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# AGRICULTURAL ECONOMICS

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## TRADEABLE DISCHARGE PERMITS AS OUTPUT QUOTAS

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Agricultural Economics
Discussion Paper: 8/90



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## Introduction

For many many years, economists advocated Pigouvian taxes as the most efficient policy instrument for environmental management. With almost as much perseverance, administrators ignored such gratuitous advice. More recently, a number of economists started to promote tradeable discharge permits as an alternative environmental policy instrument which is superior to conventional "command and control" methods, and arguably at least as efficient as pecuniary inducements.

At least some administrators have been receptive to this message, and have adopted some form of marketable emission entitlements. The most notable instance to date has been the introduction of the Emissions Trading Program for the regulation of air quality by the US Environmental Protection Authority.

In this paper, I want to raise some issues about how such rights based methods of management might operate in a world of imperfect knowledge. The starting point for doing so is the premise that, from an analytical point of view, tradeable discharge permits are equivalent to output quotas in their effect on allocative decisions by the firm. The literature on tradeable discharge permits contains a number of studies in which explicit consideration has been given to the implications of imperfect knowledge, but insufficient attention seems to have been paid to results obtained in other branches of the literature on the effect of quantity constraints on output given the intrinsically stochastic nature of the economic system. It will be argued below that if the emission generation process itself, and/or the measurement of emission levels are stochastic processes, then quotas which place an upper bound on output are likely to shift the marginal cost of abatement curve upwards. The implications of such a result for the choice between price and quantity based policy instruments, as well as the reasoning underlying the above proposition will be discussed in the third section of this paper.

Other insights into the possible impact of the introduction of tradeable discharge permits are accessible by reviewing the evidence on the operation of other forms of output quotas, such as individual transferable quotas (ITQ's) as the basis of fishery management policies. In the fourth section of the paper, some empirical evidence from the operation of the market for catch quota in the New Zealand Fishing Industry will be reviewed as a basis of a discussion for potential problems likely to arise in a permit trading market that are rarely discussed in traditional textbook treatments of this topic.

## Pollution as a Stochastic Process

When firms make investment decisions about the level of productive capacity to build, or production decisions involving the type and level of variable inputs to employ, they influence both the supply of saleable output to the market and the concentration of pollutants in the environment. In other words, saleable output and waste emissions are joint products of the production process, and will be co-determined by the interaction between the structure of economic incentives and technological interdependencies. One fairly simplistic way of conceptualising this complex system is to treat the production of saleable output as essentially deterministic, while the consequent contribution to ambient levels of unwanted wastes can be viewed as a stochastic function of planned level of output which may or may not also be susceptible to manipulation by management.

It is a well documented fact that concentrations of pollutants in the environment are subject to considerable variation.[1] The reasons for this variability in concentrations will not be discussed in any detail here, but basically come about as a result of variations in emission rates and/or changes in the assimilative capacity of the environment. Sources do not emit at constant rates for a variety of reasons, only some of which generate predictable or systematic patterns of occurrence. Apart from seasonal or daily patterns in emission rates related to variations in demand for saleable output and/or factor supply costs, there are also random fluctuations caused by breakdowns or accidents.

Probably of greater importance as a cause of changes in pollutant concentration are variations in meteorological conditions and other disturbances to the assimilative capacity of the environment. According to Baumol and Oates (1988, p.191)

> *"For example, the polluting effects of the given discharge of effluent into a river will depend on the condition of the waterway at that time - whether it has been replenished by rainfall or depleted by a drought. The amount of water and the speed of its flow are critical determinants of the river's assimilative capacity. Similarly, stagnant air can trap atmospheric pollutants, perhaps even collecting them until they become a danger to health and life. The point of all this is that emission levels that are acceptable and rather harmless under usual conditions can, under other circumstances, become intolerable. Moreover, these conditions depend on the values of variables that are largely outside the control of the policy-maker and often are not predictable much in advance.*

As Tietenberg (1984) argues, these variations in pollutant concentration have important consequences for environmental policy. Of particular concern is the effect of variations in ambient concentration levels on human health.

> *"Are short-term, high concentration exposures harmful or is human health more sensitive to cumulative exposure over some longer period of time?"*

Another important consideration is the extent to which these changes are predictable, or whether they are more or less random in occurrence. In many ways, systematic temporal variations in concentration levels raise equivalent problems to spatial variations in ambient pollutant levels, and the appropriate policy responses also have many features in common. On the other hand, those components of temporal fluctuations which are effectively unpredictable raise a quite different set of problems for environmental policy, and it is these aspects which are the main focus of the next section.

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[1]*Tietenberg (1984, p.150)*

**Tradeable Discharge Permits as Quota**

It is generally accepted that the consequences of controlling economic activity by taxes/subsidies on the one hand or by quotas on the other hand, are identical in a deterministic world, but that significant differences are likely to emerge in a stochastic world. In the context of environmental policy, Baumol and Oates (1988) demonstrate the lack of equivalence when policy makers are uncertain about the parameters of the cost function for emission reduction. When this form of uncertainty exists and the marginal benefit and marginal control cost curves are both linear, then they find that an effluent fee will be preferred by a risk-neutral regulator if the marginal control cost curve is steeper than the marginal benefits curve, and *vice versa*. Some of the more simplistic assumptions, such as linearity of the cost and benefit curves, have been relaxed in more recent studies by Watson and Ridker (1984) among others, but have only served to reinforce the general finding of Baumol and Oates that neither policy instrument dominates the other under a wide variety of conditions.

What does not seem to have been widely recognised in the literature on environmental policy is the possibility that the use of quotas as a means for regulating pollution may actually result in a shift in the marginal cost function for emission reduction. The basis for this suggestion comes from other parts of the literature where authors have focussed on the asymmetric operation of production quotas in a stochastic environment, whereas taxes and subsidies have a symmetric effect which is independent of realised outcomes. This possibility has obvious implications for the efficiency of tradeable discharge permits as an instrument for pollution control.

In the fishery economics literature, Clark (1985) seems to have been the first to recognise that expected fish catch conditional on a quota will be less than unconditional expected catch from the same investment in catching capacity. This finding has an obvious corollary if the object of policy is to achieve some target level of expected catch, which is that the quota can be set at a higher level than the target level of harvest. Just how much larger the quota can be will depend on several factors, including catch rate variability and on how fishermen adjust their investment in catching capacity in response to the quota. Lindner and Campbell (1989) suggest that the level of investment in fishing capacity by risk neutral fishermen under a quota scheme would be greater than that necessary to catch the same expected harvest in the most cost efficient manner.

Fraser (1986) derived further general results about the effect of a marketing quota on the optimal level of planned production in an uncertain environment. In particular, he demonstrated that :

> *"the introduction of production quotas may reduce planned production even if the quota exceeds the level of pre-quota planned production. Moreover, in a situation of an established quota, the relative level of the quota and the producer's planned production depends both on the size of the producer's profit margin on quota production, and on the extent of his production uncertainty. In particular, a narrower profit margin and more uncertain production emphasize the cost of unsaleable output and lead to sub-quota production on average, while a larger profit margin and less uncertain production emphasize the cost of foregone sales and lead to over-quota production on average."*

Babcock (1989) reaches very similar findings in a study of peanut production quotas for planting decisions given production uncertainty, and stresses that the basic cause of these effects is the discontinuity in the marginal revenue function introduced by production quotas.

In a somewhat different context, Anderson (1987) argues that import quota licenses are equivalent to financial options which command positive prices even when the expected return of market participation is non-positive. In an attempt to develop a stochastic framework for analysing fishing quota price determination, Lindner, Campbell and Bevin (1989) have made an equivalent suggestion with respect to ITQ prices.

It is beyond the scope of this paper to apply the analytical models used in the above studies to the case of tradeable discharge permits. However, it is clear that in an equivalent manner to other forms of production quota, and in contrast to Pigouvian taxes, tradeable discharge permits introduce a discontinuity into the marginal cost of abatement function. This basic insight can be used to suggest issues for further investigation by considering the simplest possible case of uniformly mixed assimilative pollutants. Other major classes of pollutants recognised in the US regulation of air pollution, namely non-uniformly mixed assimilative pollutants, and uniformly mixed accumulative pollutants will not be considered.

If pollutant emissions are purchased jointly and in fixed proportions with the saleable output, then it follows that the optimal level of investment in productive capacity, which co-determines the planned level of saleable production and the expected level of pollutant emissions, is likely to be higher under a system of emission quotas than one involving emission taxes. In practice of course, firms have at least a degree of elasticity in varying the mix of saleable output and level of pollutant emissions by choosing different production technologies. Hence the process of emission reduction could just as well be treated as an independent activity with its own separate cost curves, in which case quotas are likely to induce a higher than necessary level of investment in abatement capacity to achieve a given reduction in the expected level of pollution. Either way, the net effect of emission quotas is to raise the marginal cost of expected abatement above the minimum necessary.

Another case where some form of taxation would seem to be demonstrably superior to any form of tradeable discharge permit involves hazardous pollutants for which, *ex post*, the marginal social damage from any emission clearly exceeds any marginal benefit to the firm concerned. Consequently, in a deterministic world the optimal level of this form of waste emission would be zero. In a stochastic world, it still might be socially desirable, *ex ante*, to accept some level of risk of an accidental discharge because the marginal cost of reducing the probability of a spill increases exponentially as the probability tends to zero. However, even though some risk of accidental spillage might be accepted as being in the public interest, no level of discharge could be permitted, tradeable or not. Hence, the only viable policy instrument alternatives are some form of technological regulation on the one hand, and some form of *ex post* financial penalty on the other.

This case of accidental discharge of hazardous pollutants highlights the pivotal nature of the relationship between the marginal social damage due to pollutant emissions and the different dimensions of ambient concentrations of the pollutant in the atmosphere in determining the efficiency of Pigouvian taxes vis-a-vis tradeable discharge permits as pollution control instruments. The other two key issues are the predictability of variations in ambient concentration levels, and the marginal cost of short-term control measures to alter these ambient concentration levels. For some pollutants the marginal social damage will be some non-linear function of short-term (e.g. hourly) concentration levels. If this function is monotonic increasing at an increasing rate, then as an approximation marginal social damage might be specified as a function both of average annual concentration levels, and of the number of short-term time periods (hours) for which the concentration level exceeds some defined standard. Some insights into the likely results from a more sophisticated analysis can be gained from considering the two polar cases. When marginal social damage is a function only of average annual concentration levels, then there is an *a priori* case that price controls will be more cost-efficient than quantity controls for reasons already discussed above. Conversely, when marginal social damage depends exclusively on the proportion of time during the year for which a defined standard is exceeded, then tradeable discharge permits are more likely to be the preferred instrument. However, this presumes that tradeable discharge permits equalise the marginal cost of abatement between all sources of emission. Whether this outcome is realised in fact will depend, *inter alia*, on the efficiency of the price discovery process in the market for tradeable discharge permits.

**Price Discovery in the Market for Fishing ITQ's**

The conventional view of the operation of a market for tradeable discharge permits, and how it fosters efficient production of pollutant emissions, is summed up in the following quote from Baumol and Oates (1988, p. 177):

> *"The Environmental Authority can directly limit waste discharges to their target level by restricting the quantity of permits. As a market for these permits develops, a market clearing price would emerge that (like a fee) will indicate to polluters the opportunity cost of waste emissions. Since all sources would face the same price for a permit, cost-minimising behaviour would result because marginal abatement costs would be equalised among these sources."*

Note in particular that a cost-minimising outcome depends on tradeable discharge permits in fact selling at an unique price. For reasons to be presented below, there are grounds for believing that this will not in fact happen.

Recent implementation of a comprehensive Quota Management System (QMS) in New Zealand's principal fisheries provides a rare opportunity to study the operation of a tradeable quota market. To date this market for ITQ's does not appear to have performed in a "textbook" manner, and may not be performing in a manner consistent with economic theory. In particular, there is a suggestion that the process of arbitrage has broken down, or at least has failed during the first two years operation of the quota market to eliminate or even mitigate extreme dispersion of quota trading prices. Moreover, as far as can be determined, a high proportion of prices paid in the ITQ market are far in excess of any possible resource rents currently being earned from exploiting the fish stocks.

This is a matter for concern on several counts. If the quota market does not in fact operate in the predicted manner then it is possible that a QMS will not deliver all of the expected efficiency gains either, since quota prices should play a pivotal role in inducing industry to shed excess fishing capacity. As a corollary, if prices paid in the quota market do not accurately measure economic rent generated in the fishery, then quota prices should not be used as a basis by government for setting "resource rentals" as has been attempted in New Zealand. By the same token, it might not be appropriate to use them as a basis for compensating fishermen excluded from future access to the fishery. Nor will it be possible to monitor the success or otherwise of fishery management programmes as has been advocated, *inter alia*, by Arnason (1988).

The QMS is described in detail by Clark and Major (1988) and Clark (1988), as well as being analysed in some detail by Anderson (1988). Under the QMS, the basic property right typically involves an entitlement in perpetuity. It is denominated in tonnes of catch per fishing year of the specified fish stock, and any amount up to a limit equal to the total quota holding can be caught how and when the quota holder wishes.

Because this property right can be freely traded, quota owners, including the government managers, can lease their quota on an annual basis, as well as buying or selling quota in perpetuity. The details of all such trades, including tonnage traded, price per tonne, and transaction date have to be registered with the Ministry of Agriculture, Forestry and Fisheries (MAFFISH) as part of the QMS. Some of these trades over the first two years of the schemes' operation were made through a computer exchange set up by the New Zealand Fishing Industry Board to facilitate quota trades. However, apart from government to industry trades, most were arranged privately.

Unfortunately the quota trading market for most fish stocks have not been active enough to generate sufficient observations for reliable analysis. Two exceptions are the markets for Snapper in area 1, and for Hoki. It is fortuitous that these two fish stocks are commercially significant examples of New Zealand's deep-water and inshore fisheries respectively. Monthly summaries of trades for annual lease of area 1 Snapper ITQ's, and for outright sale of perpetual quota for the same fish stock, are presented in Figures 1 and 2 respectively. Each figure displays minimum, average, and maximum trading price each month, as well as number of trades per month. At least two features of this data warrant special attention.

One noteworthy feature is the extremely wide price range at which each type of quota is traded. In some months, maximum prices are greater than minimum prices by a multiple of ten or more, and in most months the price range is as big or bigger than the average price recorded. For reasons to be discussed below, at least some of the lower minimum prices can be attributed to false reporting, but even if due allowance is made for this bias in the data, the actual price range is still measured in terms of hundreds of dollars per tonne for annual lease of quota, and in terms of thousands of dollars per tonne for perpetual quota trades. Just why arbitrage should have failed in such a spectacular fashion to equilibrate this market and achieve an uniform price is one of the puzzles associated with the operation of this market.

The second noteworthy feature is the exceptionally high prices paid both for outright sale of perpetual quota, and for leasing it on an annual basis. During the time period covered by this data, the port price[2] for Snapper was estimated to be between $3,000 and $4,000 per tonne[3], so it can be seen that quota was leased out at annual rental rates up to approximately 100% of the gross return from catching Snapper. Moreover, the average price paid for purchase of perpetual quota typically ranged between $10,000 and $15,000, while maximum prices were up to double these values. In order for the resource rents derived from catching Snapper to even approximate these values, it would be necessary for the associated catching costs to be close to zero.

Figure 3 presents equivalent data on annual lease trades for Hoki quota. Again the data is characterised by an extremely wide range of prices paid in most months, and by average and maximum prices that represent a very high proportion of the estimated port price of $350 to $500 per tonne[4]. As the market for sale of perpetual Hoki quota was much thinner, monthly data would not convey an accurate impression of price variability. Instead data on individual trades for perpetual quota are presented in Figure 4. Once again the same general picture emerges of an extremely wide range of prices being registered within quite short time periods.

Conventional explanations for price dispersion include product heterogeneity, lack of competition, and/or poorly informed market participants. Markets also might exhibit extreme short-run price volatility due to thin trading, and/or due to highly inelastic demand and supply curves which are subject to unpredictable shift factors.

None of these possible explanations for widely dispersed market prices are entirely plausible in relation to the market for ITQ's, but there could be an element of truth in some of them. On the face of it, ITQ's might appear to be a perfect example of an homogeneous commodity, and it is true that ITQ's are much more homogeneous than say land. However, not all trades of ITQ's involve exchanging "like for like". In common with most contracts, ITQ's can and do differ with respect to the detail of the contractual arrangements. However such differences, which relate to entitlements to "over-fish", etc, at most can have a relatively minor impact on quota value. Moreover, a detailed examination of individual quota trades revealed many instances of quota with identical terms and conditions being traded at substantially different prices within days of each other.

It also has been suggested that the volatility of quota prices could be attributed to the "thinness" of trading volume on the quota market. While the market is unquestionably always thin for many fish stocks, and for all fish stocks in some months, it can be seen that a substantial number of trades were transacted for annual lease of quota for Snapper in area 1 in months such as October 1987.

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[2] *This is a term used to refer to the estimated price which would be paid in a competitive market for wetfish landed at the wharf.*
[3] *New Zealand Fishing Industry Board, pers. comm.*
[4] *New Zealand Fishing Industry Board, pers. comm.*

Another possible explanation for price dispersion is that it is an artefact due to blatant understatement by some market traders of the true price paid for lease or sale of quota. As Anderson (1988) has noted, so long as government attempts to use quota trading prices to determine resource rentals, industry has a clear-cut incentive to engage in this misleading practice. There seems little doubt that some market participants have succumbed to this temptation, but the number of trades taking place at clearly fictitious prices is surprisingly small. Some of the most comprehensive evidence on this issue is provided by trading data from the market for annual lease of Snapper quota in area 1. Figure 5 illustrates the monthly dispersion of prices in this market for the 1987/88 fishing year, while Figure 6 presents a frequency distribution of prices for the same market from December 1986 to March 1989. Most if not all of the trades recorded as taking place at a price less than $200 per tonne are probably fictitious, but it can be seen that the majority of trades were transacted at a price of $1,000 per tonne or greater. It is difficult to believe that price is under-reported in any of this latter set of trades given that this price is in excess of 25% of the port price for Snapper. Moreover, it is apparent from Figure 5 that even if all trading prices less than $500 per tonne are discarded, monthly price data still exhibit very considerable price dispersion.

Given the above evidence, the only other theoretically plausible explanation for the observed degree of price dispersion in a market for such a homogeneous good is that a significant proportion of traders in the quota market are extremely poorly informed, and so are prepared to make trades at prices far removed from the competitive equilibrium price. While this explanation has some credibility in markets such as that for Snapper where many small fishermen own quota, industry sources do not accept this explanation. It also is much less credible as an explanation for price dispersion in the Hoki quota market, since almost all of this type of quota is controlled by a small number of large fishing companies, most of whom employ quota market managers to conduct all of the company's quota trading. Clearly this is an issue requiring further research, but until such time as results from it are forthcoming, the degree of price dispersion observed in this market is a matter for concern.

## Conclusions

As a means for controlling pollution, tradeable discharge permits seem to be politically more acceptable than emission taxes, while offering much the same efficiency gains over conventional "command and control" methods of regulation. However, most studies investigating the relative merits of price versus quantity based pollution control instruments have not taken full account of the implications of imperfect knowledge.

Results from studies of other forms of production quotas suggests that tradeable discharge permits might not minimise the marginal cost of expected abatement. This is an issue requiring further investigation, as is the way in which fluctuations in ambient concentrations of the pollutant in the atmosphere affect the consequential marginal social damage.

Another cause for concern is the effectiveness of price discovery in the market for tradeable discharge permits. Evidence from the operation of another market for tradeable production quota on New Zealand fishing suggests that arbitrage might fail to generate an unique price. If this was to occur in a market for tradeable discharge permits, then it is unlikely that the marginal cost of abatement would be equalised between all polluters.

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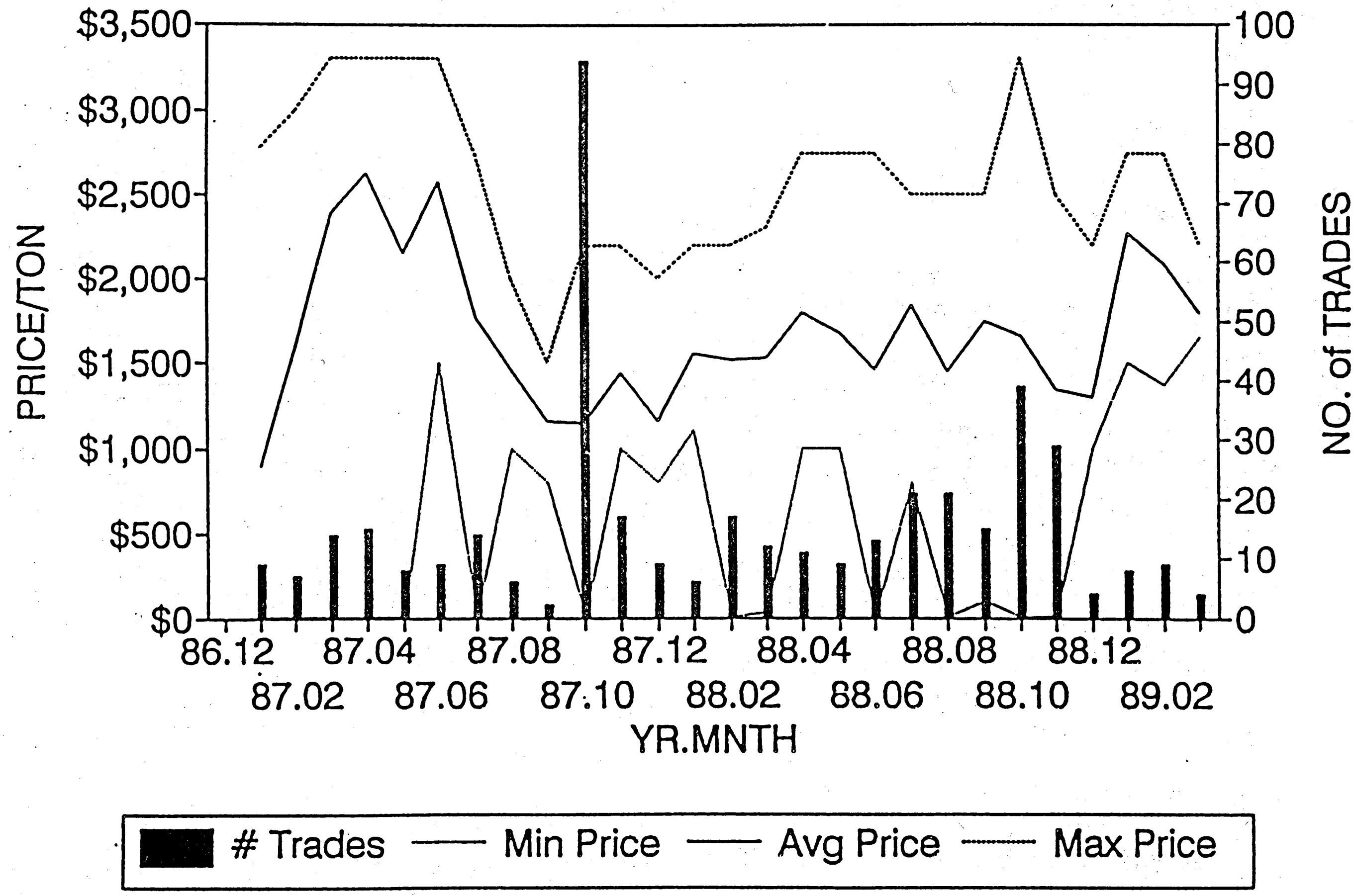
# FIGURE 1:

## TRADING DATA for SNAPPER #1

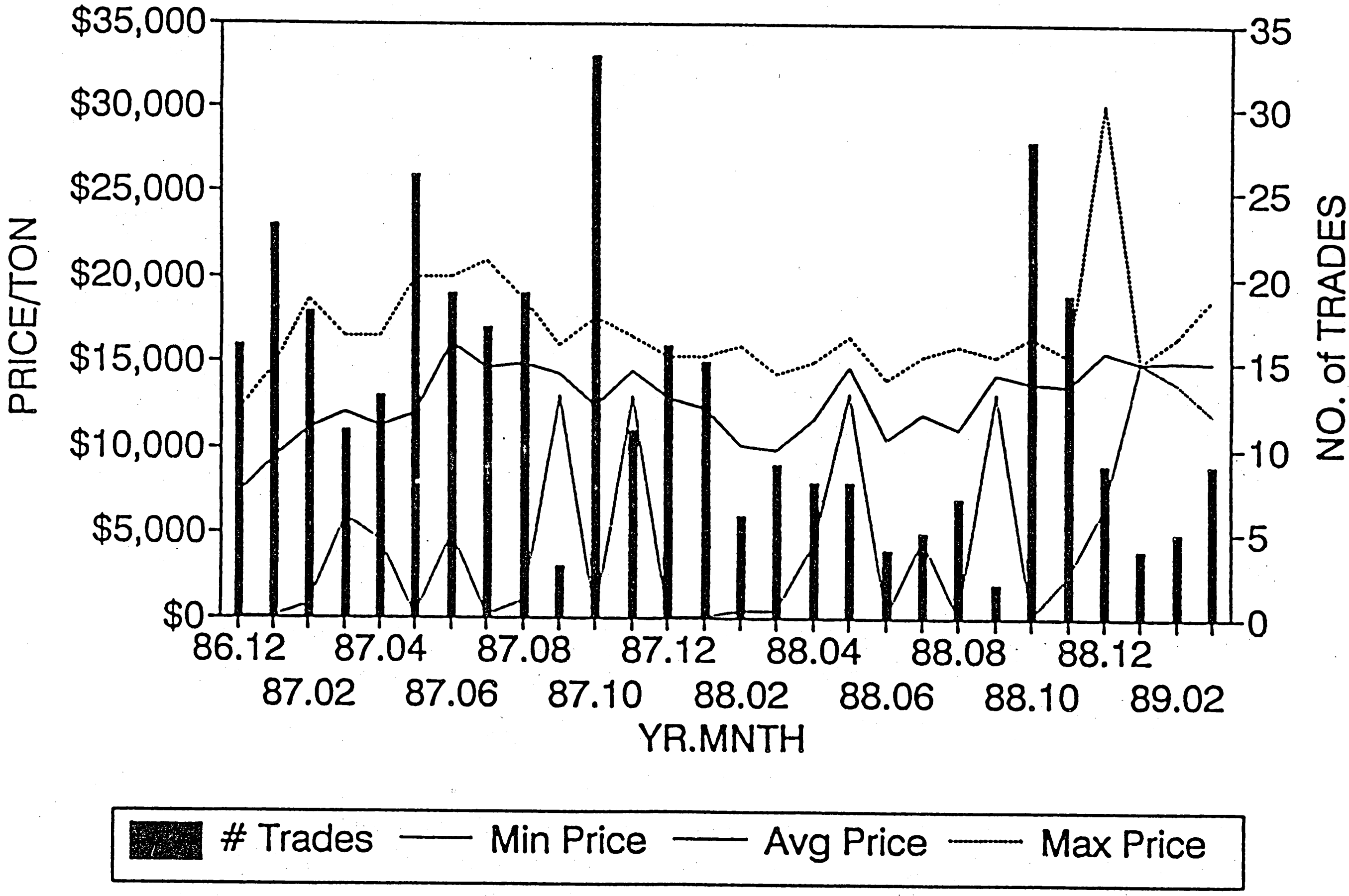
### MONTHLY PRICES for QUOTA LEASE



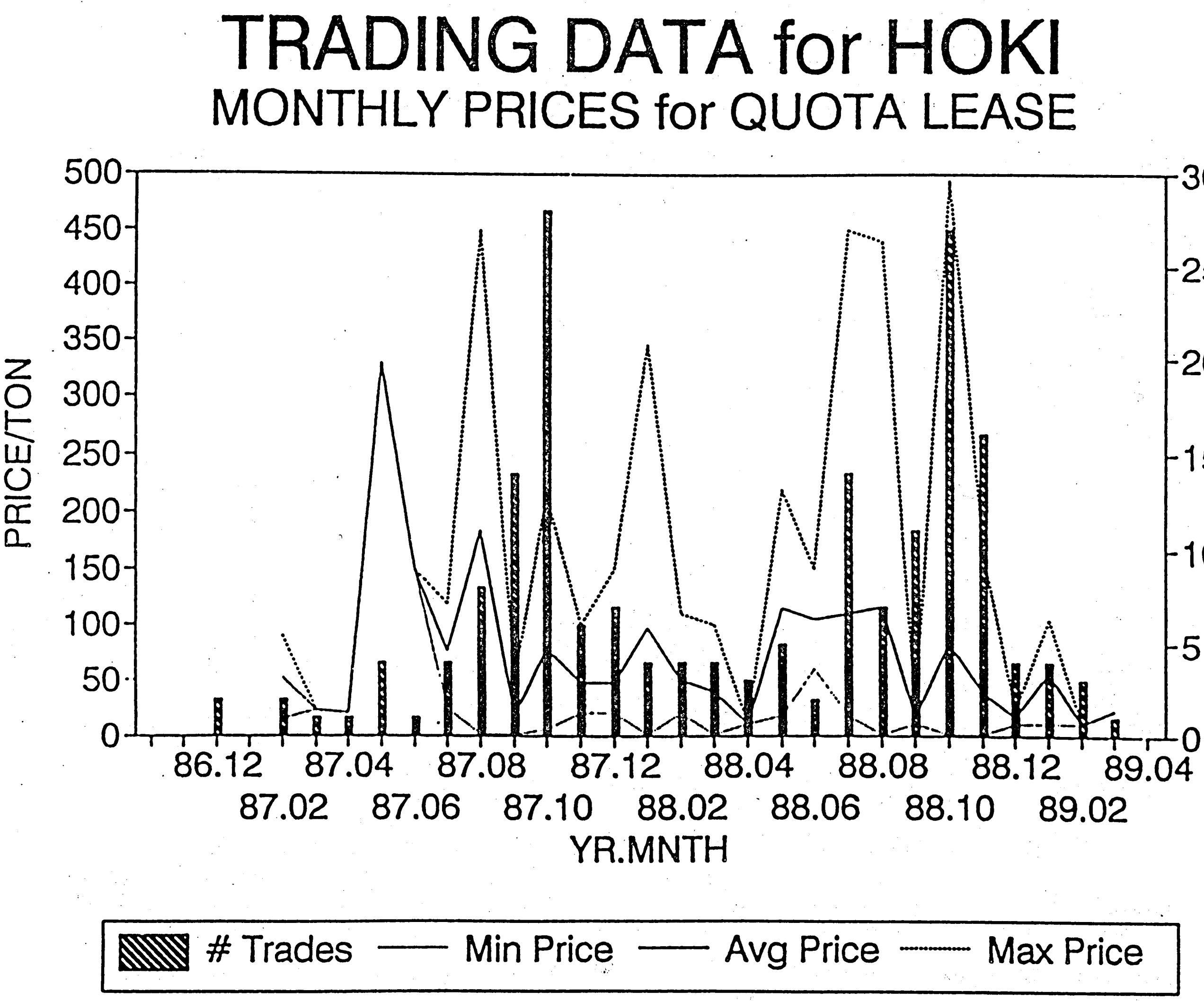
# FIGURE 2:

## TRADING DATA for SNAPPER #1

MONTHLY PRICES for PERPETUAL QUOTA



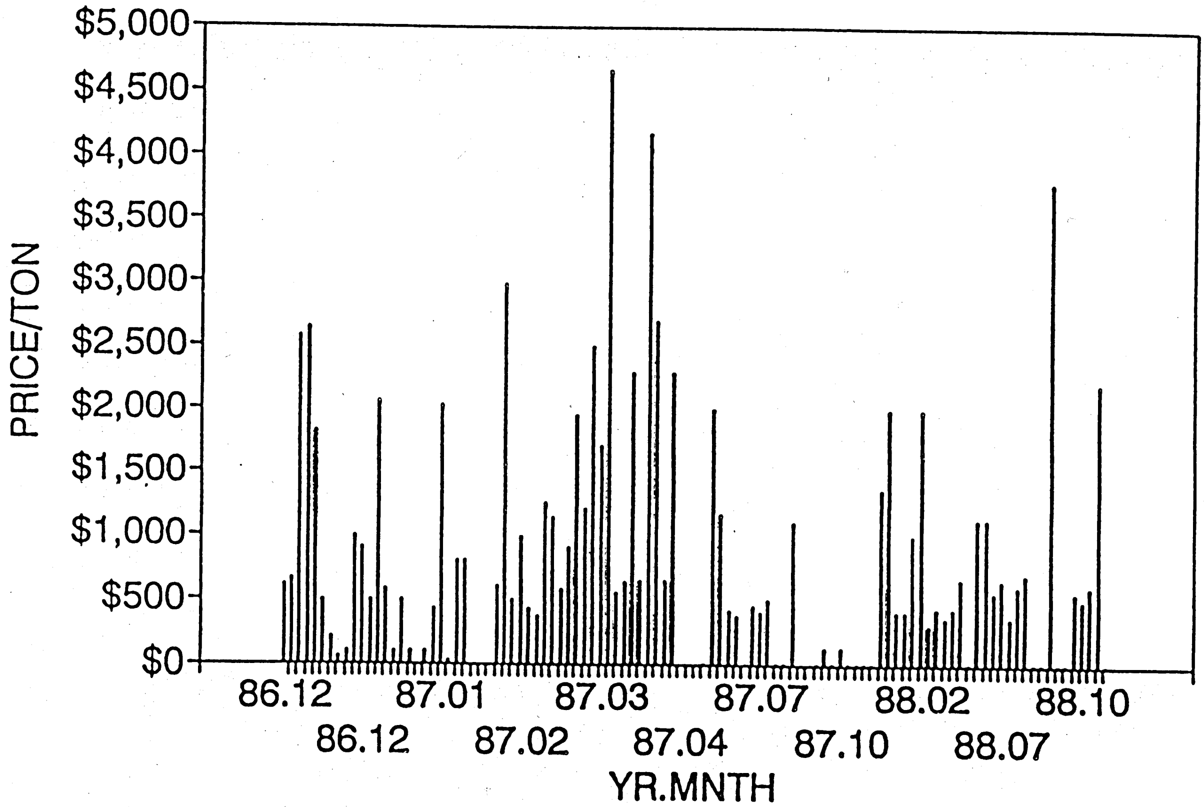
# FIGURE 3:


TRADING DATA for HOKI
MONTHLY PRICES for QUOTA LEASE
PRICE/TON
500
450
400
350
300
250
200
150
100
50
0
NO. of TRADES
30
25
20
15
10
5
0
86.12
87.02
87.04
87.06
87.08
87.10
87.12
88.02
88.04
88.06
88.08
88.10
88.12
89.02
89.04
YR.MNTH
# Trades
Min Price
Avg Price
Max Price

# FIGURE 4:

## TRADING DATA for HOKI

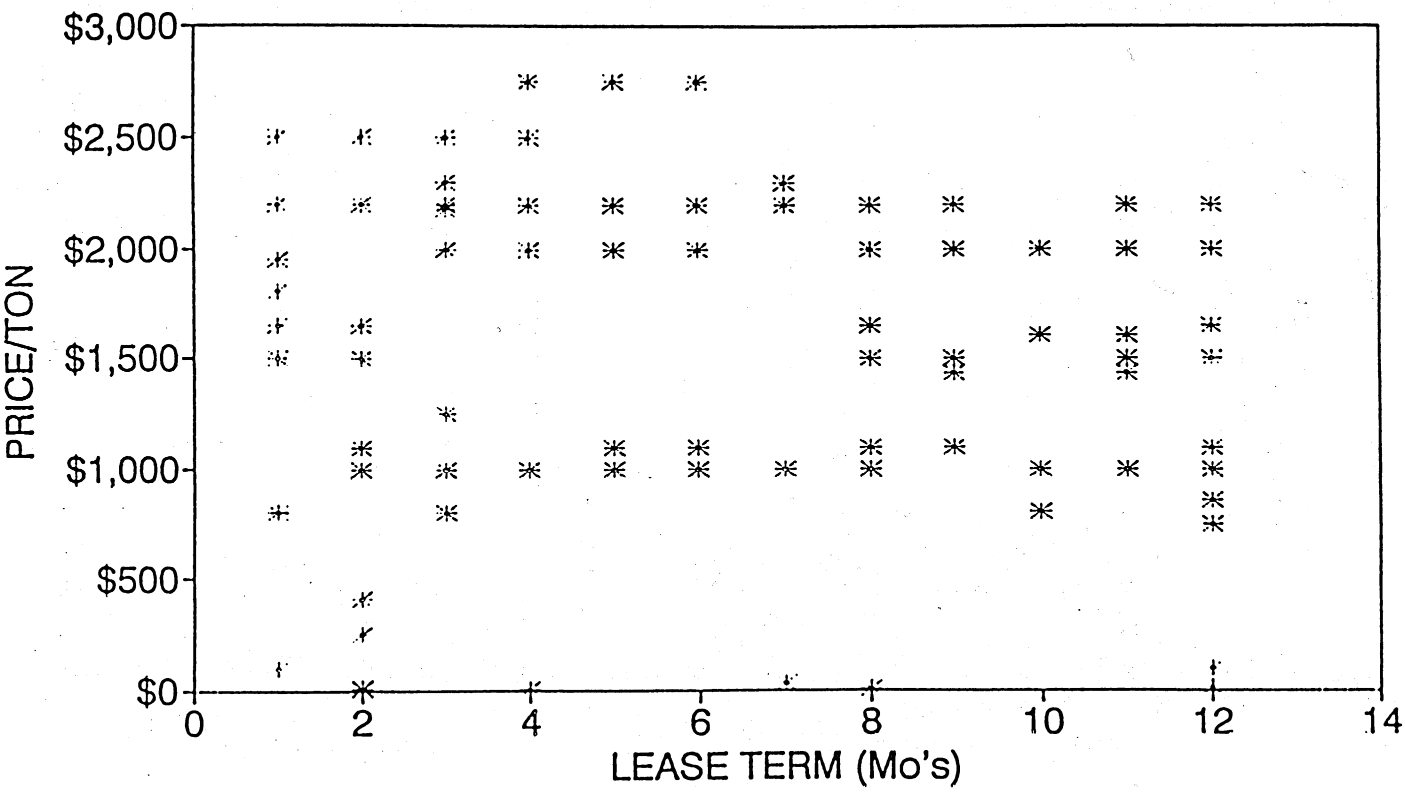
### PERPETUAL QUOTA PRICES : 1986 to 1988



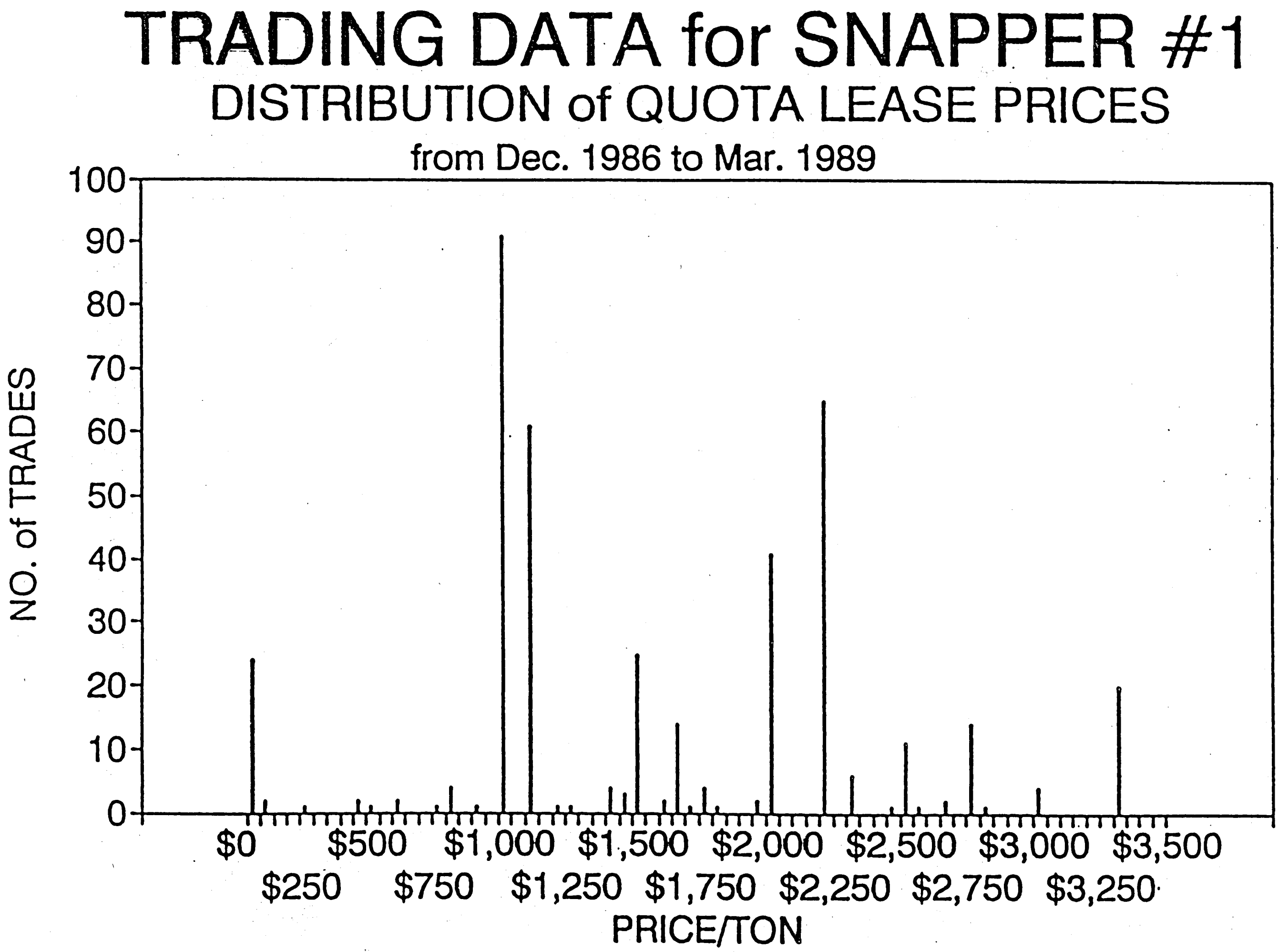
# FIGURE 5:

## TRADING DATA for SNAPPER #1

### 1987/88 QUOTA LEASE PRICES



# FIGURE 6:


TRADING DATA for SNAPPER #1
DISTRIBUTION of QUOTA LEASE PRICES
from Dec. 1986 to Mar. 1989
NO. of TRADES
0
10
20
30
40
50
60
70
80
90
100
$0
$250
$500
$750
$1,000
$1,250
$1,500
$1,750
$2,000
$2,250
$2,500
$2,750
$3,000
$3,250
$3,500
PRICE/TON