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Quality provision under conditions of oligopoly

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Abstract: We analyse an oligopoly where sunk costs depend on the quality choice. Quality and output are underprovided as compared to the socially optimal solution. Entry will bring output closer to its socially optimal level, but quality will be further reduced. It is well known that quality-related sunk costs limit the number of firms that can break even, so increased competition is feasible only if costs increase sharply with quality, or if consumer welfare is relatively insensitive to quality. Public provision might provide higher welfare even in presence of a cost disadvantage if competition is not feasible.

Key words: product quality, oligopoly, public and private provision, competition.
JEL-classification: L33, D21, D43, H42

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1. Introduction

This contribution analyses the distortion that arise on an oligopolistic market where firms have to decide about both output and quality when consumers are fully informed and where quality affects sunk costs. As shown by Sutton (1991), there is an upper limit to the number of firms in such a market, so perfect competition will not be an alternative. This upper limit is stringent in particular if it is relatively cheap to invest in real or perceived quality.

It is well known that firms have an incentive to underprovide quality if consumers are not fully informed (see, for example, Belleflamme and Peitz, 2010). However, there may be a quality distortion under full information as well. A profit maximising monopolist may over- or underprovide quality, depending on the sign of the cross-derivatives of the objective function and on whether inverse demand becomes more or less steep by a quality increase (Sheshinski, 1976, Spence, 1975). Moreover, a monopoly may provide a subobtimal product mix if consumers are heterogeneous (White, 1977).

There is a literature on quality in markets with differentiated goods. White (1977) suggests that increased competition would improve the product mix, and that a competitive market would even provide the optimal combination. However, it was subsequently shown that the spectrum of qualities that firms offer (in order to segment the market) can become narrower as new firms enter (Gal-Or, 1983). Moreover, firms can under- or overprovide quality in models based on Hotelling- or Salop-type spatial analogies, as in Ma and Burgess (1993), where firms underprovide quality in setting with heterogeneous consumers, duopoly and linear demand. A spatial duopoly is associated with an inefficient allocation in Wolinsky (1997) as well. A regulated monopoly then provides superior quality, but the comparison between a regulated monopoly and managed competition is ambiguous when it comes to welfare. A Hotelling-style duopoly will underprovide congestion-reducing investments in Matsumura and Matsushima (2007). While these contributions tend to favour regulation, Brekke et al (2006) suggest, also in a Hotelling-duopoly model, that regulation can cause firms to overprovide quality. Brekke et al (2011) consider an *n*-firm spatial oligopoly where providers are partly altruistic, suggesting that increased competition under regulation then has an ambiguous effect on quality.

However, less is known about quality in markets that generate a uniform standard even if firms have an ex ante choice do deviate. What would a basic oligopoly model predict if goods are potentially differentiated ex ante but homogeneous ex post, as might be expected if all production functions are the same and if the differences among consumers are negligible? Would there be a quality distortion under oligopoly, and can it be alleviated by entry? To fill this gap in the literature, we apply a generalised version of Sutton's model of sunk costs related to real or perceived quality (Sutton, 1991). We argue that the approach can also be interpreted as a model of how oligopolistic competition deviates from the social optimum. The model was developed for explaining the maximum number of firms that can break even on a market, it then also highlights limits to entry. However, given that entry is often sluggish (see, for example Geroski, 1995), we also ask how entry within the limits implied by the model affects output, quality and welfare.

Given the aim to explain the causes of a given market structure rather than its performance in Sutton (1991), predictions derived from the original version of the model might on the other hand appear as unduly strong. Output would always be underprovided, overpriced and of sub-standard quality, unless the costs of achieving higher quality are prohibitively high. Overpricing can be reduced by entry, but a fragmented market structure is possible only when it is expensive to achieve high quality, so the quality distortion would remain. Unlike in Sutton (1991), we therefore assume that the quality of a good can have either a stronger or a weaker impact on consumer utility than its quantity. Market provision can then work reasonably well also when sunk costs do not increase steeply with quality, provided that consumers are more concerned about quantity than quality.

The performance of an oligopoly with few or many firms as compared to the socially optimal allocation is important also when deciding on how an industry should be organised. When is for example a combination of privatisation and liberalisation superior to a public monopoly (which at least has the option of aiming for the optimal solution), and vice versa?[1] There is a growing empirical literature on such oligopolies that have replaced public monopolies. For example, while consumer prices are often lower after electricity restructuring, the reliability of the system may have been reduced (see Lieb-Dóczy, Börner and MacKerron, 2003, Brunekreeft and Keller, 2000, Moss, 2004, and Jiang amd Yu, 2004.) Railway liberalisation has also been criticised for underinvestments in infrastructure and reduced safety (Crompton and Jupe, 2003, and Newbery, 2006).[2] These pieces of evidence

[1] Some industry studies have attempted to distinguish between industries that are suitable and unsuitable for privatisation. For example, Kwoka (2005) argues that there may exist a private-sector advantages in the generation of electric power, but not in its distribution, while Hart *et al.* (1997) doubt the merits of privatising prison services, but not necessarily garbage collection or defense procurement.

[2] Problems among the railways may be related to the natural monopoly infrastructure rather than to downstream competition. We have analysed vertical separation elsewhere (see Willner and Grönblom, 2013), but not with quality and reliability in mind.

suggest that restructuring an industry can affect its quality provision. These mechanisms have to be analysed, and not only with a focus on industries with an upstream natural monopoly infrastructure.

We do not deal with quality standards by regulation or with other restrictions, because we have in mind an industry that is seemingly an obvious candidate for privatisation and liberalisation rather than regulation. In evaluating an oligopoly (that can under some conditions approach perfect competition) with the socially optimal solution as a benchmark, we assume like Sutton (1991) that the quality of a good affects consumer utility. Higher quality can cause consumption to be higher than otherwise, insofar as consuming a unit yields higher pleasure than before. Such a market is analysed in the companion paper Willner (2015). But demand may also decrease because of higher quality, as when more durable light-bulbs need less frequent replacements. Sutton’s model represents an intermediate case, where the quantity demanded is neither higher nor lower after a quality increase (despite higher utility), unless other firms provide products of different quality. For example, a moderate quality change would hardly cause consumers to change their use of for example health-care, energy, or transport services at least in the short run.

Most versions of our model suggest that an oligopoly will underprovide both output and quality. When directly applied on privatisation and liberalisation, the analysis seems to yield the strong policy conclusion that the public monopoly is superior if marginal costs are the same in both cases. However, our generalisation of Sutton’s model implies that the upper limit to the number of firms is extended if the quality of a good has a lower impact on consumer utility than its quantity. Firms would then invest less in quality than otherwise, so the sunk costs would be lower, thus enabling more firms to enter. The distortions caused by profit maximising behaviour would then be fairly limited, so market provision would be superior if it is also associated with a moderate cost advantage. We derive threshold values for the cost reductions that are necessary for this to be the case.[3]

We proceed as follows. The basic components of a model where quality matters are presented in section 2. Section 3 defines the socially optimal solution, and section 4 focuses on oligopolistic competition. Section 5 evaluates the oligopoly as compared to the optimal solution. Section 6 extends the analysis to an interpretation in terms of privatisation and

[3] To analyse how a reorganisation affects marginal costs is outside our scope in the present contribution, but we have addressed endogenous differences related to ownership and competition elsewhere (see Willner and Parker, 2007, Willner and Grönblom, 2013 and Grönblom and Willner, 2014).

liberalisation, with a possibility of differences in productive efficiency, to simultaneous maximisation, and to cases where quality is reflected in marginal rather than sunk costs. Section 7 presents some concluding remarks. Proofs are included in an appendix.

2. The model

Consider a private or public monopoly or an *n*-firm Cournot oligopoly, where a firm has to invest in product quality before deciding about industry output. Like in Sutton (1991), we assume that the quality (q) of a commodity (y) is dependent on outlays in the form of a sunk cost S, which can be written

$$S = q^{\beta}. \tag{1}$$

The parameter β then stands for the elasticity of the sunk costs with respect to quality, or shortly, *sunk cost elasticity*. Other sunk costs are ignored. We may for example think of quality as dependent on the amount of staff with long-term contracts, as when it comes to infrastructure maintenance, when short queuing time is an essential quality dimension, or when quality depends on R&D outlays. Sutton's model was developed so as to analyse branding, i.e. outlays for creating an image of quality, but the analysis can be applied on real and not only perceived quality as well (see, for example, the application of Berry and Waldfogel, 2010).

The average variable costs and marginal costs are c. Quality may also be reflected in the quality of inputs so that c becomes a function of q. Such an extension is addressed in Section 6.1. There are N identical consumers with the income m, which is normalised to unity.[4] Each individual h has the utility function

$$u(y_h, q_h, y_0) = y_h^{\alpha_1} q^{\alpha_2} y_0^{\alpha_0}, \tag{2}$$

where y_0 stands for a basket of other goods with a given price p_0. The exponents α_1, α_2, and α_0 express the sensitivity (in the form of elasticity) of utility with respect to changes in

[4] Sutton (1991) sets p_0=1. However, as we are interested in the level of quality, we need expressions that are indepentent of scale when it comes to the price level. Setting m=1 provides the simplest way to ensure that this is the case.

consumption of y, its quality and the consumption of the basket of other goods. It will be useful to denote α_2/α_1 by ρ. Utility may be either more or less sensitive to the quality than to the quantity of y (ρ>1 or ρ< 1), or equally sensitive so that α_1=α_2 like in Sutton (1991).[5]

Apart from the fact that α_1 matters for the size of the industry revenues ($R = \alpha_1 N$), the parameters of the utility function matter in our analysis only through ρ. For example, it will become obvious in the next section that we might as well transform (2) to $q^\rho y$ when deriving the socially optimal solution given y_0. In what fallows we shall therefore for brevity refer to ρ as the *quality elasticity.*

We focus on the intermediate case where higher quality will neither increase nor reduce the demand for a homogeneous good, but where the williness to pay for a firm's product is higher if it supplies a higher quality than its competitors. The market is thus characterised by potential vertical product differentiation, in the sense that expensive high-quality and cheap low-quality firms can coexist. Denote the price of y by p if it is the same in all firms, and otherwise p_i or p_j. The following Lemma will be useful for deriving the oligopolistic equilibrium:

Lemma 1. The ratio $q_i^\rho/p_i = q_j^\rho/p_j$ *is the same for all i and j.*

Proof: See Appendix.

With ρ=1 like in Sutton (1991), this means that the price/quality ratio must be the same for all firms. There is no equilibrium after privatisation unless at least two firms can break even, and it will turn out that this requires $\beta/\rho \geq 1$. However, in order to assess the impact of increased competition we have to ensure that at least three firms can break even, which requires $\beta/\rho \geq 8/3$.

3. The socially optimal solution

There is no equilibrium under profit maximisation unless $n \geq 2$, because a monopolist would always get R. The most profitable action would then be to produce as little as possible. However, the situation is different under welfare maximisation. This section analyses the welfare maximising solution, which will work as a standard of comparison. It can also be

[5] However, we may without loss of generality assume that α_0=1−α_1−α_2.

interpreted as associated with a welfare maximising public monopoly in which marginal costs can either equal or differ from the marginal costs within an oligopoly with profit maximising firms.

We assume two-stage maximisation except for when it comes to some extensions in section 6. The socially optimal solution is however the same also under simultaneous maximisation. Suppose that a public monopolist maximises the welfare of a typical consumer under a break-even constraint. Let λ denote the Lagrange multiplier. The socially optimal solution is obtained by first maximising

$$\underset{y}{\mathrm{Max}}\,\Omega = (y/N)^{\alpha_1} q^{\alpha_2} y_0^{\alpha_0} + \lambda(R - cy - q^{\beta}) \tag{3}$$

given the value of q. Note however that we would get the same result by replacing the objective function by $q^{\rho}y$. Solving for y from the constraint yields

$$y^G(q) = \frac{R - q^{\beta}}{c}, \tag{4}$$

and hence the following utility level for the typical consumer:

$$u = \frac{(R - q^{\beta})^{\alpha_1} (q^{\alpha_2}) y_0^{\alpha_0}}{cN^{\alpha_1}}. \tag{5}$$

It will be useful to abbreviate β/ρ as ε. Maximising this utility with respect to q then yields

$$q^G = \left(\frac{\rho R}{\rho + \beta}\right)^{1/\beta} = \left(\frac{R}{1 + \varepsilon}\right)^{1/\beta}, \tag{6}$$

which means that output is:

$$y^G = \frac{\beta R}{(\rho + \beta)c} = \frac{\varepsilon R}{(1 + \varepsilon)c}. \tag{7}$$

It follows that the price is $(1+1/\varepsilon)c$.

Lemma 2, where e stands for Euler's number, summarises a couple of observations that will be useful when comparing the n-firm Cournot-oligpoly to the socially optimal solution:

Lemma 2. Welfare maximisation under a break-even constraint means that a) output and quality are increasing in the size of the market (R); and b) output is decreasing in the sunk-cost elasticity (β*) and decreasing in the quality elasticity (*ρ*); c) quality is increasing in* ρ*, and decreasing in* β *except for when* $\beta > \hat{\beta} \approx (Re - 2)\rho$.

Proof: See appendix.

The fact that output is increasing in R is trivial; quality is also increasing in R because of the break-even constraint, which implies that a larger R makes it easier for society to afford a higher quality. The impact of ρ is also obvious, but the impact of β on quality is not straightforward. Output is increasing in β, because quality is expensive if β is high, in which case a higher output is a substitute for higher quality. It might be reasonable to guess that quality is decreasing in β, Lemma 2 implies that quality has a minimum for $\beta = \hat{\beta}$.

This minimum is however associated with very large values of $\hat{\beta}$ if the market is reasonably large. For example, R=100 and ρ=1 yields a minimum for $\beta = \beta \approx 269.828.$, so q^G would be increasing in β for higher values. As follows from section 5, this value of β would enable 136 firms to break even. The technical conditions would then favour (almost) perfect competition, where quality is not an issue because of the expensiveness of a quality increase. We would rarely observe public monopolies under such circumstances, so very high values of β are outside our focus on oligopoly with a benevolent public monopoly as a benchmark. Moreover, q^G approaches unity as β approaches infinity, but numerical simulations suggest that q^G approaches unity long before β approaches $\hat{\beta}$. The U-shape of q^G as a function of β is therefore hardly visible.

4. The *n*-firm Cournot oligopoly

The products are now potentially differentiated ex ante. Make use of Lemma 1, and consider with no loss of generality firm number one. It then follows that $p_j = p_1(q_j/q_1)^\rho$ for all j=2,3,...n. The sales revenues in the industry must therefore be:

$$R = y_1 p_1 + p_1 \sum_{j=2}^{n} y_j \left(\frac{q_j}{q_1} \right)^\rho . \tag{8}$$

It follows that the inverse demand for firm 1 is

$$p_1 = \frac{R}{y_1 + \sum_{j=2}^{n} y_j (q_j/q_1)^{\rho}}, \tag{9}$$

so its profits are

$$\pi_1 = \frac{R}{y_1 + \sum_{j=2}^{n} y_j (q_j/q_1)^{\rho}} y_1 - c y_1 - q_1^{\beta}. \tag{10}$$

Maximise with respect to y_1:

$$\frac{R}{y_1 + \sum_{j=2}^{n} y_j (q_j/q_1)^{\rho}} - \frac{R}{[y_1 + \sum_{j=2}^{n} y_j (q_j/q_1)^{\rho}]^2} y_1 - c = 0. \tag{11}$$

Next, consider the profit function of another firm j:

$$\pi_j = \frac{R}{y_j + \sum_{i \neq j} y_i (q_i/q_j)^{\rho}} y_j - c y_j - q_j^{\beta}. \tag{12}$$

Its first-order condition becomes:

$$\frac{R}{y_j + \sum_{i \neq j} y_i (q_i/q_j)^{\rho}} - \frac{R}{[y_j + \sum_{i \neq j} y_i (q_i/q_j)^{\rho}]^2} y_j - c = 0. \tag{13}$$

Divide all terms in (13) by $(q_j/q_1)^{\rho}$ and multiply and divide in addition the term in the middle by the same expression:

$$\frac{R}{y_j (q_j/q_1)^{\rho} + \sum_{i \neq j} y_i (q_i/q_1)^{\rho}} - \frac{R}{[y_j (q_j/q_1)^{\rho} + \sum_{i \neq j} y_i (q_i/q_1)^{\rho}]^2} y_j (q_j/q_1)^{\rho} - c\,(q_1/q_j)^{\rho} = 0. \tag{14}$$

Note that one of the terms in the sum in $\sum_{i \neq j} y_i(q_i/q_1)^{\rho}$ must equal y_1, so the denominators of (14) are in fact the same as in (11). Add (11) to the sum of the n–1 expressions represented by (14):

$$\frac{(n-1)R}{y_1 + \sum_{j=2}^{n} y_j(q_j/q_1)^{\rho}} - c\left(1 + q_1^{\rho} \sum_{j=2}^{n} q_j^{-\rho}\right) = 0. \tag{15}$$

This implies:

$$y_1 + \sum_{j=2}^{n} y_j(q_j/q_1)^{\rho} = \frac{(n-1)R}{c(1 + q_1^{\rho} \sum_{n}^{j=2} q_j^{-\rho})}. \tag{16}$$

Combine (16) and (11) to get y_1 as a function of the quality levels:

$$y_1 = \frac{R(n-1)(2 - n + q_1^{\rho} \sum_{n}^{j=2} q_j^{-\rho})}{c(1 + q_1^{\rho} \sum_{n}^{j=2} q_j^{-\rho})^2}. \tag{17}$$

Insert (16) and (17) into (10) to get the maximum profits as a function of q_1 and rearrange:

$$\pi_1(q_1) = \frac{R(2 - n + q_1^{\rho} \sum_{n}^{j=2} q_j^{-\rho})^2}{(1 + q_1^{\rho} \sum_{n}^{j=2} q_j^{-\rho})^2} - q_1^{\beta}. \tag{18}$$

Maximise with respect to q_1, impose ex post symmetry and solve for $q_1, q_2, ... q_n = q$:

$$q(n) = \left[\frac{2\rho R(n-1)^2}{\beta n^3}\right]^{1/\beta} = \left[\frac{2R(n-1)^2}{\varepsilon n^3}\right]^{1/\beta}. \tag{19}$$

Differentiating with respect to β when ρ=1 shows that the quality level has a minimum for $\beta = 2R(n-1)^2 e\rho/n^3$. Like in the case of the socially optimal solution, quality may be increasing in β for sufficiently high values.

As for market output, symmetry in output and quality means that $y = ny_1$ when $q=q_1=q_2=...q_n$. As follows from (17), we get the same expression as in a basic Cournot-oligopoly where quality is not an issue.:

$$y(n) = \frac{R(n-1)}{cn}. \tag{20}$$

5. The performance of the *n*-firm oligopoly

We first compare output and quality under oligopoly with the socially optimal solution. It is well-known that a commercial oligopoly where quality is not an issue underprovides output as compared to the socially optimal allocation, but (7) implies that the socially optimal output now depends on both β and ρ. Like in Sutton (1991), there is an upper limit for the number of firms, and this limit depends in our version on the quality elasticity as well, and not only on β:

Lemma 3. a) The feasible range of oligopolistic market structures is represented by numbers of firms such that

$$\hat{n} = 1 + \frac{\varepsilon}{4} + \sqrt{\frac{\varepsilon^2}{16} + \frac{\varepsilon}{2}} \geq n \geq 2. \tag{21}$$

b) The upper limit is increasing in the sunk-cost elasticity but decreasing in the quality elasticity.

Proof: See appendix.

This lemma is a generalisation of Sutton (1991), where high costs of branding (perceived quality) favour fragmentation and vice versa, as follows from ρ = 1, so that ε=β. However, a market can become more fragmented than in Sutton's model if β>ρ. The opposite situation cannot hold true, because a duopoly is not feasible unless β/ρ < 1, and it is not meaningful to analyse entry unless β/ρ ≥ 2.6667, or ρ ≤ 0.375β. Note also that $\hat{n}$ would be smaller in the presence of other sunk costs as well.

We might expect that allowing for ρ ≠ 1 would imply a quality and/or output distortion that can go either way, for example because of the potential extension of the feasible interval of *n*. A superficial comparison of (6) and (19) and (7) and (20) might indeed suggest an ambiguous comparison with the socially optimal solution. However, it turns out that the impact is ambiguous only outside the feasible interval, and that the quantitative significance of quality distortion depends on ρ:

Proposition 1. The n-firm oligopoly underprovides both output and quality relative to what is socially optimal.

Proof: See appendix.

Proposition 1 holds true for any n in the feasible interval, and hence also if we assume a free-entry equilibrium where $n = \hat{n}$.

However, given the stylised fact that enterprise formation is often sluggish (see Geroski, 1995), we also ask how an exogeneous change in n in the feasible interval affects the allocation.[6] Output is the same as in a conventional Cournot oligopoly, and hence increasing in n, but the impact of entry on quality and welfare needs elaboration:

Proposition 2. The following holds true for the n-firm oligopoly: a) Quality is increasing in R and increases when n increases from 2 *to* 3*, but decreases thereafter; b) consumer welfare is increasing in n and R in the feasible interval.*

Proof: See appendix.

Thus, according to part a), apart from when a third firm enters in a duopoly, increased competition will not alleviate market failures related to low quality. The intuition is based on the fact that a change in uniform quality works in the same way as a monotone transformation of the utility function. So while utility changes, there is no change in the ranking of baskets of y and y_0. Inverse demand collapses to $p = R/y$ in a symmetric equilibrium, so a quality increase is not translated into a higher willingness to pay. Producers are rewarded not for quality as such, but for providing better goods or services than their competitors, so the incentives for quality provision are insufficient. Moreover, these incentives are further weakened if more competitors enter, because the quality-related costs become more difficult to afford.

The fact that the highest quality occurs when n=3 implies a lower bound r_q^T for the percentage loss of quality:

[6] Note that n/N has to be a negligible, so that we may assume that consumers are identical.

$$r_q^T = 100\left\{1-\left[\frac{0.2962(1+\varepsilon)}{\varepsilon}\right]^{1/\beta}\right\}. \quad (22)$$

This lower bound is decreasing in both ρ and β. For example, setting ρ=1 means that values of β of 3 and 100 would imply 26.62% and 1.20% respectively. If ρ=2, the corresponding percentages are 20.97% and 29.83%, but they become 1.19% and 1.20% respectively when ρ is 0.5.

According to part b), entry would be beneficial for all values of *n* for which production is profitable. Note however that the total surplus, which is the most common welfare criterion, would suggest a lower optimal number of firms, because industry profits (*R*/*n*) are decreasing in *n*. As for the impact of the market size, it gives firms a stronger incentive to provide high quality within a given market structure.

Privatisation and liberalisation often take place because of an ambition to cut costs. We have addressed endogenous differences in genuine cost efficiency elsewhere (for example in Grönblom and Willner, 2014), but we assume equal marginal costs except for in section 6.1. In this setting, the public monopoly yields lower unit costs as well:

Corollary 1. Unit costs are the same as in the socially optimal solution in a duopoly, but otherwise higher and increasing in the number of firms.

Proof: Se appendix.

This result may seem surprising, because of the underprovision of quality under oligopoly. But entry decreases the output per firm, so the costs of the lower quality per unit of output nevertheless increase.

6. Extensions

6.1. Privatisation, liberalisation and exogeneous differences in marginal costs

Privatisation of a former welfare maximising monopoly is often believed to increase both cost efficiency and profit margins, thus making the sign of the welfare change ambiguous, unless the profit margins are also reduced through competition.[7] The common view that a public monopoly is inevitably cost inefficient is prejudiced (see the discussion in section 7). However, it will be useful to analyse the threshold cost reduction that is necessary for privatisation and liberalisation to be beneficial (or alternatively, the highest cost disadvantage that is consistent with a public monopoly being preferable). This threshold is an important indicator when deciding on how an industry should be organised.

The combination of privatisation and liberalisation is here taken to mean replacing the welfare maximising public monopoly with an *n*-firm Cournot oligopoly like in sections 4-5. Suppose that privatisation and liberalisation reduce marginal costs from c_G to c_P, because the welfare ranking would otherwise be trivial. Denote the percentage change $100(c_G - c_P)/c_G$ by μ. It is obvious from (6) and (19) that quality is not affected by marginal costs, so quality would always be lower after privatisation and liberalisation despite lower marginal costs. However, it follows from (7) and (20) that privatisation and liberalisation would reduce the price (increase output) if the percentage cost reduction is larger than a critical value μ_1^T. Consider first this critical value as a function of the number of firms within the interval [2, $\hat{n}$]:

$$\mu > \mu_1^T = 100\frac{1+\varepsilon-n}{n\varepsilon}. \tag{23}$$

It follows that this expression is the same as the relative output distortion, $1-y(n)/y_G$. The intuition is based on the fact that output is inversely proportional to marginal costs.

As for consumer welfare, there is an improvement if and only if $q^\rho y$ increases when the market becomes an *n*-firm oligopoly (see the proof of Proposition 2). Use (6), (7), (19), and (20) to formulate this condition as

$$\frac{2^{1/\varepsilon}(n-1)^{(2+\varepsilon)/\varepsilon}R^{(\varepsilon+1)/\varepsilon}}{\varepsilon^{1/\varepsilon}n^{(3+\varepsilon)/\varepsilon}c_P} > \frac{R^{(\varepsilon+1)/\varepsilon}\varepsilon}{(1+\varepsilon)^{(\varepsilon+1)/\varepsilon}c_G}, \tag{24}$$

[7] To reduce costs has been one of the main arguments for privatisation among economists (see, for example, Megginson and Netter, 2001, and Pirie, 1988). Efficiency is also mentioned in Mrs. Thatcher’s memoirs, together with an ideological remark that "[t]he state should not be in business" (Thatcher, 1993, pp. 676-677). But governments have often in practice divested assets because of a need to raise funds (see Parker, 2009).

which implies that μ must exceed another critical value μ_2^T:

$$\mu^T > \mu_2 = 100\left[1 - \frac{2^{1/\varepsilon}(n-1)^{(2+\varepsilon)/\varepsilon}[(\varepsilon+1)/\varepsilon]^{(\varepsilon+1)/\varepsilon}}{n^{(\varepsilon+3)/\varepsilon}}\right]. \tag{25}$$

It can be shown that $\mu_2^T > \mu_1^T$:

Corollary 2: A larger percentage cost increase is necessary for privatisation and liberalisation to outperform the public monopoly when it comes to consumer welfare rather than price or output.

Proof: See appendix.

This corollary means that we may observe higher unit costs and a lower output in the public monopoly, but consumer welfare may nevertheless be higher. The intuition is based on the fact that the negative effects of a cost disadvantage in the public monopoly is alleviated by higher quality.

However, me may also assume free entry until $n=\hat{n}$. The threshold values then become a function of ε, because a larger value of ε means that a greater number of firms can break even. Inserting $\hat{n}$ into (23) and (25) yields complicated mathematical expressions, but the relationship between the necessary percentage cost change and ε can be illustrated graphically. The curve μ_2^S in Figure 1 refers to the case of simultaneous maximisation (see section 6.2).

Suppose first that an increase in ε is caused by an increase in β. The intuition for the downwards-sloping lines μ_2^T and μ_2^S is based on the fact that a high β makes quality expensive, also when it comes to the socially optimal allocation, so q approaches unity in both cases. As for the case when a high value of ε is caused by a low ρ, the intuition is based on the fact that consumer utility is not sensitive in quality. The welfare convergence is then caused by the fact that the higher fragmentation caused by a higher ε leads to a higher output, as also reflected in the curve μ_1^T.

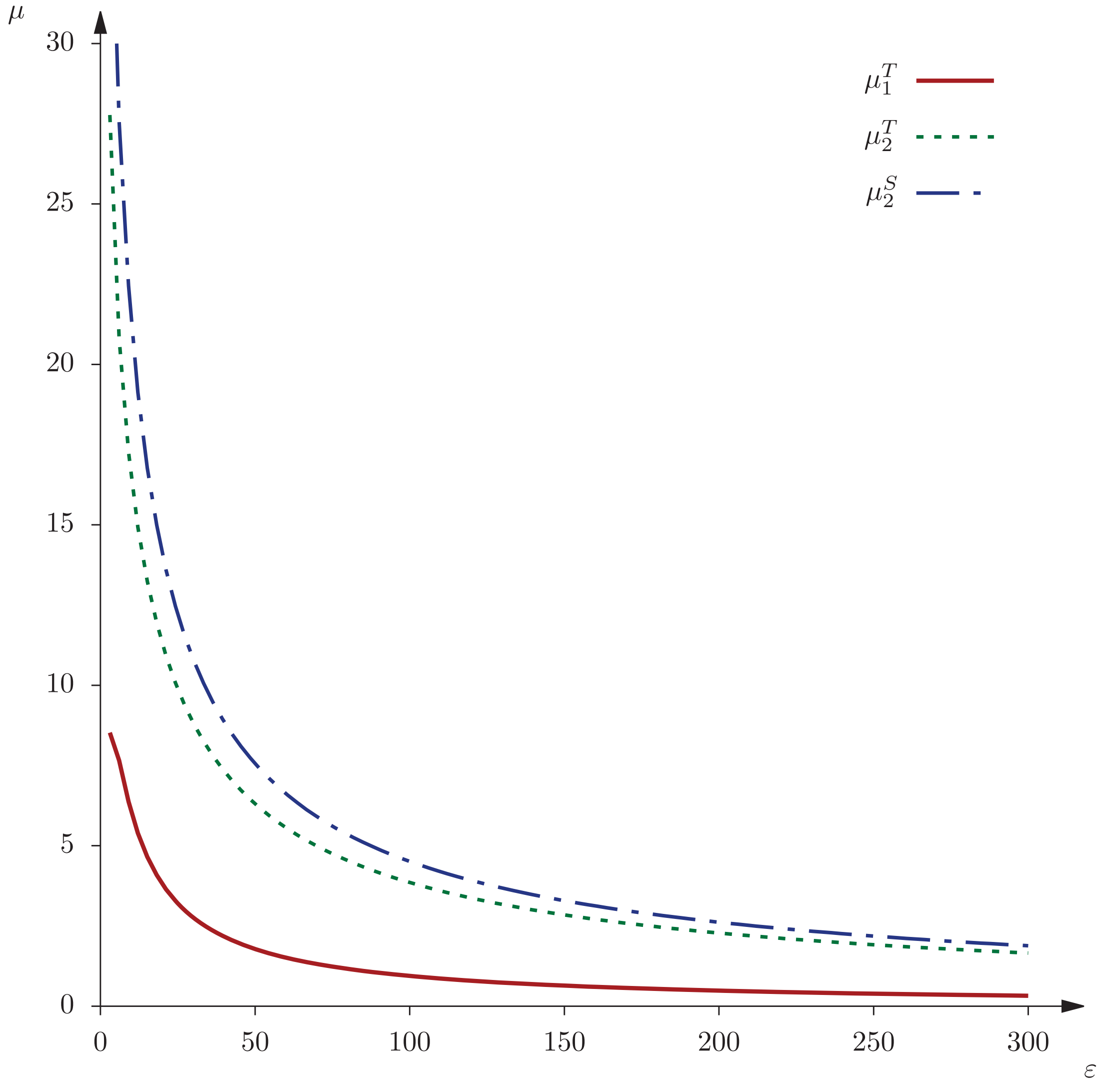

Figure 1. The cost reductions necessary for privatisation and liberalisation to be beneficial

6.2. Simultaneous maximisation

It makes sense to assume two-stage maximisation in particular when higher quality requires R&D- or other investments before the output-decision is made. However, we may also consider situations when the decisions about output and quality are made simultaneously. This also simplifies the analysis, thus providing an easier way to grasp some of the intuition behind the results.

The socially optimal solution does not change. As for the n-firm oligopoly, imposing symmetry immediately after differentiating profits as expressed by (10) yields the same expression for industry output as in the case of two-stage maximisation, i.e. (20). However, quality becomes different. Maximise (10) with respect to q_1 as well:

$$-\frac{Ry_1}{\left[y_1+\sum_{j=2}^{n} y_j (q_j/q_1)^{\rho}\right]^2}\left(-\frac{\rho\sum_{j=2}^{n} y_j q_j^{\rho}}{q_1^{1+\rho}}\right)-\beta q_1^{\beta-1}=0. \tag{26}$$

Impose ex-post symmetry and rearrange:

$$q(n)=\left[\frac{\rho R(n-1)}{\beta n^2}\right]^{1/\beta}=\left[\frac{R(n-1)}{\varepsilon n^2}\right]^{1/\beta}. \tag{27}$$

This value is otherwise lower than under two-stage maximisation, but equal when n=2, as follows from comparing (19) and (27).

The analysis of the maximum number of firms becomes considerably simpler. Imposing symmetry in (10) and inserting (27) yields:

$$\hat{n}=1+\varepsilon. \tag{28}$$

Routine calculations (see the proof of Proposition 1a) show that the maximum number of firms is higher than in the case of two-stage maximisation.

Proposition 1 cannot be extended to simultaneous maximisation without a small amendment:

Proposition 3. The following holds true under simultaneous maximisation: a) industry output is the same as in the public monopoly after privatisation and liberalisation if $n=\hat{n}=1+\varepsilon$, *but otherwise lower; b) privatisation and liberalisation underprovides quality.*

Proof: See appendix.

Output would have been the same both before and after liberalisation and privatisation for n=1+ε in the case of two-stage maximisation, but such a market structure allows firms to break even only under simultaneous maximisation. The percentage output distortion is the same as before for all n < 1+ε, but there is no distortion if there is entry until profits are zero.

Quality is on the other hand suboptimal, in the sense of being lower than (6), for all values of n, including $\hat{n}$:

$$q(\hat{n}) = \left(\frac{R}{(1+\varepsilon)^2}\right)^{1/\beta}, \tag{29$$

The highest quality occurs when n=2, so the lower bound for the percentage quality distortion is

$$r_q^S = 100\left\{1 - \left[\frac{0.25(1+\varepsilon)}{\varepsilon}\right]^{1/\beta}\right\}, \tag{28}$$

which is larger than under two-stage maximisation.

A similar argument as in the proof of Proposition 2 shows that consumer welfare would be decreasing in n for $n \geq 2+\varepsilon$. However, this number is larger than (28), so welfare is increasing in n in the feasible interval.

As for unit costs, they are now $c(1+1/\varepsilon)$ both before and after liberalisation. Corollary 1 is not robust when the setting is changed to simultaneous maximisation, but unit costs are at least not higher in the public monopoly. The fact that unit costs do not increase by privatisation and liberalisation is explained by the lower quality level.

Next, consider the threshold values of μ, which are indexed by S in the case of simultaneous maximisation. The fact that output is the same as under two-stage maximisation means that $\mu_1^S = \mu_1^T$. However, the left hand-expression in (24) changes, so the condition for welfare to increase is now

$$\frac{(n-1)^{(1+\varepsilon)/\varepsilon} R^{(\varepsilon+1)/\varepsilon}}{\varepsilon^{1/\varepsilon} n^{(2+\varepsilon)/\varepsilon} c_P} > \frac{R^{(\varepsilon+1)/\varepsilon}\varepsilon}{(1+\varepsilon)^{(\varepsilon+1)/\varepsilon} c_G}, \tag{31}$$

which implies that the critical percentage cost reduction μ_2^S becomes:

$$\mu_2^S = 100\left[1 - \frac{(n-1)^{(1+\varepsilon)/\varepsilon}\,[(\varepsilon+1)/\varepsilon]^{(\varepsilon+1)/\varepsilon}}{n^{(\varepsilon+2)/\varepsilon}}\right]. \tag{32}$$

Straightforward calculations shows that this threshold value is higher than under two-stage maximisation.

Assuming that there is entry until $n = \hat{n}$ yields the same output as in the public monopoly. This also means that any cost disadvantage under public ownership would mean a lower output. As for μ_2^S, the condition for privatisation and liberalisation to produce an increase in consumer welfare is

$$\mu > \mu_2 = 100\left[1 - \frac{1}{(1+\varepsilon)^{1/\varepsilon}}\right]. \tag{33}$$

6.3. Quality that affects marginal costs

The previous sections have focused on quality as reflected in fixed costs, like when quality is directly related to the size of the staff. But quality can also be reflected in the quality of the inputs, for example in higher quantity and/or quality of inputs. This section highlights the difference between models where quality is reflected in fixed and sunk costs, but in so doing we simplify by setting ρ=1 like in Sutton (1991).

Suppose that the cost function is of the form $TC_i = (c_0 + q^\gamma)y_i$, thus ignoring all fixed costs. A public monopoly would maximise

$$\underset{y}{\text{Max}}\,\Omega = (y/N)^{\alpha_1} q^{\alpha_1} y_0^{\alpha_0} + \lambda(R - c_0 y - q^\gamma y). \tag{34}$$

Routine calculations yield the following output and quality:

$$y^G = \frac{\gamma R}{\gamma c_0 + R}, \tag{35}$$

$$q = \left(\frac{R}{\gamma}\right)^{1/\gamma}. \tag{36}$$

Next, consider the n-firm oligopoly and assume for simplicity simultaneous maximisation. The profits of firm 1 are then:

$$\pi_1 = \frac{R}{y_1 + \sum_{j=2}^{n} y_j q_j / q_1} y_1 - c_0 y_1 - q_1^\gamma y_1. \tag{37}$$

Differentiating with respect to quality yields

$$-\frac{R y_1}{[y_1+\sum_{j=2}^{n} y_j q_j/q_1]^2}\left(-\frac{\sum_{j=2}^{n} y_j q_j}{q_1^2}\right)-\gamma q_1^{\gamma+1} y = 0. \tag{38}$$

Impose ex-post symmetry and rearrange:

$$q(n)=\left[\frac{(n-1)R}{n\gamma}\right]^{1/\gamma}. \tag{39}$$

Output as a function of quality becomes $R(n-1)/n(c_0+q^{\gamma})$. Inserting (39) yields:

$$y(n)=\frac{\gamma R(n-1)}{\gamma n c_0+(n-1)R}. \tag{40}$$

Routine calculations show that the oligopoly underprovides output and quality, so it provides an overpriced product of sub-standard quality. However, unit costs (which are here equal to marginal costs with respect to output) are now

$$ATC^{G}=c_0+\frac{R}{\gamma} \tag{41}$$

and

$$ATC(n)=c_0+\frac{n-1}{n}\frac{R}{\gamma}. \tag{42}$$

It follows that unit costs are now higher in the public monopoly, but this is explained by the fact that it provides superior quality. The model therefore predicts that a superficial cost comparison that does not take quality into consideration would find the public monopoly less cost efficient.

In contrast to models where quality is related to sunk costs, there is no upper limit to the number of firms (unless there are exogenous sunk costs). The oligopoly converges to the socially optimal solution as n approaches infinity, like in a conventional oligopoly but in contrast to the sunk-cost version of the model.

7. Discussion and concluding remarks

Our analysis has suggested that an oligopoly underprovides output, quality and welfare. While a price distortion can usually be alleviated by competition, a quality distortion may even be worsened by entry. These adverse effects apply also to the case where quality is reflected in marginal costs rather than sunk costs, but entry would then improve quality, and marginal costs will also be lower under oligopoly than in a public monopoly. To privatise and liberalise would in both cases have adverse effects, at least in the absence of changes in the marginal cost functions. This applies also to the introduction of commercial objectives (as for example suggested by the new public management) into monopolies that have previously maximised welfare.

However, our generalisation of Sutton (1991) means that the impact on consumer utility of quality can be weaker or stronger than the impact of consumption as such. This means that a scope for a relatively large number of firms can not be ruled out even if the sunk costs do not increase dramatically with quality. The market can become fragmented if the sensitivity of utility to quality is low, in which case there is no strong quality distortion. Moreover, the distortion would not have a significant negative impact on utility. Privatisation and liberalisation would then improve welfare if there is a moderate reduction in marginal costs.

Such a cost advantage should on the other hand not be taken for granted. A proper reading of the empirical literature on industries with both public and private ownership suggests that differences in cost efficiency may be nonexistent or may go either way (see surveys such as Millward, 1982; Boyd, 1986; Willner, 2001).[8] Empirical studies of the substantial experiences of privatisation in Britain fail to detect general post-privatisation improvements in cost efficiency or total factor productivity (Martin and Parker, 1997, Florio, 2004).[9] Several agency models (with and without intrinsic motivation) suggest that private ownership and competition do not necessarily yield higher cost efficiency (see for example De Fraja, 1993, Martin, 1993, Bartoletti and Poletti, 1996, Willner and Parker, 2007, Willner and Grönblom, 2013 and Grönblom and Willner, 2014).

[8] There might be a relative public-sector strength in water and electricity provision but not in refuse collection and bus transport. This may reflect different labour intensity and sensitivity to quality.

[9] The often cited survey by Megginson and Netter (2001) makes a different conclusion, but it has a strong emphasis on third-world and transition economies, while many valuable sources from industrial countries are missing.

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APPENDIX

Proof of Lemma 1. Consider an individual who consumes the output of the *i*:th firm, i=1,2,...*n*. Utility maximisation means maximising the following Lagrange function:

$$\underset{y,y_0}{\text{Max}}\, L = (y_i q_i^{\rho})^{\alpha_1} y_0^{\alpha_0} + \lambda(1 - p_i y_i - y_0 p_0). \qquad (A.1)$$

This individual then demands

$$y_i = \frac{\alpha_1/(\alpha_1+\alpha_0)}{p_i}, \qquad (A.2)$$

$$y_0 = \frac{\alpha_0/(\alpha_1+\alpha_0)}{p_0}. \qquad (B.3)$$

Insert (A.1) and (A.2) into (A.1) to get the indirect utility function. The utility level is then proportional to

$$\left(\frac{q_i^{\rho}}{p_i}\right)^{\alpha_1}. \qquad (A.4)$$

This is the only component in the indirect utility function that depends on which firm that produces *y*. All customers are identical utility maximisers, so the following must hold true for every firm *j* and *i* in the industry:

$$\frac{q_i^{\rho}}{p_i} = \frac{q_j^{\rho}}{p_j}. \qquad (A.5)$$

This implies $p_j = (q_j/q_i)^{\rho} p_i$ for all *i* and *j*. QED

Proof of Lemma 2. The propositions are otherwise trivial, but the ambiguity of the impact of β needs some elaboration. Differentiating (6) with respect to β yields $\partial q/\partial\beta = [-\ln R + \ln(1+\varepsilon) - \varepsilon/(1+\varepsilon)](R/(1+\varepsilon))^{1/\beta}/\beta^2$. It follows that the sign of the derivative is the same as for the expression $(1+\varepsilon)e^{-\varepsilon/(1+\varepsilon)} - R$ which is negative for small values of ε, and positive for large values. Interpret $R = (1+\varepsilon)e^{-\varepsilon/(1+\varepsilon)}$ as a function of ε and use a second-order Taylor approximation when we know the function and its two first derivatives for some very high value ε_0. As ε_0 approaches infinity, we get $R \approx (2+\varepsilon)/e$; the quadratic term vanishes. Using simulations for different values of R suggests that this function is a very good approximation in the relevant area where $\varepsilon \geq 8/3$. It also follows that $\partial q/\partial\beta$ is zero for $\varepsilon \approx= Re-2$ or $\beta \approx= (Re-2)\rho$. QED

Proof of Lemma 3. a) Inserting (19) into (18) after imposing symmetry and solving for n when profits are zero shows that firms can break even only for values of n between the roots of the quadratic equation

$$-2n^2 + (4+\varepsilon)n - 2 = 0. \qquad (A.6)$$

The roots are

$$n_{1,2} = 1 + \frac{\varepsilon}{4} \pm \sqrt{\frac{\varepsilon^2}{16} + \frac{\varepsilon}{2\rho}}. \qquad (A.7)$$

The upper bound is represented by the root with a plus-sign, i.e. by (21). However, the root with a minus-sign would be smaller than one, so relevant lower bound is 2, because otherwise there would be no equilibrium. b) It is obvious from the definition of ε that (21) is increasing in β and decreasing in ρ. QED

Proof of Proposition 1. It follows from (7) and (20) that privatisation and liberalisation would increase output if $n > 1+\varepsilon$. This means that there would be scope for an increase of output if $\hat{n} > 1+\varepsilon$, i.e. if

$$1 + \frac{\varepsilon}{4} + \sqrt{\frac{\varepsilon^2}{16} + \frac{\varepsilon}{2}} > 1 + \varepsilon. \qquad (A.8)$$

This would imply $1 > \varepsilon$. However, the existence of an equilibrium requires $\hat{n} \geq 2$, which requires $\varepsilon \geq 1$, or $\beta \geq \rho$. It follows that $\hat{n} < 1+\beta/\rho$. The range of market structures where output is overprovided does not in other words allow firms to make profits. As for quality, it follows from (6) and (19) that the oligopoly would provide at least the socially optimal quality if

$$\frac{\varepsilon}{1+\varepsilon} \leq \frac{2(n-1)^2}{n^3}. \qquad (A.9)$$

Rearrange this condition:

$$\varepsilon \leq \frac{2(n-1)^2}{n^3 - 2(n-1)^2}. \qquad (A.10)$$

Differentiating shows that the largest value of the expression to the right in the area where $n \geq 2$ is 0.421, which happens when n=3. The fact that $\hat{n} \geq 2$ requires $\beta/\rho \geq 1$ implies that (A.10) can never be satisfied. It follows that the n-firm oligopoly always underprovides quality. QED

Proof of Proposition 2. Part a) follows from the fact that (19) is maximised for n=3. As for b), consumer welfare depends on $(q^{\rho}y)^{\alpha_1}$, but it is sufficient to consider how $q^{\rho}y$ is affected. Use (19) and (20) to write $q(n)^{\rho}y(n)$ as

$$q(y)^{\rho}y(n) = 2^{1/\varepsilon}R^{(\varepsilon+1)/\varepsilon}c^{-1}\left[\frac{(n-1)^{\varepsilon+2}}{n^{\varepsilon+3}}\right]^{1/\varepsilon}. \qquad (A.11)$$

It is obvious that consumer welfare is increasing in R. As for the impact of the market structure, differentiate (A.11):

$$\frac{\partial q(y)^{\rho}y(n)}{\partial n} = \frac{2^{1/\varepsilon}R^{(\varepsilon+1)/\varepsilon}c^{-1}}{\varepsilon}\left[\frac{(n-1)^{\varepsilon+2}}{n^{\varepsilon+3}}\right]^{(1-\varepsilon)/\varepsilon}\frac{(n-1)^{1+\varepsilon}n^{2+\varepsilon}(3+\varepsilon-n)}{n^{2(\varepsilon+3)}}. \qquad (A.12)$$

This expression is positive for $n < \varepsilon+3$ and vice versa, so the optimal number of firms would appear to be $\varepsilon+3$. However, it is obvious that firms would then be unable to break even, because $\hat{n} > \varepsilon + 3$ would according to (21) imply

$$4 + \varepsilon + \sqrt{\varepsilon^2 + 8\varepsilon} > 4\varepsilon + 12, \qquad (A.13)$$

or

$$0 > \beta^2 + 5\beta + 8, \qquad (A.14)$$

which cannot happen. It follows that consumer welfare is increasing in the number of firms. QED

Proof of Corollary 1. Unit costs are $c+q^{\beta}/y$. For the case of a public monopoly we then get:

$$ATC^G = c + \frac{c}{\varepsilon}. \qquad (A.15)$$

As for unit costs after privatisation and liberalisation, divide (20) by n to get output per firm. Total costs per unit of output are then:

$$ATC^* = c + \frac{2(n-1)}{n\varepsilon}. \qquad (A.16)$$

Setting n=2 yields the same expression as (A.15), but (A.16) is increasing in n, so any n>2 would mean higher unit costs than in the public monopoly. QED

Proof of Corollary 2: We formulate the antithesis $\mu_1 > \mu_2$. Use (23) and (25) and rearrange:

$$\frac{2^{1/\varepsilon}(n-1)^{(2+\varepsilon)/\varepsilon}[(\varepsilon+1)/\varepsilon]^{(\varepsilon+1)/\varepsilon}}{n^{(\varepsilon+3)/\varepsilon}} > \frac{(1+\varepsilon)(n-1)}{n\varepsilon}. \qquad (A.17)$$

This implies

$$\frac{2^{1/\varepsilon}(n-1)^{2/\varepsilon}[(\varepsilon+1)/\varepsilon]^{1/\varepsilon}}{n^{3/\varepsilon}} > 1, \qquad (A.18)$$

or

$$\varepsilon \leq \frac{2(n-1)^2}{n^3 - 2(n-1)^2}. \tag{A.19}$$

This inequality cannot hold true, by a similar argument as in the proof of Proposition 1. The antithesis is in other words false. QED

Proof of Proposition 3: a) Industry output is the same as under simultaneous maximisation both in the public monopoly and after privatisation and liberalisation, but the market structure represented by n = 1+ε is now feasible. b) It follows from (27) and (6) that the oligopoly overprovides quality if

$$\frac{n-1}{\varepsilon n^2} > \frac{1}{1+\varepsilon}. \tag{A.20}$$

Set both sides of the inequality equal and solve for n. The oligopoly would overprovide quality in the interval between the solutions

$$n_{1,2} = \frac{1+\varepsilon}{2\varepsilon} \pm \sqrt{\left(\frac{1+\varepsilon}{2\varepsilon}\right)^2 - \frac{1+\varepsilon}{\varepsilon}}, \tag{A.21}$$

but this interval is empty for all ε ≥ 1/3. Less than two firms would be able to break even if ε < 1, so ε has to be larger than 1/3. This rules out the possibility of equal quality or overprovision. QED.

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