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MONOPOLY, QUALITY, AND NETWORK EXTERNALITIES

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Abstract: We describe the behaviour of a monopolist supplying a vertically differentiated good with network externalities. Assuming a convex cost of quality improvements unrelated with output, we show that the presence of network externalities enhances the incentive to expand output associated with scale economies. Although the quality distortion operated by the monopolist increases with network externalities, the output expansion effect tends to dominate, so that the welfare loss due to monopoly power shrinks as the role of network externalities in determining consumers' satisfaction becomes more relevant.

Key words: Monopoly, Quality Distortion, Network Externalities, Market Coverage, Social Planning.
J.E.L. Classification Number: D62, L12, L52.

1. INTRODUCTION

The case for or against regulating a monopolist has been long debated, and it is now being re-assessed concerning markets where consumer utility is characterised by network externalities, i.e., it is positively related to the number of consumers who purchase the same good.[1] The issue of network externalities is often related to the problem of standardization. By this, one usually refers to the possibility that several standards offered by different firms compete for the same population of consumers/adopters, and the question is whether the market will adopt a single standard or not (see Shy, 2001,

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[1] Seminal contributions in the theory of network externalities are Katz and Shapiro (1985; 1986); Farrell and Saloner (1985; 1986). For an overview, see Katz and Shapiro (1994) and the special issue of the *International Journal of Industrial Organization*, edited by Economides and Encaoua (1996).

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inter alia). The standard itself may be defined along several dimensions, including product quality. As soon as one recognizes a role to quality, then an interplay emerges between quality and network effects. Such a relationship remains there also in a monopoly regime, where the market is *de facto* standardized. When a monopolist, aware of the presence of positive network effects on the demand side, controls either price or output (i.e., ultimately, the size of the network) and product quality, the following questions arise: what kind of distortions shall we expect to observe on the part of the firm? And, how the network externality will affect the interplay between output and quality? Since both quality and network size are desirable from the consumers' standpoint, in line of principle the monopolist might substitute one for the other, exploiting an underlying tradeoff.

To our knowledge, so far, the interplay between network externalities and the monopolist's choices concerning product quality and the output level, has been evaluated considering a variable cost technology, where marginal cost is convex in the quality level (Lambertini and Orsini, 2001).[2] However, there exist several markets for goods whose production involves a large amount of fixed costs and a negligible unit variable cost, and where network effects are relevant. The software industry and, more generally, the markets for information goods, are examples of sectors with increasing returns both on the supply and on the demand side (Shapiro and Varian, 1999).

In the existing literature on vertical differentiation, the costs of quality improvements have been modelled in three alternative ways: (i) variable costs, where quality affects the unit production cost; (ii) exogenous fixed costs, that do not affect the optimum; (iii) endogenous fixed costs, that depend upon the level of quality while it is unrelated to output. The case of variable costs of quality improvements has been widely investigated. The main question is whether a monopolist supplies the socially optimal quality, or distorts it so as to induce self-selection on the part of consumers. The earliest contributions (Spence, 1975; Sheshinski, 1976) deal with a single-product monopolist. Their main conclusions are that (i) for a given output level, quality is over or undersupplied by the monopolist as compared to social planning, depending on whether the marginal valuation of quality is above or below the average valuation of quality (if they coincide, the monopolist supplies the same quality as the social planner); and (ii) the monopolist undersupplies quality if his output is close to the socially optimal one. These results extend to the case where the monopolist produces a continuum of qualities (see Mussa and Rosen, 1978; Itoh, 1983; Champsaur and Rochet, 1989).

To our knowledge, the role of fixed costs in shaping the behaviour of a monopolist, has received scanty attention, a relevant exception being Gabszewicz *et al.* (1986).[3] In their paper, however, fixed costs are exogenous, and therefore do not affect the optimal choice of quality.

[2] Positional effects in a vertically differentiated monopoly with variable costs of quality improvement are investigated in Lambertini and Orsini (2002). For the interplay between positional and network externalities in a Hotelling duopoly, see Grilo, Shy and Thisse (2001).

[3] The opposite holds in the field of oligopoly competition. See Ronnen (1991), Motta (1993) and Lehmann-Grube (1997), *inter alia*.

We propose a monopoly model where quality improvements require R&D efforts, completely independent of output. The single-product monopolist supplies a good whose production entails a fixed cost convex in the quality level, and consumers' utility function contains a network externality component. We evaluate the monopolist's performance against the social optimum in a general setting where the monopolist, in response to the presence of network effects, may over or under supply product quality as compared to the social optimum.

Resorting to a specification of the model where the distribution of consumers is uniform and the cost function is quadratic, it is possible to ascertain that the monopolist always undersupplies product quality and, as long as the market is only partially covered, such distortion is increasing in the extent of network externalities. The latter finding seemingly points to the need for quality regulation. However, this does not imply that we either could or should aim at increasing the intensity of competition in such a market, for several reasons. First of all, it is well known that, when production involves fixed costs, a competitive market structure cannot obtain (Shaked and Sutton, 1982; 1983). Second, the presence of brand-specific network externalities disrupts the conventional monotonic relationship between the number of firms on one side and consumer surplus and social welfare on the other. As a consequence, the appropriate comparison has to be carried out between a profit-seeking monopolist and a public firm maximising social surplus. We show that (i) the monopoly output and social welfare are increasing in the extent of network externalities; and (ii) the social planner serves all consumers independently of network externalities. These facts lead to a relevant conclusion, namely, that when the level of network externalities is non-negligible, the welfare loss due to monopoly power decreases as network externalities increase. To the extent that our assumptions are acceptable, our analysis implies that, in industries where the utility each individual derives from purchase is strongly related to the number of consumers patronising the same good or brand, the case for regulation is much weaker than what we usually think according to conventional wisdom.

The paper is organized as follows. Section 2 presents the general model. A specific formulation is introduced in section 3, where we derive both the monopoly equilibrium and the social optimum, which are then comparatively evaluated in section 4. Section 5 concludes.

2. THE MODEL

Consider a monopoly market for a good whose utility depends both on intrinsic characteristics, which are represented by quality q, and by the amount of market demand x. Consumers are characterised by parameter θ, which represents the individual marginal willingness to pay for quality:[4] they are distributed with density $f(\theta)$ over the interval $[\bar{\theta} - 1, \bar{\theta}]$, with $\bar{\theta} \geq 1$. The number of individuals is normalised to 1. Each consumer buys at most one unit of the good, the resulting net surplus being

[4] As emphasised by Tirole (1988, ch. 2), θ may also be interpreted as the reciprocal of the marginal utility of money. This implies that θ increases as income increases, and conversely.

$U = \max\{\theta q + \alpha x - p\ ,\ 0\}$, where p is the price charged by the monopolist, while α (the same for all the agents) is a positive coefficient representing the weight of the network externality in the utility function. Let $\hat{\theta}(\alpha, p, q, f(\theta))$ define the marginal willingness to pay of the consumer who is indifferent between buying and not buying:

$$\hat{\theta}(\alpha, p, q, f(\theta)) \equiv \{\theta : \theta q + \alpha \int_{\theta}^{\bar{\theta}} f(z)dz - p = 0\}\,. \quad (1)$$

Then, market demand is $x = \int_{\underline{\theta}}^{\bar{\theta}} f(\theta)d\theta$, where $\underline{\theta} = \max\{\bar{\theta} - 1\ ,\ \hat{\theta}\}$. When $\max\{\bar{\theta} - 1, \hat{\theta}\} = \hat{\theta}$, partial market coverage obtains; when $\max\{\bar{\theta} - 1, \hat{\theta}\} = \bar{\theta} - 1$, full market coverage obtains. i.e., $x = 1$. Consumer surplus is $CS = \int_{\underline{\theta}}^{\bar{\theta}} U(\cdot)f(\theta)d\theta$.

Production involves a fixed cost $C = C(q)$, with $C', C'' > 0$. Variable costs are assumed away. This amounts to saying that quality is the result of R&D efforts, whose cost is increasing in the quality level, while it is unrelated to the scale of production. The profit function is then $\Pi_M = p \cdot \int_{\underline{\theta}}^{\bar{\theta}} f(\theta)d\theta - C(q)$. Define social welfare as $SW = \Pi_M + CS$. Following Spence (1975), we evaluate the social incentive to modify product quality, in correspondence of the monopoly optimum w.r.t. quality, given monopoly output. We prove the following:

PROPOSITION 1. *Given $f(\theta)$, in the monopoly optimum where $\dfrac{\partial \Pi_M}{\partial q} = 0$, the derivative*

$$\frac{\partial SW}{\partial q} = \frac{\partial CS}{\partial q} = \int_{\hat{\theta}}^{\bar{\theta}} (\theta - p'_q)f(\theta)d\theta - (\hat{\theta}q - p) \cdot f(\hat{\theta}) \cdot \hat{\theta}'_q - 2\alpha x \cdot f(\hat{\theta}) \cdot \hat{\theta}'_q$$

may have either sign under partial market coverage.

Proof. See Appendix A.1.

The above proposition states that, in response to network effects, the monopolist may over or undersupply product quality as compared to the social optimum, irrespective of the difference between the marginal and average evaluations of quality.[5] Observe that, when $\alpha = 0$, the expression in proposition 1 coincides with the well known condition in Spence (1975), showing that the monopolist undersupplies (oversupplies) quality if the marginal consumer's evaluation of quality is lower (higher) than the average consumer's. This amounts to saying that, while the planner takes into account the effect of a change in quality on all customers, the monopolist only considers the effect on the marginal customer.[6] The presence of network externalities adds the last term where α appears explicitly, and modifies the other terms as well. This entails that, with any positive weight attached to network externality, the simple comparison between the marginal and average levels of the marginal willingness to pay is no longer conclusive. If we confine our attention to the first order effect of the network externality, then what

[5] Given a generic distribution of consumer preferences, this result also holds under variable costs of quality improvements (Lambertini and Orsini, 2001, p. 972).

[6] Likewise, for a given quality, we know that there exists an incentive for the monopolist to distort output.

matters is that $-2\alpha x \cdot f(\hat{\theta}) \cdot \hat{\theta}'_q > 0$ because $\hat{\theta}'_q < 0$ (see Appendix A.1). Therefore, for any given distribution of hedonic tastes, the presence of network externalities makes underprovision of quality more likely in the monopoly optimum. The intuition is that, with network effects, output expansion is a cheaper substitute for quality increase.

3. A MODEL WITH QUADRATIC COSTS AND UNIFORM DISTRIBUTION

In order to characterise in detail the influence of network externalities on the provision of quality and welfare, we investigate a version of the model which is widely adopted in the existing literature. In particular, we assume that (i) $C(q) = vq^2$; and (ii) the population of consumers is uniformly distributed over $[\bar{\theta} - 1, \bar{\theta}]$. Recall that the marginal consumer is characterised by a willingness to pay $\hat{\theta} = (p - \alpha\bar{\theta})/(q - \alpha)$, so that under partial market coverage (pmc) and full market coverage (fmc), respectively, market demand is:

$$x = \bar{\theta} - \frac{p - \alpha\bar{\theta}}{q - \alpha} = \frac{q\bar{\theta} - p}{q - \alpha} \text{ for all } \{p, q, \alpha\} \text{ such that } \hat{\theta} \in (\bar{\theta} - 1, \bar{\theta}]\,; \quad (pmc) \quad (2)$$

$$x = 1 \text{ for all } \{p, q, \alpha\} \text{ such that } \hat{\theta} \leq \bar{\theta} - 1\,. \quad (fmc) \quad (3)$$

In either case, the monopoly profit function is $\Pi_M = px - vq^2$. Observe that, having specified the cost function and consumer distribution, it is possible to justify the presence of a single firm in the market on the basis of the finiteness property (Shaked and Sutton, 1983). The introduction of an external effect, which increases consumers' reservation price for a specific brand, makes it easier for the market to become a natural monopoly, due to the fact that increasing returns on the demand side add up to those operating on the supply side.[7]

3.1. Profit maximization

Here, we first treat separately the alternative settings of partial and full market coverage. Then, we proceed to establish the parameter ranges where the monopolist adopts, alternatively, one regime or the other.

3.1.1. Partial market coverage

Suppose $\hat{\theta} \in (\bar{\theta} - 1, \bar{\theta}]$. Then, partial market coverage obtains and the monopolist's profits are given by $\Pi_M^{pmc} = p(q\bar{\theta} - p)/(q - \alpha) - vq^2$. This expression has to be maximized with respect to the two choice variables: price and quality. The first order condition w.r.t. price yields $p = \bar{\theta}q/2$. Plugging it in Π_M^{pmc} and taking the derivative w.r.t. q yields:

$$\frac{\partial \Pi_M^{pmc}}{\partial q} = \frac{\bar{\theta}^2 q}{2(q - \alpha)} - \frac{\bar{\theta}^2 q^2}{4(q - \alpha)^2} - 2vq = 0 \quad (4)$$

[7] The calculations showing this property are omitted for the sake of brevity. They are available from the authors upon request.

The quality level provided by the monopolist is therefore:[8]

$$q_M^{pmc} = \alpha + \frac{\bar{\theta}(\bar{\theta} + k)}{16v} \tag{5}$$

where $k = \sqrt{\bar{\theta}^2 - 32\alpha v}$. Clearly, the admissible range for α is $[0, \bar{\theta}^2/(32v)]$.

The equilibrium price is $p_M^{pmc} = \bar{\theta}(\bar{\theta}^2 + 16\alpha v + \bar{\theta}k)/(32v)$, and market demand is $x_M^{pmc} = (\bar{\theta}^2 + 16\alpha v + \bar{\theta}k)/[2(\bar{\theta} + k)]$. The resulting equilibrium profit is $\Pi_M^{pmc} = (16\alpha v + \bar{\theta}^2 + \bar{\theta}k)^3/[128v(\bar{\theta}+k)^2]$. Network externalities being absent, i.e., $\alpha = 0$, these results coincide with those derived in the standard model without network externalities, $q_M^* = \bar{\theta}^2/(8v)$, $p_M^* = \bar{\theta}^3/(16v)$ and $x_M^* = \bar{\theta}/2$ (see Lambertini, 1997). However, there is a discontinuity w.r.t. α, due to the fact that $\bar{\theta} \geq 4\sqrt{2\alpha v}$ in order for these results to be acceptable; this, in connection with the condition $\bar{\theta} \geq 1$, implies $\bar{\theta} \geq \max\{1, 4\sqrt{2\alpha v}\}$. In this range, it is easy to see that p_M^{pmc} is always lower than p_M^*, while x_M^{pmc} is greater than x_M^*. As to the effect of network externalities on monopoly optimum, the following results can be established:

LEMMA 1. *The optimal monopoly quality and price under partial market coverage are everywhere decreasing in α, while the optimal monopoly output is everywhere increasing and convex in α.*

Proof. See Appendix A.2.

Lemma 1 can be interpreted in the following terms. Any increase in α given $\bar{\theta}$, entails that consumers become relatively more interested in the size of demand rather than in hedonic quality. This implies that the inverse demand function becomes flatter.[9] These results, concerning the optimal price schedule and the behaviour of demand, hold irrespective of the specification of the cost function (see Lambertini and Orsini, 2001, p. 973). Accordingly, the monopolist finds it convenient to operate a substitution of intrinsic quality with additional output, since the former requires fixed costs while the latter is costless. The reduction in quality and the output expansion jointly explain the reduction in price as α becomes higher.

Notice that, unlike what happens in the variable cost case without network externalities (Spence, 1975), as long as the monopolist does not serve the whole market, a distortion is observed both in quality and in quantity. Positive network externalities increase the quality distortion made by the monopolist, who supplies a lower quality at a lower price, so as to expand the output level in order to serve lower income consumers. The welfare implications of these distortions can be traced out calculating the level of consumer surplus and monopoly profits, and the level of social welfare:[10]

[8] Second order conditions are met throughout the calculations performed in the paper, although they are omitted for the sake of brevity.

[9] This is true for any given quality, as can be verified by checking that $|\partial x/\partial p| = 1/(q - \alpha)$, which is everywhere increasing in α. This is an established result in previous literature on positive externalities in consumption, without product differentiation (see Leibenstein, 1950).

[10] The coincidence between equilibrium profits and consumer surplus arises with quadratic costs of quality improvement, while does not emerge with other cost structures.

$$CS_M^{pmc} = \int_{\hat{\theta}}^{\bar{\theta}} (\theta q_M^{pmc} + \alpha x_M^{pmc} - p_M^{pmc}) d\theta = \frac{(16\alpha v + \bar{\theta}^2 + \bar{\theta}k)^3}{128v(\bar{\theta} + k)^2} = \Pi_M^{pmc} \quad (6)$$

$$SW_M^{pmc} = \frac{(16\alpha v + \bar{\theta}^2 + \bar{\theta}k)^3}{64v(\bar{\theta} + k)^2} \quad (7)$$

In the admissible range of $\{\alpha, \bar{\theta}\}$, it can be shown that consumer surplus, profits and welfare are monotonically increasing in both parameters. The positive effect of $\bar{\theta}$ on welfare comes as no surprise, while the effect of a change in α can be given the following interpretation. Profits increase with the weight of network externalities, because the positive effects of output expansion and quality reduction outweigh the negative effect due to the reduction of price. On the other hand, consumer surplus becomes larger as network externalities increase, because the beneficial effects of price reduction and output expansion more than offset the loss due to a lower product quality.

3.1.2. Full market coverage

Under full coverage, the analysis of network externalities can be quickly dealt with, in that fixing output equal to the size of the market (which is normalised to 1) entails that the generic consumer's utility function is rescaled upwards by the size of the network effect α. Without network effects, the optimal pricing policy for a monopolist consists in fully extracting the surplus of the poorest consumer. With network effects, the optimal price follows the same baseline, in that it rescales up by the full amount of the externality. Hence, the associated monopoly quality choice remains the same as without network externalities.

Profits write as $\Pi_M^{fmc} = p - vq^2$. Since profits are always increasing in price, the monopolist always chooses the highest price compatible with full market coverage, given by $\bar{p}(q) = (\bar{\theta} - 1)q + \alpha$. The monopolist chooses the quality which maximizes $\Pi_M^{fmc} = (\bar{\theta} - 1)q + \alpha - vq^2$. The first order condition w.r.t. q yields optimal quality $q_M^{fmc} = (\bar{\theta} - 1)/(2v)$. The price set by the monopolist is $p_M^{fmc} = \bar{p}(q_M) = (\bar{\theta} - 1)^2/(2v) + \alpha$. Therefore, we can state

LEMMA 2. *Optimal monopoly price under fmc is everywhere increasing in α.*

Monopoly profits are $\Pi_M^{fmc} = \alpha + (\bar{\theta} - 1)^2/(4v)$. Social welfare at equilibrium amounts to $SW_M^{fmc} = \alpha + \bar{\theta}(\bar{\theta} - 1)/(4v)$.

3.1.3. Partial vs full market coverage

The monopolist chooses to serve all the market if $\Pi_M^{fmc} > \Pi_M^{pmc}$, provided that both regimes are admissible. If instead $x_M^{pmc} \geq 1$, fmc obtains from the outset. Since x_M^{pmc} is increasing in $\bar{\theta}$, there exists necessarily a locus along which $x_M^{pmc} = 1$. Solving this, we obtain $\alpha = (3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)$. The following holds:

PROPOSITION 2. *The monopolist serves all consumers, obtaining profits $\Pi_M^{fmc} \geq \Pi_M^{pmc}$, in the following parameter regions:*

- $\bar{\theta} \in [1, 4/3]$ *and* $\alpha \geq (\sqrt{\bar{\theta}(4 + \bar{\theta})^3} - \bar{\theta}^2 - 6\bar{\theta} - 4)/(8v)$.

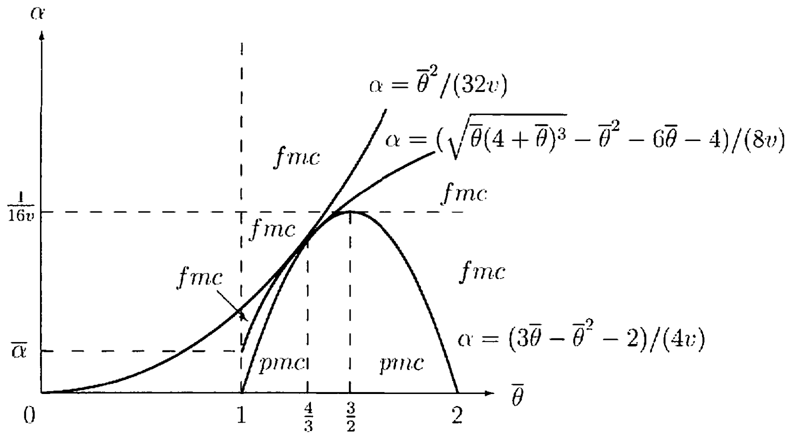

Figure 1. Full vs partial market coverage under monopoly.

- $\bar{\theta} > 4/3$ *and* $\alpha \geq \max\{0, (3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)\}$.

In the remainder of the space $\{\bar{\theta}, \alpha\}$, *pmc* obtains. Observe that the boundaries $(\sqrt{\bar{\theta}(4+\bar{\theta})^3} - \bar{\theta}^2 - 6\bar{\theta} - 4)/(8v)$ and $(3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)$ are both below $\bar{\theta}^2/(32v)$ for all $\bar{\theta}$. This entails that the condition for the reality of q_M^{pmc} is never binding. Proposition 2 has two corollaries:

COROLLARY 1. *For all* $\alpha \in [(5\sqrt{5} - 11)/(8v), 1/(16v)]$, *the monopoly output is non-monotone in* $\bar{\theta}$.

The proof follows immediately from the observation that the monopolist may be induced to serve all consumers even if the marginal willingness to pay for quality is relatively low, provided that the network effect is sufficiently large to compensate for a low valuation of quality.

The market coverage policy chosen by the monopolist in the space $\{\bar{\theta}, \alpha\}$ is described in figure 1, where the domain of $\bar{\theta}$ is to the right of the dashed line at $\bar{\theta} = 1$, and $\bar{\alpha} \equiv (5\sqrt{5} - 11)/(8v)$. For all $\alpha > (3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)$, the monopolist cannot rationally price any consumers out of the market, due to the fact that the externality enhances the reservation price enough to allow for full coverage.

The network effect on the optimal quality, price and output are described by the following:

COROLLARY 2. *For all* $\bar{\theta} \in [1, 4/3)$, *optimal monopoly quality, price and output are discontinuous in* α, *along* $\alpha = (\sqrt{\bar{\theta}(4+\bar{\theta})^3} - \bar{\theta}^2 - 6\bar{\theta} - 4)/(8v)$. *For all* $\bar{\theta} \in$ $[4/3, 2]$, *optimal monopoly quality, price and output are continuous in* α, *along* $\alpha = (3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)$. *Optimal quality is non-increasing in* α.

Proof. See Appendix A.3.

The behaviour of equilibrium quality is a consequence of the fact that the externality parameter is a substitute for the hedonic evaluation of quality. The substitutability between the demand size and the intrinsic quality disappears as soon as full coverage obtains. Under fmc, any further increase in α exerts no additional effects on optimal quality, which is then positively affected only by an increase in the marginal willingness to pay or a decrease in the cost parameter v.

3.2. *Welfare maximization*

A benevolent social planner maximizes social welfare with respect to price and quality. As is well known, with fixed costs of quality improvements, network externalities being absent, the planner would price at marginal cost, serving all consumers.[11] Consequently, any positive α can be expected not to affect the planner's output decision. Accordingly, we impose full market coverage ($x = \bar{\theta} - \hat{\theta} = 1$) from the outset. In such a case, social welfare is $SW = \alpha + q(\bar{\theta} - 1/2 - vq)$. Therefore, SW is maximised at $q_{SP} = (2\bar{\theta} - 1)/(4v)$. Social welfare in equilibrium is $SW_{SP} = [16\alpha v + (2\bar{\theta} - 1)^2]/(16v) = \alpha + vq_{SP}^2$, which is obviously larger than SW_M^{fmc}, the difference amounting to $1/(16v)$. In order to guarantee full market coverage, the price cannot be higher than $\bar{p}(q_{SP}) = (2\bar{\theta}^2 - 3\bar{\theta} + 1)/(4v) + \alpha$. Since social welfare does not depend on the price level, the social planner can choose any $p \in [0, \bar{p}\ (q_{SP})]$. The difference $\bar{p}(q_{SP}) - p$ simply implies a transfer in favour of consumers. Here, welfare maximization does not require marginal cost pricing, let alone subsidizing consumption. This is a somewhat counterintuitive result, since when a positive externality is involved, we would expect the planner to introduce a subsidy. However, this is not the case here because, given that any $p \in [0, \bar{p}\ (q_{SP})]$ yields full coverage, there is no need to incentivate consumption any further.

4. MONOPOLY VS SOCIAL PLANNING

We are now in a position to compare the choices of the social planner with those of the monopolist under both market coverage regimes, within the model investigated in the previous section. We can state the following:

PROPOSITION 3. *The optimal monopoly quality is always lower than the socially optimal quality. Moreover, the difference* $q_{SP} - q_M^{pmc}$ *is increasing in* α, *for all* α *such that the monopolist chooses partial market coverage.*

Proof. See Appendix A.4.

We can conclude that, also in the case of full market coverage, the monopolist supplies a quality which is lower than the planners', setting a price which can be lower than the price the social planner would choose: providing a higher quality, the social planner

[11] If instead quality hinges upon variable costs, there exists a range of parameters where the planner does not serve the whole market (see Lambertini and Orsini, 2001).

can set a price which is $(\bar{\theta}-1)/(4v)$ higher than p_M, being still able to satisfy the full market coverage condition.[12]

A completely different conclusion holds under variable costs of quality. In that case, both the monopolist and the planner may choose partial coverage. Quality decreases as the weight of the network effects increases in both regimes. However, under partial coverage, the monopoly quality decreases less than the socially optimal one, and oversupply emerges in monopoly (Lambertini and Orsini, 2001).

This difference can be interpreted on the following grounds. Irrespective of the features of technology, network effects drive the firm towards output expansion. However, *ceteris paribus*, combining an increase in output with a decrease in quality leaves unmodified the marginal production cost in the fixed cost case, while it decreases marginal cost when quality requires a variable cost. Accordingly, a reduction in quality is socially more desirable in the case of variable costs as it allows a decrease in price and a related output expansion.

Now focus upon the welfare distortion arising in the present model. The comparative evaluation of social welfare in the two regimes is summarised in the following proposition:

PROPOSITION 4. *Independently of the extent of market coverage, $SW_{SP} > SW_M$ for all admissible α and $\bar{\theta}$. However,*

- *When the monopolist serves all consumers, $SW_{SP} - SW_M^{fmc} = 1/(16v)$.*
- *When the monopolist covers the market only partially, then $SW_{SP} - SW_M^{pmc}$ is non-monotone both in α and in $\bar{\theta}$.*

Proof. The result that $SW_{SP} > SW_M$ for all admissible α and $\bar{\theta}$ is fairly intuitive, because, for any pair $\{\alpha, \bar{\theta}\}$, the social planner can at least replicate the monopolist's performance in terms of social welfare. Comparing SW_{SP} with SW_M^{pmc} over the parameter space $\alpha \in [0, 1/(16v)]$; $\bar{\theta} \in [1, 2]$, the surface $SW_{SP} - SW_M^{pmc}$ appears as in figure 2 (with $v = 1$), which conveys the following information: (i) for any admissible α, the difference $SW_{SP} - SW_M^{pmc}$ is non-monotone in $\bar{\theta}$; (ii) when α is close to zero, and $\bar{\theta}$ is close to one (in particular, $\bar{\theta} \in [1, 1.42)$), the difference $SW_{SP} - SW_M^{pmc}$ is increasing in α, while the opposite happens in any other region of the parameter space.

The non-monotonicity observed in both cases is to be traced back to the behaviour of social welfare under monopoly. To ascertain this, notice that SW_{SP} is linear w.r.t. either α or $\bar{\theta}$, while SW_M^{pmc} is convex w.r.t. the same parameters.

Examine first the non-monotonicity of the welfare distortion with respect to $\bar{\theta}$, for a given value of α. In this case, the behaviour of $SW_{SP} - SW_M^{pmc}$ reflects the non-monotone behaviour of the optimal monopoly quality which is increasing and convex in $\bar{\theta}$, (as it can be quickly ascertained from (5)), while the planner's quality is linear in $\bar{\theta}$. Now consider the effect of a variation in α on $SW_{SP} - SW_M^{pmc}$, for low levels of both

[12] Notice that, since p_M^{fmc} belongs to a subset of $[0, \bar{p}(q_{SP})]$, the planner could set $p_{SP} = p_M^{fmc}$. In such a case, the comparison between qualities would be carried out at the same price, as in the general case examined in proposition 1, yielding thus quality undersupply in the monopoly optimum.

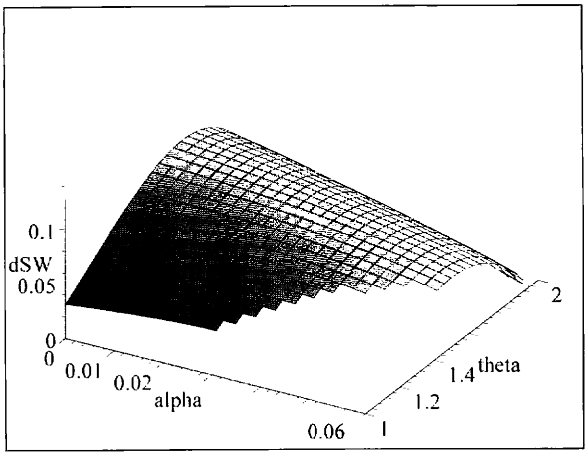

Figure 2. Welfare comparison, $dSW \equiv SW_{SP} - SW_M^{pmc}$ ($\alpha \in [0, 1/16]$; $\bar{\theta} \in [1, 2]$; $v = 1$).

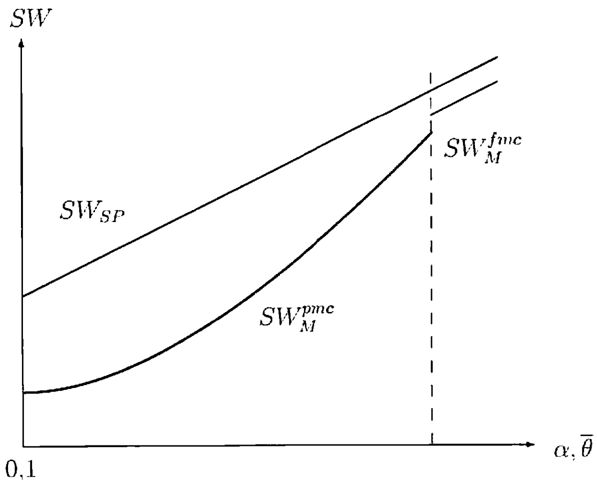

Figure 3. Comparative welfare assessment.

α and $\bar{\theta}$. This can be traced back to the behaviour of output w.r.t. α in the two regimes. The planners' output is constant, while the monopoly output is increasing and convex in α.

Suppose that α and $\bar{\theta}$ are alternatively fixed at an appropriate value. This allows us to plot the two social welfare levels in two dimensions, obtaining in both cases a picture like figure 3, which describes the situation where $\bar{\theta} \in [1, 4/3)$, i.e., the optimal monopoly quantity is discontinuous in $\{\alpha, \bar{\theta}\}$ in switching from partial to full market coverage. For all $\bar{\theta} \geq 4/3$, SW_M becomes continuous.

This picture obtains either (i) if we let $\bar{\theta}$ vary, given any α compatible with *pmc* under monopoly, or (ii) if we let α vary, provided that $\bar{\theta}$ is close to 1. ■

The above discussion has some interesting implications as to the scope for regulation when consumer preferences are characterised by network externalities. First, from figure 2 it clearly appears that (i) $SW_{SP} - SW_M^{pmc}$ is single-peaked in $\bar{\theta}$ for any given α ;[13] and (ii) excluding the region where the network externality and the marginal willingness to pay are both close to the lower bounds of their respective admissible intervals, any increase in α reduces the welfare loss imputed to the monopolist. The straightforward corollary to this result is that, as long as the monopolist does not serve all consumers, the argument for regulation becomes weaker as the extent of network externalities increases, except in the case of a relatively poor market with very low network effects.

This result may depend upon (i) the distribution of consumer tastes and (ii) the shape of technology. As to (i), very little can be said since, as is well known from the existing literature, vertical differentiation models become hardly manageable when one departs from the linear distribution hypothesis. Concerning (ii), we can figure out two alternatives to the cost function assumed here. First, suppose the technology involves a constant marginal cost and a fixed cost which can be either completely unrelated with quality or linear in quality. In both cases, it can be easily shown that the firm (irrespective of whether it maximises profits or social welfare) produces the maximum quality level which is technologically feasible. Since such a boundary is exogenous, this entails that network externalities have no bearings on quality supply. As they instead affect positively the output level, then in such settings the deadweight loss is everywhere decreasing in the extent of the externality. The second alternative consists in envisaging a variable cost increasing in quality and quantity (Lambertini and Orsini, 2001). In such a case, the planner does not necessarily serve all consumers, and the deadweight loss is monotonically increasing in the level of the externality, as long as partial coverage prevails in both monopoly and social planning and the monopolist oversupplies quality.

5. DISCUSSION AND CONCLUDING REMARKS

According to the current antitrust legislation, both in Europe and in the US, the case for the intervention of the legal authorities arises whenever competition is threatened, regardless of any welfare considerations. The foregoing analysis sheds some new light on the amount of welfare loss and the resulting need for public intervention in a monopoly market for a product whose network externalities are a relevant component of consumer's utility. A discussion on these issues is currently taking place regarding the market for mobile telephones (in Europe) and the software industry (in the US).[14]

[13] With a global maximum at $\{\bar{\theta} = 1.675, \alpha = 0\}$.

[14] For an exhaustive account of the related debate, see the web page http://www.stern.nyu.edu/networks/site.html, by Nicholas Economides.

In the light of the foregoing analysis, the existence of network externalities may entail that monopoly is not so evil as one usually thinks. In markets for information goods, where the cost of quality improvement hinges upon development activities but does not affect variable costs, the presence of network externalities enhances the incentive towards output expansion associated with decreasing average cost. On the other hand, the quality distortion operated by the monopolist increases as the weight of network externalities increases. However, on the aggregate, the output expansion effect dominates the quality distortion, yielding as a result that the welfare loss due to monopoly power shrinks as the role of network externalities in determining consumers' satisfaction becomes more relevant. Since the demand function becomes more elastic as the network effect increases, the output expansion benefits both the firm and the consumers, while the quality reduction hurts consumers but reduces the costs borne by the firm.

Of course our results do not imply that monopoly performs better than competition (see Economides and Himmelberg, 1995); intuition suggests that promoting competition is *a priori* desirable if access rules are designed so as to ensure that the resulting network effects are not brand-specific.[15]

Under the assumption of uniform consumer distribution, the model reveals that quality is always undersupplied at the monopoly optimum. One possible policy towards the underprovision of quality consists in using a minimum quality standard (see Besanko, Donnenfeld and White, 1987, *inter alia*). However, a minimum quality standard in a growing sector is potentially counterproductive, since it may reduce the incentive to innovate (Maxwell, 1998).

Another *caveat* is that, in our model, the output expansion effect jointly exerted by scale economies and network externalities clearly goes in the direction of a welfare increase, but it must be taken into account that a different preference structure might alter the results significantly. In particular, preference for variety may play a decisive role (Church and Gandal, 1992). Finally, goods characterised by network externalities may be durables, and there arises a need for modelling the intertemporal choices of producers and consumers (Cabral, Salant and Woroch, 1998; Fudenberg and Tirole, 1998). For these reasons, future research should produce a deeper understanding of these phenomena in order to design appropriate policy interventions in industries where network externalities are a relevant feature.

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[15] This is the case, e.g., in the telecom industry. Provided regulation ensures that traffic flows across networks with the same efficiency as within any individual network, consumers may enjoy the predictable reduction in prices without suffering from network segmentation.

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APPENDIX

A.1. *Proof of Proposition 1*

Consider first the monopoly optimum under partial market coverage, i.e., when $\max\{\bar{\theta}-1,\hat{\theta}\}=\hat{\theta}\equiv\{\theta:\theta q+\alpha\int_{\theta}^{\bar{\theta}}f(z)dz-p=0\}$. The relevant first order condition is:

$$\frac{\partial \Pi_M}{\partial q}=-p\cdot f(\hat{\theta})\cdot\hat{\theta}_q'+p_q'\cdot\int_{\hat{\theta}}^{\bar{\theta}}f(\theta)d\theta-C'=0\,, \qquad \text{(a1)}$$

where $\hat{\theta}_q'=\partial\hat{\theta}(\alpha,p,q,f(\theta))/\partial q$ and $p_q'=\partial p(\alpha,p,q,f(\theta))/\partial q$. As quality increases, the location of the marginal consumer shifts in a way determined by $\hat{\theta}_q'=(p_q'x-C')/pf(\hat{\theta})$, where sign $\{\hat{\theta}_q'\}=\text{sign}\{p_q'x-C'\}$. In particular, $p_q'x-C'<0$ since

$$\frac{\partial \Pi_M}{\partial q}=0\Leftrightarrow p_q'x+x_q'p=C' \qquad \text{(a2)}$$

where $x_q'>0$ for any given price. Therefore, $\hat{\theta}_q'<0$.

Since in the monopoly optimum, $\partial\Pi_M/\partial q=0$, differentiating social welfare w.r.t. quality yields:

$$\frac{\partial SW}{\partial q}=\frac{\partial CS}{\partial q}=\int_{\hat{\theta}}^{\bar{\theta}}(\theta-\alpha\cdot f(\hat{\theta})\cdot\hat{\theta}_q'-p_q')f(\theta)d\theta \qquad \text{(a3)}$$
$$-[\hat{\theta}q-p+\alpha x]\cdot f(\hat{\theta})\cdot\hat{\theta}_q'\,,$$

which can be rearranged as:

$$\frac{\partial CS}{\partial q}=\int_{\hat{\theta}}^{\bar{\theta}}(\theta-p_q')f(\theta)d\theta-(\hat{\theta}q-p)\cdot f(\hat{\theta})\cdot\hat{\theta}_q'-2\alpha x\cdot f(\hat{\theta})\cdot\hat{\theta}_q'\,. \qquad \text{(a4)}$$

The presence of the third term on the r.h.s. of the above equation suffices to prevent us from determining the sign of (a4) on the basis of the comparison between marginal and average willingness to pay for quality. This concludes the proof. ■

A.2. *Proof of Lemma 1*

Taking the derivative of (5) and simplifying, we get

$$\text{sign}\left(\frac{\partial q_M^{pmc}}{\partial\alpha}\right)=\text{sign}(k-\bar{\theta})=\text{sign}(-32\alpha v) \qquad \text{(a5)}$$

which is negative for all $\alpha\in[0,\bar{\theta}^2/(32v)]$. To prove that p_M^{pmc} is also everywhere decreasing in α, it suffices to observe that $p_M^{pmc}=\bar{\theta}q_M^{pmc}/2$. The derivative of output w.r.t. α is $\partial x_M^{pmc}/\partial\alpha=4v/k>0$, with $\partial^2x_M^{pmc}/\partial\alpha^2=64v^2/k^3>0$. ■

A.3. *Proof of Corollary 2*

Consider the first statement in corollary 2. Observe that, for $\bar{\theta}\in[1,4/3)$, $x_M^{pmc}<1$ along $\alpha=(\sqrt{\bar{\theta}(4+\bar{\theta})^3}-\bar{\theta}^2-6\bar{\theta}-4)/(8v)$. This goes along with an analogous discontinuity in quality and price. To prove the second statement in corollary

2, it suffices to check that $x_M^{pmc} = 1$, $p_M^{pmc} = p_M^{fmc}$ and $q_M^{pmc} = q_M^{fmc}$ along $\alpha = (3\bar{\theta} - \bar{\theta}^2 - 2)/(4v)$, which is the relevant boundary between pmc and fmc for all $\bar{\theta} \in [4/3, 2]$. To prove the third statement, consider first q_M^{fmc}. This is increasing in $\bar{\theta}$ and invariant in α. As to q_M^{pmc}, we know from lemma 1 that $\partial q_M^{pmc}/\partial\alpha \leq 0$ for all $\alpha \in [0, \bar{\theta}^2/(32v)]$. ■

A.4. Proof of Proposition 3

Consider first the case where the monopolist covers the market entirely. We have that $q_{SP} - q_M^{fmc} = 1/(4v)$, i.e., the difference between the two quality levels is positive and independent of both α and $\bar{\theta}$. Second, in the case where the monopolist covers the market only partially, observe that, if $\alpha = 0$, $q_M^{pmc} = q_M^* < q_{SP}$ for all $\bar{\theta} \in [1, 2]$. Then, from lemma 1, we know that $\partial q_M^{pmc}/\partial\alpha < 0$ in the admissible range for α and $\bar{\theta}$. This suffices to prove the proposition. ■