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# Quality externalities among hotel establishments: what is the impact of tour operators?

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This paper is about quality decisions in a vertical structure, in which competitive producers sell to 'powerful retailers'. Specifically, the analysis focuses on the role played by the tour operator (TO) in quality investments when distributing the capacity of a given tourism destination. The authors emphasize the presence of quality externalities among hotel establishments, and find that TO distribution can sometimes provide a solution to the 'tragedy of the commons' in quality provision. Thus they assess the implications of vertical relationships for quality in the hotel industry and derive appropriate policy recommendations.

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A distinguishing feature of the tourism hospitality industry is that the quality of a specific hotel affects the environment and, consequently, the quality of the whole area in which the hotel is located. This means that there are externalities across hotel owners in a specific region. For example, the design of the

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surrounding buildings can be as important as the design of the hotel itself. Similarly, one is likely to meet customers of nearby hotels in restaurants, on the beach, etc, so if a visitor dislikes nightlife, for example, he or she will avoid certain areas as unsuitable, regardless of the intrinsic characteristics of a particular hotel. Most importantly, hotels can be more or less environmentally friendly, depending on how they dispose of rubbish, wastewater and so on. Since environmental issues are increasingly perceived as important in the tourism sector (Bywater, 1992; Huybers and Bennet, 2000), this alone suggests that externalities across hotels are a key factor in understanding the industry.[1] Clearly, the presence of these externalities creates the commons problem: quality is produced jointly by all hotel owners in a region and so will tend to be under-provided.

In this paper we study quality choices in a vertical structure under a framework that emphasizes the presence of quality externalities among producers. As we focus on the tourism industry, we consider competitive producers (hotel establishments) that sell to powerful retailers (tour operators). In other words, we analyse the implications of vertical relationships among hotel establishments and tour operators for quality in the industry, and examine whether or not there is a role for public policy.

Our primary insight is that a tour operator (TO), to the extent that it distributes a large share of the supply in a region, internalizes, at least partially, the externalities that arise in quality investments by hotel establishments. The paper's main contribution is twofold. First, it contributes to the literature by showing that a powerful TO could provide a solution to the commons tragedy that affects hotel owners. Second, and very importantly, it characterizes the conditions under which a TO can solve the commons problem in the provision of environmental quality. As will be seen, the hotel capacity in a region plays a crucial role in the ability of a TO to solve the problem of an under-provision of environmental quality. We believe that the relationship between quality provision and capacity is new in the literature. The following paragraphs summarize most of the insights we offer.

TOs exhibit market power (see, for example, Baum and Mudambi, 1994) and consequently have an incentive to restrict the capacity they distribute to the market segment under their control. Thus there is a trade-off: to have the incentive to request quality upgrades from the hotel owners (HOWs) with whom it establishes agreements, a TO needs to be distributing a sufficiently large capacity, but market power leads it to restrict the capacity it distributes. In the resolution of this trade-off, the capacity of the region is critical. In a region with a large accommodation capacity, the TO would have to contract with too many hotels if it wanted to increase the quality of the region substantially, and this might involve too great a reduction in the price charged to tourists. This implies that the impact of the tour operator on quality depends on existing capacity, and thus that public policy has an important part to play. More specifically, we identify conditions under which, in equilibrium, the TO will request quality upgrades. While a minimum accommodation capacity is required to ensure that the TO has incentives to request quality upgrades, if there are too many hotels the TO will find it more profitable not to increase the quality of the region.

Finally, we also study how alternative vertical structures influence quality choices by the establishments of the region. We find that reducing the monopoly power of the tour operator may have very different consequences on quality, depending on whether market power is eroded through cooperation among hotel owners or through direct distribution to tourists via the Internet. Indeed, while eroding monopoly power through joint ventures will result in overall higher quality levels, direct Internet distribution will decrease the overall quality, since there will then be no internalization of the quality externalities.

To our knowledge, this is the first paper to study the effect of vertical relationships in quality investments in the presence of externalities among producers. The problem that quality tends to be under-provided within a commons framework is not at all new to the literature. However, the way in which vertical structures influence this quality provision has been neglected. For instance, Chiang and Masson (1988) analyse a framework in which there are informational externalities among producers: a good's perceived quality is the average quality of the goods produced in the same country. This is because of the presence of asymmetric information between consumers and producers. In this situation, quality provision in export goods is also an issue. Chiang and Masson show that restraining the number of exporting firms might increase the quality of export goods. However, they do not examine whether an intermediary can also provide a solution to the commons problem. An analysis of the role of vertical structures under the tragedy of the commons in the joint production of quality is the distinguishing feature of this paper.

It should be noted that our scenario differs from a more conventional setting in which more standard solutions would apply. When there are informational asymmetries between consumers and producers concerning the intrinsic quality of hotels (room quality, restaurant quality, etc), then one would expect the franchising of reputable names (Sheraton, Hilton, Sol-Melià, etc) to overcome the problem. However, this does not apply in our setting of environmental quality, in which there are direct externalities among producers so that environmental quality is produced jointly by all the hotels of the area. Even a Hilton hotel, for example, cannot prevent surrounding hotels from disposing of waste inappropriately. The paper is concerned with a commons problem in the production of a good, rather than with externalities that arise from asymmetric information which can be solved by more standard tools, such as certification or franchising.

Thus, even though informational asymmetries between tourists and producers are also an important characteristic of the industry, our framework of perfect information emphasizes the importance of direct externalities among hotel establishments. Hence we view the role of tour operators in our setting as complementary to that which they might play within a framework with imperfect information, in which they would assist in certifying and revealing quality to consumers (tourists) – see Lizzeri (1999) and Admati and Pfleider (1986, 1990). We also exclude from our analysis, by assumption, the role of intermediaries as agents who can become 'experts' as in Biglaiser (1993) and Biglaiser and Friedman (1994). Similarly, we do not engage with the strand of literature that deals with the quality of intermediaries as do, for instance, Matutes and Vives (1996).

In our model, access to customers is an 'essential facility'. Unlike the theory of essential facilities (for a survey see Rey and Tirole, forthcoming) we do not address the possibility of foreclosure through contractual restraints or vertical integration. Yet some of the ingredients in our model appear in the literature exploring vertical restraints (for example, Mathewson and Winter, 1984; Rey and Tirole, 1986). Mathewson and Winter (1984), for instance, assume that there are informational externalities across differentiated retailers, who as a result advertise less than optimally whenever the marginal price they pay equals or exceeds the cost of production. A manufacturer will give incentives to retailers to advertise optimally by offering a contract with a two-part tariff and will set the marginal price below cost. Rey and Tirole (1986) study retail price maintenance and exclusive territories as ways of mitigating the problem of externalities among retailers, as opposed to the externalities that arise among producers in our framework.

The paper proceeds as follows. The next section presents the model and the subsequent one characterizes the equilibrium. We then analyse alternative vertical structures and conclude with a discussion of the empirical evidence and the policy implications of the paper. All proofs are relegated to a technical Appendix.

## The model

We envisage the tourist sector as one in which relatively small but not powerless hotel owners negotiate with a rather powerful tour operator. We also take the view that quality, and especially environmental quality, is an important element in these negotiations. There are several examples. TUI, the largest European TO, surveys the hotels with which it contracts using an environmental checklist that includes information on the steps the hotel has taken to protect the environment. Also, Finnair Travel Services, a Finnish TO, has developed a Policy and an Environmental Programme for Sustainable Tourism, the main aim of which is to provide incentives to contract partners (mainly accommodation establishments) to improve their environmental performance, primarily by introducing environmental criteria into their contracts. Other examples of TOs that have programmes on environmental quality are Orizzonti (an Italian TO), the Japan Travel Bureau and the Scandinavian Leisure Group.[2]

More specifically, we focus on the negotiation between a TO that 'controls' the distribution for tourist services in one demand segment – which, for instance, corresponds to a given country and a series of HOWs. On the one hand, we model TOs that exhibit substantial market power. Fitch (1987), Baum and Mudambi (1994) and Evans and Stabler (1995) confirm this hypothesis.[3] Moreover, the industry trend is currently clearly towards concentration, with Thomson, the primary player in the UK market and controlling 40% of the Scandinavian market, having accepted the take-over offer of Preussag, its largest German counterpart.[4,5] On the other hand, we also model HOWs that are small, but not powerless – since they have the option to target a different demand segment (that is, to sell their product in the international market, or in other words to a different country), and gain profit from this 'outside' option.

We consider fixed hotel capacity. When negotiation with the TO takes place, the HOWs have already chosen a certain *ex-ante* quality level; for instance, the hotel has been built in a specific location and thus the quality of the construction is already in place, as are the swimming pool and other recreational facilities. The TO, however, can negotiate some upgrading of quality: for instance, it can request that the building is painted, that the gardening is improved or that the furniture is replaced. Indeed, quality upgrades are an essential component of negotiations between HOWs and TOs, which may agree to pay higher prices provided that certain investments are made to improve the hotel.

Next, quality externalities are an essential building block of our framework. In practice, both the *ex-ante* quality choice and the quality upgrades have an impact on the intrinsic quality of the hotel and also affect the environment, and hence the average quality of the region (as already noted above). The presence of these externalities creates a commons problem: quality is jointly produced by all HOWs in the region. In consequence, quality will tend to be under-provided in our setting. However, the TO internalizes the benefit generated by quality upgrades, and can provide incentives for the hotels to undertake them by setting appropriate prices.

We now present the timing and details of the model. The timing is as follows:

- *Stage 1. Negotiation between TO and HOWs.* The TO chooses those HOWs with which it wishes to negotiate and offers them a price. The price can be conditional on a quality upgrade (and on initial quality): that is, the TO can offer prices $y_0^j$ to $n_0$ HOWs of quality $j$ for their capacity. In addition, it may choose to offer a price $y_1^j$ to $n_1$ HOWs if they invest in upgrading their quality. HOWs accept or reject the TO's offer.
- *Stage 2. Quality upgrades.* HOWs that have signed contracts to upgrade quality make their investments. The other HOWs may also upgrade their quality.
- *Stage 3. Production and payments.* The TO sells the hotel capacity it has bought in its domestic market and payments are made. Those HOWs that rejected the TO's offer or did not receive a proposal from the TO obtain their 'outside' option.

### *Hotel establishments and the production of quality*

For the sake of simplicity, we focus on a scenario in which there is a mass $n$ of infinitesimal hotels with unit capacity and zero operational costs. Each hotel belongs to a different HOW.[6] As noted above, each infinitesimal hotel has already chosen a certain *ex-ante* quality level; for instance, they have built a specific location and thus the quality of the construction is already in place. This *ex-ante* quality has been chosen prior to negotiations with the TO. For simplicity, we assume that it does not exhibit externalities and that it is the same for each hotel establishment; that is, $\hat{Q}$.

When the negotiations take place, the TO can impose some quality upgrading by a discrete amount of $\Delta$. The cost of this quality upgrading is $c > 0$. Given the nature of the problem we analyse, we assume that quality upgrading has full external effects, and hence quality upgrading determines the environmental quality of the hotel. The overall quality of a hotel is then given by a weighted average of its *ex-ante* quality and the average environmental quality of all hotels in the region. In particular, if $n_1$ HOWs have upgraded their quality, the overall quality of hotel $i$ is:

$$q_j = \alpha\hat{Q} + (1 - \alpha)\frac{1}{n}\int_0^{n_1} \Delta di.$$

Thus, unless upgrades are contractually agreed with the TO, individual HOWs will never have the incentive to invest in upgrading since they are infinitesimal and their quality is not affected.

### *Outside option of HOWs*

The outside opportunity of a hotel of quality $j$ is given by $Ej = E\ (q_j)$, where

$$E_j(q_j) = \mu + \beta q_j\ ,$$

where $\mu > 0$ and $\beta > 0$. Thus if the TO negotiates with a hotel of quality $q_j$ it must offer a price $y_0 = E_j$ and, if it requests a quality upgrade, it must offer a price $y_1 = E_j + c$.[7] Otherwise the hotel owner would reject the offer. We assume that the TO is strategically aware in that it realizes that requesting upgrades will enhance the quality of the region and thus increase the outside option. On the other hand, for the sake of simplicity, the outside option does not depend on quantity, which basically means that the tourist region is small relative to the international market that does not operate through the TO.

Thus we model the outside option in a reduced form. Presumably, when dealing for example with a powerful UK TO, the outside option is to deal with another powerful, perhaps a German TO. Thus TOs compete for capacity (more than for customers, since markets are quite segmented). We ignore these complex strategic interactions between TOs but incorporate the fact that the TO, while powerful, cannot completely expropriate the profits of HOWs.

### *Demand for tourist services in the TO market segment*

The market in which the TO distributes tourist services is as follows. As stated in Shaked and Sutton (1982), consumers have unit demands and different valuations for quality, represented by the parameter $\theta$. There is a mass 1 of consumers, with their valuation for quality uniformly distributed in the interval [0, 1]. Thus the utility function of a tourist $i$ with valuation for quality $\theta_i$ is given by

$$u_i = \mathrm{r} + \theta_i \cdot q - p,$$

where $q$ is the quality of the tourist destination visited and $p$ is the price paid. The parameter $r$ is the gross utility of visiting a destination with zero quality. We assume that $r$ is high enough to ensure that consumers always visit a destination. We also assume that consumers can choose either to visit a destination with the services sold by the TO at prices and qualities ($p$, $q$) or go to the rest of the world, of higher quality $q_R$ and at price $p_R$ (which makes sense since we are analysing a problem of quality under-provision). Thus, the indifferent tourist is the one with a valuation for quality $\bar{\theta}$ for which $\bar{\theta} \cdot q - p = \bar{\theta} \cdot q_R - p_R$, which implies

$$\bar{\theta} = \frac{p_R - p}{q_R - q}.$$

Therefore demand and inverse demand functions are, respectively,

$$n_{TO} = \int_0^{\bar{\theta}} ds = \bar{\theta} = \frac{p_R - p}{q_R - q},$$

$$p = p_R - (q_R - q) \cdot n_{TO},$$

where $n_{TO}$ is the quantity sold by the TO in its market segment.

## Equilibrium

Given that there are $n$ HOWs in the market, all with the same basic quality $\hat{Q}$, how many HOWs will the TO contract with and how many will be asked to upgrade their quality in stage 1? Note that, when asking an HOW to upgrade its quality, the TO must pay enough to cover its outside option plus the full cost of upgrading $c$. Otherwise, the HOW will not agree to sign the contract. The TO's problem is thus

$$\max_{\{n_0, n_1\}} \int_0^{n_0} (p - y_0)di + \int_0^{n_1} (p - y_1)di$$

subject to

$$y_0 = E(q),$$

$$y_1 = E(q) + c,$$

$$n_0 + n_1 \leq n,$$

$$n_1 \geq 0, \; n_0 \geq 0,$$

where $n_0$ is the hotel capacity contracted by the TO that is not requested to upgrade quality and $n_1$ is the hotel capacity for which quality upgrading is requested; and $y_0$, $y_1$ is the price paid by the TO to the HOWs, depending on whether quality upgrading is requested ($y_1$) or not ($y_0$). By substituting $y_0$ and $y_1$, it can immediately be seen that the problem becomes:

$$\max_{\{n_0, n_1\}} (p - E(q)) * (n_0 + n_1) - c * n_1$$

subject to

$$n_0 + n_1 \leq n,$$

$$n_1 \geq 0, \; n_0 \geq 0.$$

Remember that, since upgrades are a pure public good, only those hotels that are asked to do so and are given incentives by the TO will upgrade their quality.

It follows that the quality marketed by the TO is $\hat{q} = \alpha \cdot \hat{Q} + (1 - \alpha)\Delta\frac{n_1}{n}$. The following lemma starts to characterize the solution of the TO problem:

*Lemma 1. The TO requests quality upgrades from all the hotels it contracts with or from none.* All proofs are presented in the Appendix.

Intuition suggests the following. Since upgrades are a pure public good, the TO cannot extract more from the hotels that are asked to upgrade than from the others. In fact, since all HOWs have the same outside option, the TO must give incentives to HOWs to invest in upgrading and must cover the whole cost. There are, then, two possibilities: the higher revenue that the TO can achieve for the higher-quality upgraded product either covers or does not cover the cost of upgrading the quality. That cost includes both the direct payments to the HOWs asked to upgrade and an indirect cost, given the fact that the higher quality of the region results in higher outside opportunity cost for all HOWs.

*Lemma 2. Two local optima are candidates for providing the optimal solution of the TO problem. In one, the TO contracts with $n_0^{TO}$ hotels where*

$$n_0^{TO} = \min\left[ n, \hat{n}_0 = \frac{p^r - \mu - \beta H_1}{2(q^r - H_1)} \right],$$

*and requests no quality upgrades. $n_0^{TO}$ is a local optimum when*

$$n_0^{TO} < \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{cn}{(1 - \alpha)\Delta} \right)^{1/2}.$$

*In the other case, the TO contracts with $n_1^{TO}$ hotels and asks them to upgrade their quality, with $n_1^{TO} = \min(n, \hat{n}_1)$, where $\hat{n}_1$ is the negative root of the following equation:*

$$3H_2(\hat{n}_1)^2 + 2(H_1 - q^r - \beta H_2)\,\hat{n}_1 + p^r - \mu - \beta H_1 - c = 0.$$

$$n_1^{TO} \textit{ is a local optimum when } n_1^{TO} > \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{cn}{(1 - \alpha)\Delta} \right)^{1/2}.$$

These lemmas lead us to the following propositions, in which we first examine quality upgrading conditions for the case in which the TO contracts with all HOWs in the region. Note that this is a useful benchmark, since in this case the TO fully internalizes all the quality externalities. However, this does not mean that the TO will always upgrade quality since it has to bear both the direct and indirect costs of doing so.

*Proposition 1. When the TO contracts with all HOWs, it imposes quality upgrading if and only if*

$$n > \frac{c}{(1 - \alpha)\Delta} + \beta .$$

When the TO contracts with all HOWs it internalizes all externalities from quality upgrades. To request upgrading on the part of all HOWs, there needs to be a minimum capacity (relative to both the direct and indirect costs of upgrading) such that the externalities which arise from quality upgrading are profitable. Note that the ratio between $c$ and $(1 - \alpha)\Delta$ reflects the fact that the cost must be small relative to the increase in quality due to upgrading $(1 - \alpha)\Delta$. A small $\beta$ indicates that the outside option will not increase much due to the upgrading.

In many cases, however, the TO will not contract with all HOWs in the region. This erodes the incentive of the TO to request quality upgrades. On the one hand, the TO alone has to pay both the direct and the indirect costs of upgrading, and, on the other hand, it does not fully internalize the benefits of upgrading since some HOWs do not contract with it but nevertheless benefit because some of the hotels in the region have been upgraded. One possibility for the TO is to contract with more HOWs, so that it can internalize the externalities that accrue from quality upgrading to a greater extent. However, increasing the capacity it distributes to its own market segment involves a reduction in the price tourists pay, a reduction which is non-optimal beyond a certain level.

Thus we see that there is a strategic trade-off to be confronted by the TO. Contracting with more HOWs is good because it enables greater internalization of the externalities that accrue from quality upgrading. However, it also involves a reduction in the price the TO can charge. In addition, by limiting the distribution of capacity to its own market segment, the TO dilutes its own incentive to undertake quality upgrading.

This trade-off explains why, in many cases, the TO will not contract with all HOWs, even though the consequence will be less quality upgrading or no quality upgrading at all. Thus upgrading will take place only when capacity is not too large, and we also expect that there is still a minimum regional capacity requirement below which the TO will not ask for quality upgrading. The following proposition formalizes these intuitions.

*Proposition 2. When the TO does not contract with all the HOWs, then (1) when $n$ is 'neither too large nor too small' the optimal strategy is to impose quality upgrades provided that $\beta$ and $c$ are 'small enough' and (2) when $n$ is very large, the TO does not require any quality upgrading to the HOWs with which it contracts.*

When capacity is not too large the TO will request quality upgrading, even when it does not completely internalize all quality externalities, provided that the costs of upgrading are low and there is low sensitivity of the outside option to quality improvements. However, when capacity is very large the benefits of upgrading are too much diluted among HOWs that have not contracted with the TO, and so the TO does not find it profitable to request quality upgrading.

The role of the intermediary (the TO) in solving the tragedy of the commons in the provision of the public good thus becomes clear. The TO faces a trade-off when deciding on the number of HOWs with which it should contract. On one hand, contracting with more HOWs increases the internalization of the externalities of quality upgrading and thus increases the incentive to undertake such upgrading. On the other hand, since the TO enjoys market power in its own market segment, contracting and distribution of hotel room capacity beyond a certain level will cause a non-optimal reduction in the price the it can charge to tourists.

## Alternative vertical structures

We now assess quality investments in our model relative to two other vertical structures.

The first is a competitive industrial structure in which HOWs distribute their hotel rooms directly to all tourists via the Internet. The second is the case in which all HOWs in the region form a joint venture to market their rooms jointly.

### *Internet distribution without tour operators: competitive outcome*

Assume that consumers in the TO market have access to the Internet and can thus buy directly from the HOWs without any intermediation. Any HOW would supply its capacity to this market if the price exceeded $E$, the outside opportunity. In other words, direct distribution through the Internet would be equivalent to the tour operator being replaced by an auctioneer allocating hotels to the TO market and to the outside option so that, given prices, revenue could not be increased by reassigning hotels.[8] Thus, the auctioneer assigns capacity to the TO market and to the rest-of-the-world market so that $P(q, n^A_{TO}) = E(q)$.

The following proposition analyses the impact of eliminating monopoly power through direct distribution via the Internet.

*Proposition 3. (1) When distribution is carried out directly via the Internet, there is no quality upgrading. (2) When HOWs distribute their rooms directly via the Internet, more capacity is allocated to the TO market and therefore less is allocated to the outside option market.*

The first result is immediately apparent from the assumption that firms are infinitesimal. Since there is no TO that requires quality upgrading through a contract, it is never in the interest of HOWs to upgrade the quality of their hotels. And the second result is also clear: as long as $p > E$ the auctioneer will allocate hotel rooms to the market instead of to the rest of the world, which provides the outside option.

Thus we see that, when distribution of capacity is done via the Internet, the profits of HOWs are smaller than when the TO distributes capacity and requests quality upgrading. On the one hand, with Internet distribution there is no quality upgrading at all in hotel rooms, and this decreases the value of the outside option to HOWs which distribute capacity to the rest of the world. On the other hand, HOWs which distribute capacity to the 'TO market' also obtain this lower outside option (since $p = E$).[9]

### *A joint venture: a TO controlled by HOWs*

We next consider the case in which competitive HOWs in the industry associate and form a TO that will control distribution both to the TO market and to the rest of the world. That is, we consider the case in which the industry-controlled TO (ICTO) maximizes the joint profit of all HOWs at the resort, and then its profits are distributed among all members of the industry. Thus the objective function of the ICTO is

$$\pi = p \cdot n_{TO} + (n - n_{TO}) \cdot E - c \cdot n_U ,$$

where $n_{TO}$ is the capacity distributed to the former 'TO market', and $n_U$ is the capacity of the region for which the ICTO requests quality upgrading. Note that the ICTO, since it also distributes the regional capacity to the rest of the world, can also request quality upgrading (and pay $c$ for it) from those HOWs that distribute their capacity to the outside option market (rest of the world), and not only from those that distribute to the former 'TO market'.

The following proposition states that it is sometimes to the benefit of the ICTO to request quality upgrades from the hotels that distribute their capacity to the rest of the world.

*Proposition 4. (1) The ICTO requests quality upgrades from all HOWs of the region or from none. (2) For the same capacity distributed to the former TO market, the ICTO requests quality upgrades from HOWs for a strictly larger parameter constellation than does the TO monopolist. (3) When the costs of quality upgrades are not so large, increases in capacity do not reduce the quality of the region.*

When the ICTO decides to request quality upgrading, it requires this of more HOWs than does the TO – specifically, it asks all HOWs of the region to upgrade. An ICTO internalizes all the externalities from upgrading quality in all HOWs of the region, not only those that it distributes to the former TO market. This, of course, increases the incentive to request quality upgrading. Furthermore, the effect of quality upgrading in increasing the outside option is not a cost for the ICTO (as it is, by contrast, for the monopolist TO).

Furthermore, the ICTO does not face the trade-off faced by the TO monopolist. As explained above, the monopolist is able to internalize the externalities of the quality upgrades to a larger extent as long as it contracts with more HOWs and distributes them to the TO market, but this strategy pushes down the prices it can charge to tourists. Now, the ICTO captures all the benefits of quality upgrades without having to increase the capacity it distributes to the former TO market, since it can request quality upgrades from the HOWs that distribute to the rest of the world.

## Discussion and concluding remarks

This paper has analysed how vertical structures influence quality choices when producers face a tragedy of the commons in quality production. We have paid particular attention to the tourism market, in which environmental quality externalities among hotel establishments are important, as is the presence of intermediaries such as TOs. A TO can play a role in the tragedy of the commons of a destination. We have shown that the TO faces a trade-off. On one hand, increasing the share of capacity that it distributes leads to a higher incentive to request quality upgrading in the hotels, since then the TO will internalize to a greater extent the externalities of quality investments. On the other hand, since the TO enjoys market power in the demand segment it serves, it has an incentive to restrict quantity to maintain higher prices. This trade-off limits its ability to solve the tragedy of the commons in the provision of environmental quality. Our main contribution is both to state this trade-off and to show how resort capacity plays a key role in solving it. As we noted at the beginning of the paper, our model applies to externalities that arise in the joint production of a good (that is, environmental quality) rather than to informational externalities, to which standard solutions such as certification or branding can be applied.

We have also studied the effect of alternative vertical structures on quality investments in a tourist destination. Inducing the HOWs of a region to cooperate by forming a joint venture to market their capacity through an industry-controlled tour operator produces more environmental quality than promoting direct distribution of hotel capacity via the Internet. This is because the former further enhances the incentive to make investments in quality, while the latter eliminates those incentives.

### *Empirical evidence and testable predictions*

Given the limited attention that economic analysis has paid to the tourism market, it is hard to find empirical evidence on the issues addressed in this paper. Consistent with our model, González and León (2001), in an analysis of Spanish hotels, find that stakeholder pressure (that is, pressure from TOs) helps to explain the adoption of environmental management practices. Also, Llull (2002) finds that tour operators are the main external agents (after hotel shareholders and managers) in influencing the environmental consciousness of hotel establishments – well ahead of suppliers, public administration, environmental regulation and competition.

There is also firm-specific evidence. Since 1992, according to its Website, the leading European tour operator TUI has kept an eye on the environmental performance of the hotels with which it contracts by means of an environmental checklist. TUI's contracts state that this checklist has to be completed annually. It provides information on what steps the hotel has taken to protect the environment, and thus helps the tour operator to assess the extent of effort devoted to environmental sustainability by individual hotels, hotel chains or the hotels in holiday regions or countries as a whole.[10]

The sharper test of our results should focus on Proposition 2, since Proposition 1 considers the case in which a TO contracts with all the HOWs in the area, which is unlikely to occur. Following Proposition 2, the probability that a tour operator will request quality upgrades should be higher when the resort capacity is neither too large nor too small. Hence, the probability of quality upgrading should follow an inverted U-shape for resort capacity. Another testable implication that arises in our framework concerns the impact of the recent trend in the accommodation sector towards direct distribution via the Internet. According to Proposition 3, this trend should decrease the level of environmental quality implemented by hotel establishments. However, this result might be difficult to test empirically since governments are, at the same time, making environmental regulations tighter and tourists are becoming more aware of environmental issues – factors which will also have an impact on the environmental behaviour of hotel establishments.

## *Policy implications*

Quality is a permanent issue on the agenda of governments of tourist regions and tourism organizations, accompanied by a wide array of policy instruments. Two policy implications derive directly from the above analysis, relating to capacity and entry regulations and the organization of distribution.

First, we have shown that increasing capacity will never lead to reduced quality *only* if the TO contracts with all the HOWs of the region. When the TO does not contract with all hotel establishments, an increase in capacity may involve a reduction in the quality it requests. A higher capacity implies that the TO does not capture the effects of quality upgrading, and this dilutes its incentives to request hotels to upgrade quality. This means that increases in regional capacity can lead to a reduction in the quality of the resort. Such an effect provides a rationale for capacity and entry restrictions that are already present in many tourist destinations – in Spain, for example, the local governments in the Balearic and Canary Islands have recently established capacity restrictions that prevent the construction of new hotels.[11]

Second, our analysis supports governmental policies that encourage cooperation among HOWs in a region so that they can market their accommodation capacity jointly, since such a joint venture of HOWs will precipitate an increase in the overall quality of the region.[12] At the same time, the trend towards direct distribution via the Internet by hotel chains and other hotel establishments should be watched with caution by the authorities, because of its potential negative impacts on investments in environmental quality.

## Endnotes

1. Tourism is an important economic sector from an international perspective. The number of international tourists travelling in the world reached 703 million in 2002. France, Spain and the USA were the top three destinations. Germany, the UK and the USA spent US$151 billion on international tourism in 2002 (WTO, 2003). According to Bywater (1992), 'The demand for a higher quality product is universal across Europe. [It] is expressed not just in expectations of the standard of the accommodation and service at the destination, but also in demand for a better environment'. Along the same lines, Huybers and Bennet (2000) study the relative importance of the natural environment on the choices made by prospective UK tourists regarding overseas holiday destinations. They highlight the importance of the environment among the attributes of destinations. In fact, they find that potential overseas tourists are willing to pay a substantial premium to visit a destination with a high level of environmental quality.
2. TUI's checklist elicits information on matters such as wastewater treatment and energy saving (*source:* TUI Website, www.tui-umwelt.com, visited on 22 October 2003). Information on other tour operators' practices was obtained from the Website of the Tour Operators Initiative (www.toinitiative.org), 'Good Practices' section, visited on 11 October 2003.
3. Gratton and Richards (1997) find mixed evidence: whereas the UK TO market seems to be contestable, the German market is a stable oligopoly.
4. See *The Economist*, 20 May 2000.
5. TOs had traditionally kept their markets rather segmented, with UK TOs controlling the UK and the Scandinavian countries, and German TOs expanding around Belgium and Holland (see Bywater, 1992).
6. Calveras (2002) analyses the interaction between expansion strategies by hotel chains and environmental quality.
7. Notice that, because the quality upgrade is a public good and firms are infinitesimal, the outside opportunity of a firm is independent on whether or not it performs the quality upgrade: hence its costs must be fully covered.
8. By 'TO market' we mean the market served by the TO in the previous section.

9. This is under the assumption that *n* is large enough for equilibrium to be distributed to the rest of the world.
10. Other examples of TOs that implement environmental checklists and programmes are mentioned above, in the first paragraph of the section entitled 'The model'.
11. Canary Islands government law number 6/2001 (www.gobiernodecanarias.org).
12 During the 1990s, HOWs in the Canary Islands tried to market their capacity jointly through an ICTO called SATURNO. Apparently the attempt was unsuccessful, given the market power of the established tour operators in the UK, the Scandinavian countries and Germany.

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# Appendix

## Proof of Lemma 1

For notational purposes let $H_1 \equiv \alpha \cdot \hat{Q}$ and $H_2 \equiv \frac{(1 - \alpha)\Delta}{n}$.

Then $q = H_1 + n_1 H_2$. First we analyse for $n_0 + n_1 < n$. Then, first derivatives of the TP profit function are:

$$\frac{\partial \pi}{\partial n_o} = p - E + (n_o + n_1)(q - q_R), \text{ substituting } p, E$$

$$= p_R - \mu - \beta q + 2(q - q_R)(n_0 + n_1), \text{ substituting } q,$$

$$= 2H_2(n_1)^2 + n_1(- \beta H_2 + 2H_1 - 2q_R) + \quad (1)$$

$$2H_2 n_o n_1 + 2(H_1 - q_R)n_o + p_R - \mu - \beta H_1 . \quad (2)$$

$$\frac{\partial \pi}{\partial n_1} = \frac{\partial \pi}{\partial n_o} + (n_o + n_1)^2 H_2 - \beta H_2(n_o + n_1) - c \quad (3)$$

The second derivatives are:

$$\frac{\partial^2 \pi}{\partial n_o^2} = 2H_2 n_1 + 2H_1 - 2q_R ,$$

$$\frac{\partial^2 \pi}{\partial n_o \partial n_1} = 4H_2 n_1 + 2H_2 n_0 + 2(H_1 - q_R) - \beta H_2 ,$$

$$\frac{\partial^2 \pi}{\partial n_1^2} = \frac{\partial^2 \pi}{\partial n_o \partial n_1} + 2(n_0 + n_1)H_2 - \beta H_2$$

$$= 6H_2 n_1 + 4H_2 n_0 - 2\beta H_2 + 2(H_1 - q_R) .$$

We can rewrite them as:

$$\frac{\partial^2 \pi}{\partial n_o^2} = 2(q - q_R), \quad \frac{\partial^2 \pi}{\partial n_1^2} = 2\frac{\partial^2 \pi}{\partial n_o \partial n_1} - 2(q - q_R) ,$$

$$\frac{\partial^2 \pi}{\partial n_o \partial n_1} = \beta H_2 + 2H_2(n_0 + n_1) + 2(q - q_R) .$$

The determinant of the hessian $|H|$ is:

$$\frac{\partial^2\pi}{\partial n_1^2}\ \frac{\partial^2\pi}{\partial n_o^2} - \left(\frac{\partial^2\pi}{\partial n_o \partial n_1}\right)^2 = 2(q - q_R)\ (2\ \frac{\partial^2\pi}{\partial n_o \partial n_1} - 2(q - q_R)) - \left(\frac{\partial^2\pi}{\partial n_o \partial n_1}\right)^2$$

$$= 4(q - q_R)\ \frac{\partial^2\pi}{\partial n_o \partial n_1} - 4(q - q_R)^2 - \left(\frac{\partial^2\pi}{\partial n_o \partial n_1}\right)^2 = -(2(q - q_R) - \left(\frac{\partial^2\pi}{\partial n_o \partial n_1}\right))^2 < 0$$

Since the determinant of the Hessian is smaller than zero, the interior solution can be neither a maximum nor a minimum, since both require the determinant to be positive. Thus when $n_0 + n_1 < n$ interior solutions are neither a maximum nor a minimum. Therefore, the optimal solution to the TO problem is either $\{n_0 > 0,\ n_1 = 0\}$ or $\{n_0 = 0,\ n_1 > 0\}$.

Now we examine the case in which the constraint is binding; that is, $n_0 + n_1 = n$. To do so, we solve the TO problem imposing the case that the constraint is binding and, by substituting the constraint ($n_0 = n - n_1$) into the objective function of the TO, its profit function becomes:

$$\pi_B = [p_R - (q_R - H_1 - n_1 H_2) \cdot n - \mu + \beta(H_1 + n_1 H_2)] \cdot n - c \cdot n_1 .$$

The derivative of $\pi_B$ with respect to $n_1$ is

$$\frac{\partial \pi_B}{\partial n_1} = n^2 \cdot H_2 - \beta H_2 \cdot n - c .$$

Doing some algebra, we find that this is positive for all

$$n > \beta + \frac{c}{(1 - \alpha)\Delta}$$

and negative for all

$$n < \beta + \frac{c}{(1 - \alpha)\Delta} .$$

Hence, for any given $n$, except for the trivial case when

$$n = \beta + \frac{c}{(1 - \alpha)\Delta} ,$$

the derivative is either always positive or always negative. Therefore, the solution to the problem is either all upgrading or no upgrading; that is, either $\{n_0 = n,\ n_1 = 0\}$ or $\{n_0 = 0,\ n_1 = n\}$.

## Proof of Lemma 2

Notice that, from Lemma 1, the TO requires upgrading from all the hotels with which it contracts ($n_1^{TO}$) or from none ($n_0^{TO}$). We have to consider several possibilities depending on whether or not the constraint ($n = n_0 + n_1$) is binding.

*First part, step 1.* $n_0^{TO} = \hat{n}_0$ is a local optimum when the following is satisfied:

(i) $\frac{\delta\pi}{\delta n_0}\Big|(n_1 = 0, \hat{n}_0) = 0;$ (ii) $\frac{\delta\pi}{\delta n_1}\Big|(n_1 = 0, \hat{n}_0) = 0;$

(iii) $\frac{\delta\pi^2}{\delta n_0^2}\Big|(n_1 = 0, \hat{n}_0) < 0;$ (iv) $\hat{n}_0 < n$ .

What is $\hat{n}_0$? In order to verify condition (i), substitute $n_1 = 0$ and solve for $n_0$. This yields

$$\hat{n}_o = \frac{p_R - \mu - \beta H_1}{2(q_R - \mathrm{H}_1)} ,$$

which is well defined since we assume that both numerator and denominator are positive. (This means that the reservation price of the market to which the monopolist sells is high enough, so that the monopolist can extract a surplus by selling to the hotel at the outside option value; and the denominator is assumed in our presentation of the model.)

Given that

$$\frac{\partial^2\pi}{\partial n_o^2}\Big|_{n_1=0} = 2\ H_1 - 2q_R ,$$

condition (iii) satisfies since $(q_R - H_1) > 0$ has been assumed above.

In order to verify condition (ii), note that (from Lemma 1)

$$\frac{\partial\pi}{\partial n_1}\Big|_{n_1=0,\hat{n}_0} = \frac{\partial\pi}{\partial n_0}\Big|_{n_1=0,\hat{n}_0} + \hat{n}_0^2 H_2 - \beta H_2 \hat{n}_0 - c$$

and

$\frac{\partial\pi}{\partial n_o}\Big|_{n_1=0,\hat{n}_0} = 0$ due to the calculus above.

Thus,

$$\frac{\partial\pi}{\partial n_1}\Big|_{(n1=0,\hat{n}0)} = \hat{n}_0^2 H_2 - \beta H_2 \hat{n}_0 - c.$$

In order to guarantee condition (ii), we need $\hat{n}_0^2 H_2 - \beta H_2 \hat{n}_0 - c < 0$, which is true when

$$\hat{n}_0 < \frac{\beta}{2} + \left(\frac{\beta^2}{4} + \frac{c \bullet n}{(1 - \alpha)\Delta}\right)^{½}.$$

Hence, for large enough $n$ (since then conditions (ii) and (iv) hold), $\hat{n}_0$ is a local optimum.

*First part, step 2.* $n_0^{TO} = n$ is a local optimum when

$$\hat{n}_0 > n, \text{ and } \frac{\partial \pi_B}{\partial n_1} = n^2 \cdot H_2 - \beta H_2 \cdot n - c < 0.$$

The second condition ensures that $n_1 = 0$, and holds when

$$n < \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{c \cdot n}{(1-\alpha)\Delta} \right)^{½}.$$

Consequently, both conditions hold when $n < \hat{n}_0$ and

$$n < \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{c \cdot n}{(1-\alpha)\Delta} \right)^{½}.$$

Hence for small enough $n$, $n_0^{TO} = n$ is a local optimum.

Therefore, from step 1 and step 2, $n_0^{TO} = \min \left| n, \hat{n}_0 \right|$ is a local optimum when

$$n_0^{TO} < \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{c \cdot n}{(1-\alpha)\Delta} \right)^{½}.$$

Let us now prove the second part of the Lemma.

*Second part, step 1.* $n_1^{TO} = \hat{n}_1$ is a local optimum when

(i) $\frac{\delta \pi}{\delta n_1} \Big| (n_0 = 0, \hat{n}_1) = 0$; (ii) $\frac{\delta \pi^2}{\delta n_1^2} \Big| (n_0 = 0, \hat{n}_1) < 0$;

(iii) $\frac{\delta \pi}{\delta n_o} \Big| (n_0 = 0, \hat{n}_1) < 0$; (iv) $\hat{n}_1 < n$ .

Condition (i) is:

$$\frac{\partial \pi}{\partial n_1} \Big|_{(n_0=0,\hat{n}_1)} = 3H_2(\hat{n}_1)^2 + 2(H_1 - q_R - \beta H_2)\hat{n}_1 + p_R - \mu - \beta H_1 - c = 0$$

This equation has two solutions:

$$\hat{n}_{1_+}; \hat{n}_{1_-} = \frac{2(q_R+\beta H_2-H_1) \pm \sqrt{(2(q_R+\beta H_2-H_1))^2+12H_2(-p_R+\mu+\beta H_1+c)}}{6H_2}.$$

Assuming that $p_R - c - (\mu + \beta H_1) > 0$ (the reservation price is great enough to enable the monopolist to retain a surplus in paying to the hotel the outside option when $n_1 = 0$ and the cost of upgrading, that is, $p_R - y_1 > 0$), both solutions are positive. However, we will show that only $\hat{n}_{1_-}$ satisfies condition (ii), while $\hat{n}_{1_+}$ does not. In order that a given $\hat{n}_1$ satisfies condition (ii), it must be the case that

$$\hat{n}_{1_+} < \frac{2(q_R + \beta H_2 - H_1)}{6H_2}$$

It can immediately be seen that

$$\hat{n}_{1_-} < \frac{2(q_R + \beta H_2 - H_1)}{6H_2} < \hat{n}_{1_+} .$$

Therefore, we set $\hat{n}_1 = \hat{n}_{1_+}$.

Now we must study when $\hat{n}_1$ verifies condition (iii). We can write:

$$\frac{\partial \pi}{\partial n_0}\Big|_{(n_0=0,\hat{n}_1)} = \frac{\partial \pi}{\partial n_1}\Big|_{(n_0=0,\hat{n}_1)} - (H_2\hat{n}_1^2 - \beta H_2\hat{n}_1 - c).$$

Due to condition (i) the first part of the right-hand side is zero, so we must guarantee that the second part is negative; that is, that the expression within brackets is positive. This will be verified when

$$\hat{n}_1 > \tilde{n} \equiv \frac{\beta H_2 + \sqrt{(\beta H_2)^2 + 4H_2 c}}{2H_2} = \frac{\beta}{2} + \sqrt{\left(\frac{\beta}{2}\right)^2 + \frac{c \cdot n}{(1-\alpha)\Delta}} .$$

*Second part, step 2.* $n_1^{TO} = n$ is a local optimum when $n < \hat{n}_1$ and

$$\frac{\partial \pi_B}{\partial n_1} > 0;$$

that is, when $n > \tilde{n}$.

Then, from steps 1 and 2, it is easy to see that the second part of the Lemma is verified.

## Proof of Proposition 1

From Lemma 1, if the TO contracts with all HOWs there are two possible local optima: $\{n_0^{TO} = n, n_1^{TO} = 0\}$ and $\{n_0^{TO} = 0, n_1^{TO} = n\}$

From Lemma 2, if $n > \tilde{n}$, that is,

$$n > \beta + \frac{c}{(1-\alpha)\Delta},$$

then $\{n_0^{TO} = n, n_1^{TO} = 0\}$ cannot be an optimal solution, while $\{n_0^{TO} = 0, n_1^{TO} = n\}$ satisfies the conditions for a local optimum. Therefore, it is the optimal solution.

The proof is analogous for the inverse.

## Proof of Proposition 2 (1)

In order to prove this proposition we need to prove that $\hat{n}_1$ is a local optimum (step 1) and that $\hat{n}_0$ is not a local optimum (step 2), for $n$ 'neither too large nor too small', and provided that $\beta$ and $c$ are not too large.

*Step 1.* According to Lemma 2, for $\hat{n}_1$ to be a local optimum it must be the case that $\hat{n}_1 > \tilde{n}$. First take $c = 0$. Then $\hat{n}_1 > \tilde{n}$ when:

$$\frac{2(q_R - H_1 + \beta H_2) - \sqrt{(2(q_R - H_1 + \beta H_2))^2 + 12H_2(-p_R + \mu + \beta H_1)}}{6H_2} > \frac{\beta H_2 + \sqrt{(\beta H_2)^2}}{2H_2}$$

$$q_R - H_1 - 2\beta H_2 > \sqrt{(q_R - H_1 + \beta H_2)^2 + 3H_2(-p_R + \mu + \beta H_1)}.$$

If $(q_R - H_1 - 2\beta H_2) > 0$ (it is clear that if it were negative the condition would not be satisfied), that is,

$$n > \frac{2\beta(1 - \alpha)\Delta}{q_r - H_1},$$

squaring the two terms we obtain

$$(q_R - H_1 - 2 * \beta H_2)^2 > (q_R - H_1 + \beta H_2)^2 + 3H_2(-p_R + \mu + \beta H_1).$$

Doing some more algebra, we find that this is satisfied if and only if $\beta^2 H_2 + (p_R - \mu - \beta(2q_r - H_1)) > 0$ and

$$n > \frac{2\beta(1 - \alpha)\Delta}{q_r - H_1}.$$

A sufficient condition for this is

$$\beta > \frac{p_R - m}{(2q_r - H_1)} \quad \text{and} \quad n > \frac{2\beta(1 - \alpha)\Delta}{q_r - H_1}.$$

Now, we examine the derivatives of $\hat{n}_1$ and $\tilde{n}$ with respect to $c$:

$$\frac{\partial \tilde{n}}{\partial c} = \frac{\partial \left( \dfrac{\beta H_2 + \sqrt{(\beta H_2)^2 + 4H_2 c}}{2H_2} \right)}{\partial c} = \sqrt{(\beta H_2)^2 + 4H_2 c} > 0 ,$$

$$\frac{\partial \hat{n}_1}{\partial c} = -\sqrt{(2(q_R - H_1 + \beta H_2))^2 + 12H_2(-p_R + \mu + \beta H_1 + c)} < 0 .$$

Therefore, there is $c^* > 0$ such that for $0 < c < c^*$ and above conditions, the condition $\hat{n}_1 > \tilde{n}$ is satisfied. Thus, $\hat{n}_1$ is a local optimum.

*Step 2.* We want to show that, for some parameter constellations, $\hat{n}_0$ is not a local optimum. $\hat{n}_0$ is not a local optimum if $\hat{n}_0 > \tilde{n}$, that is, if

$$\frac{p_R - \mu - \beta H_1}{2(q_R - H_1)} > \frac{\beta}{2} + \left( \frac{\beta^2}{4} + \frac{c \bullet n}{(1 - \alpha)\Delta} \right)^{½}.$$

For $c = 0$, this condition is true if and only if

$$\beta < \frac{p_R - m}{(2q_r - H_1)} \quad .$$

Hence, for $c = 0$ and

$$\beta < \frac{p_R - m}{(2q_r - H_1)}$$

this condition does hold and $\hat{n}_0$ is not a local optimum. Finally, note that, for given $\beta$ and $c$, $n$ cannot be too large; otherwise, the above condition would not hold.

Since steps 1 and 2 have been proven, QED.

## Proof of Proposition 2 (2)

In order to have quality upgrading as a local optimum we need: $\hat{n}_1 > \tilde{n}$, that is (setting $H_1 = 0$ simply for ease of exposition):

$$\frac{2(q_R+\beta H_2) - \sqrt{(2(q_R+\beta H_2))^2+12H_2(-p_R+\mu+c)}}{6H_2} > \frac{\beta H_2 + \sqrt{(\beta H_2)^2+4H_2 c}}{2H_2},$$

$$2q_R > \beta H_2 + 2\sqrt{(q_R + \beta H_2)^2 + 3H_2(-p_R + \mu + c)} + 3\sqrt{(\beta H_2)^2 + 4H_2 c} \ .$$

Take $\beta = 0$ amd c $> 0$. Then,

$$2q_R > 2\sqrt{(q_R)^2 + 3H_2(-p_R + \mu + c)} + 6\sqrt{H_2 c} \ ,$$

$$q_R - \sqrt{9H_2 c} > \sqrt{(q_R)^2 + 3H_2 c + 3H_2(-p_R + \mu)} \ .$$

Assuming that $q_R - \sqrt{9H_2 c} > 0$ (if it were negative, the condition would not hold), we obtain

$$\sqrt{H_2} > \frac{2q_R\sqrt{c}}{2c + p_R - \mu} \ .$$

This holds for $n$ small, since then

$$H_2 = \frac{(1 - \alpha)\Delta}{n}$$

is large. Thus, for $\beta = 0$ and $c > 0$, necessary and sufficient conditions for quality upgrading to be an optimum are

$$\sqrt{H_2} > \frac{2q_R\sqrt{c}}{2c + p_R - \mu}$$

and

$$\frac{(q_R)^2}{9c} > H_2 \ .$$

That is,

$$\left(\frac{2q_R\sqrt{c}}{2c + p_R - \mu}\right)^2 < H_2 < \frac{(q_R)^2}{9c} \ .$$

[This is possible as long as

$$\left(\frac{2q_R\sqrt{c}}{2c + p_R - \mu}\right)^2 < \frac{(q_R)^2}{9c} \ ,$$

that is,

$$\frac{4c}{(2c + p_R - \mu)^2} < \frac{1}{9c} \ .]$$

So we have shown that for $\beta = 0$ and $c > 0$ upgrading is not an optimum for $n$ large. As for $\beta > 0$, if for a given $n$ it is not an equilibrium then nor will it be an equilibrium for $n$ large, since it simply adds $\beta H_2 > 0$ to the RHS of the equation/condition.

## Proof of Proposition 4

The ICTO $\max_{(n_{TO}, n_U)} \pi = p \cdot n_{TO} + (n - n_{TO}) \cdot E - c \cdot n_U$. The derivatives are

$$\frac{\partial \pi}{\partial n_U} = n_{TO} \cdot \frac{(1 - \alpha)\Delta}{n} (n_{TO} - \beta) + \beta(1 - \alpha)\Delta - c \ ,$$

$$\frac{\partial \pi}{\partial n_{TO}} = p - E - (q_R - q) \cdot n_{TO} \ .$$

Note that the first derivative does not depend on $n_U$, given a value of $n_{TO}$. Thus

$$\frac{\partial \pi}{\partial n_U}$$

is positive or negative depending on the value of $n_{TO}$. Hence, there are only two possible solutions. For those $n_{TO}$ such that

$$\frac{\partial \pi}{\partial n_U} > 0, \ n_U = n;$$

whereas for those $n_{TO}$ such that

$$\frac{\partial \pi}{\partial n_U} < 0, \ n_U = 0.$$

The first point of the proposition has been shown.

For a given $n_{TO}$, according to Lemma 2, for the monopolist TO to request upgrading it is necessary that

$$n_{TO} > \frac{\beta}{2} + \left( \left( \frac{\beta}{2} \right)^2 + \frac{c \cdot n}{(1 - \alpha)\Delta} \right)^{½}.$$

In the case of the ICTO, in order to have

$$\frac{\partial \pi}{\partial n_U}$$

positive, it is enough that

$$n_{TO} > \frac{\beta}{2} + \left( \left( \frac{\beta}{2} \right)^2 + \frac{(c - \beta(1 - \alpha)\Delta) \cdot n}{(1 - \alpha)\Delta} \right)^{½}.$$

Hence, the second point of the proposition has been shown.

In order to prove the third point of the proposition, assume that $c < \beta(1 - \alpha)\Delta$. Furthermore, note that as long as there is upgrading ($n_U = n$),

$$n_{TO} = \frac{p_R - \mu - \beta q}{2(q_r - q)}$$

does not vary with $n$. Hence, if for a given $n$ we have upgrading, that is,

$$\frac{\partial \pi}{\partial n_U} > 0,$$

increases in $n$ do not change the sign of the derivative, and therefore quality upgrading will still take place.