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IMPEDIMENTS TO TRADE IN MARKETS FOR POLLUTION PERMITS

by

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ABSTRACT

This paper considers nine possible reasons why firms might trade less often in permit markets than was expected in the early development, and consequent simulations, of the theory. Fewer trades are bad in the sense that they lead to a potential erosion of the cost-saving properties of tradeable permit systems. The first reason considered is one which has popular currency, namely that of imperfect competition in the permit market. However, we reject this as a convincing explanation. The paper then reviews eight other possible explanations; these are oligopoly in the output market; future endowments of property rights; loss aversion; asymmetric information; non-convexities in cost functions; agency problems within the firm; transactions costs; and the sequential nature of trading.

INTRODUCTION

This paper considers a variety of possible reasons why firms might fail to reap the apparent gains available from the trade of pollution permits. If opportunities for cost-saving trades are foregone, then the claim that tradeable permits are least cost means of reducing pollution (Montgomery, 1972) is violated. Permits may offer cost-savings on design and performance standard-based systems, but smaller cost-savings than were forecast in early simulation studies (for a review, see Tietenberg, 1987). This paper makes use of the results of discussions with managers of factories which are major point sources of Biological Oxygen Demand (a measure of the polluting potential of biodegradeable liquid wastes) in the Forth Estuary, Scotland, on their views of the major impediments to trade. Apart from providing a survey of the contending explanations, the paper has one other purpose: to rule out one theory which, though popular as a reason for the scarcity of trade in actual permit markets, nevertheless seems fatally flawed to us.

POSSIBLE THEORIES.

We begin by listing the explanations before discussing each in greater detail[1],

1. Market power in the permit market.
2. Oligopoly in the output market.
3. Future endowments of property rights.
4. Loss Aversion.
5. Asymmetric information.
6. Non-convexities in cost functions.
7. Agency problems within the firm.

8. Transaction costs.

9. The sequential nature of trade.

I. Market Power in the Permit Market.

In its simplest form this theory argues that, because there are only a few sellers involved, sellers will use their market power to reduce the supply of permits on the market and raise their selling price. If there is only one seller, that price will at the monopoly level. Similarly, with few buyers, oligopsony - or its extreme form, monopsony- will lower the price paid for permits. In either case the number of trades falls below the competitive equilibrium tally. With a little hand-waving this 'small' number of trades may be reduced to zero. This explanantion for a reduction in the cost-savings associated with a permit market has been advanced by several authors (eg Hahn, 1984; Maloney and Yandle, 1984).

This argument is, however, flawed. The monopolist which sets a constant price for all units sold only does so because it cannot successfully price discriminate or, more fundamentally, because the costs of organising price discrimination outweigh the gross profits achieved. For most monopolists, selling a small number of units to millions of individual consumers, the constraint on perfect price discrimination is created by the costs which would be involved in retailing each unit separately. With a small number of potential buyers, each purchasing a sizeable fraction of the units sold (which is normally the case in a permit market) organisational costs are greatly diminished. Indeed it is precisely under these conditions that Pareto efficiency via individual bargaining, in the manner of the Coase theorem, is most likely to be achieved.

Price discrimination is still problematic if either a) the good is storable or b) the second-hand market for it is liquid. Storability undermines the feasibility of second-degree price discrimination, but not first degree discrimination where the seller knows the identity of the buyer. However, the second-hand market is more problematic for the monopoly permit seller. Suppose a firm faces two buyers. It deals with one first and sells it permits, then, when it negotiates with the second firm, it is in competition with the first firm which may wish to sell on its permit[2]. Note though that arbitrage of this form does not necessarily reduce trade, although it may reduce the monopolist's gains from trade. Furthermore, by leasing permits, rather than selling, the monopolist may inhibit this form of behaviour.

The fundamental point here is that in the absence of transaction costs, having few firms involved in trade makes it easier to achieve Pareto efficient outcomes - there is no reason why all trades should occur at one particular price and because of this, there is a greater likelihood that gains from trade will be achieved. Monopoly or monopsony is only a potential source of inefficiency when the numbers of agents on the other side of the market makes price discrimination impracticable, and that is not the case in most permit markets.

2. Oligopoly in the Output Market.

Oligopoly in the output market and oligopoly in the permit market may be associated, but it is possible for two firms to face one another in a concentrated output market, yet form part of a large and competitive market for permits. With oligopoly in the output market there are two possible reasons why a firm's price for selling a permit may depart from the shadow value. First, if the firm buying the permit is in the same oligopolistic industry, then the seller may require compensation for the loss of profits created by the raised output of its competitor.

Additionally if there are returns to scale the permit may represent the difference between profit and loss (and therefore exit) for the buyer. This latter possibility is taken up under the issue of non-convexities (section 5).

The basic cost-minimizing properties of tradeable permits may remain however if returns to scale are constant or decreasing. This claim may seem surprising, given that it is often argued that oligopoly may be a reason for failure to make cost reducing trades, but we have to make a distinction between those inefficiencies which arise because of oligopoly and those which may or may not arise via the use of permits. In the standard competitive industry model of permits the cost minimization properties of the system arise through two separate stages:

(i). For any given vector of outputs, it can be shown that a competitive market for permits (and other factors) will lead to the least cost solution for that vector.

(ii). If output is homogeneous across all the firms, then a competitive output market will lead to a vector of outputs which is the least cost means of producing total output. Marginal cost will therefore be the same across all firms producing at equilibrium.

In oligopoly, however, (ii) will not usually hold (unless all firms are identical) because some firms will have lower marginal costs than others. This is one reason why oligopoly is inefficient (the other being that price is higher than marginal cost). Presumably firms would rearrange production amongst themselves if they could. All could gain from the coordination of production. The fact that such coordination is not often observed must be because they are constrained in some way - by the threat of anti-trust action. It follows that we cannot 'blame' oligopoly if a market in tradeable permits fails to lead to cost minimization as in (ii), since the source of that failure is the constraints placed upon the firms for other reasons[3]. Thus only if (i) fails to hold can we claim that permit markets do not lead to the least cost solution for oligopoly.

The conditions when (i) will occur can be explored using a simple model. Let $f^k(x^k,s^k)$ be the production function for the kth firm (k=1,...,m), using an input vector x^k and producing waste emissions s^k. Let w be the vector of input prices, y a vector of outputs and s^* the total emissions target (for simplicity we concentrate on the case where the damage constraint can be formulated in this way), then the minimum cost of producing the vector y subject to the constraint is found by maximizing:

$$L = -\sum_k wx^k + \sum_k \lambda^k(f^k - y^k) + \gamma(s^* - \sum_k s^k) \qquad (1)$$

Where the y^ks are the individual firm output levels and λ^ks and γ are Lagrangean multipliers associated with the constraints. The first order conditions are:

$$\begin{aligned} -w_j + \lambda^k f_j^k &= 0 \quad j=1,...,n;\ k=1,...,m \\ -\gamma + \lambda^k f_s^k &= 0 \quad k=1,...,m. \end{aligned} \qquad (2)$$

Where w_j (j=1,..n) is the price of the jth input, f_j^k is its marginal product at the kth firm and f_s^k is the marginal product of an extra unit of emissions. If the technology is convex then the first order conditions are necessary and sufficient for the minimization. Thus the crucial requirement for efficiency is that:

$$\frac{w_j f_s^k}{f_j^k} = \gamma \qquad j=1,...,n; \quad k=1,...,m. \tag{3}$$

If the price of an extra unit of emissions is equal to the left hand side of (3) we have cost efficiency.

Now consider a Cournot oligopoly with a homogeneous product. Let P be the inverse demand function and P' its first derivative, then profit maximizing yields:

$$Pf_j^k - w_j + f^k P' f_j^k = 0 \qquad j=1,...,n; \quad k=1,...,m. \tag{4}$$

The maximum amount a firm will be willing to pay for a permit is equal to the extra profits this creates. That is:

$$\sum_j \frac{dx_j^k}{ds}\left[Pf_j^k - w_j\right] + f^k P' \sum_j \frac{dx_j^k}{ds} f_j^k + [P + f^k P'] f_s^k \tag{5}$$

Or, using (4):

$$[P + f^k P'] f_s^k \tag{6}$$

This is simply the marginal product of a rise in emissions multiplied by marginal revenue - i.e. the marginal revenue product. In the market for permits the gains from trade will be exhausted if the price firms are willing to pay for a permit lies below all the reservation prices for firms selling. Given sufficient differentiability of the production and demand functions, the buying and selling prices will be the same for each firm. If we use (4) again we get the price each firm is willing to pay/accept if all gains from trade are exhausted[4]:

$$\frac{w_j f_s^k}{f_j^k} = \gamma \qquad j=1,\ldots,n; \quad k=1,\ldots,m. \tag{7}$$

In other words, exactly the condition required for cost efficiency. Thus oligopoly itself does not destroy the desirability for cost minimization for firms.

One objection to this argument lies in the conjectures the firm makes when engaging in trade. In the Cournot model, the firm conjectures that a change in output will have no effect on its rivals' production levels. However, when it sells a permit to another firm, it has to make a conjecture about how the rival's output will alter as a result and how, consequently, the price of the good will change. If the buying firm is i, then the additional change to firm k's profits is:

$$f^k P' \left(\sum_j \frac{dx_j^i}{ds} f_j^i + f_s^i \right) \tag{8}$$

The bracketed term represents the change in firm i's output from the acquisition of another permit. If this is positive the firm selling a permit will require a higher price for its permit than it would if it were selling to a firm operating in another market. However the firm acquiring the permit will also be willing to pay more if the firm selling the permit will cut back its output as a result and produces output for the same market. Under these circumstances therefore the firms' reservation prices are dependent on the identity of those they are trading with. More pertinently, there is no guarantee that, when the gains from trade are exhausted, cost minimization results. Of course if the firms have a Cournot-style conjecture that no change in their rival's output will result from the sale of the permit, or if the cross effects on profits are the same for all firms (which will occur if all firms are identical) then (7) will still hold at the point where gains from trade are exhausted.

A third and perhaps more interesting case where cost minimization (in the sense of (i)) will result occurs when some firms in the permit market are not members of the oligopoly - that is they produce a different product. Trade with and between these firms will be governed by (7), thus these firms can act as arbitrageurs, provided that in selling or buying from them, the oligopolistic firms do not see through the veil and conjecture about the original source or destination of their permits[5].

In summary therefore, oligopoly in the output market need not lead to a reduction in trade. If exit is not a possibility, and Cournot conjectures hold, the fewness of firms need not limit trade between firms.

3. Future Consequences of Permit Sales.

As part of this study, interviews were conducted with environmental managers of firms which are major point sources of BOD on the Forth Estuary, Scotland. One of the purposes of these interviews was to see what the managers themselves saw as impediments to trade in a possible future market in tradeable permits. A result which emerged quite clearly in the course of the discussions was that uncertainty over future property rights in permits was seen as a major barrier to trading. If selling or leasing a permit was likely to lead to a reduced allocation from the regulator to the firm in the future, then firms were less likely to be interested in the sale (firms were told that any future permit market would be based on grandfathering rather than auctions).

To understand this in theoretical terms, suppose the discount rate for a emitter is ρ and the opportunity cost for a firm is c per unit of time. The firm is offered a deal where it leases out a permit at a price p per unit of time for x years. When should it accept? If it does not, it makes $c/(1-\rho)$. If it leases the permit out then its reward is:

$$p + p\rho + ... + p\rho^{x-1} + c\rho^{x} + ... \quad (9)$$

Its net gain is therefore:

$$(p - c)\left(\frac{1 - \rho^{x}}{1-\rho}\right) \quad (10)$$

The firm should sell the permit if the price offered is above its opportunity cost. However, suppose that x is the lifetime of the initial permit system and there is a probability q that the firm will lose the ownership of the permit if it has leased it from someone else. Profits from the lease are now:

$$p\left(\frac{1-\rho^{x}}{1-\rho}\right) + (1-q)(c\rho^{x} + c\rho^{x+1} ...) \quad (11)$$

Thus the firm should be willing to sell provided

$$(p-c)(1-\rho^{x}) - qc\rho^{x} \geq 0 \quad (12)$$

Or,

$$p \geq c + \frac{qc}{1-\rho^x} \qquad (13)$$

As an example, if x is five years, ρ is 0.9 (so that time is discounted by around 10% per annum) and the probability of losing the permit is just 0.1, then the reservation price will be approximately 25% above the true opportunity cost, while a three year deal would require a 37% mark up in order to persuade the firm to release the permit.

At first sight this seems a strong argument, but note that the buying firm will face the same inflation of its maximum price provided it attaches the same probability q to acquiring the permit. If both firms are risk neutral and were willing to deal[6] in the absence of uncertainty over the future home of the permit, then gains from trade still exist when q > 0. Thus in order for uncertainty of this kind to affect the potential for trade we require either a) risk aversion on the part of one or both players or b) the sum of the buying firm's probability that it will acquire future property rights over the permit and the selling firm's probability that it will still have property rights in the future must be less than the probability that the selling firm will still have the property rights in the future if it does not sell. This might be reasonable when both firms attach some non-zero probability to the situation that either (i) the permit will disappear for good or (ii) there is some chance that it will go back into the general pool of permits and not automatically be allocated to the firm which rented it (and that this probability is increased if the permit is traded).

4. Loss Aversion.

An alternative explanation for the gap between willingness to pay to acquire a permit and the minimum compensation required to offset its loss is the concept of 'loss aversion' - a term used by Tversky & Kahneman (1991) to describe the increasingly well-documented phenomenon of the divergence between individuals' willingness to pay to acquire an object and their willingness to accept compensation for its loss. Some attempts have been made to explain this phenomenon as it arises in the contingent valuation method (cvm) in terms of the elasticity of substitution and income effects, (Hahneman (1991), Randall & Stoll (1980)). However, such explanations require the existence of income effects much larger than those actually discovered in cvm. More fundamentally, the divergence remains even when income effects have been allowed for[7].

Tversky & Kahneman (1991) call the phenomenon 'loss aversion' because agents seem to place a higher value on a change in their consumption bundle when it represents a loss than when it is a gain. To the extent that loss aversion occurs in managers, then those selling will place a higher reservation price on the permit than if they were buying and this will therefore reduce trade (a point also made by Knetsch, 1989b). Such behaviour by individuals would not be in the interests of the firms themselves, so should rightly be classified as a form of the agency problem discussed under heading seven.

5. Asymmetric Information.

Because firms can always renegotiate deals if an initial offer is refused, asymmetric information over the reservation price of the opponent firm cannot, in itself, be a reason for a lack of trade as long as there are potential gains from trade. I can attempt to bluff my opponent by asking for a high price for my permit. If they refuse to accept the deal, I can always suggest a lower price and while I might wait a short while before dropping the price, it appears foolhardy for me to wait out the entire lifetime of the permit, unless there is the possibility of repeated interaction with my opponent.

Consider a simple game[8] where the seller has a reservation price of c_1 (low) with probability q and c_2 (high) with probability (1-q). A buyer makes a sequence of offers p_1, p_2 ..., which the seller can either accept or reject. In between each offer, some time must elapse and the discount rate for both firms is ρ. Suppose for simplicity that the buyer will only make two offers before moving on. Clearly a high cost seller will accept anything over c_2. A low cost seller may want to pretend to be high cost in order to get a better price. It may therefore reject initial offers that it would actually profit from. It will only do this if waiting for the second offer is more (or equally) rewarding. However the buyer will offer $p_2 = c_1$ if

$$q^2(v-c_1) \geq v-c_2 \tag{14}$$

where q^2 is its belief about the nature of its opponent in the second time period, given behaviour in the previous period. Thus if q is greater than the critical value of q^2 implied by (14), then the low cost firm must accept a proportion of the offers made in the first round in order (via Bayes' theorem) to reduce q. It follows that, since it pursues a mixed strategy, it must be indifferent between its payoffs between the two time periods:

$$(p_1-c_1) = \rho(p_2-c_1) = \rho(c_2-c_1) \tag{15}$$

Thus,

$$p_1 = \rho c_2 + (1-\rho)c_1 \qquad (16).$$

So, although the price in the first period is above the reservation price for the low cost seller, nevertheless the low cost firm accepts only with probability π (which is derived by finding the value of π such that q^2 falls below the critical value in the second period of bargaining).

The point of this can be seen when we consider future negotiations, once the initial lease has expired or a new round of permits have been allocated to the firms. Suppose that there is no further time discounting to consider, that the expected revenue for the low cost firm in the first round of negotiations is R(q), and that there will be no further allocations of permits then the expected revenue of the low cost seller in the second round of negotiations will be, $\pi c_1 + (1-\pi)R(q^2)$. The first term appears because, in some cases, the buyer will know for sure that the seller is low cost and hence need only offer the seller's true reservation price. Thus, by accepting sometimes in the first period of the first negotiations, the firm lowers its revenue later on. It follows that when the relationship between the bargainers is likely to be repeated many times, the firm will be less willing to make a deal that reveals its true costs early on and this reduces the scope for trade.

In summary, as was the case in the previous section, this argument does not imply that no trades will ever occur. On the other hand if the reservation price for the high cost firm is above the maximum the buyer is willing to pay then there may be periods during which no trade occurs.

5. Non-Convexities.

There are two types of non-convexities. The first involves firms' abatement cost functions, since it may be that the larger the number of permits the firm needs to purchase to meet target levels of emissions, the greater the costs involved in buying up permits. Secondly, and this seems more relevant when the firms involved in the permit market also face one another in the output market, there is the question of whether to produce at all. If two duopolists, facing each other in a homogeneous product market, exchange permits and profit functions are strictly quasi-concave in output, then the standard marginal analysis holds true: one firm will sell to the other provided its marginal cost of abatement is lower than the other firm's. However, if, as would usually be the case, there are fixed costs, or more generally, increasing returns, then failure for the buying firm to capture an extra permit may mean exit and thus greatly increased profits for the remaining firm. Of course we might then suppose that the buying firm will be willing to pay extra to avoid exit, but note that since total output in a Cournot duopoly is greater than under monopoly, total profits are lower also. The firm going bankrupt will not therefore be able to successfully bribe the other firm to hand over a permit.

It is not clear that this is the whole answer, since it would matter whether the permits were returned to the pool upon exit or if the firm leaving could auction them off. One interesting comparison may be with the cartels which operated in pre-war British coal mining (see Vickers and Yarrow (1988)). The cartels formed during a period of declining demand for British coal. Despite the wide dispersion in cost structures, there was an absence of efficient trades in the right to produce coal. High cost firms did not cease production as might have been expected, perhaps because they would have then lost their only valuable assets: the rights over production.

To conclude: the possibility of forcing the exit of a rival could be a strong motive for withholding the sale of a permit. However, interviews with the Forth Estuary managers suggested a high degree of cooperation with apparent competitors. When asked if they would charge a premium on the sale of a permit to an output market rival, all firms stated that they would not. In fact one firm argued that it would offer a lower price to its rivals, since the companies were in the habit of smoothing production by buying and selling output from one another to meet fluctuations in demand. Lowering the price would support the policy of being 'good neighbours'.

6. Principal Agent Problems.

One of the interesting features of the Forth Estuary study is the way firms did not seem to consider output reductions as a response to emissions restrictions. This is contrary to most simple economic treatments of the problem and merits examination. It could be that the division of responsibilities within large firms makes the control of pollution and the level of output two totally separate areas of decision-making. Theoretically, of course, this increases the advantages of permits, since (according to the Le Chatelier principle) if output is fixed, cost functions will be more concave in emission control activities. However it may mean that the groups who control emissions have little to gain from the buying and selling of permits. For instance, suppose that it is engineers who are in charge of emissions and they like large capital budgets and technical challenges, but receive no direct benefits from any contribution which they make to the profits of the firm. It may therefore be cheaper for the firm to buy permits rather than installing a new pollution control system, but it may nevertheless pursue the latter course because of the goals of its managers.

7. Transaction Costs.

To be useful as a potential argument, this has be more specific because otherwise transaction costs are a potential 'deus ex machina'. It seems reasonable to us to make two suppositions about the nature of transaction costs in a permit market:

A. Transaction costs are increasing in the number of firms that have to be party to any particular deal.

B. Transaction costs are increasing for a firm, the larger the number of potential partners it has to contact to set up a deal.

The crucial issue is whether thin markets are better than thick. In markets with few traders each player can consider all possible trades quickly. Moreover, each firm is more likely to have a clearer picture of its rivals' abatement costs. Against this are two arguments: first, with a large number of traders the fixed costs of setting up a formal market may have been overcome. Once the market has been created, perhaps with brokers or a specialist trading centre, then the costs of searching out a deal may be reduced.

Secondly there is an argument which is hard to formalise. In order to meet pollution constraints at a number of measurement sites, a firm may have to buy a number of different permits in order to increase (or not decrease) its emissions. Typically this might mean dealing with several different firms, with the acquired permits valueless unless all the trades are made. Multilateral bargaining in this way is therefore risky for the firm attempting to relax the constraint on its emissions. Moreover, while bargaining with two parties is common, instances of two, three or more sides to a deal are much rarer, suggesting that there are major costs involved[9]. These costs may mean that three sided deals are not considered, and that firms are forced to accept inferior two party deals or even abandon the notion of trade altogether.

However, as the number of firms operating in the permit market rises then the chances of making an ideal match with one single firm might rise. An example will suggest how this might occur. Suppose that there are three types of firms involved. Firm A wishes to acquire rights to emit; firms B and C are potential sellers. Any trade must meet pollution constraints at two sites, x and y. A permit bought from B will enable the firm to raise pollution by 0.5 units at site x and so on (see Table One below). The reservation price for the selling firms is a random variable which can take on the values 1 or 1.5 with equal probability.

Table 1 Permitted discharges by three firms at two sites

Firm	Pollutant at site x per unit emitted	Pollutant at site y per unit emitted
A	2	1
B	0.5	0
C	0.5	0.5

Firm A can either deal with B and C, buying 2 units off each, or just with C, in which case it must buy 4 permits. Dealing with C only leaves the constraint slack at location y. Now with one firm of each type, the possible outcomes are as shown in Table Two:

Table 2: Possible trading outcomes

	Reservation prices			
Firm B	1	1	1.5	1.5
Firm C	1	1.5	1	1.5
Minimum cost of trade with B+C	4	5	5	6
Minimum cost of trade with C	4	6	4	6

It can be seen that the bilateral trade is no dearer than the multilateral with probability 0.75. Suppose that bilateral trade is costless, but a three way deal costs 1.5 and A's reservation price for buying is 6, then trade can occur 75% of the time.

What happens as the number of firms increases? Suppose that firms of type B and C are replicated, but as before, their reservation prices are drawn at random. Then the probability that no trade is profitable is :

(1 - probability [one B firm at least has a reservation price of 1 and all D firms have a reservation price of 1.5]).

For n firms of firms of type B and n of type C this probability is $1 - 0.5^n + 0.5^{2n}$, which tends to 1 as n increases. Thus the probability of a feasible deal rises as the number of firms increases.

In summary, therefore, it is not clear which way the transaction costs argument goes. Fewness lowers the costs of shopping in a market which is not formally structured. However a large number of firms raises the probability of feasible trade and increases the likelihood that the market will have a formal structure which reduces search costs.

8. Sequential Nature of Trade.

It is possible that if the 'wrong' parties make a deal, then this can reduce the possibility of successful deals for other members of the permit group. For instance, if there are two 'sellers' with reservation prices of 1 and 5, and two 'buyers' with maximum bid prices of 8 and 4 then if the 1 firm makes a deal with the 8 firm, no trade will be possible between the 4 and the 5. However, if the 4 firm trades with the 1, then the 8 firm can deal with the 5. Since the sellers with the lowest reservation prices and the buyers with the highest willingness to pay are likely to be the most active searchers for deals, obstacles of this kind are probable. However, it does mean that the main gains from trade are reaped, thus the welfare loss from limited trade might be small. If we are looking for reasons why trade is sequential in this way, then again it probably comes back to the costs involved with multi-party bargaining. Atkinson and Tietenberg (1991) found that, in a simulation study of air quality control in St Louis, the erosion of cost savings under sequential trading depended on the choice of the order in which trades are made. Cost savings under sequential trading amounted to between 13% and 88% of those under simultaneous trading depending on the order of trading. Similarly, Klaasen and Forsund (1993) found that, for European trading of sulphur dioxide permits, sequential trading falls short of the least cost solution. However, sequential trading still achieves a cost saving over the command and control alternative.

CONCLUSIONS

As stated in the introduction, the purpose of this paper is not to isolate one particular theory as the explanation of why markets for permits might fail. One theory (that of imperfect competition in the permit market), however, was decisively ruled out as an explanation. Of the others, only the idea that uncertainties over the future implications of selling permits might inhibit trade received support when interviews were conducted with the managers of pollution-emitting firms along the Forth Estuary. We have already noted, though, that uncertainty itself cannot be the sole explanation since any reduction in the probability a seller will be re-issued with the permit in the future must be matched by an increase in probability that a buyer will receive the permit. Risk and loss aversion can explain a divergence from the expected monetary value of a trade, but whether these theories provide an adequate explanation still has to be tested empirically.

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ENDNOTES

1. Note that few of the theories are mutually exclusive.

2. So the Coase theorem comes up against the Coase conjecture!

3. The simplest way of ensuring cost efficient production would be to allow all firms to merge, but this would be at the expense of a higher price of output for consumers. Once this trade off is recognised it can be seen that cost efficiency will not in general be a desirable goal of public policy in an oligopolistic industry.

4. Note that we have not said 'when the market clears' - i.e. there is no assumption of price taking behaviour in the market.

5. In some situations cost efficiency will result even without the firms producing alternative products acting as true market makers (i.e. both buying and selling some permits or buying permits solely for the purpose of selling them on).

6. That is the buyer's maximum willingness to pay was above the seller's minimum willingness to accept.

7. For instance in the famous Knetch (1989a) mugs and candy experiment, where two sub groups drawn at random are endowed with either a mug or a piece of chocolate. Standard theory predicts that the proportions in the two groups willing to swap their endowment for the alternative should add up to 1. In fact the sum fell far short of this figure.

8. See Sutton (1986) for a survey of the noncooperative approach to bargaining, with and without asymmetric information.

9. Perhaps related to this is the absence of clear non-cooperative theory of bargaining with more than two players. Indeed, a standard example due to Shaked, (and which can be found in Osborne and Rubinstein, 1990), shows that any split of the pie can be a perfect Nash equilibrium in 3 sided bargaining, for the simple alternating offers game which yields a unique perfect Nash equilibrium in the case of two individuals.

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