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Raising Rivals' Fixed Costs

by

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Abstract: This paper analyses the strategic use of fixed costs to deter entry or monopolize a market in a standard Cournot framework. First of all a general case shows how the presence of fixed costs can affect the possible equilibria to the Cournot game. It is shown that the presence of a firm with a first-mover advantage can have important implications if fixed costs are raised. In addition the forward induction process becomes important in determining plausible equilibria. The use of firstly regulation and secondly 'nuisance' law-suits are considered as strategies to increase fixed costs.

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1. Introduction

An idea that has existed for some time in the Industrial Organization literature is that a firm may be able to obtain a strategic advantage by increasing a rival or potential rivals' costs. However, despite the appeal as a theoretical idea there has been much debate concerning applications to 'real-world' scenarios. One explanation is that much of the evidence cited of this form of strategic conduct is simply an alternative way of approaching more established forms of anti-competitive behaviour such as foreclosure.[1] The recent Office of Fair Trading (OFT) (2003) Merger Guidelines state that one of the competition concerns with vertical mergers is that they can have a raising rivals' cost effect and foreclose market access. The existing literature focuses largely on the strategic raising of rivals' variable costs. However, as Mason (2002) shows the scope for such a strategy to be profitable is limited because in many scenarios raising a rival firms costs leads to an identical increase in the firms own costs. There are however, situations where raising rivals fixed costs may be a more plausible strategy, such as the costs of complying with regulation. It will be shown that this can still be a profitable strategy despite the increase in fixed costs affecting all firms equally. In addition much of the recent Industrial Organisation literature has focused on the importance of sunk costs, whereas this paper considers fixed costs that do not have to be sunk costs. A set of guidelines produced by OFT (2002) highlight the potential effect regulation can have on competition. It is recognized that regulation can have a substantial effect on firm's costs and may disadvantage certain firms, for example, smaller firms. The impact of regulation on competition therefore has important policy implications, especially if the strategic raising of costs leads to a reduction in competition. However, despite the important policy implications this is currently an under-researched area.

This paper is firstly an attempt to formalise the possibility of strategically raising the level of fixed costs in an industry, by adapting an idea suggested in Dixit (1979). The model is then used in an attempt to analyze the use of lobbying for regulation or alternatively pursuing legal proceedings to raise fixed costs and disadvantage rivals. The lobbying for regulation application potentially applies to a wide variety of types of regulation including; various codes-of-practise, the regulation of professional services, environmental and health and safety regulation. The

[1] See for example Brennan (1988) and Coate and Kleit (1994).

literature review in the subsequent section provides some important examples of the possible strategic use of regulation, for example in the US ophthalmic industry.

The potential strategic use of legal proceedings is becoming an increasingly relevant issue as it has been suggested that the European Commission is now encouraging competition law to be enforced via private litigation.[2] Some early examples where this form of strategic behaviour has been claimed in the European courts are provided later in the paper. Regulation and legal proceedings are therefore perhaps less obvious but extremely plausible settings for the use of a raising rivals' costs (RRC) strategy and are not covered by the existing literature.

The paper proceeds as follows; section 2 summarises the relevant literatures from economics and law, section 3 formalises the effect of symmetric increases in fixed costs in a Cournot model and considers the implications for consumer welfare. Then section 4 discusses the possible approaches to the equilibrium selection problems that arise when fixed costs are present and applies these in the context of; regulation and 'nuisance' law suits, finally section 5 concludes.

2. Relevant Literature

The classic RRC model is by Salop and Scheffman (1983 & 1987). In these papers, it is suggested that RRC may be a more realistic strategy for a firm than predatory pricing; the main reasons for this are that a RRC strategy is more credible, does not require the rival to exit the market and allows short run gains. Their model uses a dominant firm, competitive fringe setup to show how strategic RRC can be achieved. Crucial to the model is a variable-cost raising parameter, which can for example be interpreted as a regulatory parameter, the price of an input or expenditure on R&D. The model shows that a RRC strategy is profitable if the increase in this cost raising parameter leads to an increase in the dominant firm's residual demand, which exceeds the shift in its average cost curve. They show that this may have a negative or a positive effect on the fringe firm's profits and on consumer welfare. More structure is then placed on the cost raising parameter to illustrate a RRC strategy in a more realistic setting. They firstly model overbuying strategies when increasing the purchase of an input raises rivals costs and secondly vertical integration. It is shown to be potentially profitable for a vertically integrated dominant firm to purchase an

[2] Jones and Surfin (2001), pp. 958.

input from elsewhere, even if it can produce the input more efficiently itself, because of the RRC effect.

One example of a RRC strategy is discussed in Williamson (1968). In a case brought against Pennington, a US mining firm in the 1960s, it was alleged that they used a wage agreed with the labour union in order to RRC. By increasing the wage, variable costs for all firms would go up, effecting labour-intensive firms more and potentially benefiting Pennington as a more capital-intensive firm. The court despite finding some evidence of RRC could not prove intent and consequently no action was taken. However, Williamson suggests that there was in fact evidence of intent and that this strategy despite not actually giving Pennington monopoly power had a significant effect on discouraging small scale entry and forced some firms to exit the market.

Mason (2002) provides an alternative rationale for a RRC strategy by showing that in a dynamic setting a symmetric increase in variable costs can be profitable for all firms if it leads to a subsequent reduction in competition.

The term government assisted predation was introduced by Miller and Pautler (1985).[3] They define government-assisted predation as; 'firms efforts to use the coercive powers of government for their own advantage against their rivals'.[4] They suggest that there is little 'real-world' evidence of successful predatory pricing strategies and that the use of predation strategies involving non-price variables, for example, government assisted predation, could be much more plausible. As a possible example, they suggest that a larger firm can disadvantage a smaller rival by filling for a law-suit. Even if this costs both firms an identical amount they argue that the larger firm can obtain an advantage. This law-suit could be interpreted as a fixed cost imposed on the smaller firm. It is suggested that the FTC and other government agencies now recognize the potential anti-competitive effects of this form of conduct and have moved to counter the effects and expanded the focus of traditional anti-trust activities to recognise this. In addition Baumol and Ordover (1985) suggest the potential use of antitrust action to deter competition, for example moves to deter entry by a rival firm or to prevent rival firms setting up a joint venture.[5] All of these examples of government assisted predation can be regarded as attempts to increase or impose some form of fixed costs on a rival firm. The model described in the

[3] See also Bork (1978).
[4] Miller and Paulter (1985), pp.500.
[5] Baumol and Ordover (1985), pp.256-57, MCI v AT&T and the GM-Toyota Joint Venture.

proceeding sections of this paper therefore, formalises this form of strategic behaviour.

The model developed in section 3 of this paper is based on the model in Dixit (1979), which shows that the presence of fixed costs can enable an incumbent monopolist to deter entry by a comparable sized rival firm. It is shown that if fixed costs are high enough the incumbent firm can blockade entry by continuing to produce as a monopolist. However, with lower fixed costs entry deterrence may still be possible if the incumbent produces an output in excess of the monopoly level. The model described in the proceeding sections is similar to that of Dixit however the crucial difference is that the model is now used to consider strategic increases in fixed costs as the level of fixed costs is modelled as a choice variable. In contrast in Dixit's model fixed costs are exogenously determined.

The idea that a firm may be able to strategically use regulation was first formalized by Oster (1982). The case of branded US generic drugs in the late 1970s is used as an example; evidence suggests that the producers of brand name drugs lobbied for regulation, which would disadvantage producers of the equivalent generic drugs. The strategic lobbying for regulation is also modelled in Michaelis (1994), where two political parties compete for campaign contributions by firms in an industry subject to regulation.

Another example of the possible strategic use of the regulatory process to deter entry is provided in the US ophthalmic industry. Haas-Wilson (1986) shows that in this industry commercial practise restriction such as restrictions on optical store locations and the operation of multiple stores have lead to increased prices. Then Haas-Wilson (1989) finds empirical evidence that these commercial practise restrictions limited chain-store entry into the market and suggests that self-employed opticians successfully lobbied for these commercial practise restrictions to deter entry.

3. i) The basic model: symmetric increases in fixed costs in a Cournot model

Assume a standard Cournot model, where there are 2 firms denoted 1 and 2, producing homogenous goods and facing the inverse demand function:

$P(Q) = a - bQ$ where: $Q = q_1 + q_2$ (1)

The two firms have identical marginal costs (c) and potentially a fixed cost (F). We will assume that either of the two firms can take some discrete action γ which leads to an increase in industry wide fixed costs.[6] Formally:

$F(g)$ where: $g \in \{0, \gamma\}$ and $\gamma > 0$ (2)

We will also assume that that fixed costs are increasing in the action γ and initially that if no action is taken there are no fixed costs, formally;

$F(\gamma) > 0$ and $F(0) = 0$ (3)

It will be assumed that γ affects the two firms fixed costs equally so that the two firms always have identical fixed costs. Total costs for each firm are therefore;

$TC_i = c.q_i + F(\gamma)$ (4)

We can then find the best-reply function for a given firm taking into account the fact that when fixed costs are present the firm has the option to exit the industry when the best-reply to a given output choice by a rival involves non-positive profits[7] (see Appendix 1.1):

$BR_i(q_j) = 0$ *iff* $q_j \geq ((a-c)/b) - \sqrt{4F}$ (5)

$BR_i(q_j) = ((a-c)/2b) - (q_j/2)$ *iff* $q_j < ((a-c)/b) - \sqrt{4F}$ (5.1)

Proposition 1 then shows that the set of equilibria depends on the level of fixed costs.

Proposition 1: If $\gamma > 0$ then the set of equilibria available depends on the level of fixed costs:

i) $F(g) < F_1^*$ The Cournot equilibrium is unique.

ii) $F_1^* \leq F(\gamma) < F_2^*$ There are three equilibria; firm 1 as a monopolist, firm 2 as a monopolist or the Cournot equilibrium.

iii) $F_2^* \leq F(\gamma) < F_3^*$ There are two equilibria; firm 1 as a monopolist and firm 2 as a monopolist.

iv) $F_3^* \leq F(\gamma)$ No firm is active.

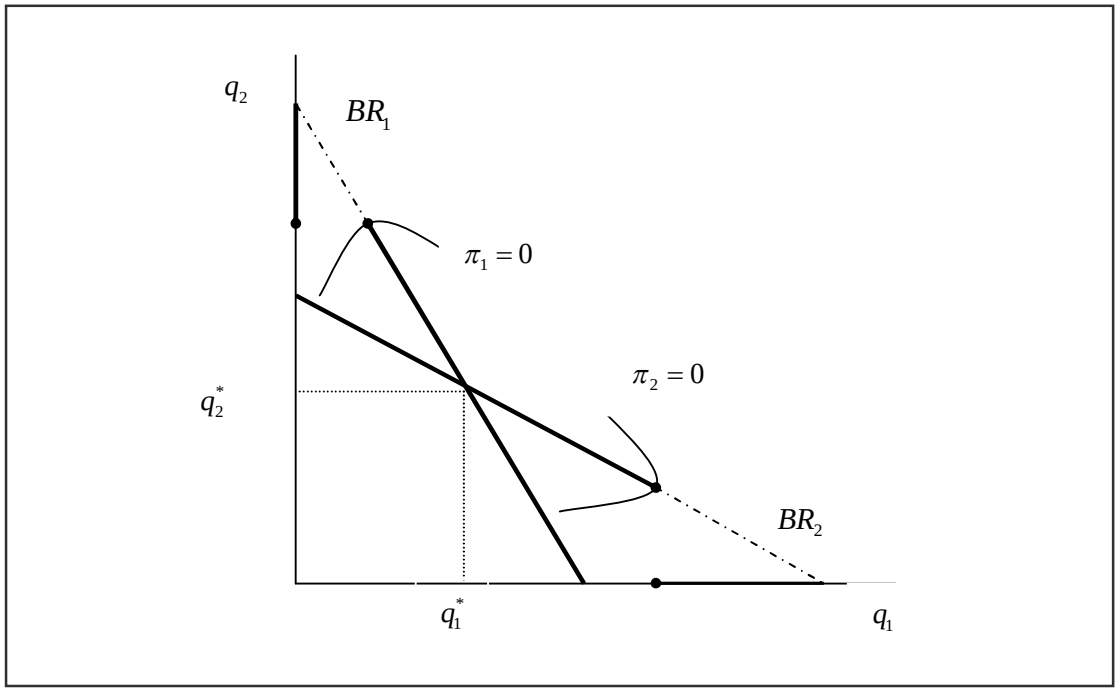
[6] The action γ is assumed to be discrete for simplicity however; it could also be modelled as a continuous action.

[7] Exit is assumed to be costless.

Where F_1^*, F_2^* and F_3^* are defined in Appendix 1.2.

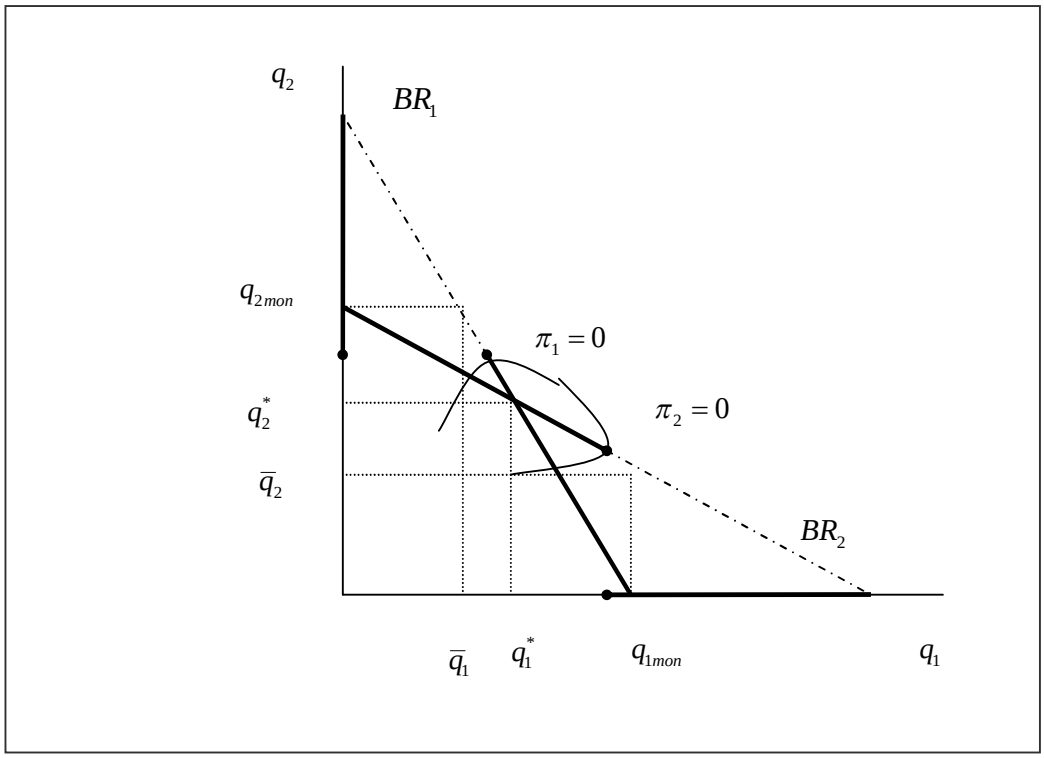
The intuition behind Proposition 1 can be explained diagrammatically. Figure 1 shows the effect that fixed costs have on the standard Cournot best-reply diagram:

Figure 1: Best-replies in the presence of fixed costs



From Figure 1, as fixed costs continue to be increased for both firms the zero profit point along each best-reply curve approaches the Nash equilibrium. There is a critical point at which the effect of increasing fixed costs has a significant effect, this is the output level at which the best-reply to the rival firm producing the monopoly quantity is to produce no output. This critical value for fixed costs is F_1^*. Figure 2 shows the revised best-reply diagram when fixed costs exceed this critical value.

Figure 2: Best-reply diagram for increased fixed costs

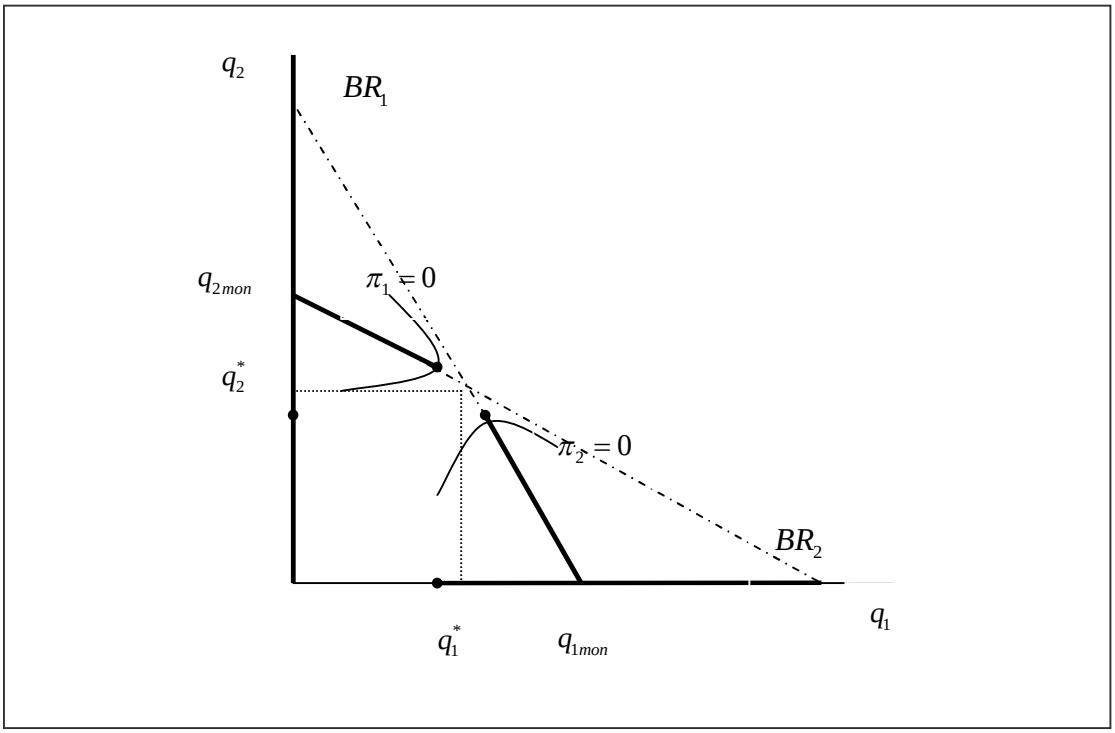


In Figure 2 $\bar{q}_1$ and $\bar{q}_2$ are each firms best-replies to their rival producing the monopoly outcome. The fixed costs are at a high enough level so that these best-reply quantities would result in the firm making a loss, and this firm would therefore prefer to exit the market.[8] By inspection there are therefore three Nash equilibrium to this game; Firm 1 as a monopolist with Firm 2 exiting the market and vice versa, or the Cournot Nash equilibrium outcome described earlier (but with lower profits due to the fixed costs). All three of these Nash equilibria yield non-negative profits for both firms.

We can now analyse the situation in which fixed costs are increased even further so that the Cournot Nash equilibrium is no longer an option because at the relevant quantities both firms make zero profits, as shown in Figure 3.

[8] It is assumed that exit is costless.

Figure 3: Best-reply diagram for a further increase in fixed costs



The critical value for the fixed costs that leads to this outcome as F_2^*. By inspection we can see that if fixed costs exceed this level then there are two pure strategy Nash equilibria, involving one the two firms as a monopolist.

ii) Welfare

Corollary 1: In proposition 1 for the levels of fixed costs where multiple equilibria exist ((ii) and (iii)) consumer surplus is highest at the Cournot equilibrium and is unaffected by the level of fixed costs given that the Cournot outcome remains the equilibrium. The consumer welfare loss which occurs if fixed costs are raised to any level above F_1^* and a monopoly outcome results is the same for all $F_3^* > F \geq F_1*$. If $F \geq F_3^*$ consumer surplus is zero as no firm provides the product (see Appendix 1.3).

4. The Equilibrium Selection Problem and Applications

Section 3 has shown that for $\gamma > 0$ i.e. some action taken by the two firms to increase fixed costs, if fixed costs are within a certain range defined in ii) and iii) in proposition 1, there are multiple Nash equilibria. There are a number of possible

approaches to the equilibrium selection problem, which will now be considered and applied to a number of potential sources for the increase in fixed costs.

One way in which fixed costs could be strategically raised is by using the regulatory process as discussed in the introduction. Many different forms of regulation impose significant costs on firms competing within an industry or firms considering entering an industry. Various examples described in the literature review provide evidence of lobbying for regulation by firms with the suggestion that the aim was to disadvantage rivals or deter potential rivals. An alternative form of raising fixed costs strategy could be the use of a 'nuisance' law suit, which informally can be defined as a law-suit imposed on a rival firm with the aim of disadvantaging them rather than for the claimed infringement for which the case is taken. The following quote suggests an example of a nuisance-suit to disadvantage a rival firm; the Managing Director of HOVIS, on learning that a case against a rival firm for trade-mark infringement had been unsuccessful was alleged to have said:

> 'Well, that will teach them to infringe our trade-mark.'[9]

This quote from Whish (2003) shows that the European Commission recognises the potential for law-suits to be used for strategic purposes:

> 'The Commission acknowledges that undertakings have a fundamental right of access to a judge but considers that a dominant undertaking might be guilty of an abuse where litigation cannot reasonably be considered as an attempt to establish rights but instead serves to harass the other party and where it is conceived in the framework of a plan whose goal is to eliminate competition.'[10]

Whish goes on to suggest that this form of behaviour is particularly likely to be a problem in industries in which intellectual property rights are particularly important, for example the pharmaceutical and bio-technology industries, because in these industries threats of action and action against infringement are often observed. Examples of complaints concerning 'nuisance' law-suits in European cases include

[9] Dawson, N. and Firth, A., (2000), pp. 14.
[10] Whish (2003), pp. 679-80.

the *BBI/Boosey & Hawkes* case where Boosey and Hawkes was alleged to have claimed copyright breaches in the UK and Germany to exclude a new entrant from the market. In a similar fashion in *Promedia v* Commission, Promedia a firm in the Belgium telecommunications industry claimed that Belacom had abused its dominant position by taking legal action at the national level against them.[11] We would expect the cost allocation rules for litigation cases to be an important determinant in the possibility of using 'nuisance' law suits for strategic objectives. In the US all parties pay their own costs whereas generally in the UK the loser of the case must pay all the costs associated.[12] Therefore, given these cost allocation rules we would expect 'nuisance' law-suits to be a more plausible strategy in the US. This may also partly explain the fact that private litigation cases are much more common in the US.

i) Simultaneous production and a possible potentially ambiguous increase in fixed costs

The proceeding analysis will make it clear that for any given firm the potential profitability of a strategy of increasing fixed costs depends on the precise details of the strategies the firms each have. One possibility is that an increase in fixed costs can occur but the source of the increase is not common knowledge. This would be for example a possibly scenario in the case of lobbying for regulation. Any given firm knowing that they did not lobby for regulation themselves may still be unable to attribute any fixed cost increasing regulation to an action by a rival firm or simply government intervention not brought about by lobbying. In addition it will initially be assumed that when Cournot competition takes place the firms production decisions are made simultaneously. These two assumptions lead to Proposition 2.

Proposition 2: When any given firm cannot attribute an increase in fixed costs to an action by a rival firm and output decisions are made simultaneously a strategy to raise fixed costs cannot be profitable (see Appendix 2).

The intuition underlying Proposition 2 is simply that raising fixed costs is only profitable if it allows the firm to monopolize the industry. However, when output

[11] *BBI/Bossey & Hawkes* and *Promedia v Commission* in Jones and Surfin (2001), pp.423. In both cases the complaints were not upheld by the Commission. Suggesting that in some cases complaints of this nature may also be made for strategic reasons.
[12] Bevan, Fenn and Rickman (1998), pp. 9.

levels are determined simultaneously a firm undertaking a strategy to increase fixed costs does not have a chance to monopolize the industry as the outcome in the quantity competition stage will be the Cournot equilibrium.[13]

ii) A first-mover advantage in the product market

In contrast to the above scenario we can now alter the game and give one player a first-mover advantage in the output setting stage. This could for example be an incumbent firm in the industry which can provide its output to the market before the arrival of any potential entrant. In this case the incumbent could lobby for regulation which increases fixed costs. Alternatively an incumbent firm could use a law-suit against a potential entrant for example by claiming patent infringement. Allowing a first-mover advantage in the product market leads to the following proposition:

Proposition 3: An increase in fixed costs such that $F_2^* \geq F \geq F_1^*$ is a profitable strategy for a firm with a first-mover advantage in the product market (see Appendix 3.1).

The intuition is again simple, the first mover advantage means that once fixed costs have been raised this firm can produce the monopoly output which due to the strategic increase in fixed costs for a rival firm the best-reply is to produce no output. In this way therefore, the firm with the first-mover advantage can force a rival firm to exit the market or prevent the entry of a rival.

The preceding analysis has shown that when $\gamma > 0$ the first firm to produce its output can produce the monopoly quantity and effectively foreclose the market. However, it may be that 'mistakes' occur i.e. both firms believe that they are producing first and therefore, both produce the monopoly quantity. Corollary 2 shows the effect this has on consumer surplus.

Corollary 2: If the probability of mistakes occurring is greater that approximately 0.26 then consumer surplus is higher if the required increase in fixed costs takes place (see Appendix 3.2).

[13] In the case where $F \geq F_2^*$, this outcome will involve a war of attrition and therefore other considerations such as 'deep-purses' become important.

This is due to the fact that two firms both producing the monopoly output forces price down to marginal cost and consumer surplus is therefore, higher than at the Cournot equilibrium. If this occurs with a high enough probability compared to the probability of the alternative monopoly outcome consumer welfare increases.

iii) A unilateral fixed costs raising strategy - forward induction

An alternative approach to considering the equilibrium selection problem to the game and assume only one firm, say firm 1 can make the decision as to whether or not to increase industry wide fixed costs. In the context of the regulation to increase fixed costs this could occur because only one firm has access to the regulatory process or in the law-suit example if only one firm has the potential to claim some infringement. Figure's 4 and 5 show the extensive form of this game when the action (γ) raises fixed costs to F_1^* and F_2^* respectively, the pure strategy Nash equilibria are labelled NE and the player's strategies are restricted to possible equilibrium strategies:

Figure 4: The extensive form game of an increase in fixed costs

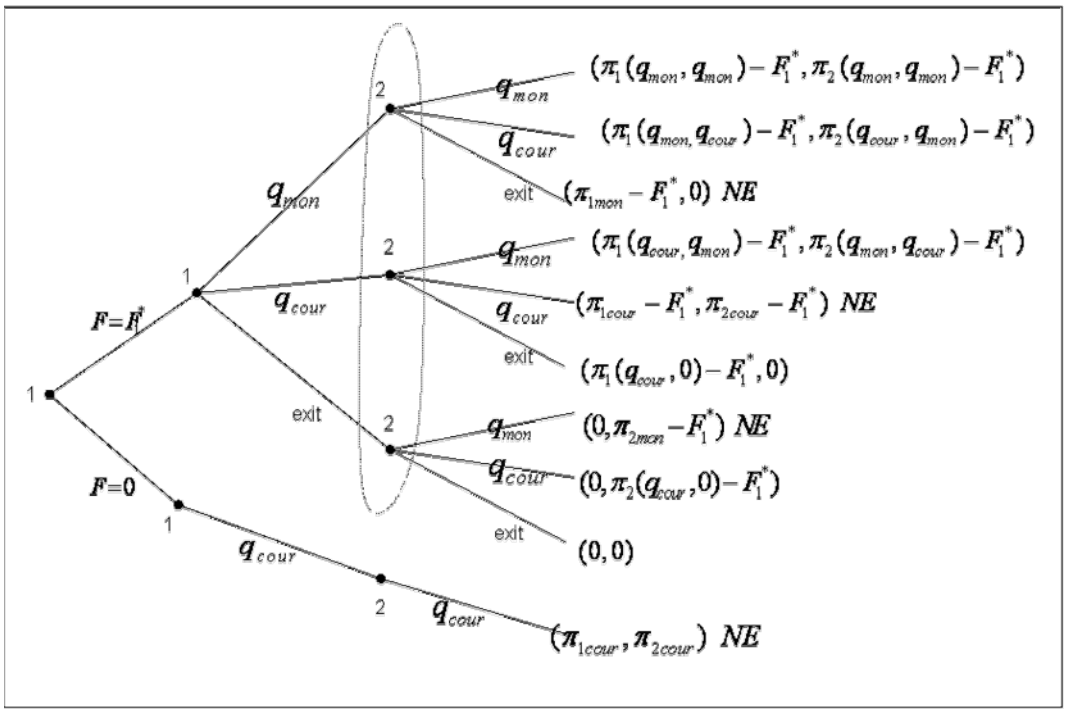
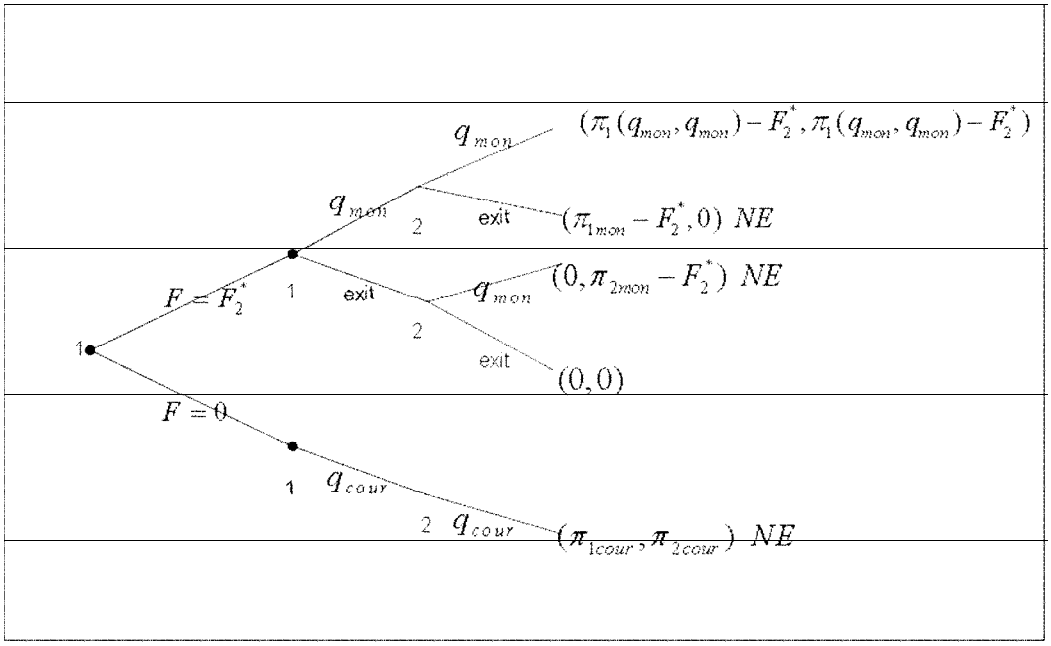


Figure 5: The extensive form game of a further increase in fixed costs



Proposition 4: When $F_3^* > F \geq F_1^*$ and only firm 1 can take the action γ to increase fixed costs, there are two pure strategy Perfect Bayesian Nash Equilibria (PBNE); $\gamma > 0$ $q_1 = q_{mon}$ $q_2 = 0$ and $\gamma = 0$ $q_1 = q_2 = q_{cour}$ (see Appendix 4.1).

The intuition is the same for $F_2^* > F \geq F_1^*$ and $F_3^* > F \geq F_2^*$, firm 2 knows that it is only profitable for firm 1 to increase fixed costs if firm 1 goes on to monopolize the market. The only consistent belief for firm 2 is therefore that once fixed costs have been raised player 1 will produce the monopoly output and therefore firm 2 should exit the industry even when the output decisions are made simultaneously. Alternatively if no action has been taken by firm 1 the equilibrium is simply the Cournot outcome. Proposition 6 however refines the equilibrium selection process further by using the forward induction refinement.

Proposition 5: Using forward induction the unique equilibrium for $F_2^* \geq F \geq F_1^*$ when only firm 1 can take the action γ is $\gamma > 0$ and $q_1 = q_{mon}$ $q_2 = q_{mon}$ (see Appendix 4.2).

Forward induction removes the PBNE with fixed costs at zero because firm 1 can reason forward and knows that if fixed costs are strategically increased the resulting PBNE is more profitable than the outcome which occurs without this strategy.

Propositions 4 and 5 therefore illustrate that an asymmetry in access to the means to strategically increase fixed costs has a substantial impact on the predicted outcome. A firm with the means to strategically increase fixed costs is able to credibly commitment to producing the monopoly output even when output decisions are made simultaneously. This commitment allows the firm to monopolize the market and a raising fixed costs strategy is therefore profitable.

5. Conclusion

The basic model in Section 3 has shown that a strategy of symmetrically raising fixed costs can be profitable. However, in the case where both firms can take some action to raise fixed costs this requires the firm to have either a first-mover advantage in production or alternatively at least a high enough probability of producing first. In contrast if only a single firm has the possibility of taking the action to raise fixed costs then the forward induction argument shows that the firm can credibly commit to monopolizing the industry. The standard raising rivals costs literature as already stated, focuses on variable costs but this paper has shown that a raising fixed costs strategy can in certain scenarios be more applicable. In addition as already discussed it has previously been shown that a raising rival's variable costs strategy generally requires the rival firm(s) costs to increase by more than the costs of the firm using the strategy. However, the strategic behaviour considered in this paper has always assumed the often more plausible setting where the two firms fixed costs are affected equally. The paper analyzed two possible applications for a raising fixed costs strategy; regulation and 'nuisance' law suits. Comparing these two possible applications for raising rivals fixed costs to deter entry the use of regulation would seem to be more likely to succeed in a dynamic setting as it involves increasing a fixed cost that will exist for every period rather than a once only cost. This consequently reduces the profitability of such a strategy but crucially this strategy also prevents future entry attempts without relying on the creation of reputation effects. It is also likely that some of the regulation brought about by lobbying is in fact

beneficial to society.[14] If this is the case then the welfare loss generated by such a strategy may be less than in the law-suit example.[15]

The main policy implications from the paper are firstly that as suggested by the OFT (2002) regulation can have an adverse effect on competition in certain scenarios and therefore that policy makers should consider this impact on the industry. In addition the fact that 'nuisance' law-suits may be used for strategic purposes suggests that caution should be taken in advancing the private enforcement of competition policy. Courts should be aware of the use of legal proceedings in this manner and as much as possible the burden of proof should fall on the firm making the claims of infringement by their rivals. Importantly the cost-allocation rules for litigation cases in the UK appear to be structured to reduce the possibility of strategic 'nuisance' law-suits and this may have important implications for the different cost-allocation rules used in other countries such as the US.

Finally, this paper has focused on the strategic increase in fixed costs to deter entry or force a rival to exit the industry. There are however, at least two possible alternative motives for a raising fixed costs strategy which are worth noting and may provide avenues for further research. One alternative rationale for such a strategy is suggested in Durham et al (2004). If at least part of the fixed costs is, a sunk fixed cost then firms may prefer to stay in the industry and make losses rather than immediately exit the industry. A change in industry conduct i.e. a more towards more collusive behaviour however, would potentially allow all firms to continue to make positive profits, thus leading to an inefficient number of firms to compete in the industry. Therefore, the motive for raising industry wide fixed costs could be to change conduct in the industry rather than to attempt to force a rival to exit the industry. This is similar to the idea in Mason (2002), mentioned above, where a symmetric increase in marginal costs reduces competition. An experiment conducted by Durham et al using a double-auction experiment in a Bertrand setting, found some evidence that when large fixed costs were present, price signalling behaviour took place to attempt to reduce competition, enabling firms to maintain profitable. A similar motive is provided by the 'failing firm' defence to mergers. Increasing fixed

[14] i.e. some proportion of the increase in the fixed costs should be included in total welfare because of the benefits the regulation brings such as regulation that improves safety standards.
[15] Assuming the law-suit method is also successful in deterring future entry.

costs such that one or both of the firms involved in a merger is not profitable may encourage leniency to the merger from the competition authorities.

Appendix

Appendix 1.1

Proof that:

$BR_i(q_j) = 0 \ \ iff \ q_j \geq \left((a-c)/b\right) - \sqrt{4F}$

$BR_i(q_j) = \left((a-c)/2b\right) - \left(q_j/2\right) \ \ iff \ q_j < \left((a-c)/b\right) - \sqrt{4F}$

For the standard Cournot game described in Section 3 i) the best-reply function for *firm i* is given by:

$$BR_i(q_j) = ((a-c)/2b) - (q_j/2) \qquad (6)$$

It is then possible to solve for *firm i's* profits for a best-reply to any output by firm j:

$$\pi_i(BR_i(q_j), q_j) = (a - bq_j - bq_i)q_i - F \qquad (7)$$

Substituting (6) into (7):

$$\pi_i(BR_i(q_j), q_j) = \left[a - bq_j - b\left(((a-c)/2b) - q_j/2\right)\right]\left(((a-c)/2b) - q_j/2\right) - F \qquad (8)$$

Rearranging this expression gives:

$$\pi_i(BR_i(q_j), q_j) = (a - c - bq_j) - \sqrt{4F} \qquad (8.1)$$

Therefore;

$$\pi_i(BR_i(q_j), q_j) > 0 \ \ iff \ \ (a - c - bq_j) > \sqrt{4F} \qquad (9)$$

Firm i therefore produces $BR_i(q_j) \ \ iff \ \ (a - c - bq_j) > \sqrt{4F}$

Rearranging (9) and combing this with equation (6) gives equation (5.1).

Otherwise *firm i* produces zero output, which gives equation (5).

Appendix 1.2

Proof of Proposition 1:

At F_1* the level of fixed costs are sufficiently high such that the best-reply for *firm i* to *firm j* producing the monopoly output results in non-positive profit.

First of all solving for the monopoly price and output:

$$q_{mon} = (a-c)/2b \quad (10)$$

$$p_{mon} = (a+c)/2 \quad (11)$$

Using equation (6):

$$BR_i(q_j) = ((a-c)/2b) - (q_j/2)$$

Substituting in for $q_j = q_{mon}$:

$$BR_i(q_{mon}) = (a-c)/4b \quad (12)$$

The resulting price is therefore:

$$p(q_{mon}, BR_j(q_{mon})) = (a+3c)/4 \quad (13)$$

This leads to the following profit for *firm i*:

$$\pi_i = (a-c)^2/16b \equiv F_1^* \quad (14)$$

When fixed costs are at F_2^* profits at the Cournot outcome are zero.

Solving for the price, quantity and profit levels to the Cournot game yields:

$$q_{cour} = (a-c)/3b \quad (15)$$

$$p_{cour} = (a+2c)/3 \quad (16)$$

$$\pi_{cour} = (a-c)^2/9b \equiv F_2^* \quad (17)$$

When fixed costs are at F_3^* a monopolist makes zero profits, using (10) and (11):

$$\pi_{mon} = (a-c)^2/4b \equiv F_3^* \quad (18)$$

Appendix 1.3

Proof of Corollary 1:

From (15) and (16) consumer surplus at the Cournot equilibrium is:

$$CS_{cour} = \left[\left(a - ((a+2c)/3)\right)\left(2(a-c)/3b\right)\right]/2 \; = 2(a-c)^2/9b \quad (19)$$

This level of consumer surplus at the Cournot equilibrium is unchanged regardless of the level of fixed costs as long as there are two firms in the market.

However, as Proposition 1 shows if fixed costs are such that $F_1^* \leq F < F_3^*$ a monopoly outcome becomes possible in equilibrium. If a monopoly outcome occurs the resulting consumer surplus, using (10) and (11) is given by:

$$CS_{mon} = \left[\left(a-(a+c)/2\right)\left((a-c)/2b\right)\right]/2 \ = (a-c)^2/8b \qquad (20)$$

Again the level of consumer surplus is independent of the level of fixed costs as long as only a single firm exists in equilibrium.

Comparing (18) and (19) clearly the consumer surplus at the Cournot outcome is always higher than at the monopoly outcome i.e.:

$$2(a-c)^2/9b > (a-c)^2/8b \qquad (21)$$

If $F \geq F_3^*$ no firm produces an output as it is not profitable to do so. Therefore;

$$CS = 0 \qquad (22)$$

Appendix 2

Proof of Proposition 2:

Consider an increase in fixed costs to $F \geq F_1^*$ because this increase cannot be attributed to the action of a particular firm it does not act as a commitment to a given output in the product market. In addition because output decisions are then made simultaneously each firm expects the other firm to produce the Cournot output and thus produces the best-reply to this, i.e. the Cournot output.

The profit for *firm i* if fixed costs are raised to $F > F_1^*$ are thus:

$$\pi_{cour} - F \qquad (23)$$

Assuming if *firm i* does not strategically increase fixed costs $F = 0$, *firm i's* profits are:

$$\pi_{cour} \qquad (24)$$

Clearly;

$$\pi_{cour} > \pi_{cour} - F \qquad (25)$$

Therefore, a strategy to increase fixed costs to $F > F_1^*$ is not profitable.

Appendix 3.1

Proof of Proposition 3:

Assume without loss of generality that *firm i* has a first-mover advantage in the product market, this means that if $F_1^* \leq F < F_3^*$ *firm i* can potentially monopolize the market. This is a profitable strategy for *firm i iff:*

$$\pi_{mon} - F > \pi(q_{mon}, BR_j(q_{mon})) \quad (26)$$

Using (14) to define F_1^* and (18):

$$\pi_{mon} - F_1^* = 3(a-c)^2/16b \quad (27)$$

From (6) and (10):

$$\pi(q_{mon}, BR_j(q_{mon})) = (a-c)^2/8b \quad (28)$$

Clearly (27) is greater than (28) and therefore increasing fixed costs to F_1^* is a profitable strategy for *firm i.*

Similarly, if $F = F_2^*$, using (17) and (18):

$$\pi_{mon} - F_2^* = 5(a-c)^2/36b \quad (29)$$

Comparing (29) with (28) shows that increasing fixed costs to F_2^* is a profitable strategy for *firm i* as (29)> (28). Clearly the same argument holds for $F_1^* < F < F_2^*$. The same argument can also be applied for some values of fixed costs such that $F_2^* < F < F_3^*$. However not for all $F_2^* < F < F_3^*$ because when $F = F_3^*$ $\pi_{mon} = 0$ so for some $F_2^* < F < F_3^*$:

$$\pi_{mon} - F_2^* = \pi(q_{mon}, BR_j(q_{mon})) \quad (30)$$

Appendix 3.2

If both firms produce the monopoly output simultaneously, using (10) and (1):

$$p(q_{mon}, q_{mon}) = a - b\left(2(a-c)/2b\right) = c \quad (31)$$

Therefore from (31) and (10);

$$\pi(q_{mon}, q_{mon}) = (c-c)q_{mon} - F = -F \quad (32)$$

Given these output decisions consumer surplus is;

$$CS_{p=c} = (a-c)^2/2b \quad (33)$$

Define δ as the probability that 'mistakes' occur.

Consumer surplus is higher *iff* δ is sufficiently high such that:

$$\delta(CS_{p=c}) + (1-\delta)CS_{mon} > CS_{cour} \quad (34)$$

Therefore using (19), (20) and (33);

$$\delta((a-c)^2/2b)+(1-\delta)((a-c)^2/8b)>2(a-c)^2/9b \quad (35)$$

Solving for δ:

$$\delta > 0.26 \quad (36)$$

Appendix 4.1

Assume *firm 1* takes the action which raises fixed costs.

If $F_1^* \le F < F_3^*$ assume *firm 1* is restricted to only the 3 possible strategies for which a Nash equilibria is possible; q_{mon}, q_{cour} and *exit*. However, it is then trivial to rule out the strategy *exit* as it is strictly dominated by the strategy of not raising fixed costs and producing the Cournot equilibrium quantity (exiting the industry yields zero profits compared to the positive profits at the Cournot equilibrium with no fixed costs).

Once it has raised fixed costs *firm 1* therefore has 2 possible strategies; q_{mon} and q_{cour}. Attach a probability μ to firm 1 producing the monopoly output, this means that *firm 1* exits the industry with probability $(1-\mu)$. In addition restrict *firm 1* to *pure* strategies i.e.:

$$\mu \in (0,1) \quad (37)$$

Firm 2 has 3 possible strategies q_{mon}, q_{cour} and *exit*.

Now consider *firm 2's* payoff from each strategy conditional on μ:

If $\mu = 1$:

$$exit: \ 0 \quad (38)$$

$$q_{cour}: \ \pi_2(q_{cour}, q_{mon}) - F \quad (39)$$

$$q_{mon}: \ \pi_2(q_{mon}, q_{mon}) - F = -F \quad (40)$$

From (32):

$$\pi_2(q_{mon}, q_{mon}) - F = -F$$

Using (10) and (15):

$$\pi_2(q_{cour}, q_{mon}) - F = (a-c)^2/18b - F \quad (41)$$

Using (14) it can be shown that:

$$\pi_2(q_{cour}, q_{mon}) - F < 0 \text{ for all } F \ge F_1^* \quad (42)$$

As (38) is greater than (42) and (40) the optimal strategy for *firm 2* given $\mu = 1$ is to exit the industry.

If $\mu = 0$:

$$exit: 0 \tag{43}$$

$$q_{cour}: \pi_2(q_{cour}, q_{cour}) - F \tag{44}$$

$$q_{mon}: \pi_2(q_{mon}, q_{cour}) - F \tag{45}$$

Given (6) and (15):

$$\pi_2(q_{cour}, q_{cour}) - F > \pi_2(q_{mon}, q_{cour}) - F \text{ for all } F \tag{46}$$

Using (17) and (18):

$$\pi_2(q_{cour}, q_{cour}) - F > 0 \text{ for } F^*_1 \le F < F_2^* \tag{47}$$

$$\pi_2(q_{cour}, q_{cour}) - F < 0 \text{ for } F_2^* < F < F_3^* \tag{48}$$

The optimal strategy for *firm 2 given* $\mu = 0$ is therefore to produce q_{cour} if $F^*_1 \le F < F_2^*$ and *exit* if $F^*_2 \le F < F_3^*$.

Now consider *firm 1's* payoffs conditional on μ given *firm 2's* optimal strategies:

$$\mu = 1: \pi_{mon} - F \tag{49}$$

$$\mu = 0: \pi_{cour} - F \text{ if } F^*_1 \le F < F_2^* \text{ or } \pi(q_{cour,} 0) \text{ if } F_2^* < F \le F_3^* \tag{50}$$

From (17) and (18):

$$\pi_{mon} - F > \pi_{cour} - F$$

Given (10) and (6):

$$\pi_{mon} - F > \pi(q_{cour}, 0) - F \tag{51}$$

Therefore, *firm 1* raising fixed costs and producing the monopoly output is a Sub-game Perfect Nash Equilibrium. In contrast *firm 1* raising fixed costs and exiting the industry or producing the Cournot output are not Sub-game Perfect Nash Equilibria.

In addition when fixed costs are not raised the Cournot equilibrium is a Sub-game Perfect Nash Equilibrium.

Appendix 4.2

Proof of Proposition 5:

Using forward induction when considering whether to raise fixed costs *firm 1* can compare the payoffs from the two outcomes:

For all $F_1^* \leq F < F_3^*$ as shown in Appendix 4.1 *firm 1's* payoffs are:

Raise fixed-costs: $\pi_{mon} - F$ (52)

Not raise fixed costs: π_{cour} (53)

For $F^*_1 \leq F < F_2^*$ using (14) and (17):

$$\pi_{mon} - F > \pi_{cour} \quad (54)$$

Therefore it is more profitable for *firm 1* to raise fixed costs.

This forward induction refinement can also be used for some levels of fixed costs such that $F_2^* \leq F < F_3^*$. However, once fixed costs are sufficiently high the Cournot outcome with no fixed costs yields higher profits.

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