

ISSN 0143-4543



Centre for European Labour Market Research



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discrimination and limited durability: Theory and evidence
By

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Discussion Paper 2004-07
October 2004

Editor: Dr W David McCausland
www.abdn.ac.uk/business/

Effects of rotation scheme on fishing behaviour with price discrimination and limited durability: Theory and evidence

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(The paper is available upon request from the authors)

Abstract:

This paper examines how rotation arrangement between two groups of Japanese fishers with different institutional arrangements affects fishing behaviour and economic outcomes in a particular economic environment characterised by price discrimination and product durability. In one group, fishers cooperate and maximise the extraction of rents, while fishers in the second group behave non-cooperatively. Except for a few months in which only the first group operates, the two groups fish on alternating days. We apply a model of alternating duopoly and examine the effects of the rotating arrangement on fishers' behaviour in the two groups. Our model shows that the cooperating group behaves like a price discriminating monopolist and tends to uphold prices. When the two groups rotate fishing days, interesting strategic interdependence arises: the cooperating group tends to produce more, which prevents the non-cooperating group from unprofitable demand pre-emption. The empirical analysis of original data confirms this result.

Keywords: price discrimination, durable goods, alternating duopoly, rotation, fisheries

JEL classification: D23, Q22

Acknowledgements: I am grateful to the CRED (University of Namur) and IAS (United Nations University) for financial support. Special thanks are due to Shiminato Fisheries Cooperative Association for providing me with essential data. I would like to thank Siwan Anderson, Paul Belleflamme, Patrick Francois, Frédéric Gaspard, Margaret Slade, Xavier Wauthy for their valuable comments at different stages of preparing this paper. I am particularly indebted to Jean-Marie Baland, Jean-Philippe Platteau (University of Namur), and Euan Phimister (University of Aberdeen) whose guidance were essential in pursuing this research. I also thank two anonymous referees for their helpful comments and suggestions.

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Effects of rotation scheme on fishing behaviour with price discrimination and limited durability: Theory and evidence*

Erika Seki[†]

Abstract

This paper examines how rotation arrangement between two groups of fishers with different institutional arrangements affects fishing behaviour and economic outcomes in a particular economic environment characterised by price discrimination and product durability. In one group, fishers cooperate and maximise the extraction of rents, while members in the second group behave non-cooperatively. Applying a model of alternating duopoly, we show that the cooperating group behaves like a price discriminating

*I am grateful to the CRED (University of Namur) and IAS (United Nations University) for financial support. Special thanks are due to Shiminato Fisheries Cooperative Association for providing me with essential data. I would like to thank Siwan Anderson, Paul Belleflamme, Patrick Francois, Frédéric Gaspart, Margaret Slade, Xavier Wauthy for their valuable comments at different stages of preparing this paper. I am particularly indebted to Jean-Marie Baland, Jean-Philippe Platteau and Euan Phimister whose guidance were essential in pursuing this research. I also thank two anonymous referees for their helpful comments and suggestions.

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monopolist and tends to uphold prices. When the two groups rotate fishing days the cooperating group tends to produce more, which prevents the non-cooperating group from unprofitable demand pre-emption.

Key words: price discrimination, durable goods, alternating duopoly, rotation, fisheries; JEL classification: D23; Q22

1. Introduction

Local-level cooperative institutions play a substantial role in regulating and resolving conflicts over the usage of local natural resources (Baland and Platteau 1996). These local informal institutions are of particular interest because a significant part of the livelihood of the poor in developing countries depends on local natural resources such as forestry, irrigation, grazing, and fisheries. There is also a growing recognition that local-level community organisations have the potential to manage natural resources and alleviate poverty more effectively than state and private control (Bowles and Gintis 2002; Bardhan 1993; Ostrom 1990).

Rotation is one of the institutional arrangements commonly applied to allocate irrigation water, firewood and other forests products, and access to fishing spots¹. While it is fairly obvious that these rotation arrangements promote equity and resolve conflicts among the people concerned, its effects on economic outcomes, particularly how it affects individual usage of resources and overall efficiency, are ambiguous. Most empirical studies on rotational arrangements in fishing communities seem to endorse the general view that the effectiveness of rotation arrangements is limited: it avoids conflicts and ensures equitable allocation of resources among the users but it does not address fundamental issue of internalisation of negative externalities, that is control of individual fishing efforts². However, evidence does suggest that the advent of commercialisation and technological progress can threaten such schemes (Alexander 1977; Baland and Platteau

¹See for instance Maas and Anderson (1986) for detailed historical studies of traditional irrigation communities in Spain, McKean (1986) for in-depth field investigation of management of precious communal forest product in Japan, and Alexander (1977) and Schlager (1990) for informal rules of regulating access to favourable fishing spots in various countries.

²On the basis of comprehensive international case studies of existing institutional arrangements for inshore fisheries management, Schlager (1994) concludes that self-management institutional arrangement of fisheries, of which rotation is one, do not directly address regulation of fishing effort.

1996, pp.199-210; Berkes 1992; Schlager 1994).

Such a pessimistic view about the effectiveness of rotation arrangements seem to be at odds with other empirical observations of long-lived and sustained practice of rotation among resource users. Ostrom (1990), for instance, reveals on the basis of in-depth field observations that rotation of irrigation water in Sri Lankan village has induced cooperative behaviour among resource users with differing interests. The documentation of self-management institutions among local fishers in Japan also suggest that rotational fishing arrangements can also be associated with the effective control of fish catches (Zengyoren 1992). But why in some cases do rotation arrangements contribute to internalisation of negative externalities, while in other cases not? Particularly, why do some rotation arrangements manage to induce cooperative outcomes while inhibiting competitive pressure to behave non-cooperatively?

This paper aims to analyse how a rotation scheme influences individual behaviour and affects economic outcome in an actual field setting. More specifically, using unique data on a rotation arrangement between two groups of fishers in Japan, we examine formally how rotation arrangement induces strategic interactions between the groups, and how this then affects the individual fishing behaviour and economic outcomes in a particular market environment. These two groups harvest the same type of shrimp and sell them at the same market. Except for a few months in which only the first group (Group A) operates, the two groups adopt a rotation scheme by fishing on alternating days. These two groups have different institutional set-ups: the group A fishers pool income and fish cooperatively, while in the other group (Group B), the members do not pool income and fish non-cooperatively. The shrimp is sold daily through an auction procedure in which buyers are price discriminated. The differences in the way the two groups are organised plus the fact that the first group is also observed operating alone, provides us with a unique opportunity to examine how rotation combined with increasing competitive pressures affects outcomes.

In order to obtain theoretical predictions concerning the effects of rotation arrangement on fishing behaviour, we build a game theoretical model of alternating duopoly inspired by Maskin and Tirole (1988a). Assuming Markov strategies, our model shows that the cooperating Group A approximated as a price discriminating monopolist, underproduce in order to prevent pre-emption of future demand, while Group B, composed of non-cooperative fishers would overproduce due to intra group competition. However, when the two groups rotate fishing days, theory suggests that an interesting strategic interdependence arises: the cooperating group should produce more so as to prevent the non-cooperating group from unprofitable demand pre-emption. Consequently, under the rotation arrangement, Group B's tendency to dissipate rent is reduced, while Group A's tendency to uphold price inefficiently is mitigated. Adopting Slade's (1992, 1995) approach, these theoretical implications are then tested against empirical data.

This paper is organised as follows. In section 2, our field observations are briefly described. Section 3 presents the baseline case of a price discriminating monopolist. We show, in congruence with standard theory, that the equilibrium effort level is Pareto optimal, if members of the group as a whole behave like a price discriminating monopolist. Section 4 examines oligopolistic competition with price discrimination and with storability of product. We find that the non-cooperating group tends to dissipate rent by overproducing. In section 5, we present a final version of the model with all the elements in place, i.e. alternating arrangement between the two groups, possibility of price discrimination and partial durability of shrimp. Section 6 sets out the empirical model, which is then applied to estimate and test the theoretical implications using our data on Japanese fishers. Section 7 concludes.

2. Fishermen's groups in Toyama Prefecture

There are two competing groups of fishermen who operate in the same coastal area along the Toyama Bay of Shinminato city in Japan. These two groups harvest the same species, *shiroebi* (Japanese glass shrimp), and use the same fishing technology. Both groups belong to the same local cooperative known as the Shinminato Fishery Cooperative Association where they are the only two groups entitled to fish *shiroebi*. One of these groups, which we call Group A in this study, is composed of seven fishing units and has intra-group cooperation so that members operate in a coordinated manner and make production decisions collectively. The second group, Group B, is composed of five units but, unlike Group A, does not have intra-group coordination. The members of Group B thus operate individually and make their production decisions non-cooperatively. The two groups have adopted a rotating system to share the *shiroebi* stock within the Shinminato area. Between April and May, and again between September and October, only Group A is allowed to catch *shiroebi*. Whereas, between June and August, Groups A and B operate on alternating days: Group A fishes on Monday, Wednesday and Friday, and Group B on Tuesday, Thursday and Saturday. Group A has an exclusive fishing right in the former fishing season mainly because of historical reasons. That is, Group A has specialised in *shiroebi* fishing for several centuries, while Group B members have only been allowed to enter this fishery recently (since 1992) after six long years of negotiation with Group A (Platteau and Seki 2001, for more details of institutional characteristics of the two groups).

On a given fishing day, each boat will make about 4-5 hauls. Since *shiroebi* is highly perishable, fishing boats return to the harbour immediately after each haul in order to land and hand over their catches to fish merchants who wait on the shore. The fish merchants will then either sell them for immediate consumption or store them in a deep freezer for future consumption. The sale procedure used to dispose of the *shiroebi* is a two-step auctioning system that consists of a 'morning'

auction and an *aota* auction³. The morning auction starts immediately after the landing of the first hauls of the day which are brought back to shore by each boat between 5.30 and 6.00 am. All subsequent landings are sold through the *aota* auction. Both forms of auctions are characterised as a bidding process in a descending order. The critical difference between the ‘morning’ and *aota* auctioning mechanisms is that, while the former takes place only after the fish obtained from the first hauls has been unloaded on the jetty, the latter is held before actual landings from subsequent hauls are realised. When landing their first hauls, fishermen are indeed asked to provide an estimate of the total expected landings of the day, and it is on the basis of such estimates that the *aota* auction is held⁴. In fact, the actual handing over of *shiroebi* takes place immediately after the landing and, as a rule, the fish merchant bidding the highest price has priority access to it, while the other merchants with lower bids are served as subsequent catches reach the harbour and pay the lower prices to which they have committed themselves. Consequently, the earlier the shrimp reaches the jetty, the higher the unit price it fetches. If total landings are less than the estimated supply, some low bidders will therefore be left without shrimp.

This procedure can be viewed as a variant of the Dutch auction where arbitrage

³*Aota* auction’ literally means the purchasing of a green or standing rice crop, i.e. a forward purchase.

⁴The precise steps of the auctioning processes work as follows. (i) An auctioneer declares a total quantity to be traded; (ii) he then points to a given portion of that quantity for immediate bidding and proposes a unit price for that portion; (iii) the buyers raise their hands to indicate the quantity they are willing to buy at the proposed price; (iv) if demand (i.e. the sum of all the quantities indicated by the traders) does not happen to exceed the size of that portion, the requests of all fish merchants are met and the auctioneer proposes a lower price to dispose of the remaining fish in the same portion. If there is excess demand, the auctioneer revises the initial unit price upwards. The process continues until excess demand is eliminated and the portion is completely sold. Finally, once the whole portion is disposed of, the auctioneer indicates a new one to be offered for sale. Another bidding process takes place until the total landings are sold.

may occur between catches. Due to possible arbitrage between earlier and later catches, bids are likely to be lower than actual reservation values⁵. Nevertheless, from the above described procedure it follows that fishermen face a downward sloping effective demand schedule and can price discriminate among the buyers. Put it differently, the earlier bidders pay more than the later ones and fishermen become aware of a downward-sloping demand curve while continuing their fishing operations. Thus Group A members that fish cooperatively are able to capture a large surplus when it operates each day, analogous to a price discriminating monopolist. Whereas Group B members who do not act cooperatively are not able to reap the same advantages. This is because Group B members face price uncertainty due to intra-group competition (which will be discussed later in section 4).

The fact that there are two distinct periods, as noted earlier, enables us to study closely the interactions between the two groups. An empirical analysis of such interactions requires testable theoretical predictions about the consequences of strategic interactions between the two groups. In the following sections, we assume a downward sloping demand schedule and consider Group A as a price discriminating monopolist. We then build a tractable model by adding successive complications to the durable-goods monopoly problem.

3. Group A as a price discriminating monopolist

In this section, we analyse the base line case of a price discriminating monopolist with partly durable goods. To do this we must first construct a consumer demand

⁵In addition, the Dutch auction is not an exact demand revealing mechanism because the expected utility maximising bids depend on each bidder's risk preference and on his/her expectation about the rivals' bids. It is known, however, that it induces bidders with higher reservation values to announce higher bids if all bidders have the same risk preferences and expectations about the rivals' reservation values (Philips 1988, pp.91-95).

for shrimp. This is not entirely straightforward because there are timing effects which arise from the storability of the shrimp. Since shrimp can be frozen and conserved for future consumption, current demand bears upon future demand in the sense that consumers' demand for shrimp in a given period is not only to satisfy current consumption, but also to serve future consumption. The implications of such storability of shrimp and interdependence of demands across fishing days are analysed later in this section, but first, for comparison purposes, we consider the simple static case with non-durable goods.

3.1. Static framework

First consider the case of consumers who demand shrimp only for present consumption. We consider a group of producers, denoted as Group A, who are the sole operators in the fishing ground each day. We further assume that group members organise production activities cooperatively: they collectively decide levels of total daily production. In this sense, Group A, as a whole, can be described as a monopolist. The monopolist producer faces a linear demand schedule:

$$q = a - bp$$

where the variables q and p are respectively cumulative output produced by the monopolist and the corresponding unit prices. a and b are the exogenously given parameters. Notice that, by virtue of the auctioning system described in section 2, different portions of output can be sold at different unit prices, and the earlier landings are sold at higher prices than the later ones. In what follows, we will denote by \bar{p} , the lowest price above which some positive transactions take place. We call \bar{p} the marginal price. Assuming the production technology with a constant marginal cost, c , the monopolist's profit function can then be written as:

$$\pi = \int_0^q (p - c) dq.$$

From the first-order condition of the monopolist's profit maximisation problem, we obtain the equilibrium marginal price, \bar{p}^m , output level, \bar{q}^m , and profit level, $\bar{\pi}^m$, as follows:

$$\bar{p}^m = c \tag{3.1}$$

$$\bar{q}^m = a - bc \tag{3.2}$$

$$\bar{\pi}^m = \frac{1}{2b} (a - bc)^2.$$

Unlike in the case of the classical monopolist whose equilibrium marginal revenue is greater than the marginal cost, the price discriminating monopolist attains the Pareto-optimal outcome as implied by (3.1).

We now construct a dynamic setting by considering that shrimp can be stored and consumed in the following days. Thus we introduce additive cost, δ per day, for storing harvested shrimp in deep freezers. The current demand faced by the monopolist producer can therefore be broken down into two parts, a residual demand on date t for present consumption q_t^t , and the discounted demand for future consumption q_t^{t+1} . In order to keep the exposition simple, we assume the followings. The implications of these assumptions for the results are discussed in section 5.

Assumption 1: *One period storability*

Harvested shrimp is stored for only one period. This assumption implies the

following boundary condition for the discount factor in our algebraic example⁶:

$$\frac{1}{3} \left(\frac{a}{b} - c \right) < \delta < \frac{1}{2} \left(\frac{a}{b} - c \right). \quad (3.3)$$

Assumption 2: *Substitutability of stored shrimp*

Harvested shrimp can be frozen and consumed as a substitute for fresh shrimp by some consumers. Given one-period storability, the demand for consumption in the next period spills over into the current period, and thus can be written as a function of price p_t , and storage cost δ (i.e., an additive discount factor):

$$q_t^{t+1} = a - b(p_t + \delta). \quad (3.4)$$

This assumption implies that the monopolist faces the following residual demand for current consumption:

$$\begin{aligned} q_t^t &= a - bp_t - q_{t-1}^t \\ &= a - bp_t - \{a - b(\bar{p}_{t-1} + \delta)\} \\ &= b(\bar{p}_{t-1} + \delta) - bp_t. \end{aligned} \quad (3.5)$$

The aggregated demand that monopolist faces on day t has a kink at $p_t = \frac{a}{b} - \delta$:

$$\begin{aligned} q_t &= b(\bar{p}_{t-1} + \delta) - bp_t, & \text{if } p_t > \frac{a}{b} - \delta, \\ &= a - b(2p_t - \bar{p}_{t-1}), & \text{if } p_t \leq \frac{a}{b} - \delta. \end{aligned} \quad (3.6)$$

Figure 3.1 shows a graphical illustration of the demand curve (3.6). The products priced above the kink level, $\frac{a}{b} - \delta$, are for immediate consumption, while the

⁶The assumption of one period spill-over is implied by:

$$\frac{a}{b} - 2\delta < \bar{p}_t^m < \frac{a}{b} - \delta.$$

Using the equilibrium marginal price for the monopolist producer (3.10), this is equivalent to:

$$\frac{a}{b} - 2\delta < c + \delta < \frac{a}{b} - \delta.$$

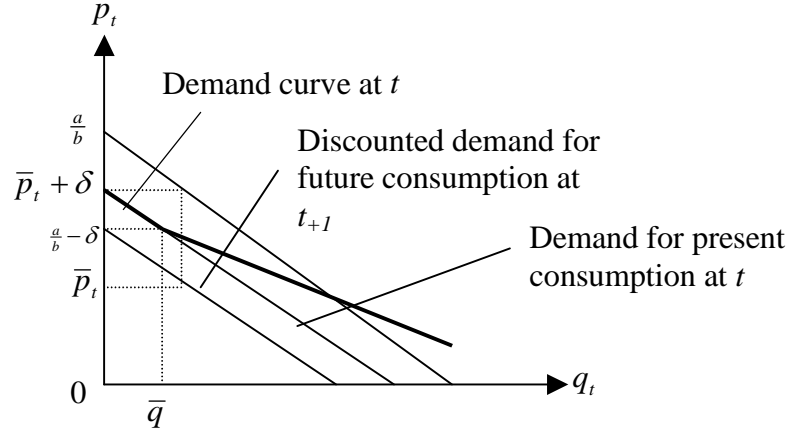


Figure 3.1: Demand curve in period t when harvested products are storable

products with prices lower than the kink level are partly purchased for immediate consumption and partly for future consumption.

The monopolist maximises the following profit function:

$$\Pi^M = \sum_{t=0}^{\infty} \eta^t \pi_t = \sum_{t=0}^{\infty} \eta^t (\pi_t^t + \pi_t^{t+1}) \quad (3.7)$$

where π_t denotes instantaneous profit from day t that can be broken down into π_t^t , the profits from the sales to consumers with contemporaneous demand, and π_t^{t+1} , the profit gained from selling to those who store them for future consumption. The variable η is a usual time discount factor which we set equal to one in this study. Since the changes in marginal price \bar{p}_t only affect π_t^t, π_t^{t+1} and π_{t+1}^{t+1} , the monopolist's intertemporal profit maximisation problem (3.7) can be simply written as:

$$\text{Max}_{\bar{p}_t} (\pi_t^t + \pi_t^{t+1} + \pi_{t+1}^{t+1}). \quad (3.8)$$

From the first-order condition of the above problem, we have:

$$2b(c - \bar{p}_t^m) + b(\bar{p}_t^m + \delta - c) = 0. \quad (3.9)$$

The equilibrium marginal price is therefore:

$$\bar{p}_t^m = c + \delta. \quad (3.10)$$

Since the second-order condition is satisfied, (3.10) corresponds to a global maximum. Equation (3.10) characterises a stable equilibrium, in the sense that starting from any level of marginal price, the marginal price will reach this equilibrium level and remain stationary.

From (3.10), we obtain the following equilibrium levels of output and profit respectively

$$\bar{q}_t^m = a - b(c + \delta), \quad (3.11)$$

$$\bar{\pi}_t^m = \frac{1}{2b} (a - bc)^2 - \frac{\delta}{2} (2a - 2bc - 3b\delta). \quad (3.12)$$

Selling products for future consumption at a discounted price inevitably implies losing some profit in the future period as depicted in (3.12). Since the monopolist is unable to differentiate present and future consumers, the producer surplus will be reduced by preempting future demand. Henceforth, we call this effect, “*demand preemption*”. In order to prevent future consumers from preempting demand, the monopolist therefore tends to inefficiently raise the marginal price by restricting output. In other words, when product is partially durable, a price discriminating monopolist will under-produce so as to avoid the unprofitable *demand preemption* effect.

It is interesting to contrast the above with the Coase conjecture. In the Coase conjecture, the standard durable-goods monopolist is unable to price discriminate intertemporally. In such a circumstance, the monopolist tends to lose market power as his pricing decision today creates his own future competition. Being unable to price discriminate, the monopolist is obliged, in the limit, to charge the competitive marginal price as “the producer of an infinitely durable good loses all his monopoly power when the period between his price adjustments converges

		<i>j</i> 's strategy	
		One haul	Two hauls
<i>i</i> 's strategy	One haul	x,x	y,z
	Two hauls	z,y	w,w

Table 4.1: Payoff structure of two fishermen with two strategies

to zero” (Tirole 1988, p.81). When the monopolist producer can price discriminate among buyers, as in our model, the durable-goods monopolist will raise the equilibrium marginal price so as to prevent future demand pre-emption.

4. Group B as a price discriminating oligopoly

In this section, we examine the other group, Group B, composed of non-cooperative producers. First, we consider the static case without storability of shrimp, we then incorporate the partial storability.

4.1. Static framework

As explained in section 2, landed shrimp fetches different prices in accordance with the timing of landings. The existing auction system allows fishermen to behave as a price discriminating monopolist, provided they can agree to coordinate their production decisions. Without such coordination, each fisherman faces the situation in which he trades off the incentive to fish competitively for a larger quantity on the one hand, or to fish less to sell at higher prices on the other. In order to take account of such tradeoffs, let us consider a simple case in which two identical fishermen operate non-cooperatively and they decide whether to make one haul or two hauls during one fishing trip. The payoff structure of this game can be represented as the bi-matrix in Table 4.1. Note that if both fishers choose either strategies of One haul or Two hauls in an equilibrium, they will

land simultaneously, i.e. the probabilities of landing first or second is $\frac{1}{2}$. As in the previous section, demand for shrimp is represented as:

$$q = a - bp.$$

Fisherman i 's expected payoff can be written as:

$$E\pi_i(q_i, q_j) = \int_0^q [Ep(q_i, q_j) - c] dq_i$$

where $Ep(q_i, q_j)$ is the expected prices for fisherman i 's landing. $Ep(q_i, q_j) = \frac{a}{b} - \frac{q_i}{b}$ when i lands first, while $Ep(q_i, q_j) = \frac{a}{b} - \frac{q_i + q_j}{b}$ when i lands second. There are three main cases to consider: (a) $x < z$ and $y < w$, (b) $x > z$ and $y > w$, and (c) $x = z$ and $y = w$. Since:

$$\begin{aligned} x &= \frac{1}{2} \int_0^{2\bar{q}} \left(\frac{a}{b} - c - \frac{q}{b} \right) dq \\ y &= \int_0^{\bar{q}} \left(\frac{a}{b} - c - \frac{q}{b} \right) dq \\ z &= \int_0^{2\bar{q}} \left(\frac{a}{b} - c - \frac{q + \bar{q}}{b} \right) dq \\ w &= \frac{1}{2} \int_0^{4\bar{q}} \left(\frac{a}{b} - c - \frac{q}{b} \right) dq, \end{aligned}$$

we obtain the following results.

Case (a) $x < z$ and $y < w \iff a - bc > \frac{7}{2}\bar{q}$. Strategy Two (to make two hauls) strictly dominates strategy One (to make one haul), thus both fishers make two hauls and land simultaneously in equilibrium.

Case (b) $x > z$ and $y > w \iff a - bc < \frac{7}{2}\bar{q}$. Strategy One strictly dominates Two. Thus, both fishers make just one haul and land simultaneously in equilibrium.

Case (c) $x = z$ and $y = w \iff a - bc = \frac{7}{2}\bar{q}$. All strategies (One, Two, and any mixed strategies of One and Two) are equilibrium strategies.

From the above, it is implied that when demand is relatively elastic, i.e. small b and large $a - bc$, as typically in Case (a), the incentive to fish is stronger resulting in simultaneous landings of larger quantities. Conversely, when $a - bc$ is relatively small, i.e., demand is less elastic, as in Case (b), the incentive to fish less for possibly higher prices becomes stronger and offsets the incentive to fish more to some extent. Intuitively, this is because when price elasticity of demand is small enough, the potential gains from fishing less for higher prices become more compelling. Case (c) is a trivial situation in which each fisher is indifferent between choosing strategy One or Two regardless of the other's strategy. Further, the range of elasticity of demand under which two fishers both decide to fish One haul diminishes as the number of group member increases, while the range that generates mixed strategy equilibria expands⁷. In this paper, we adopt a simple model with two fishers and concentrate our attention on the case in which demand is sufficiently elastic so that incentive to fish more is dominant. This makes the analysis of the strategic interactions between the two groups tractable when there is significant competition among non-cooperative fishers.

The expected inverse demand function of two non-cooperative fishers can therefore be written as:

$$Ep_i(q_i, q_j) \equiv \frac{1}{2} \left(\frac{a}{b} - \frac{q_i}{b} \right) + \frac{1}{2} \left(\frac{a}{b} - \frac{q_i + q_j}{b} \right).$$

Assuming no risk aversion, individual producer i 's profit maximising problem

⁷Mixed strategy equilibria give rise to a situation in which homogeneous fishers choose to land at different times and may experience the trade-off between landing early for higher prices and fishing longer for larger quantities. Analysis of such mixed strategy equilibria, though interesting, is beyond the scope of this paper.

becomes:

$$Max_{q_i} E\pi_i(q_i, q_j) = Max_{q_i} \int_0^{q_i} [Ep_i(q_i, q_j) - c] dq_i. \quad (4.1)$$

Taking the first-order condition of (4.1), we obtain

$$\left(\frac{a}{b} - \frac{\bar{q}_i}{b} - c\right) + \left(\frac{a}{b} - \frac{\bar{q}_i + \bar{q}_j}{b} - c\right) = 0. \quad (4.2)$$

Symmetric reaction function can be written as:

$$\bar{q}_i(\bar{q}_j) = a - bc - \frac{\bar{q}_j}{2}.$$

The Nash equilibrium level of output, \bar{q}_i^N becomes

$$\bar{q}_i^N = \frac{2}{3}(a - bc), \quad (4.3)$$

and the corresponding levels of total quantity, marginal price and profit are:

$$\bar{q}^N = \frac{4}{3}(a - bc), \quad (4.4)$$

$$\bar{p}^N = c - \frac{1}{3}\left(\frac{a}{b} - c\right) < c, \text{ and} \quad (4.5)$$

$$\bar{\pi}^N = \frac{1}{2b}(a - bc)^2 \left(\frac{8}{9}\right).$$

Comparing the above with (3.1) and (3.2), we can state the following.

Result 4.1: Rent-dissipation effect with price uncertainty:

Two non cooperative producers will over-produce when they can price discriminate among buyers but they are uncertain about the price schedules they actually face.

It is noteworthy, that when the price elasticity of demand is low, the “*rent-dissipation*” effect becomes milder. This is consistent with the previous observation that the incentive to fish more is reduced when the demand becomes inelastic.

4.2. Dynamic framework with two myopic producers

Let us now turn to the group of two non-cooperative producers in a dynamic setting with demand interdependence. First we consider the situation in which two producers are myopic in the sense that they maximise the expected payoff from the current period only. The expected profit of producer i on day t can be written as:

$$E\pi_{i,t} = \frac{1}{2} \int_0^{q_i} [p_t(q_i) - c] dq_i + \frac{1}{2} \int_0^{q_i} [p_t(q_i + q_j) - c] dq_i. \quad (4.6)$$

As we have seen in Figure 3.1, fishermen face demand curve with a kink at $p = \frac{a}{b} - \delta$. It is therefore useful for the purpose of identifying the equilibrium outcomes to distinguish two cases depending on the location of the kink. In the following sections, we therefore refer to the following two cases; case (i) when the market is relative large (i.e., large $\frac{a}{b} - c$), and case (ii) when the market is relatively thin (i.e., small $\frac{a}{b} - c$). The individual equilibrium output levels and the marginal prices for the two cases are as follows (see Appendix A for a formal proof):

Equilibrium marginal prices:

$$(i) \bar{p}_t^M = c - \frac{a - bc}{7b}, \text{ when } \frac{a}{b} - c > \frac{7}{6}\delta \quad (4.7)$$

$$(ii) \bar{p}_t^M = c + \frac{a - bc - 2b\delta}{5b}, \text{ when } \frac{a}{b} - c \leq \frac{7}{6}\delta \quad (4.8)$$

Equilibrium individual output levels:

$$(i) \bar{q}_i^M = \frac{4}{7}(a - bc) \quad (4.9)$$

$$(ii) \bar{q}_i^M = \frac{2}{5}(a - bc) + \frac{b\delta}{5} \quad (4.10)$$

From (4.7) and (4.8), we observe $\bar{p}_t^M \leq c - \frac{\delta}{6}$ in both cases. This implies that the *rent dissipation* effect persists in the dynamic setting with demand spill-overs. By comparing (4.9) and (4.10) with (4.3), we notice in case (i), the equilibrium

output level with inter-temporal demand spill-over turns out to be smaller than the equilibrium output level without demand spill-over. This is because, when δ is relatively small, a greater proportion of future demand, q_t^{t+1} , spills over into current period and generates a **demand preemption effect** in the sense that the highly priced portion of demand is pre-empted by the quantity supplied at low marginal prices in the previous day. On the other hand, when δ is relatively large, as in the case (ii), the equilibrium output level become greater with the demand spill-over than without it. As both *rent-dissipation* and *demand preemption* effects are simultaneously at work, we observe,

Result 4.2: Suppose duopolists can price discriminate buyers and the produced goods are partially durable. Suppose also they maximise instantaneous profit without taking account of future profit. Then, when storage costs are relatively small (or market is large), the *demand preemption* effects offsets some of the *rent dissipation* effect arising from competition between the duopolists. As storage costs become larger (or market size diminishes), the *rent dissipation* effect becomes more prominent.

4.3. Dynamic framework with two non-myopic producers

In this subsection, we consider the case of non-myopic duopolists that maximise their intertemporal expected payoff. Following the same steps as in section 3, the non-myopic producers' expected inter-temporal profit maximisation can be simplified to:

$$\underset{\bar{p}_t}{Max} (E\pi_t^t + E\pi_t^{t+1} + E\pi_{t+1}^{t+1}).$$

Equilibrium marginal prices of the two non-myopic producers \bar{p}_t^{NM} , for the two cases are (detailed derivations are included in Appendix B):

$$(i) \bar{p}_t^{NM} = c + \frac{7a - 8b\delta - 3bc}{23}, \text{ when } \frac{a}{b} - \frac{117c}{135} > \frac{7}{6}\delta + \frac{\delta}{30} \quad (4.11)$$

$$(ii) \bar{p}_t^{NM} = c + \frac{9a - 12b\delta - 7bc}{27}, \text{ when } \frac{a}{b} - \frac{117c}{135} \leq \frac{7}{6}\delta + \frac{\delta}{30}. \quad (4.12)$$

Comparing these with (4.7) and (4.8), we observe the followings. When δ is relatively small, notably in the case (i), the equilibrium marginal price of non-myopic agents may become greater than that of myopic agents, i.e. $\bar{p}_t^{NM} > \bar{p}_t^N$. While when δ is relatively large, or demand is fairly inelastic, the marginal price with non-myopic fishers becomes lower than myopic ones, i.e. $\bar{p}_t^{NM} \leq \bar{p}_t^N$. This implies that if δ is sufficiently small then the expected payoff of non myopic fishers is higher than the case when both producers behave myopically. This is because non-myopic fishers are able to prevent *demand pre-emption* effect by curtailing output levels. On the other hand, if δ is sufficiently large then non-myopic fishers tend to increase output as expected gains override the expected losses from pre-empting future demand.

5. The alternating duopoly between Groups A and B

In summary, Group A is composed of cooperative members so that decisions concerning the aggregate level of output are made collectively and thus Group A as a whole can behave like a price discriminating monopolist. When the harvested shrimp is storable, Group A tends to under-produce by setting the marginal price higher than the marginal cost so as to prevent unprofitable *demand preemption*. The second group, Group B, is composed of two non-cooperative members who decide individually how much to produce by setting an expected marginal revenue equal to a marginal cost. As a result, given a sufficiently elastic demand and a substantial storage cost, Group B as a whole tends to over-produce and dissipates the rent. The goal in this section is to examine how Groups A and B should behave

when they alternate fishing by day in the presence of price discrimination and intertemporal demand spill-overs due to partial durability of harvested shrimp.

Here, alternating duopoly is considered as a rotation scheme in which duopolists take turns to produce. What is important is the fact that the rotation allows producers to react immediately to the opponents/competitors. Such strategic interactions embodied in the alternating duopoly have been analysed comprehensively by Eric Maskin and Jean Tirole in a series of articles (1987, 1988a, 1988b). We adopt, in this section, the approach of Maskin and Tirole (1988a) to study the behaviour of alternating groups by taking the rotating system as exogenously given and by restricting the fishermen to Markov strategies. Under the Markov assumption, the players use only the most recent history, unlike in a standard repeated game analysis model in which agents typically take into account an entire history including one's own past actions. Though restrictive, the Markov assumption has some intuitive appeal and is justifiable when people are committed to a rotation scheme: one producer is committed to a particular action in one period — whether a quantity or a price — that cannot be altered for a finite period during which the other producer moves. Such a commitment naturally implies that recent actions have a stronger bearing on current and future payoffs than those of the more distant past (Maskin and Tirole 1988a, p.553). Moreover, the Markov assumption ensures that “players use the same strategies in identical subgames (Slade 1995, p.370)”. From this it follows that “if we start a game in a period that is chosen so that everything that matters from an economic point of view is the same as in the first period, behaviour should remain unchanged” (ibid.). In a nutshell, the Markov strategy limits players to respond only to the payoff relevant history and enables us to transform the dynamic features of the interactions between the alternating groups into a reduced-form static competition.

In this section we assume myopic behaviour of Group B members, and that they maximise instantaneous profit. This assumption will be tested in our data but there are a number of reasons why, a priori, this would appear a reasonable

working hypothesis. First, when δ is relatively small, it may become profitable for an individual member of Group B to deviate from the myopic behaviour by taking future benefits into consideration. However, such profitable deviation is difficult, because the reduction of instantaneous income from producing less in current period is solely borne by the deviating individual, while the future gain derived from increased future residual demand is distributed equally among the Group B members. Secondly it is intuitive to think that a rotation scheme with Group A makes future expected benefit of Group B members far less important, which drives them to behave myopically.

5.1. Alternating moves between Groups A and B

Let us first describe the rotating sequence of quantity and marginal price setting. On each day, only one of the two groups produces and earns income. At day t , Group A operates and produces \bar{q}_t with a corresponding marginal price \bar{p}_t . Its instantaneous profit is denoted as π_t . In day $t + 1$, Group B members will have observed \bar{p}_t and \bar{q}_t , and produce non-cooperatively. We denote the instantaneous profit accruing to member i of Group B as $\pi_{i,t+1}$. On day $t + 2$, Group A observes the marginal price of the previous day, \bar{p}_{t+1} and \bar{q}_{t+1} , and produces \bar{q}_{t+2} by choosing \bar{p}_{t+2} . This rotating sequence continues infinitely.

As we have discussed in the previous sections, producers can price discriminate among buyers on each day and harvested shrimp can be stored with an additive cost δ for one day. This storability of shrimp makes the demand for future consumption spill-over into the present day. Consequently, Group A can no longer take full advantage of being a price discriminating monopolist. Instead, Groups A and B are made to interact as alternating-move duopolists.

Table 5.1 summarises the demand, for current and future consumption, faced by the groups on respective days. Notice in Table 5.1 that each group's decision depends only on the marginal price of the competitor on the previous day.

Days	t	$t + 1$	$t + 2$
Operating group	A	B	A
Demand for current period consumption	q_t^t $= b(p_{t-1} + \delta) - bp_t$	q_{t+1}^{t+1} $= b(p_t + \delta) - bp_{t+1}$	q_{t+2}^{t+2} $= b(p_{t+1} + \delta) - bp_{t+2}$
Discounted demand for next period consumption	q_t^{t+1} $= a - b(p_t + \delta)$	q_{t+1}^{t+2} $= a - b(p_{t+1} + \delta)$	q_{t+2}^{t+3} $= a - b(p_{t+2} + \delta)$

Table 5.1: Decomposition of demand faced by Groups A and B

Some remarks are in order. First, in our problem, the rotation arrangement is exogenous. Secondly, decisions over quantity and marginal price have the same meaning since marginal revenue and demand schedules coincide. Thus, regardless of whether we take marginal prices or output levels as choice variables, our results remain the same. So Group A's problem is solved as a price analogue of Cournot competition.

Let us suppose that Group A operates on odd-numbered days; $t = 2k - 1$ and Group B in even-numbered days; $t = 2k$, $k = 1, 2, \dots$. Let the marginal costs of the production technologies available for Groups A and B be constant and denoted by c_A and c_B , respectively. On day t , Group A's instantaneous profit π_t is a function of the current marginal price \bar{p}_t and the marginal price of the previous day \bar{p}_{t-1} . This instantaneous profit can be further broken down into the profit from selling to current consumers π_t^t and the profit from selling to future consumers π_t^{t+1} . From the Markov assumption, Group A's strategy depends only on the pay-off relevant state variable, i.e., the marginal price of the previous day. We can thus write:

$$\pi_t = \pi_t(\bar{p}_t, \bar{p}_{t-1}) = \pi_t^t(\bar{p}_t, \bar{p}_{t-1}) + \pi_t^{t+1}(\bar{p}_t).$$

Group A will maximise the sum of the discounted future profit, given the marginal

price of Group B on the previous day, \bar{p}_{t-1} :

$$\underset{\bar{p}_t}{Max} [\pi_t (\bar{p}_t, \bar{p}_{t-1}) + \eta \pi_{t+2} (\bar{p}_{t+2}, \bar{p}_{t+1}) + \eta^2 \pi_{t+4} (\bar{p}_{t+4}, \bar{p}_{t+3}) + \dots] \quad (5.1)$$

where η is the time discount factor. The Markov assumption also allows us to introduce the following valuation function for Group A⁸:

$$V^A (\bar{p}_t) = \underset{\bar{p}_t}{Max} [\pi_t (\bar{p}_t, \bar{p}_{t-1}) + \eta W^A (\bar{p}_t)] \quad (5.2)$$

$$W^A (\bar{p}_t) = \pi_{t+2} (\bar{p}_{t+2}, \bar{p}_{t+1}) + \eta V^A (\bar{p}_{t+2}). \quad (5.3)$$

The second term in (5.2) is the discounted value of the profit from the future, which will be maximised at day $t + 2$, the next time Group A operates. In this formulation, “the future appears as the same starting from next time period (Maskin and Tirole 1988a, p.552).” Consequently, the intertemporal maximisation problem in (5.1) can be reduced to the maximisation problem concerning the relevant time period only. In other words, we can concentrate on the maximisation problem of the present value of profits in the future so long as the current action has an impact. We can now rewrite Group A’s maximisation problem in the following reduced-form:

$$\underset{\bar{p}_t}{Max} [\pi_t (\bar{p}_t, \bar{p}_{t-1}) + \eta \pi_{t+2} (\bar{p}_{t+2}, \bar{p}_{t+1})]. \quad (5.4)$$

The profit function in (5.4) can be further decomposed as:

$$\underset{\bar{p}_t}{Max} [\pi_t^t (\bar{p}_t, \bar{p}_{t-1}) + \pi_t^{t+1} (\bar{p}_t) + \eta \pi_{t+2}^{t+2} (\bar{p}_{t+2}, \bar{p}_{t+1} (\bar{p}_t)) + \eta \pi_{t+2}^{t+3} (\bar{p}_{t+2})]. \quad (5.5)$$

Notice that the last term in the objective function (5.5) is irrelevant for today’s decision, since it will be considered in the maximisation on the future day, $t + 2$.

Finally, letting $\eta = 1$, the relevant reduced-form problem of Group A becomes:

$$\underset{\bar{p}_t}{Max} [\pi_t^t (\bar{p}_t, \bar{p}_{t-1}) + \pi_t^{t+1} (\bar{p}_t) + \pi_{t+2}^{t+2} (\bar{p}_{t+2}, \bar{p}_{t+1} (\bar{p}_t))] \quad (5.6)$$

⁸These valuation equations originate from dynamic programming. More detailed exposition of the dynamic programming equations can be found in Tirole (1988a, pp.265-266).

$$s.t. \quad \bar{p}_{t+1}(\bar{p}_t) = R_B(\bar{p}_t).$$

where $R_B(\bar{p}_t)$ represents the marginal price determination of Group B with respect to the marginal price chosen by Group A in the previous day t . We consider by virtue of intra-group cooperation, Group A behaves as a leader: it chooses the marginal price on day t , anticipating Group B's actions on day $t+1$, which will in turn affect Group A's profit on day $t+2$. We first need to solve the problem with Group B as a follower. As in the preceding sections, Group B members behave non-cooperatively and maximise the following individual expected profit:

$$Max_{q_i^t} E\pi_{i,t}(q_i^t, \bar{q}_j^t).$$

To solve Group B's problem, we follow the same steps taken in Subsection 4.2. Using the results (4.7) and (4.8), we obtain two expressions for the Nash equilibrium marginal prices attained by Group B on day $t+1$ given the marginal price chosen by Group A on previous day t . Since we assume that Group B members behave myopically and maximise instantaneous profit, the derived marginal price determination equations of Group B in each period can be written as follows:

$$\begin{aligned} \text{(i)} \quad \bar{p}_{t+1} = R^B(\bar{p}_t) &= \frac{8bc_B - a - b\bar{p}_t}{6b}, \text{ when } \frac{5a}{b} - 4c_B > \bar{p}_t + 6\delta \\ \text{(ii)} \quad \bar{p}_{t+1} = R^B(\bar{p}_t) &= \frac{4bc_B + a - b\bar{p}_t - 2b\delta}{4b}, \text{ when } \frac{5a}{b} - 4c_B \leq \bar{p}_t + 6\delta. \end{aligned}$$

Solving (5.6) for each case obtains the results shown in Table 5.2 (step by step derivations are shown in Appendix C). Group A always chooses a marginal price lower than its marginal cost. This aggressive behaviour of Group A is a strategic reaction to the *rent-dissipation effect* caused by non-cooperative Group B members. To put it another way, over-production of Group B implies preemption of the high value demand faced by Group A, which depresses Group A's profit on the subsequent day. Anticipating this, Group A tries to maximise profit by drastically undercutting the marginal price. Such a strategy of Group A, in return, prevents Group B from producing a *rent-dissipation effect*.

Case (i)	Case (ii)
$\bar{p}_A < c_A$ $\bar{p}_B < c_B + \delta$ when $c_A = c_B = c, \bar{p}_B < \bar{p}_A$	$\bar{p}_A < c_A$ $c_B < \bar{p}_B < c_B + \delta$ when $c_A = c_B = c, \bar{p}_B > \bar{p}_A$

Table 5.2: Equilibrium marginal prices for Groups A and B

To gain further insights from these results, it is useful to recall that individual decisions of Group B's members are made on the basis of their 'expected' marginal revenue, which lies above the actual demand. Group A is able to correct this expected price schedule by *demand preemption*. In other words, Group A encroaches upon the highly priced portion of the demand schedule faced by Group B. Particularly when the discount factor δ is large and/or demand is relatively inelastic (i.e. large b), typically in the case (ii), demand preemption by Group B implies a serious marginal loss of highly valued portion of demand faced by Group A. Group A will then take vigorous action to recoup the highly valued portion of the demand by undercutting the marginal prices.

The basic intuition gained from our analysis is robust in more general settings, particularly in a model with infinite storability and imperfect substitutability of stored shrimp. In our model, partial durability imposes a lower bound on the storage cost δ . Relaxing this changes the shape of demand curve (with multiple kinks at $\frac{a}{b} - \delta, \frac{a}{b} - 2\delta, \frac{a}{b} - 3\delta \dots$) and the equilibrium outcome, but it does not alter the fundamental nature of demand interactions. For instance, infinite durability implies an infinitely small value of δ , that is the special case of (i). Imperfect substitutability between stored and fresh shrimp implies that stored shrimp is not substitutable for the higher valued portion of demand but only substitutable for the lower valued part. Then the theoretical implications of the static framework can be applied to the market of high valued products, while the basic intuitions gained in this section remain applicable to the lower valued ones.

There may be a possibility of collusion between Groups A and B in which Group A's monopolistic outcome is realised everyday. Such a collusive outcome could be sustained when the two groups agree on a punishment rule where, in the event of a deviation, the group switches to Nash behaviour the following day, provided that the time discount rate is low enough to make a one period deviation unprofitable. If there is a promising offer of collusion with Group A, Group B members may be encouraged to establish a collective production arrangement.

6. Empirical evidence

6.1. Model specification

The central implication of the theoretical analysis is that in the presence of price discrimination and partial durability of the products, the rotation scheme between Groups A and B makes them interact as alternating duopolists. Consequently, the model predicts that, due to the strategic interactions between the groups, the equilibrium marginal price of Group A becomes significantly lower when the two groups rotate fishing days than when only Group A fishes daily.

In this section, we attempt to verify the validity of the alternating duopoly model in the observed rotation arrangement using original field data. We first estimate the marginal price determination equation in which our alternating duopoly model is nested. After testing for validity of parameters implied by the theoretical model, we then proceed to estimate the marginal prices of the two groups for the first period when only Group A operates and for the second when both Groups A and B fish on alternating days.

Following the estimation strategy of alternating duopoly proposed in Slade (1992), we estimate a marginal price determination equation. While Slade (1992) simultaneously estimates the supply and demand of gasoline producers as dynamic oligopoly, we examine only the supply behaviour of the alternating duopoly pro-

ducers. This is because, in our setting, the demand schedule is known by the producers while they continue fishing, so the producers can price discriminate among the buyers. These facts imply that the demand schedule is already incorporated in the supply behaviour chosen by the producers. We therefore sidestep the estimation of demand equation and examine the following marginal price determination equation:

$$\begin{aligned} \bar{p}_t = & \alpha + \beta_1 \text{Group} * \text{Season} * \bar{p}_{t+1} + \beta_2 (1 - \text{Group}) * \bar{p}_{t+1} \\ & + \gamma_1 (1 - \text{Season}) * \bar{p}_{t+1} + \gamma_2 (1 - \text{Group}) * \bar{p}_{t-1} \\ & + D_1 \text{Season} + D_2 \text{Group} * \text{Season} + D_3 \text{Day} + D_4 \text{Day} * \text{Season} + \varepsilon_t \end{aligned} \quad (6.1)$$

where dummy variables for Group and Seasons are set as Group=1 for Group A, and 0 for Group B, Season=0 for April - May when only Group A operates, and Season=1 for June - August when Groups A and B operate alternately. Day dummies control for possible influences arising from particular days of the week.

Coefficients β_1 and γ_1 reflect Group A's intertemporal reactions in the second and the first season respectively. According our model of alternating duopoly, they are expected to take positive values. Coefficient β_2 captures Group B's intertemporal reaction while γ_2 reflects Group B's myopic behaviour. That is, if γ_2 is positive and significant but β_2 is not significant, the hypothesis of myopic behaviour of Group B is not rejected by the data.

The theoretical model predicts that prices should be lower when Groups A and B alternates. By calculating the equilibrium marginal prices using the estimated model parameters, it allows us to further examine the consistency of the empirical model with the theory.

After testing for the validity of the specification of the marginal determination equation and underlying model of alternating duopoly, but before we proceed to estimate the equilibrium marginal prices, constancy of estimated parameters must be tested. As discussed in Slade (1992), we do this by testing it against

	April-May	June-August
Group A	$\frac{\alpha+D_3}{1-\gamma_1}$	$\frac{(1+\beta)(\alpha+D_1)+D_2+\beta_1(D_3+D_4)}{1-\beta_1(\beta_2+\gamma_2)}$
Group B		$\frac{(1+\beta_2+\gamma_2)(\alpha+D_1)+\gamma_2 D_2+D_3+D_4}{1-\beta_1(\beta_2+\gamma_2)}$

Table 6.1: Equilibrium marginal prices

an alternative hypothesis of gradual changes in the parameters using residual diagnostics.

If the constancy of the estimated parameters is not rejected, we can calculate the implied equilibrium marginal prices as follows (Slade 1995). Assuming Markov strategies, the dynamic marginal price determination process can be approximated by dynamic reaction functions:

April - May:

$$\bar{p}_t - p^* = R(\bar{p}_{t+1} - p^*), \quad t = 1, 2, 3 \dots \quad (6.2)$$

June - August:

$$\bar{p}_t - p_A^* = R_A(\bar{p}_{t+1} - p_B^*), \quad t = 2k - 1, k = 1, 2, 3 \dots \quad (6.3)$$

$$\bar{p}_t - p_B^* = R_B(\bar{p}_{t-1} - p_A^*) + \widetilde{R}_B(\bar{p}_{t+1} - p_A^*), \quad t = 2k, k = 1, 2, 3 \dots \quad (6.4)$$

where p^* , p_A^* and p_B^* are the long-run equilibrium marginal prices, and R , R_A , R_B and \widetilde{R}_B measure intertemporal responses of Group A and Group B. Solving the above equations for equilibrium marginal prices, we obtain equilibrium marginal prices as shown in Table 6.1 (Appendix D contains step by step derivations).

6.2. Description of the data

The data set of daily transactions of Shiroebi collected by Shinminato Fishery Cooperative Association is used for the analysis. Details of each transaction such as unit prices, quantities, identities of buyers, and identities of producers (in the case of Group B), are recorded by auctioneers and collated electronically for the Cooperative's accounting purposes. Table 6.2 shows some basic information

	April~May	June~August	
		Group A	Group B
Number of fishing days per month	19.5	12.7	12.3
Lowest price of each fishing day (yen/kg)	1274.8 (228.6)	811.9 (130.0)	824.3 (177.8)
Total landings per day (kg)	1358.2 (625.5)	1804.8 (1198.3)	932.1 (477.1)
Highest price of each fishing day (yen/kg)	1771.0 (524.4)	1164.6 (522.2)	1381.7 (603.6)
Average price (yen/kg)	1457.4 (280.6)	898.4 (162.0)	1025.3 (223.3)
Average monthly landings (kg)	25,862	29,776	
Average monthly revenue (1000 yen)	38,650	29,930	

Notes: 94 observations on 30 fishing days in April~May and 64 fishing days in June~August, of which 34 days of Group A and 30 days of Group B, are used. Standard deviations are shown in brackets.

Table 6.2: Means and standard deviations of price and daily landings

on 2,281 transactions that took place during 94 fishing days between April and August 1997 (30 fishing days in April-May and 64 fishing days in June-August).

From the table it is clear that more fishing took place during the second season than in the first season. In fact, Groups A and B operated during more than 85% of the total number of possible fishing days in the latter period, compared with a proportion of only 65% during the former season. For Group A, the mean daily landings in the latter season were higher than those in the first season at 95% confidence level (p value of the one-sided test of equal mean is 0.0359). Consistent with this, the mean value of the lowest prices in the first season is 1,274.8 yen/kg, significantly higher than 811.9 yen/kg for the second season (p-value of the one-sided test of equal mean is less than 0.0001). Mean values of the highest and average prices of each fishing day also indicate that the daily demand schedule in the second season is significantly depressed relative to that in the first season (p values of F-test are 0.0001 and less than 0.0001 respectively). Finally, aggregated monthly landings and revenues for Groups A and B are greater and smaller in the season respectively.

6.3. Results

We use OLS procedure to estimate the parameters of the marginal price determination equation (6.1). Estimation [1] in Table 6.3 reports results of a general model. The results of more restricted models are shown in column [2] and in Appendix D. As the estimation [1] provides our initial test of the theoretical model, we focus our attention on this specification.

First, overall, the model appears to fit the data satisfactorily. The high \bar{R}^2 indicates that it explains a high proportion of the variance in \bar{p}_t , the lowest price of each fishing day, while residual diagnostics do not suggest serious misspecification. Using the White test the null hypothesis of homoskedasticity is not rejected (p-value = 0.2987), while the Durbin-Watson Test confirms no serious autocorrelation. Second, the signs and significances of estimated parameters are consistent with the theoretical model. The coefficients β_1 , γ_1 , and γ_2 are positive and significant, while the coefficient β_2 is not significant. Furthermore, there are no significant seasonal effects except through interaction terms with *Saturday* and *Group*⁹.

As in Slade (1992), the residual diagnostics also provide a formal test of parameter constancy against an alternative hypothesis of gradual changes in the parameters. As these appear satisfactory, this suggests the use of the constant parameter model to compute the equilibrium marginal prices is valid.

The restricted model estimation which is consistent with the theoretical model is reported in the column [2]. Although the significance of coefficient β_1 falls to the 10% level, the overall specification remains satisfactory and consistent with the underlying model of alternating duopoly. Hence the parameters from this estimation are used to calculate the equilibrium marginal prices.

⁹Other possible extraneous influences may be associated with specific days of the week, such as Monday for the beginning of the week, Wednesday when there is no prefectural wholesale market, and Saturday for weekends, and national holidays. The effects of these days were found to be statistically insignificant.

	[1]	[2]
α : Constant	432.16** (151.04)	521.23** (157.78)
β_1 : Group*Season* \bar{p}_{t+1}	0.2339* (0.1031)	0.2168 ϕ (0.1103)
β_2 : (1 - Group) * \bar{p}_{t+1}	0.2822 (0.2488)	
γ_1 : (1 - season) * \bar{p}_{t+1}	0.6674** (0.1163)	0.5842** (0.1206)
γ_2 : (1 - Group) * \bar{p}_{t-1}	0.5472* (0.2317)	0.7009** (0.2184)
D ₁ : Season	-330.68 (251.26)	-263.79 (238.48)
D ₂ : Group*Season	502.99* (220.71)	367.12 ϕ (204.36)
D ₃ : Saturday	108.04 (87.167)	
D ₄ : Saturday*Season	71.723 (102.15)	
\bar{R}^2	0.7510	0.6958
White test for homoskedasticity	0.2987	0.3609
Skewness/Kurtosis test for normality	0.5097	0.2080
Durbin-Watson	1.6350	1.5684
d-statistic	(d _L =1.489, d _U =1.852)	(d _L =1.557, d _U =1.778)

Notes: In each model, the dependent variable is the lowest price of each fishing day. Standard deviations are shown in brackets. **, *, and ϕ denote significance at 99%, 95%, and 90% levels of confidence, respectively. 94 observations of lowest prices of *Shiroebi* sold between 1st April 1997 and 30 August 1997 are used for the estimation.

Table 6.3: Estimation of marginal price determination equation

	April-May	June-August
Group A	1253.56	802.33
Group B	-	819.80

Table 6.4: Estimated equilibrium marginal prices

Table 6.4 reports the estimated equilibrium marginal prices. The estimated marginal equilibrium prices implied by alternating duopoly model are consistent with the theoretical prediction: the equilibrium marginal price of Group A is lower in the second season than in the first season. In addition, the predicted equilibrium prices appear relatively close to the actual mean value of the lowest price of each fishing day given in Table 6.2. This provides additional evidence of model validity.

7. Concluding remarks

This paper investigates how rotation arrangement may induce strategic interactions between two groups of fishermen, which then affects the individual fishing behaviour and economic outcomes in a particular market environment, characterised by price discrimination and product durability. In order to obtain theoretical predictions concerning the effects of the rotation arrangement on fishing behaviour, we build a game theoretical model of alternating duopoly inspired by Maskin and Tirole (1988a).

Our theoretical model suggests that the rotation system induces strategic interactions between the groups. Group A, with a collective arrangement, behaves like a price discriminating monopolist and tends to uphold prices inefficiently in order to discourage consumers from pre-empting demand. Group B composed of non-cooperative fishermen tends to overproduce, given sufficiently elastic demand. The model reveals that the rotation scheme where fishing days are alternated has some interesting theoretical predictions: it reduces Group B's tendency to dissipate rent on the one hand, and mitigates Group A's tendency to uphold price inefficiently on the other. The model is estimated and tested using data of Japanese fishermen. The evidence suggests that behaviour of the two groups is consistent with the predictions of the alternating duopoly model.

Some remarks on more general insights gained from this study are in order. The most noteworthy is that we have shown that rotation may induce strategic interdependencies through which cooperative outcomes are realised through non-cooperative individual action. Unlike in the case of cooperation sustained by reputation effects, the cooperative outcomes discussed in the paper are achieved without relying on repeated interactions. While most of field studies of rotation emphasise that the effects of rotation arrangements are limited to promoting equity, the present paper shows that it has potential to enhance efficiency. In particular, this study demonstrates that, in certain circumstances, there need not

be an efficiency-equity trade-off.

Further, it shows the way in which cooperation in one group can affect non-cooperative behaviour in the other via particular institutional arrangements. The social capital literature has emphasised the difficulty of maintaining cooperative norms in a competitive economic environment, particularly where there are non-cooperative actors (Portes and Landolt 2000). We have demonstrated that a rotation scheme can give rise to strategic interactions between cooperative and non-cooperative groups through demand interlinkages, which produce positive spill-overs. That is, it makes the non-cooperative actors refrain from unprofitable demand preemption and behave seemingly cooperatively. The conditions under which the positive ‘contagion’ of the cooperative outcomes demonstrated in this paper occurs is obviously one area for further research¹⁰.

Our paper also provides a specific empirical example of how the community enforcement of social norms might emerge among non-cooperative agents as suggested by Kandori (1992) and Postwaite and Okuno-Fujiwara (1995). These authors do not specify explicitly how such norms are actually transmitted and influence individual incentives. Our analysis shows that a specific institutional arrangement (i.e. rotation system) may give rise to a particular information structure and strategic interactions between the groups conducive for producing cooperative outcomes.

In developing countries, the continuous encroachment of competitive forces, population pressure and the gradual erosion of tradition co-operative norms would appear to threaten the management of common resources vital for so many. Our analysis demonstrates that such dismal outcomes are by no means pre-determined and that sustainable self-governance institutional arrangements are possible.

¹⁰I am grateful to one of the referees for suggesting this point.

A. Equilibrium marginal price of non-cooperative group composed of two myopic agents with dynamic demand spill-over

The expected profit of producer i in period t is:

$$E\pi_{i,t} = \frac{1}{2} \int_0^{q_i} [p_t(q_i) - c] dq_i + \frac{1}{2} \int_0^{q_i} [p_t(q_i + q_j) - c] dq_i.$$

As current demand can be broken down into a demand for current period consumption and a discounted demand for future consumption, the demand function in period t has a kink at $p_t = \frac{a}{b} - \delta$. Let us denote demand level at the kink by \hat{q} :

$$\hat{q} = b(\bar{p}_{t-1} + \delta) - b\left(\frac{a}{b} - \delta\right) = b\left(\bar{p}_{t-1} - \frac{a}{b} + 2\delta\right). \quad (\text{A.1})$$

At prices above the kink point, consumers demand the product only for immediate consumption, while for the prices lower than the kink point, the products are consumed by two types of consumers some of whom consume them immediately, and others freeze them for future consumption. Producers, however, cannot differentiate between the two types of consumers. From this it follows that the expected profit function is represented by different expressions, depending on whether the equilibrium individual output level is greater or smaller than the kink point \hat{q} . We consider the two cases separately: Case (i) when $q_i > \hat{q}$,

$$E\pi_{i,t} = \frac{1}{2} \left\{ \int_0^{\hat{q}} [p_t(q_i) - c] dq_i + \int_{\hat{q}}^{q_i} [p_t(q_i) - c] dq_i \right\} + \frac{1}{2} \int_{q_j}^{q_i+q_j} [p_t(q_i + q_j) - c] dq_i$$

Case (ii) when $q_i \leq \hat{q}$,

$$E\pi_{i,t} = \frac{1}{2} \int_0^{q_i} [p_t(q_i) - c] dq_i + \frac{1}{2} \left\{ \int_0^{\hat{q}-q_j} [p_t(q_i + q_j) - c] dq_i + \int_{\hat{q}-q_j}^{q_i} [p_t(q_i + q_j) - c] dq_i \right\}$$

The above expected profit functions can be rewritten explicitly as follows: (i) when $q_i > \hat{q}$,

$$E\pi_{i,t} = \frac{1}{2} \left\{ \int_0^{\hat{q}} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i}{b} \right) dq_i + \int_{\hat{q}}^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i}{2b} \right) dq_i \right\} \\ + \frac{1}{2} \int_0^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i + q_j}{2b} \right) dq_i.$$

(ii) when $q_i \leq \hat{q}$,

$$E\pi_{i,t} = \frac{1}{2} \int_0^{q_i} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i}{b} \right) dq_i \\ + \frac{1}{2} \left\{ \int_0^{\hat{q}-q_j} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i + q_j}{b} \right) dq_i + \int_{\hat{q}-q_j}^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i + q_j}{2b} \right) dq_i \right\}$$

From the first-order conditions of the expected profit maximisation problem, we obtain the following reaction functions:

$$(i) \text{ when } q_i > \hat{q}, \quad \text{then } q_i(q_j) = a + b\bar{p}_{t-1} - 2bc - \frac{q_j}{2} \\ (ii) \text{ when } q_i \leq \hat{q}, \quad \text{then } q_i(q_j) = \frac{a}{3} + b\bar{p}_{t-1} - \frac{4}{3}bc + \frac{2}{3}b\delta - \frac{q_j}{3}.$$

Given the reaction functions above, the Nash equilibrium is symmetric and given by:

$$\begin{aligned} \text{(i)} \quad q_i^M &= \frac{2}{3} (a + b\bar{p}_{t-1} - 2bc), \text{ when } \frac{5a}{b} - 4c > \bar{p}_{t-1} + 6\delta \\ \text{(ii)} \quad q_i^M &= \frac{1}{4} (a + 3b\bar{p}_{t-1} - 4bc + 2b\delta), \text{ when } \frac{5a}{b} - 4c \leq \bar{p}_{t-1} + 6\delta. \end{aligned}$$

From this, we obtain equilibrium marginal prices in period t :

$$\text{(i)} \quad \bar{p}_t^M = \frac{a + b\bar{p}_{t-1} - (\bar{q}_i^M + \bar{q}_j^M)}{2b} = \frac{8bc - a - b\bar{p}_{t-1}}{6b} \quad (\text{A.2})$$

$$\text{(ii)} \quad \bar{p}_t^M = \frac{a + b\bar{p}_{t-1} - (q_i^M + q_j^M)}{2b} = \frac{4bc + a - b\bar{p}_{t-1} - 2b\delta}{4b}. \quad (\text{A.3})$$

With an infinite time horizon, the game beginning at date t looks the same for all t , in the sense that the feasible strategies and the prospective payoffs are always the same. As we are interested in studying the *long-run* steady-state, we find a stationary equilibrium by requiring $\bar{p}_{t-1} = \bar{p}_t$. Thus, when such an equilibrium exists:

$$\begin{aligned} \text{(i)} \quad \bar{p}_t^N &= c - \frac{a - bc}{7b}, \text{ when } \frac{a}{b} - c > \frac{7}{6}\delta \\ \text{(ii)} \quad \bar{p}_t^N &= c + \frac{a - bc - 2b\delta}{5b}, \text{ when } \frac{a}{b} - c \leq \frac{7}{6}\delta. \end{aligned}$$

Comparing the above results with (4.3), we observe that for $\frac{a}{b} - c > \frac{3}{4}\delta$, $\bar{q}_i^M < \bar{q}_i^N$, and for $\frac{a}{b} - c \leq \frac{3}{4}\delta$, $\bar{q}_i^M \geq \bar{q}_i^N$.

B. Equilibrium marginal price of non-cooperative group composed of two non-myopic agents with dynamic demand spill-over

Non-myopic agents will maximise the following expected profits.

Case (i): when $\bar{q}_i > \hat{q}$

$$\begin{aligned}
& E\pi_t^t + E\pi_t^{t+1} + E\pi_{t+1}^{t+1} \\
&= \frac{1}{2} \left\{ \int_0^{\hat{q}} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i}{b} \right) dq_i + \int_{\hat{q}}^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i}{2b} \right) dq_i + \int_0^{q_i} \left(\bar{p}_t + \delta - c - \frac{q_i}{b} \right) dq_i \right\} \\
&+ \frac{1}{2} \left\{ \int_0^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i + \bar{q}_j}{2b} \right) dq_i + \int_0^{q_i} \left(\bar{p}_t + \delta - c - \frac{q_i + \bar{q}_j}{b} \right) dq_i \right\}.
\end{aligned}$$

Case (ii): when $\bar{q}_i \leq \hat{q}$

$$\begin{aligned}
& E\pi_t^t + E\pi_t^{t+1} + E\pi_{t+1}^{t+1} \\
&= \frac{1}{2} \left\{ \int_0^{q_i} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i}{b} \right) dq_i + \int_0^{q_i} \left(\bar{p}_t + \delta - c - \frac{q_i}{b} \right) dq_i \right\} \\
&+ \frac{1}{2} \left\{ \int_0^{\hat{q}-q_j} \left(\bar{p}_{t-1} + \delta - c - \frac{q_i+q_j}{b} \right) dq_i + \int_{\hat{q}-q_j}^{q_i} \left(\frac{a}{2b} + \frac{\bar{p}_{t-1}}{2} - c - \frac{q_i+\bar{q}_j}{2b} \right) dq_i \right. \\
&\quad \left. + \int_0^{q_i} \left(\bar{p}_t + \delta - c - \frac{q_i+\bar{q}_j}{b} \right) dq_i \right\}.
\end{aligned}$$

From the first-order conditions of the expected profit maximisation problem, we obtain the following reaction functions:

$$\begin{aligned}
\text{(i) when } q_i > \hat{q}, \quad & \text{then } q_i(q_j) = \frac{3a + 3b\bar{p}_{t-1} + 4b\bar{p}_t - 10bc + 4b\delta - 3\bar{q}_j}{6} \\
\text{(ii) when } q_i \leq \hat{q}, \quad & \text{then } q_i(q_j) = \frac{2a + 4b\bar{p}_{t-1} + 4b\bar{p}_t - 10bc + 6b\delta - 4\bar{q}_j}{7}
\end{aligned}$$

Given the reaction functions above, the Nash equilibrium is symmetric and given by:

$$\begin{aligned}
\text{(i) } \bar{q}_i^{NM} &= \frac{3a + 3b\bar{p}_{t-1} + 4b\bar{p}_t - 10bc + 4b\delta}{9}, \quad \text{when } \frac{a}{b} - \frac{5}{6}c > \frac{\bar{p}_{t-1}}{2} - \frac{\bar{p}_t}{4} + \frac{7}{6}\delta \\
\text{(ii) } \bar{q}_i^{NM} &= \frac{2a + 4b\bar{p}_{t-1} + 4b\bar{p}_t - 10bc + 6b\delta}{11}, \quad \text{when } \frac{a}{b} - \frac{5}{6}c \leq \frac{\bar{p}_{t-1}}{2} - \frac{\bar{p}_t}{4} + \frac{7}{6}\delta.
\end{aligned}$$

By letting $\bar{p}_t = \bar{p}_{t+1}$ we find a long-run stationary equilibrium marginal prices:

$$(i) \bar{p}_t^{NM} = c + \frac{3a - 21bc - 8b\delta}{23b}, \text{ when } \frac{a}{b} - \frac{117c}{135} > \frac{7}{6}\delta + \frac{\delta}{30} \quad (B.1)$$

$$(ii) \bar{p}_t^{NM} = c + \frac{7a - 29bc - 12b\delta}{5b}, \text{ when } \frac{a}{b} - \frac{117c}{135} \leq \frac{7}{6}\delta + \frac{\delta}{30} \quad (B.2)$$

The comparison of equilibrium marginal prices implies the following results.

When $\frac{a}{b} - \frac{117c}{135} > \frac{7}{6}\delta + \frac{\delta}{30}$ (from (4.7) and (B.1)),

$$\bar{p}_t^{NM} - \bar{p}_t^N = \frac{44a - 170bc - 56b\delta}{23 \times 7b}.$$

When $\frac{a}{b} - \frac{117c}{135} \leq \frac{7}{6}\delta + \frac{\delta}{30}$ and $\frac{a}{b} - c > \frac{7}{6}\delta$ (from (4.7) and (B.2)),

$$\bar{p}_t^{NM} - \bar{p}_t^N = \frac{76a - 23bc - 84b\delta}{27 \times 7b}$$

When $\frac{a}{b} - c \leq \frac{7}{6}\delta$, from (4.8) and (B.2),

$$\bar{p}_t^{NM} - \bar{p}_t^N = \frac{5(6a - 6bc - 7b\delta) - 110bc - 15b\delta}{135b} < 0.$$

From the above,

$$\bar{p}_t^{NM} \geq \bar{p}_t^N, \text{ if } \frac{a}{b} - c \leq \frac{84\delta + 53c}{76}.$$

C. Marginal prices when Groups A and B produce alternately

Taking the first-order conditions of Group A's profit maximising problem (5.6), we have:

$$\frac{\partial \pi_t^t}{\partial \bar{p}_t} + \frac{\partial \pi_t^{t+1}}{\partial \bar{p}_t} + \frac{\partial \pi_{t+2}^{t+2}}{\partial \bar{p}_{t+1}} \frac{\partial \bar{p}_{t+1}}{\partial \bar{p}_t} = 0$$

For case (i)

$$\begin{aligned} &\Leftrightarrow 2b(c_A - \bar{p}_t) + b(\bar{p}_{t+1} + \delta - c_A) \left(-\frac{1}{6}\right) = 0 \\ &\Leftrightarrow \bar{p}_t(\bar{p}_{t+1}) = \frac{13c_A - \delta - \bar{p}_{t+1}}{12}. \end{aligned} \quad (\text{C.1})$$

For case (ii)

$$\begin{aligned} &\Leftrightarrow 2b(c_A - \bar{p}_t) + b(\bar{p}_{t+1} + \delta - c_A) \left(-\frac{1}{4}\right) = 0 \\ &\Leftrightarrow \bar{p}_t(\bar{p}_{t+1}) = \frac{9c_A - \delta - \bar{p}_{t+1}}{8}. \end{aligned} \quad (\text{C.2})$$

As for Group B, reaction functions take the same forms as (A.2) and (A.3). Thus:

For case (i)

$$\bar{p}_{t+1}(\bar{p}_t) = \frac{8bc_B - a - b\bar{p}_t}{6b}. \quad (\text{C.3})$$

For case (ii)

$$\bar{p}_{t+1}(\bar{p}_t) = \frac{4bc_B + a - b\bar{p}_t - 2b\delta}{4b}. \quad (\text{C.4})$$

Solving (C.1) and (C.3): Case (i) when $59a - 13bc_A - 46bc_B - 70b\delta > 0$,

$$\begin{aligned} \bar{p}_t &= \frac{a + 78bc_A - 8bc_B - 6b\delta}{71b} \\ \bar{p}_{t+1} &= \frac{-12a - 13bc_A + 96bc_B + b\delta}{71b}. \end{aligned} \quad (\text{C.5})$$

Similarly, from (C.2) and (C.4): Case (ii) when $39a - 9bc_A - 30bc_B - 46b\delta \leq 0$,

$$\begin{aligned} \bar{p}_t &= \frac{-a + 36bc_A - 4bc_B - 2b\delta}{31b} \\ \bar{p}_{t+1} &= \frac{8a - 9bc_A + 32bc_B - 15b\delta}{31b}. \end{aligned} \quad (\text{C.6})$$

Let us assume that Group A members have access to a lower cost technology than Group B members do, say by virtue of cooperativeness among group members,

i.e. $c_A \leq c_B$. By assuming one-period spill over (3.3), we obtain the following inequalities:

$$\frac{1}{3} \left(\frac{a}{b} - c_A \right) < \delta < \frac{1}{2} \left(\frac{a}{b} - c_A \right), \text{ and}$$

$$\frac{1}{3} \left(\frac{a}{b} - c_B \right) < \delta.$$

Using these inequalities, we evaluate the equilibrium marginal prices for each case.

Case (i) when $59a - 13bc_A - 46bc_B - 70b\delta > 0$,

$$\bar{p}_t = c_A + \frac{7b(c_A - c_B) + (a - bc_B - 6b\delta)}{71b} < c_A$$

$$\bar{p}_{t+1} = c_B + \delta + \frac{(59a - 13bc_A - 46bc_B - 70b\delta) - 71(a - bc_B)}{71b} < c_B + \delta$$

Case (ii) when $39a - 9bc_A - 30bc_B - 46b\delta \leq 0$,

$$\bar{p}_t = c_A + \frac{5b(c_A - c_B) - (a - bc_B + 2b\delta)}{31b} < c_A$$

$$\bar{p}_{t+1} = \frac{8a - 9bc_A + 32bc_B - 15b\delta}{31b} = c_B + \frac{8(a - bc_A - 2b\delta) + b(c_B - c_A) + b\delta}{31b} > c_B$$

also $\bar{p}_{t+1} = c_B + \delta + \frac{(39a - 9bc_A - 30bc_B - 46b\delta) - 31(a - bc_B)}{31b} < c_B + \delta,$

Summarising the above, we obtain the results in Table 5.2.

D. Derivation of the marginal prices

Parameters of intertemporal reaction functions can be obtained by rearranging them and solving for \bar{p}_t . For instance, using (6.3) and (6.4), the reaction function of Group A in the second season can be written as:

$$\bar{p}_t = p_A^* + R_A(\bar{p}_{t+1} - p_B^*).$$

Similarly, Group B's reaction function becomes:

$$\bar{p}_{t+1} = p_B^* + R_B(\bar{p}_t - p_A^*) + \widetilde{R}_B(\bar{p}_{t+2} - p_A^*).$$

Using $\bar{p}_t = \bar{p}_{t+2} = p_A$, and $\bar{p}_{t-1} = \bar{p}_{t+1} = p_B$ at the stationary equilibria in solving the above reaction functions, we obtain:

$$p_A = \frac{\alpha_A + R_A \alpha_B}{1 - R_A (R_B - \widetilde{R}_B)}, \quad p_A = \frac{\alpha_B + \alpha_A (R_B + \widetilde{R}_B)}{1 - R_A (R_B - \widetilde{R}_B)}$$

where $\alpha_A = p_A + R_A p_B$ and $\alpha_B = p_B - R_B p_B + \widetilde{R}_B p_A$.

Replacing coefficients with the parameters with the marginal price-determination equation (6.1) yields Table 6.1

E. Alternative estimations of the marginal price determination equations

	[1]	[2]	[3]	[4]
α : Constant	432.16** (151.04)	521.23** (157.78)	392.94** (112.77)	521.23** (157.91)
β_1 : Group*Season* \bar{p}_{t+1}	0.2339* (0.1031)	0.2168 ϕ (0.1103)	0.2334* (0.1052)	0.2168* (0.1104)
β_2 : (1 - Group) * \bar{p}_{t+1}	0.2822 (0.2488)			0.2459 (0.2666)
γ_1 : (1 - Season) * \bar{p}_{t+1}	0.6674** (0.1163)	0.5842** (0.1206)	0.6807** (0.0872)	0.5842** (0.1207)
γ_2 : (1 - Group) * \bar{p}_{t-1}	0.5472* (0.2317)	0.7009** (0.2184)	0.4737** (0.1406)	0.5926 ϕ (0.2481)
D ₁ : Season	-330.68 (251.26)	-263.79 (238.48)		-373.4 (226.60)
D ₂ : Group*Season	502.99* (220.71)	367.12 ϕ (204.36)	212.14 (146.91)	476.70* (236.52)
D ₃ : Saturday	108.04 (87.167)			
D ₄ : Saturday*Season	71.723 (102.15)		174.34** (54.25)	
\bar{R}^2	0.7510	0.6958	0.7240	0.6953
White test for homoskedasticity	0.2987	0.3609	0.4228	0.3411
Skewness/Kurtosis test for normality	0.5097	0.2080	0.0798	0.1607
Durbin-Watson d-statistic	1.6350 (d _L =1.489, d _U =1.852)	1.5684 (d _L =1.557, d _U =1.778)	1.5326 (d _L =1.557, d _U =1.903)	1.6314 (d _L =1.535, d _U =1.802)

Notes: In each model, the dependent variable is the lowest price of each fishing day. Standard deviations are shown in brackets. **, *, and ϕ denote significance at 99%, 95%, and 90% levels of confidence, respectively. 94 observations of lowest prices of *Shiroebi* sold between 1st April 1997 and 30 August 1997 are used for the estimation.

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