corresponds to the autarchy level. Again, consumer surplus is the same in both countries, $CS_i = 8\bar{\theta}^3/243$. The same obviously holds for social welfare.

(c) Cournot competition with fixed costs. When both firms operate with a fixed cost technology, it appears reasonable to assume that they can only adjust quantities under free trade, since qualities are the result of R&D investments undertaken in autarchy, interpreted as a period of patent shelter. Qualities are as in (12), so that goods are perfect substitutes. The profit functions are:

$$\pi_H = \frac{\bar{\theta}^2}{64}(8\bar{\theta}x_H - \bar{\theta}^2 - 4x_H x_L - 4x_H^2); \tag{70}$$

$$\pi_L = \frac{\bar{\theta}^2}{64}(8\bar{\theta}x_L - \bar{\theta}^2 - 4x_H x_L - 4x_L^2). \tag{71}$$

The optimal quantities are $x_H = x_L = 2\bar{\theta}/3$. Equilibrium profits are:

$$\pi_H^{ff}(q_A) = \pi_L^{ff}(q_A) = \frac{7\bar{\theta}^4}{576}. \tag{72}$$

Of course, $p_H = p_L = \bar{\theta}^3/24$, and $CS_i = \bar{\theta}^4/36$.

We may sum up the above results into

Proposition 2 In all cases in which technological choices are the same for the two contenders, the sequence of payoffs does not depend on the upper bound of the marginal willingness to pay ($\bar{\theta}$), i.e.: $\pi_H^{vv}(x_A; x_A) > \pi_L^{vv}(x_A; x_A) > \pi_H^{vv}(q_A; q_A) = \pi_L^{vv}(q_A; q_A) > \pi_H^{ff}(q_A; q_A) = \pi_L^{ff}(q_A; q_A)$. This entails that flexibility in quality setting strictly dominates flexibility in quantity.

4.2 Asymmetric choices with variable costs

(a) High quality variable, low quality fixed. Here, we come back to the setting where both firms have a variable cost technology, and consider the case where the low quality is set under autarchy, while the high-quality firm is constrained to produce the same quantity as in autarchy. Hence, $q_L = \bar{\theta}/3 = x_H$. The profit functions look as follows:

$$\pi_H = \frac{\bar{\theta}}{18}(5\bar{\theta}q_H - 6q_H^2 - \bar{\theta}x_L); \tag{73}$$

$$\pi_L = \frac{\bar{\theta}x_L}{6}(\bar{\theta} - x_L). \tag{74}$$

At equilibrium, $q_H = 5\bar{\theta}/12$, $x_L = \bar{\theta}/2$, and profits are:

$$\pi_H^{**}(x_A) = \frac{13\bar{\theta}^3}{432}; \; \pi_L^{**}(q_A) = \frac{\bar{\theta}^3}{24}; \tag{75}$$

with $\pi_H^{**}(x_A) < \pi_L^{**}(q_A)$. The low-quality firm is able to obtain higher profits than the high-quality firm by free-riding over the rival's output constraint; in other words she takes advantage of the high-quality firm's inability to expand production when market size increases as a consequence of trade liberalization. This implies that firm L's market share increases. As to consumer surplus, we obtain $CS_i = 13\bar{\theta}^3/432$.

(b) High quality fixed, low quality variable. We now describe the opposite case, where the high-quality firm sets her quality in autarchy, and the low-quality firm is constrained to produce the autarchic level of output, $q_H = \bar{\theta}/3 = x_L$. The profit functions are:

$$\pi_H = \frac{\bar{\theta}x_H}{18}(4\bar{\theta} - 3q_L - 3x_H); \tag{76}$$

$$\pi_L = \frac{\bar{\theta}q_L}{18}(5\bar{\theta} - 6q_L - 3x_H). \tag{77}$$

We then get the optimal controls, $x_H = 11\bar{\theta}/21$ and $q_L = 2\bar{\theta}/7$. Equilibrium profits amount to:

$$\pi_H^{**}(q_A) = \frac{121\bar{\theta}^3}{2646}; \; \pi_L^{**}(x_A) = \frac{4\bar{\theta}^3}{147}. \tag{78}$$

Again, consumers in both countries enjoy the same surplus, $CS_i = 295\bar{\theta}^3/10584$. Since $\pi_H^{**}(q_A) > \pi_L^{**}(x_A)$, it is immediately verified that social welfare is higher in the country where firm H operates.

(c) High quality with variable costs, low quality with fixed costs, and Cournot competition. In this mixed case, the high-quality good is produced with a variable cost technology. Notice that the other way round is not possible because the fixed technology is less efficient and therefore is confined to the production of the low quality. Both qualities are set in autarchy, and firms optimize over quantities. Their profit functions are:

$$\pi_H = \frac{\bar{\theta}x_H}{144}(32\bar{\theta} - 24x_H - 9\bar{\theta}x_L); \tag{79}$$

$$\pi_L = \frac{\bar\theta^2}{64}(8\bar\theta x_L - \bar\theta^2 - 4x_H x_L - 4x_L^2). \tag{80}$$

Equilibrium quantities and profits are:

$$x_H = \frac{2\bar\theta(9\bar\theta - 32)}{9\bar\theta - 96};\; x_L = \frac{64\bar\theta}{96 - 9\bar\theta};$$

$$\pi_H^{vf}(q_A) = \frac{2\bar\theta^3(9\bar\theta - 32)^2}{27(3\bar\theta - 32)^2};\; \pi_L^{vf}(q_A) = \frac{\bar\theta^4(224 - 9\bar\theta)(32 + 9\bar\theta)}{576(3\bar\theta - 32)^2}. \tag{81}$$

Consumer surplus is the same in both countries, and amounts to

$$CS_i^{vf}(q_A) = \frac{\bar\theta^3(1024 + 576\bar\theta - 135\bar\theta^2)}{54(3\bar\theta - 32)^2}.$$

From (81), it emerges that $\pi_L^{vf}(q_A) > \pi_H^{vf}(q_A)$ if $\bar\theta > 1.509$. Since the only difference between the two countries is due to profits, the same condition holds for social welfare comparison as well. As to quantities, $x_L > x_H$ for all acceptable values of $\bar\theta$.

(d) High quality with variable costs and quantity constraint, low quality with fixed costs and quality constraint. The last case that remains to be investigated is that where the high quality firm operates with variable costs and supplies the same quantity as in autarchy, while the low quality being produced through fixed costs, is obviously set in autarchy. Profit functions are:

$$\pi_H = \frac{\bar\theta(40\bar\theta q_H - 48q_H^2 - 3\bar\theta^2 x_L)}{144};\; \pi_L = \frac{\bar\theta^2(6x_L - \bar\theta)(3 - 2x_L)}{192}. \tag{82}$$

At equilibrium, we get $q_H = 5\bar\theta/12$, and $x_L = 5\bar\theta/6$, so that profits are:

$$\pi_H^{vf}(x_A) = \frac{5\bar\theta^3(10 - 3\bar\theta)}{864};\; \pi_L^{vf}(q_A) = \frac{\bar\theta^4}{36}. \tag{83}$$

If $1 < \bar\theta < 1.282$, then $\pi_H^{vf}(x_A) > \pi_L^{vf}(q_A)$. Consumer surplus is:

$$CS_i^{vf}(x_A; q_A) = \frac{5\bar\theta^3(8 + 27\bar\theta)}{6912}.$$

We can then sum up the asymmetric cases with

Proposition 3 In the asymmetric setting, the payoff ranking is not invariant with respect to $\bar\theta$; i.e. there is no dominance in the choice of controls.

4.3 A three-stage game

We may now figure out the interactions between the two firms as taking place through three different stages. In the first, the choice of technology between fixed and variable costs has to be undertaken. The decision to adopt the variable cost technology leaves open the possibility to fix either quality or quantity in the second stage, while the adoption of the fixed cost technology implies that the firm must compete in quantities given the autarchic quality chosen beforehand. The third stage describes market competition.

Matrix 3 describes the three-stage game in normal form, where the payoffs are those found in the previous section. Firms are labelled as 1 and 2, since their location along the quality spectrum depends upon the specific subgame considered. In each cell, the first payoff refers to firm 1, the second to firm 2.

			2		
			f	v	
			q_A	q_A	x_A
1	f	q_A	$\pi_L^{ff}(q_A;q_A);\pi_H^{ff}(q_A;q_A)$	$\pi_L^{vf}(q_A;q_A);\pi_H^{vf}(q_A;q_A)$	$\pi_L^{vf}(q_A;x_A);\pi_H^{vf}(q_A;x_A)$
	v	q_A	$\pi_H^{vf}(q_A;q_A);\pi_L^{vf}(q_A;q_A)$	$\pi_H^{vv}(q_A;q_A);\pi_L^{vv}(q_A;q_A)$	$\pi_H^{vv}(q_A;x_A);\pi_L^{vv}(q_A;x_A)$
		x_A	$\pi_H^{vf}(x_A;q_A);\pi_L^{vf}(x_A;q_A)$	$\pi_H^{vv}(x_A;q_A);\pi_L^{vv}(x_A;q_A)$	$\pi_H^{vv}(x_A;x_A);\pi_L^{vv}(x_A;x_A)$

Matrix 3

We now consider different three-stage games according to the level of the key parameter $\bar{\theta}$; whose admissible range is $]1;2]$.

i) Homogeneous products and variable cost technology

Proposition 4 In the most part of the admissible range of $\bar{\theta}$; the subgame perfect equilibrium of the three-stage game involves both firms choosing the variable cost technology and the autarchic quality. Then, they compete in quantities in the market stage with homogeneous products.

Proof. When $1 < \bar{\theta} < 1.498$, we can order the payoffs in matrix 3 according to the following inequalities:

$$\pi_H^{vf}(q_A;q_A) > \pi_H^{vv}(q_A;x_A) > \pi_L^{vv}(x_A;q_A) > \pi_H^{vf}(q_A;x_A) =$$

$$= \pi_H^{vf}(x_A;q_A) > \pi_H^{vv}(x_A;x_A) = \pi_L^{vv}(x_A;x_A) > \pi_H^{vv}(q_A;q_A) =$$

$$= \pi_L^{vv}(q_A, q_A) > \pi_H^{vv}(x_A, q_A) > \pi_L^{vf}(x_A, q_A) = \pi_L^{vf}(q_A, x_A) >$$

$$> \pi_L^{vv}(q_A, x_A) > \pi_L^{vf}(q_A, q_A) > \pi_H^{ff}(q_A, q_A) = \pi_L^{ff}(q_A, q_A). \quad (84)$$

Given this sequence of inequalities, the three-stage game has a unique subgame perfect equilibrium represented by the triple pairs of sequentially chosen strategies $\{(v,v), (q_A, q_A), (x,x)\}$. The corresponding outcome is $\pi_H^{vv}(q_A, q_A) = \pi_L^{vv}(q_A, q_A)$. This is a perfectly symmetric equilibrium where firms become indistinguishable in all respects. ■

Notice that the subgame perfect equilibrium of the three-stage game is simultaneously the equilibrium of the subgame where strategy x_A is absent, so that the latter appears to be redundant.

ii) Heterogeneity of products and technologies: multiple equilibria with predetermined quality

Proposition 5 For reasonably high values of $\bar{\mu}$, the three stage game has two subgame perfect equilibria. Firms operate with heterogeneous technologies, fix qualities in autarchy and then compete à la Cournot with differentiated products.

Proof. When $\bar{\mu} \in [1.498, 1.919]$, we have the following inequalities:

$$\pi_L^{vf}(x_A, q_A) = \pi_L^{vf}(q_A, x_A) > \pi_H^{vv}(q_A, x_A) > \pi_L^{vv}(x_A, q_A) >$$

$$> \pi_H^{vv}(x_A, x_A) > \pi_L^{vf}(q_A, q_A) > \pi_L^{vv}(x_A, x_A) > \pi_H^{vv}(q_A, q_A) =$$

$$= \pi_L^{vv}(q_A, q_A) > \pi_H^{vv}(x_A, q_A) > \pi_H^{vf}(q_A, q_A) > \pi_H^{vf}(x_A, q_A) =$$

$$= \pi_H^{vf}(q_A, x_A) > \pi_L^{vv}(q_A, x_A) > \pi_H^{ff}(q_A, q_A) = \pi_L^{ff}(q_A, q_A). \quad (85)$$

On the basis of (85), we have two subgame perfect equilibria of the three-stage game, which are represented by the triple pairs $\{(v, f), (q_A, q_A), (x, x)\}$; $\{(f, v), (q_A, q_A), (x, x)\}$. ■

Again, strategy x_A can be disregarded, and the equilibrium belongs to the subgame where firms set qualities in autarchy. Firms turn thus out to be unable to coordinate over the technological choice and then also on quality standards.

iii) Heterogeneity of products and technologies: multiple equilibria with mixed predetermined variables

Proposition 6 For values of $\bar{\mu}$ near to the upper bound of the admissible range, the three stage game has two subgame perfect equilibria. Firms operate with heterogeneous technologies, set different variables in autarchy and use different controls in the market game.

Proof. When $\bar{\mu} \in]1.919, 2]$, we have the following sequence of inequalities:

$$\pi_L^{vf}(x_A, q_A) = \pi_L^{vf}(q_A, x_A) > \pi_L^{vf}(q_A, q_A) > \pi_H^{vv}(q_A, x_A) >$$

$$> \pi_L^{vv}(x_A, q_A) > \pi_H^{vv}(x_A, x_A) > \pi_L^{vv}(x_A, x_A) > \pi_H^{vv}(q_A, q_A) =$$

$$= \pi_L^{vv}(q_A, q_A) > \pi_H^{vv}(x_A, q_A) > \pi_L^{vv}(q_A, x_A) > \pi_H^{vf}(q_A, x_A) =$$

$$= \pi_H^{vf}(x_A, q_A) > \pi_H^{ff}(q_A, q_A) = \pi_L^{ff}(q_A, q_A) > \pi_H^{vf}(q_A, q_A). \qquad (86)$$

Given (86), the three-stage game exhibits two subgame perfect equilibria where firms choose heterogeneous technologies and set different controls as a result of the commitments taken in autarchy. We then obtain the triple pairs $\{(f, v), (q_A, x_A), (x, q)\}$, $\{(v, f), (x_A, q_A), (q, x)\}$. ■

Notice that the equilibrium of the three-stage game does not coincide with the equilibrium of the subgame where firms are constrained to adopt quantity as the control variable in the market stage. This subgame has actually a unique symmetric equilibrium represented by $\{(f, f), (q_A, q_A), (x, x)\}$, which is the result of the adoption of dominant strategies in a situation reproducing the prisoner's dilemma.

4.4 Discussion

We wish to investigate the coordination aspects of equilibria in terms of technologies and quality standards. Moreover we are concerned with the time consistency of the choice of technology by each firm, since any asymmetric equilibrium entails time inconsistency, and, from the autarchic perspective, the variable cost technology is chosen when $1 < \bar{\mu} < 48/27 \simeq 1.777$ and vice versa.

We have seen that in most of the cases (i.e. when $1 < \bar{\mu} < 1.498$), automatic coordination over both technology and quality standard obtains. This appears to imply that if the market is not extremely affluent, firms tend to adopt a highly competitive behavior, supplying homogeneous goods produced through the most e±cient technology. This is a case where complete coordination and time consistency emerge.

As consumers get richer (µ 2 [1:498; 1:919]), we do not observe any more a unique subgame perfect equilibrium. We loose the common standard since the increase in market a²uence leads ¯rms to diverge in qualities and technologies, adopting thus a less competitive behavior. This, however, is just a part of the story. Since we assume that countries are similar in all respects, we should plausibly anticipate that both ¯rms adopt the most e±cient technology, i.e., technology v, as long as $1 < \overline{µ} < 48=27 \cong 1:777$: If that is the case, we should con¯ne to a two-stage game which corresponds to the south-east quadrant of Matrix 3, where the subgame perfect equilibrium in dominant strategies is represented by f$(q_A; q_A); (x; x)$g; where ¯rms produce the same quality and the same quantity. This is the only means to get time consistency in this range of $\overline{µ}$: The pair of strategies (f; f) is never subgame perfect, no matter how the matrix is reduced.

For even higher levels of the marginal willingness to pay ($\overline{µ}$ 2]1:919; 2]), we still get two subgame perfect equilibria of the three-stage game, where ¯rms fail to coordinate in all stages and thus behave inconsistently. However, di®erent results obtain if we go through two subgames. Consider the ¯rst, represented by the north-west quadrant of Matrix 3, which obtains by dropping strategy x_A. The equilibrium in dominant strategies is given by f(f; f); (x; x)g which is time consistent since it can be envisaged as the result of autarchic choice. The second subgame is represented by the south-east quadrant of Matrix 3. Again, we have an equilibrium in dominant strategies, given by f$(q_A; q_A); (x; x)$g: >From the ¯rms' standpoint, the latter equilibrium is preferred to that associated with the former subgame, yet it su®ers from time inconsistency.

4.5 Welfare assessment

We now consider social welfare in each country, con¯ning our attention to those market con¯gurations that are candidates as subgame perfect equilibria of the game between ¯rms. To this purpose, we may consider an alternative three-stage game played by the governments of the two countries, aiming at maximizing social welfare.

			2		
			f	v	
			q_A	q_A	x_A
	f	q_A	$W_1^{ff}(q;q); W_2^{ff}(q;q)$	$W_1^{vf}(q;q); W_2^{vf}(q;q)$	$W_1^{vf}(q;x); W_2^{vf}(q;x)$
1	v	q_A	$W_1^{vf}(q;q); W_2^{vf}(q;q)$	$W_1^{vv}(q;q); W_2^{vv}(q;q)$	$W_1^{vv}(q;x); W_2^{vv}(q;x)$
		x_A	$W_1^{vf}(x;q); W_2^{vf}(x;q)$	$W_1^{vv}(x;q); W_2^{vv}(x;q)$	$W_1^{vv}(x;x); W_2^{vv}(x;x)$

Matrix 4

We envisage a new matrix, where payoffs are represented by social welfare levels instead of profits. This is done in Matrix 4. Hence, the equilibria of the game can be detected by looking at the sequence of inequalities, specified for the relevant intervals of $\bar{\mu}$.

i) $1 < \bar{\mu} < 1.498$:

For a large chunk of the range of the marginal willingness to pay, the welfare levels can be ranked as follows:

$$W_1^{vf}(q,q) > W_1^{vv}(q,x) > W_1^{vv}(q,q) > W_1^{vf}(x,q) > W_1^{vv}(x,q) > W_1^{vv}(x,x)$$

$$> W_1^{vf}(q,x) > W_1^{vf}(q,q) > W_1^{ff}(q,q). \tag{87}$$

$$W_2^{vf}(q,q) > W_2^{vv}(x,q) > W_2^{vv}(q,q) > W_2^{vf}(q,x) > W_2^{vv}(x,x) > W_2^{vv}(q,x)$$

$$> W_2^{vf}(x,q) > W_2^{vf}(q,q) > W_2^{ff}(q,q). \tag{88}$$

Given the above inequalities, it appears that the subgame perfect equilibrium of the game played by social welfare maximizing governments is $\{(v,v);(q_A,q_A);(x,x)\}$, which coincides with the equilibrium of the game between firms. Moreover, this is also the equilibrium of the subgame which obtains by deleting strategy x_A. This allows to claim what follows:

Proposition 7 For most of the values of $\bar{\mu}$, the duopoly game gives rise to the equilibrium that would be selected by governments aiming at noncooperatively maximizing social welfare in each country. This equilibrium happens to be associated with common standards both in technology and in quality.

ii) $\bar{\mu} \in [1.498, 1.919]$:

In this range, the relevant inequalities are:

$$W_1^{vf}(q,x) > W_1^{vf}(q,q) > W_1^{vv}(q,x) > W_1^{vf}(q,q) > W_1^{vf}(x,q) > W_1^{ff}(q,q)$$

$$> W_1^{vv}(q,q) > W_1^{vv}(x,q) > W_1^{vv}(x,x). \tag{89}$$

$$W_2^{vf}(x,q) > W_2^{vf}(q,q) > W_2^{vv}(x,q) > W_2^{vf}(q,q) > W_2^{vf}(q,x) > W_2^{ff}(q,q)$$

$$> W_2^{vv}(q,q) > W_2^{vv}(x,x) > W_2^{vv}(q,x). \tag{90}$$

This game has two subgame perfect equilibria, given by $\{(f,v);(q_A,q_A);(x,x)\}$, and $\{(v,f);(q_A,q_A);(x,x)\}$, that coincide with those emerging from the duopoly market game. In each of these equilibria, the welfare of the country operating with the fixed cost technology is higher than the other country's. Hence,

Proposition 8 *When $\bar{\theta} \in [1.498, 1.919]$, governments face the same coordination problem as firms. No common standard arises endogenously, either in technology or in quality.*

iii) $\bar{\theta} \in]1.919, 2]$.
When the marginal willingness to pay for quality is high, we have:

$$W_1^{vf}(q,x) > W_1^{vf}(q,q) > W_1^{ff}(q,q) > W_1^{vv}(q,x) > W_1^{vf}(x,q) > W_1^{vf}(q,q)$$

$$> W_1^{vv}(q,q) > W_1^{vv}(x,q) > W_1^{vv}(x,x). \tag{91}$$

$$W_2^{vf}(x,q) > W_2^{vf}(q,q) > W_2^{ff}(q,q) > W_2^{vv}(x,q) > W_2^{vf}(q,x) > W_2^{vf}(q,q)$$

$$> W_2^{vv}(q,q) > W_2^{vv}(x,x) > W_2^{vv}(q,x). \tag{92}$$

In this setting, the game yields a unique equilibrium in dominant strategies, given by $\{(f,f),(q_A,q_A),(x,x)\}$, where the fixed cost technology is adopted and quality is fixed in autarchy in both countries. Notice that, in this case, we loose the coincidence between the duopoly game and the governments' game equilibria. We may thus claim what follows:

Proposition 9 *When $\bar{\theta}$ is high, there is a unique equilibrium of the governments' game, where a common standard is adopted as far as both technology and quality are concerned.*

As a last general remark, it is worth observing that, for all levels of $\bar{\theta}$, governments should encourage firms to remain flexible in terms of quantities, since this would decrease the power of firms. If that were the case, we could reduce the governments' game to a two-stage game, while this was not possible in the duopoly game. As a way of implementing such a policy of welfare maximization and/or common standards, one could envisage the introduction of common quality standards in autarchy in both countries. Once firms are confined to compete à la Cournot in the market stage, they automatically coordinate their strategies over the equilibrium that would be selected by governments. This represents an instance of the possible reasons justifying the adoption of quality standards in open economies, as a device for enhancing competition through standardization.[8] A consequence of that is the complete absence of time inconsistency in the choice of standards, in that, under free trade, governments would have no incentive to renege the standard adopted in the autarchic environment.

[8] A related literature deals with Minimum Quality Standards. The role of MQSs in open economies with imperfect competition has been investigated by Boom (1995). The possibility that an MQS policy yields long run pro-competitive effects is dealt with by Ecchia and Lambertini (1997).

5 Conclusions

In this paper we have tried to examine, in a partial equilibrium framework, the e®ects of di®erent sorts of competition on (i) quality standards; (ii) technology adoption; and (iii) welfare, when vertically di®erentiated goods are traded among similar countries.

First, we have considered price competition between ¯rms operating with technologies characterized by di®erent degrees of °exibility and e±ciency. When ¯rms are allowed to set the timing of moves in the free trade market game, they select sequential play since it invariably yields higher pro¯ts than simultaneous play. The social damage caused by Stackelberg competition in prices prompts for the intervention of governments in the form of common antidumping measures aimed at forcing producers to move simultaneously, avoiding that either ¯rm may consider undercutting as a feasible policy. This provides a theoretical case in favor of coordinated antidumping policy, given that consumers are unharmed.

Moving to Cournot competition, we have a greater variety of controls in the market stage, which, coupled with the choice of technology, allows for a thorough analysis of the issue of coordination over standards on both technology and product design. Firms' behavior leads to di®erent equilibria, conditional upon consumers' willingness to pay. In a wide range of the key parameter, competition intensi¯es, and ¯rms are pushed to adopt the same technology and sell homogeneous products, so that they converge to the equilibrium that a social planner would select. The decisions of both the social planner and the ¯rms turn out to be time consistent. Otherwise, when consumers are richer, competition softens and such a coincidence disappears, with ¯rms adopting di®erent standards in all respects, that is, one of them is time inconsistent. If ¯rms are compelled to set quality in autarchy or in an environment protected by a patent system, they noncooperatively select the socially preferable equilibria independently of consumers' income. This appears to justify the adoption of quality standards regardless of whether they are introduced in an autarchic perspective or by taking into account the consequences of trade liberalization.

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