Essays in Industrial Organisation

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I, Seyed Farshad FATEMI ARDESTANI, confirm that the work presented in this thesis is my own. Where information has been derived from other sources, I confirm that this has been indicated in the thesis.

Abstract

This thesis consists of three independent chapters:

In the first chapter, we consider a Hotelling model of price competition where firms may acquire information regarding the preferences (i.e. "location") of customers. By purchasing additional information, a firm has a finer partition regarding customer preferences, and its pricing decisions must be measurable with respect to this partition. If information acquisition decisions are common knowledge at the point where firms compete via prices, we show that a pure strategy subgame perfect equilibrium exists, and that there is "excess information acquisition" from the point of view of the firms. If information acquisition decisions are private information, a pure strategy equilibrium fails to exist. We compute a mixed strategy equilibrium for a range of parameter values.

The second chapter investigates a case of national versus regional pricing. Competition authorities frequently view price discrimination by firms as detrimental to consumers. In the case of the UK supermarket industry they suggested a move to uniform pricing. Yet theoretical predictions are ambiguous about whether third degree price discrimination is beneficial or detrimental to consumers, and in general there will be some consumers who benefit while other lose out. In this chapter, we estimate the impact that the move from regional to uniform pricing had on Tesco's profits and consumer's surplus. We estimate an AIDS model of consumer expenditure in the eggs market in a multi-stage budgeting framework allowing for very flexible substitution patterns between products at the bottom level. We use data on farm gate prices to instrument price in the demand equation. Our results suggest that switching to a regional pricing policy can potentially increase Tesco's profit on eggs by 37%. However, while there are winners and losers, the overall effect on consumer welfare is not significant.

In the third chapter, we study the kidney market in Iran. The most effective treatment for end-stage renal disease is a kidney transplant. While the supply of cadaveric kidneys is limited, the debate has been focused on the effects of the existence of a free market for human organs. Economists as well as medical and legal researchers are divided over the issue. Iran has a unique kidney market which has been in place for over 20 years, frequently reporting surprising success in reducing the waiting list for kidneys. This paper demonstrates how the Iranian system works and estimates the welfare effect of this system.

To my parents;

for their inspirational role in my life

&

To my family;

for their support during this course.

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Chapter 1

Information Acquisition and Price Discrimination

1.1. Introduction

Usually, any type of price discrimination requires customer-specific information[1]. In general, it is costly to acquire information regarding customers. Recent developments in information technology allow firms to acquire more information on their customers, which may be used to practise price discrimination. Loyalty cards issued by supermarkets and customer data collected by specialist companies are just two examples of information acquisition.

Consider a model of competition between firms who are able to charge different prices if they can distinguish customer characteristics. Most research on discriminatory pricing assumes that the information regarding consumers is exogenously given. The price discrimination literature concentrates on monopolistic price discrimination (Pigou, 1920; Robinson, 1933; Schmalensee, 1981; Varian, 1985; Varian, 1989; and Hamilton & Slutsky, 2004). Such discrimination always leads to higher profits for the monopolist, since she solves her profit maximisation problem with fewer constraints.

Some of the more recent work on competitive price discrimination concentrates on efficiency from society's point of view, the firm's profit, and the number of the firms in

[1] The exceptions for this claim are the case in which the firm practices price discrimination through setting a uniform price when the cost of supply is different and when firm uses a non-linear pricing strategy.

a free entry and exit case[2] (Borenstein, 1985; Corts, 1998; Armstrong & Vickers, 2001; and Bhaskar & To, 2004), but still the information regarding consumers is exogenously given.

Bhaskar & To (2004) prove that without free entry, perfect price discrimination is socially optimal, but in free entry case, the number of firms is always excessive.

Liu & Serfes (2004, 2005) study the relation between of the exogenously given quality of firm information and market outcomes in oligopoly. They show that when the information quality is low, unilateral commitments not to price discriminate arise in equilibrium. However, once information quality is sufficiently high, firms discriminate. Equilibrium profits are lower, the game effectively becoming a prisoners' dilemma.

Shaffer & Zhang (2002) investigate one-to-one promotions. They assume that customers can be contacted individually, and firms know something about each customer's preferences. They find that one-to-one promotions always lead to an increase in price competition and average prices will decrease. However, they show that if one of the firms has a cost advantage or higher quality product, the increase in its market share may outweigh the effect of lower prices..

Corts (1998) investigates price discrimination by imperfectly competitive firms. He shows that the intensified competition, leading to lower prices, may make firms worse off and as a result firms may wish to avoid the discriminatory outcome. Unilateral commitments not to price discriminate may raise firm profits by softening price competition.

In this paper, we endogenise the information firms have by introducing an information acquisition technology. We assume that firms decide on how many units of information to acquire. Then each firm can charge different prices for different customers based on the information she acquired. We study a Hotelling type model where two firms are located at the ends of the unit interval. Each unit of information gives a firm a finer partition over the set of customers. Specifically, a firm's information consists of a partition of the unit interval, and an extra unit of information allows the firm to split one of the subintervals into two equal-sized segments. In our benchmark

[2] For a more detailed survey on recent literature in price discrimination see Armstrong (2006).

model, the information acquisition decisions of firms are common knowledge at the point where firms compete via prices.

Our main result is that the equilibrium outcome is partial information acquisition, even if information costs are arbitrarily small. Quite naturally, a firm has no incentive to acquire information on customers who are firmly in its rival's turf, i.e. those that it will never serve in equilibrium. But more interestingly, we find that a firm has an incentive not to fully acquire information on customers it competes for with the other firm. This allows it to commit to higher prices, and thereby softens price competition. Finally, as in the existing literature, we find that there is "excess information acquisition" from the point of view of the firms, in the sense that profits are lower as compared to the no information case.

Information acquisition results in tougher competition, and lower prices. After information acquisition stage when firms compete via prices, if two firms share the market over a given set of customers, a decrease in the price of one firm over this interval decreases the marginal revenue of the other firm by decreasing its market share on this interval. As a result this reinforces the other firm to decrease its price over that interval. We can interpret this result in context of strategic complementarity as defined by Bulow et al (1985). In our benchmark model, pricing decisions are strategic complements. Since a firm's optimal price is an increasing function of her opponent's price. The literature on strategic complementarity finds similar results to our results when firms' actions are strategically complements. Fudenberg & Tirole (1984) show that in a two stage entry game of investment, the incumbent might decide to underinvest in order to deter entry. d'Aspremont et al (1979) consider a Hotelling framework, with quadratic transportation costs, when firms should choose their location. They show that in the equilibrium in order to avoid tougher competition, firms locate themselves at the two extremes (maximum differentiation). Similarly, in our model, a firm acquires less information in order to commit to pricing high, thereby increases the price of her rival.

We also analyse a game where a firm does not know its rival's information acquisition decision at the point that they compete in prices. We show, quite generally that there is no pure strategy equilibrium in this game. We compute a mixed strategy equilibrium for a specific example.

Section 1.2 presents the basic model. Section 1.3 analyzes the extensive form game; where each firm observes her rival's information partition so that the information acquisition decisions are common knowledge. Section 1.4 studies the game where information acquisition decisions are private. Section 1.5 compares our benchmark model with a multi-store retailers' example. Section 1.6 summarises and concludes. The appendices 1.A and 1.B contain all the proofs.

1.2. The Model

The model is based on a simple linear city (Hotelling model) where two firms (A and B) compete to sell their product to customers located between them. Both firms have identical marginal costs, normalised to zero. The distance between two firms is normalized to one; firm A is located at 0 and firm B at 1. The customers are uniformly distributed on the interval [0,1] and the total mass of them is normalized to one. Each customer, depending on her location and the prices charged by firms, decides to buy one unit from any of the firms or does not buy at all. The utility of buying for each customer has a linear representation $U = V - P - TC$ where *P* stands for price, and *TC* represents the transportation cost to buy from each firm that is a linear function of distance and *t* is the transport cost per unit distance. Assume that *V* is sufficiently high to guarantee that all the market will be served. Then the utility of the customer who is located at $x \in [0,1]$ is

$$U(x) = \begin{cases} V - P_A(x) - tx & if \;\; she \;\; buys \;\; from \;\; A \\ V - P_B(x) - t(1-x) & if \;\; she \;\; buys \;\; from \;\; B \end{cases}. \tag{1.1}$$

A unit of information enables the firm to split an interval segment of her already recognised customers to two equal-sized sub-segments. The information about the customers, below and above the mid-point of [0,1] interval, is revealed to the firm if it pays a cost $t(0)$. Every unit of more information enables the firm to split an already recognised interval, $[a, b]$ to two equal-sized sub-intervals. The cost to the firm is $t(k)$ where $b - a = \left(\frac{1}{2}\right)^k$ (where $k \in \aleph \cup \{0\}$). The information cost function can be represented by the infinite sequence $\left\langle \; t(k) \; \right\rangle_0^\infty$. It seems reasonable to assume that $t(k)$ is decreasing in *k*. Intuitively the smaller the interval, the fewer consumers on whom information is needed. Then a reasonable assumption for the information cost function is that t is a decreasing function.

We assume a decreasing information cost function when the cost of acquiring information on an interval $[a,b]$ is:

$$t(k) = \frac{t_0}{2^k}, \quad \text{where} \quad b - a = \left(\frac{1}{2}\right)^k, \quad (1.2)$$

and t_0 is a constant. Note that because of our information acquisition technology k is always an integer.

By buying every extra unit of information, a firm is acquiring more specific information with less information content in terms of the mass of customers.

The general results of the paper, i.e. the excessive information acquisition, the trade-off between information acquisition and tougher competition, and the characteristics of equilibrium are consistent for a wide range of information cost functions. In appendix 1.B, we extend our results to two other functional formats.

We analyse two alternative extensive form games. In the first game, each firm observes its rival's information acquisition decision. That is, the information partitions become common knowledge before firms choose prices.

The first game is defined as follows:

- **Stage 1:** *Information acquisition*: Each firm ($f \in \{A,B\}$) chooses a partition I_f of $[0,1]$ from a set of possible information partitions Ω
- *Observation*: Each firm observes the partition choice made by the other firm, e.g. firm A observes I_B. Note that firm f's information partition remain I_f.
- **Stage 2:** *Price decision*: Each firm chooses $P_f : [0,1] \rightarrow \Re^+ \cup \{0\}$ which is measurable with respect to I_f. Once prices have been chosen, customers decide whether to buy from firm A or firm B or not to buy at all.

The vector of prices chosen by each firm in stage 2 is segment specific. In fact a firm's ability to price discriminate depends on the information partition that she acquires in stage 1. Acquiring information enables the firm to set different prices for different segments of partition.

In the second game firms do not observe their rival's information partition. It means that the firms simultaneously choose a partition and a vector of prices measurable with their chosen partition. In order to make it simpler, the two games are called the *two-stage game* and *the simultaneous move game* respectively.

Following we formally define the information acquisition technology. Intuitively, in this setting when a firm decides to acquire some information about customers, it is done by assuming binary characteristics for customers. Revealing any characteristics divides known segments customers to two sub-segments. We assume that these two sub-segments have equal lengths.

> **Definition:** The information acquisition decision for player *f* is the choice of I_f from the set of feasible partitions Ω on [0,1]. Ω is defined using our specific information acquisition technology:

Suppose *I* is an arbitrary partition of [0,1] of the form $[0,a_1)$, $[a_1,a_2)$,…,$[a_{n-1},1]$ if and only if:[3]

$$
\begin{gathered}
s_0 = [a_0, a_1] \qquad \& \qquad s_i = (a_{i-1}, a_i] \qquad i \in \{2,3,\ldots,n\} \\
\forall i \in \{1,2,\ldots,n-1\} \quad \exists l,k \in \{0,1,\ldots,n\} \;\; , \;\; l \neq k \quad \therefore \quad a_i = \frac{a_l + a_k}{2} \\
s_k \bigcap s_l = f \qquad \forall l,k \in \{1,2,\ldots,n\} \;\; \& \;\; l \neq k \\
\bigcup_{k=1}^{n} s_k = [0,1]
\end{gathered} \quad . \tag{1.3}
$$

A firm’s action in stage 1 is the choice of an information partition from the set of possible information partitions. This choice can be represented by a sequence of {Yes, No} choices on a decision tree (figure 1.1). The firm begins with no information so that any customer belongs to the interval [0,1]. If the firm acquires one unit of information, the unit interval is partitioned into the sets [0,0.5] and (0.5,1]. That is, for any customer with location *x*, the firm knows whether *x* belongs to [0,0.5] or (0.5,1], but has no further information. If the firm chooses No at this initial node, there are no further choices to be made. However, if the firm chooses Yes, then it has two further decisions to make. She must decide whether to partition [0,0.5] into the subintervals [0,0.25] and (0.25,0,5]. Similarly, she must also decide whether to partition (0.5,1] into (0.5,0.75]

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[3] The set of equations in (1.3) are the technical definition of our information acquisition technology. Defining each element of the partition as a half-closed interval is without loss of generality, since customers have uniform distribution and each point is of measure zero.

and (0.75,1]. Once again, if she says *No* at any decision node, then there are no further decisions to be made along that node, whereas if she says *Yes*, then it needs to make two further choices. The cost associated with each *Yes* answer is $t(k)$ (see equation (1.2) and figure 1.1). A *No* answer has no cost.

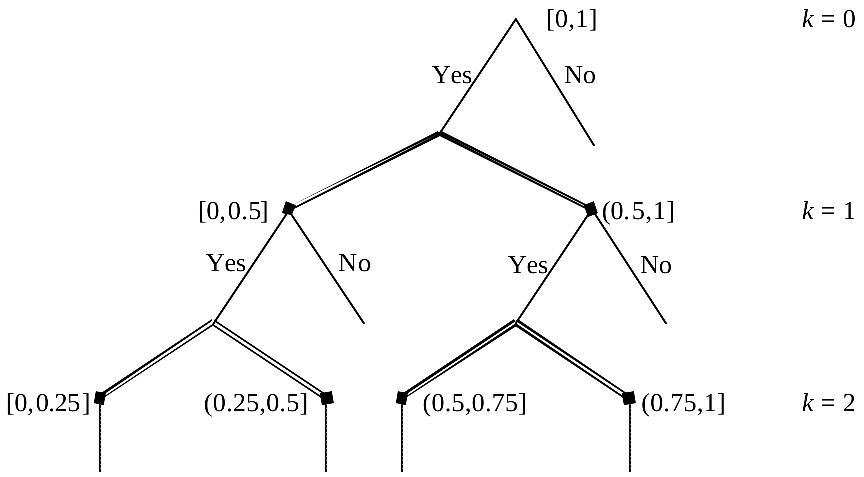


Figure 1.1: The decision tree for each firm regarding the information acquisition

Acquiring information enables a firm to price discriminate. The prices are segment-specific. The price component of any strategy (P_f) is a non-negative step function measurable with respect to I_f:

$$\begin{array}{l} P_f : [0,1] \longrightarrow \Re^+ \cup \{0\} \\ x, y \in s_i \quad \Rightarrow \quad P_f(x) = P_f(y) \end{array} \qquad (1.4)$$

Then a feasible strategy for player f (S_f) can be written as:

$$S_f = (I_f, P_f) \text{ where } P_f \text{ is measurable with respect to } I_f.$$

Figure 1.2 shows a possible choice of strategy for one of the players.

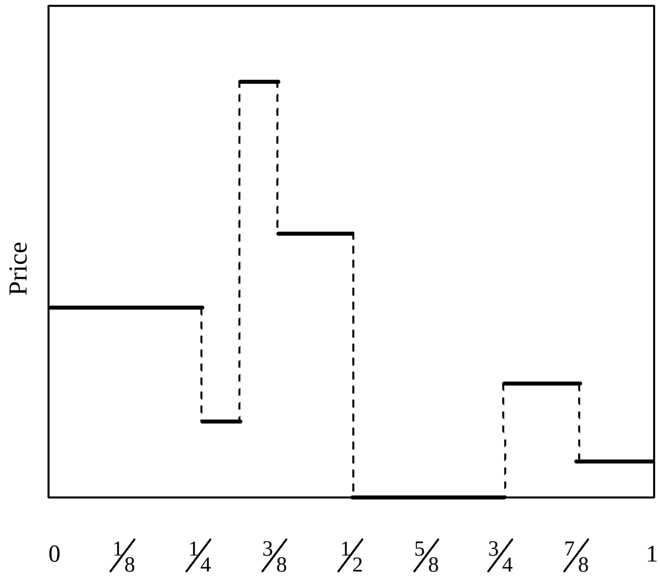


Figure 1.2: A price function consistent with the information acquisition definition

If firm f acquires n units of information, then her payoff is:

$$p_f = \int_{x\in Z_f} P_f(x).dx - \Gamma \quad \text{where} \quad Z_f = \{x | x \in [0,1] \quad , \quad U_f(x) > U_{-f}(x)\},$$

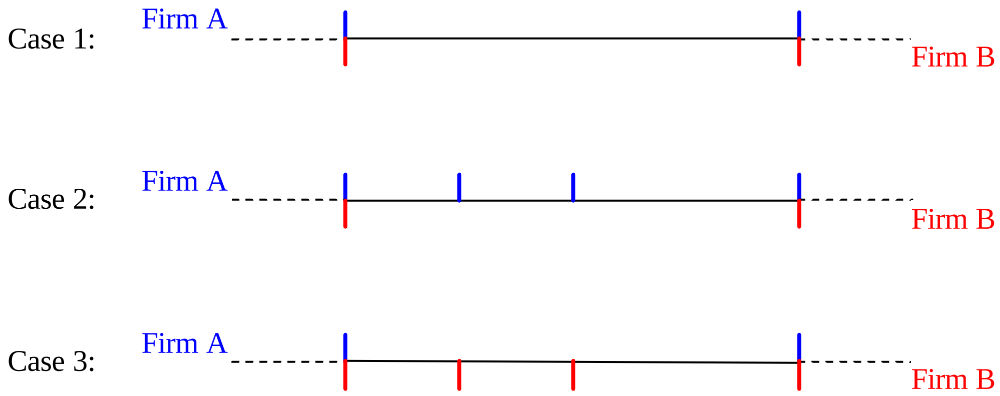
and Γ is the total information cost for the firm, $U_f(x)$ represents the utility of customer located at x if she buys from firm f with the general form of (1.1), $-f$ stands for the other firm, and Z_f represents the set of customers who buy from f.

Lemma 1: Suppose $s_i \in I_A$ and $s_j \in I_B$, where $s_i \cap s_j \neq \emptyset$, Then either s_i is a subset of s_j or s_j is a subset of s_i.

Proof: By acquiring any information unit a firm can divide one of her existing intervals into two equal-sized sub-intervals. Given s_i is an element of A's information partition, three possible distinct cases may arise: i) s_i is al element of firm B's information partition. ii) s_i is a strict subset of an element of firm B's information partition. iii) s_i is the union of several elements from B's information partition.[4]

Figure 1.3 shows these three possibilities where i) s_i and s_j are equal (case 1), ii) s_i is a proper subset of s_j (case 2), and iii) s_j is a proper subset of s_i (case 3).

[4] It is expected that in each firm's turf the preferred segmentation scenario of the firm contains smaller segments compared with her rival's preferred segments, but all cases are solved.



The blue and red lines show the partitions for s_i and s_j respectively (the information partition chosen by firm A and firm B).

Figure 1.3: Three possible segmentation scenarios

1.3. The Two-Stage Game

This game can be broken down into four different scenarios (figure 1.4). The first scenario relates to the case when neither of the firms acquires information. The second scenario represents the case where both firms acquire information. The third and fourth scenarios represent the situation where only one of the firms decides to acquire information.

		Firm B	
		NI	I
Firm A	NI	1st Scenario	4th Scenario
	I	3rd Scenario	2nd Scenario

Note: 3rd and 4th scenarios are symmetric

Figure 1.4: Four different scenarios for the two-stage game

1.3.1. Scenario One: Neither firm acquires information

The first scenario (the case of acquiring no information and therefore no price discrimination) is easily solvable. In the equilibrium both firms charge uniform prices ($P_A = P_B = t$), they share the market equally, and each firm's profit is $\frac{t}{2}$.

1.3.2. Scenario Two: Both firms acquire information

In this scenario each firm acquires at least one unit of information that splits the interval [0,1] into subintervals ([0,0.5] and (0.5,1]. Let us consider competition on an interval that is a subset of [0,0.5] (given the symmetry of the problem, our results also extend to the case where the interval belongs to (0,5,1]).

Let $\hat{s} \subseteq [0,0.5]$ and $\hat{s} \in I_A$, i.e. assume that $\hat{s}$ is an element of firm A's information partition. Consider first the case where $\hat{s}$ is the union of several elements of B's information partition, i.e. $\hat{s} = \bigcup_{i=1}^{n} s_i$, for $i = 1,2,\ldots n$; This situation corresponds to case 3 in figure 1.3.

Since firm A's profits on the rest of the interval do not depend upon $P_{\hat{s}}$, she must choose $P_{\hat{s}}$ aiming to maximise her profit on $\hat{s}$. By lemma 1, firm B's profits on the components of s do not depend upon her prices on this interval. Therefore, a necessary condition for the Nash equilibrium is that:

a) A chooses $P_{\hat{s}}$ to maximize her profits on $\hat{s}$,

b) B chooses $P_1, \ldots, P_n$ to maximize her profits on $\hat{s}$.

An analogous argument also applies in cases 1 and 2.

From the utility function (1.1), the indifferent customer x_i in each $s_i = (a_{i-1}, a_i]$ is located at:

Case 1: $x_i = \frac{1}{2} + \frac{P_B - P_A}{2t}$, for $i = 1$; (1.5)

Case 2: $x_i = \frac{1}{2} + \frac{P_B - P_{iA}}{2t}$, for $i = 1,2,\ldots,n$; (1.6)

Case 3: $x_i = \frac{1}{2} + \frac{P_{iB} - P_A}{2t}$, for $i = 1,2,\ldots,n$. (1.7)

In addition, these values for x_i must lie in within the interval, i.e. the following inequality should be satisfied for each x_i:

$a_{i-1} \le x_i \le a_i$, for $i = 1,2,\ldots,n$. (1.8)

Where a_{i-1} and a_i are respectively the lower and upper borders of the segment s_i and $0 \le a_{i-1} < a_i \le 0.5$.

In each segment s_i, the customers who are located to the left of x_i buy from firm A, and the customers to the right of x_i buy from firm B. If x_i (calculated in (1.5) or (1.6) or (1.7)) is larger than the upper border (a_i) all customers on s_i buy from firm A. In this situation to maximise her profit, firm A will set her price for s_i to make the customer on the right border indifferent. Similarly, if $x_i < a_{i-1}$, firm B is a constrained monopolist on s_i and will set her price to make the customer on the left border indifferent.

Profits for the firms in each section of case 1 are:

$$p_A = P_A\left(\frac{1}{2} + \frac{P_B - P_A}{2t} - a_0\right), \text{ and} \qquad (1.9)$$

$$p_B = P_B\left(a_1 - \frac{1}{2} - \frac{P_B - P_A}{2t}\right). \qquad (1.10)$$

In cases 2 and 3, as mentioned before since the profit for each firm over s_i ($i = 1,2,\ldots,n$) can be presented only as a function of the prices over $\hat{s}$, the maximization problem is solvable for $\hat{s}$ independently. In case 2, firms' profits on $\hat{s}$ are:

$$p_{iA} = P_{iA}\left(\frac{1}{2} + \frac{P_B - P_{iA}}{2t} - a_{i-1}\right), \qquad \text{for } i = 1,2,\ldots,n \text{ ; and} \qquad (1.11)$$

$$p_B = P_B\sum_{i=1}^{n}\left(a_i - \frac{1}{2} - \frac{P_B - P_{iA}}{2t}\right) = P_B\left(\sum_{i=1}^{n}a_i - \frac{n}{2} - \frac{nP_B - \sum_{i=1}^{n}P_{iA}}{2t}\right). \qquad (1.12)$$

Similarly for case 3, the profits can be written as:

$$p_A = P_A\sum_{i=1}^{n}\left(\frac{1}{2} + \frac{P_{iB} - P_A}{2t} - a_{i-1}\right) = P_A\left(\frac{n}{2} + \frac{\sum_{i=1}^{n}P_{iB} - nP_A}{2t} - \sum_{i=1}^{n}a_{i-1}\right), \text{ and} \qquad (1.13)$$

$$p_{iB} = P_{iB}\left(a_i - \frac{1}{2} - \frac{P_{iB} - P_A}{2t}\right), \qquad \text{for } i = 1,2,\ldots,n. \qquad (1.14)$$

So for cases 2 and 3, there are *n+1* maximization problems on each $\hat{s}$ which should be solved simultaneously.

Let I_A and I_B be two feasible information partitions for A and B respectively. Let I^* be the join of I_A and I_B, i.e. the coarest partition of [0,1] that is finer than either I_A or I_B. Let s^* be the element of I^* is of the form [a,0.5), i.e. s* is the element that lies on the left and is closest to the midpoint.

Lemma 2: s^* is the only element of I^* which lies to the left of 0.5 such that both firms share the market. On every other element of I* which lies to the left of the midpoint, all customers buy from firm A.[5]

Proof: See appendix 1.A.

So both firms sell positive quantities only in the most right hand segment of firm A's turf and the most left hand segment of firm B's turf.

This lemma has the following important implication. A firm has no incentive to acquire information in its rival's turf. For example if firm A acquires some information on interval (0.5,1]; then firm B can choose a set of profit maximising prices where only she shares this part of the market with firm A only on the very first segment on this interval. So acquiring information on the interval (0.5,1] makes no difference on firm A's ability to attract more customers.

As a result of lemma 2, each firm sets a uniform price for all customers located in her rival's turf. Let us call these prices P_{RA} and P_{LB}. P_{RA} is the price firm A sets for [0.5,1] and P_{LB} is the price firm B sets for [0,0.5). This price is set to maximize firm's profit in the only segment in the opposite turf that firm sells positive quantity in it. This uniform price affects the rival's price in her constrained monopoly segments. Thus the pricing behaviour of firm A can be explained by these rules:

– In all segments on [0,0.5] except the very last one, s^*, firm A is a constrained monopolist. She sets her prices to make the customer on the right hand border of each segment indifferent.

– On s^*, the last segment to the right hands side of [0,0.5], firm A competes against the uniform price set by firm B for the [0,0.5] interval.

[5] The solution for the interval [0,0.5] can be extended to interval (0.5,1] where the solution is the mirror image of the result on [0,0.5].

– On (0.5,1] she only can sell on the very first segment then sets her uniform price for (0.5,1] in order to maximise her profit on that very first segment.

So, firm A's partition divides [0,0.5] into *n* segments and she acquires no information on (0.5,1]. Equivalently, firm B acquires no information [0,0.5] and has *m* segments in her partition for (0.5,1].

We now solve for equilibrium prices. The prices for loyal customers in each side would come from:

$$P_{iA} + ta_i = P_{LB} + t(1-a_i), \text{ for } a_{i-1} \le x \le a_i \quad ; \quad i = 1,2,\cdots,n-1, \text{ and}$$

$$P_{RA} + ta_{i-1} = P_{iB} + t(1-a_{i-1}), \text{ for } a_{i-1} \le x \le a_i \quad ; \quad i = n+2,\cdots,n+m.$$

The prices for two shared market segments are represented by (recall from (1.A1) and (1.A2)):

$$P_{nA} = \frac{2t}{3}(1-2a_{n-1}) \qquad \text{and} \qquad P_{n+1,B} = \frac{2t}{3}(2a_{n+1}-1).$$

And the uniform prices for the opposite side could be written as:

$$P_{RA} = \frac{1}{2}P_{n+1,B} \qquad \text{and} \qquad P_{LB} = \frac{1}{2}P_{nA}.$$

Then given the prices for these two segments prices for other segments can easily be calculated as:

$$P_A(x) = \begin{cases} 2t\left(\frac{2}{3} - a_i - \frac{1}{3}a_{n-1}\right) & a_{i-1} < x < a_i \quad ; \quad i = 1,2,\cdots,n-1 \\ \frac{2t}{3}(1-2a_{n-1}) & a_{n-1} < x < \frac{1}{2} \\ \frac{t}{3}(2a_{n+1}-1) & \frac{1}{2} < x < 1 \end{cases} \quad ; (1.15)$$

and

$$P_B(x) = \begin{cases} \frac{t}{3}(1-2a_{n-1}) & 0 < x < \frac{1}{2} \\ \frac{2t}{3}(2a_{n+1}-1) & \frac{1}{2} < x < a_{n+1} \\ 2t\left(\frac{1}{3}a_{n+1} + a_{i-1} - \frac{2}{3}\right) & a_{i-1} < x < a_i \quad ; \quad i = n+2,\cdots,n+m \end{cases} \quad . \quad (1.16)$$

The associated gross profits are (market shares for border segments are calculated using the prices by (1.5)):

$$p_A = 2t\sum_{i=1}^{n-1}(a_i - a_{i-1})\left(\frac{2}{3} - a_i - \frac{1}{3}a_{n-1}\right) + \frac{2t}{3}(1-2a_{n-1}).\frac{2}{3}\left(\frac{1}{2} - a_{n-1}\right) + \frac{t}{3}(2a_{n+1}-1).\frac{1}{3}\left(a_{n+1} - \frac{1}{2}\right) \text{ and}$$

$$p_B = \frac{t}{3}(1-2a_{n-1}).\frac{1}{3}\left(\frac{1}{2} - a_{n-1}\right) + \frac{2t}{3}(2a_{n+1}-1).\frac{2}{3}\left(a_{n+1} - \frac{1}{2}\right) + 2t\sum_{i=n+1}^{n+m}(a_i - a_{i-1})\left(\frac{1}{3}a_{n+1} + a_{i-1} - \frac{2}{3}\right).$$

After simplifying, the net profits are represented by (Note that each firm pays only for the information in her own turf):

$$p_A = t\left(2a_{n-1}\left(\frac{2}{3} - \frac{1}{3}a_{n-1}\right) - 2\sum_{i=1}^{n-1}a_i(a_i - a_{i-1}) + \frac{8}{9}\left(\frac{1}{2} - a_{n-1}\right)^2 + \frac{2}{9}\left(a_{n+1} - \frac{1}{2}\right)^2\right) - \Gamma_A\text{, and} \quad (1.17)$$

$$p_B = t\left(-\frac{4}{3} + 2a_{n+1} - \frac{2}{3}a_{n+1}^2 + 2\sum_{i=n+2}^{n+m}a_{i-1}(a_i - a_{i-1}) + \frac{2}{9}\left(\frac{1}{2} - a_{n-1}\right)^2 + \frac{8}{9}\left(a_{n+1} - \frac{1}{2}\right)^2\right) - \Gamma_B\text{.} \quad (1.18)$$

where Γ_A, Γ_B are the information costs paid by firms A and firm B in order to acquire information.

If we want to follow the firm's decision making process we can suppose that the firm starts with only one unit of information and splitting [0.1] interval to [0,0.5] and (0.5,1]. This first unit enables the firm to start discriminating on their half. Paying for one more unit of information on their own half means that firm is now a constrained monopolist on one part and should share the market on the other (i.e. for firm A, the customers on [0,0.25] are her loyal customers and she shares the market on (0.25,0.5] with firm B). In the loyal segment the only concern for the information acquisition would be the cost of the information. Firms fully discriminate the customers depending on the cost of information.

But there is a trade off in acquiring information to reduce the length of shared segment. On one hand, this decision increases the profit of the firm through more loyal customers. On the other hand, since her rival charges a uniform price for all customers in the firm's turf, the firm should lower the price for all of her loyal segments. Therefore the second effect reduces the firm's profit. These two opposite forces affect the firm's decision for acquiring a finer partition in the border segment. Proposition 1 shows how each firm decides on the volume of the customer-specific information she is going to acquire.

Proposition 1: Firm A uses these three rules to acquire information:

1-1. if $\frac{t_0}{t} \leq \frac{1}{16}$, then firm A fully discriminates on [0,0.25]. The equal-size of the segments on this interval in the equilibrium partition is determined by the information cost.

1-2. Firm A acquires no further information on (0.25,0.5].

1-3. Firm A acquires no information on (0.5,1].

Proof: In order to avoid unnecessary complications, the first part of the proof has been discussed in appendix 1.A. It shows that firm A should make a series of decisions regarding to split the border segment (see figure 1.1). Starting form the pint of acquiring no information on the left hand side, firm A acquires information in her own turf as long as this expression is non-negative:

$$\Delta p_A = \left[\frac{t}{2^k}\left(\frac{1}{2^k}\left(\frac{7}{12} - \frac{1}{2^{r+2}}\right) - \frac{1}{6}\right) - \Gamma\right], \qquad (1.19)$$

where $\frac{1}{2} - a_{n-1} = \left(\frac{1}{2}\right)^k$ is the length of the border segment,

$\left(\frac{1}{2}\right)^r$ is the preferred length of loyal segments (where $r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor$ [6]), and

$\Gamma = \frac{t_0}{2^k}\left(\frac{r-k+1}{2}\right)$ is the total information cost.

We follow this chain of decision makings, starting with $n = 1$ (i.e. no initial loyal segment for firm A). The procedure is that firm A starts with $k = 1$, if equation (1.19) is non-negative then she decides to acquire information on [0, 0.5], splitting this interval to [0, 0.25] and (0.25,0.5]. After this he is the constrained monopolist on [0, 0.25] and the preferred length for all loyal segments is:

[6] $\lfloor\ \rfloor$ notation represents the floor function (or the greatest integer).

$$\left(\frac{1}{2}\right)^r, \qquad \text{where} \qquad r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor. \qquad (1.20)$$

After buying the first unit of information on [0, 0.5] (and consequently the preferred units of information on [0, 0.25]) then firm A checks non-negativity of (1.19) for $k = 2$ and so forth.

Table 1.1 shows the chain of the first two decision statements. As it is clear the value of the decision statement on the second row (and also for every $k > 1$) is always negative.

Table 1.1: Firm A's chain of decision statements

a_{n-1}	a_n	k	Decision statement
0	$\frac{1}{2}$	1	$\left[\frac{t}{16}\left(1-\frac{1}{2^r}\right)-\frac{rt_0}{4}\right] \geq 0$ where $r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor$
$\frac{1}{4}$	$\frac{1}{2}$	2	$\left[\frac{t}{32}\left(-\frac{1}{6}-\frac{1}{2^r}\right)-\frac{(r-2)t_0}{8}\right] \geq 0$ where $r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor$

The minimum value for r is 2 (the biggest possible length for a loyal segment is 1/4). It can be shown that the value of decision statement (equation (1.19) for $k = 1$) is non-negative if and only if $\frac{t_0}{t} \leq \frac{1}{16}$. It is clear the second row's decision statement is always negative. That means the length of the shared segment, regardless to the information cost, equals 0.25. Assuming $\frac{t_0}{t} \leq \frac{1}{16}$, then the preferred segmentation scenario for firm A is to fully discriminate between [0,0.25] (the preferred segment length in this interval is a unction of information and transportation cost) and acquiring no information for (0.25,0.5]. ♦ *QED*

Each firm prefers to just pay for information in her own turf, and the segmentation in the constrained monopoly part depends on the transportation and information cost. The only segment in each turf that may have a different length is the border segment and firms prefer to buy no information on their rival's turf.

One of the findings in the proof of proposition 1 is the functional form of firms' marginal profit of information in loyal segment. Equation (1A.16) shows that the marginal profit of information in a loyal segment (dividing a loyal segment to two) is

$\frac{t}{4}\left(a_i - a_{i-1}\right)^2 - t\,(k) = \frac{1}{2^k}\left(\frac{t}{4\times 2^k} - t_0\right)$ where a_i and a_{i-1} are the boundaries of the loyal segment and $a_i - a_{i-1} = \frac{1}{2^k}$. As it is clear the marginal profit of information is decreasing. Decreasing marginal profit guarantees that if the firm decides not to split a loyal segment, there is no need to worry about the profitability of acquiring a finer partition.

When the information cost is insignificant (t_0 =0) the preferred length of a loyal segment goes to zero. In other words firms acquire information for every individual customer on [0,0.25] and charges a different price for each individual based on her location. In this case, in equation (1.19) k® ¥, starting with a_{n-1} = 0 and a_n = 0.5 and based on the proposition 1 the chain of decisions for t =0 is:

i) On [0,0.5], a_{n-1} = 0 then equation (1.19) turns into $\frac{t}{16} > 0$ and the result is to acquire the first unit of information, and consequently acquire full information on [0,0.25].

ii) On (0.25,0.5], a_{n-1} = 0.25 then $-\frac{t}{192} < 0$ and the result is to acquire no further information on (0.25, 0.5]. That means even when the information cost is insignificant, the positive effect of acquiring more information in the interval of (0.25,0.5] is dominated by the negative effect of falling the constrained monopolistic prices on segments on [0,0.25].

Figure 1.5 shows an example for an equilibrium strategy for firm A. Firm B's preferred strategy will be a mirror image of this example.

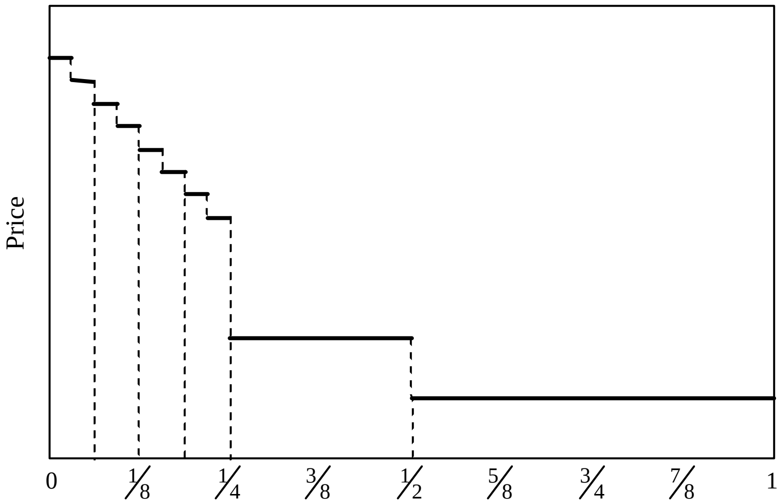


Figure 1.5: An example of the equilibrium strategy for firm A in the second scenario

Figure 1.6 shows the preferred number of segments by firm A in her turf against the ratio of information cost to transportation cost. This figure also shows the net profit of the firm in her own turf as a multiplication of transportation cost.

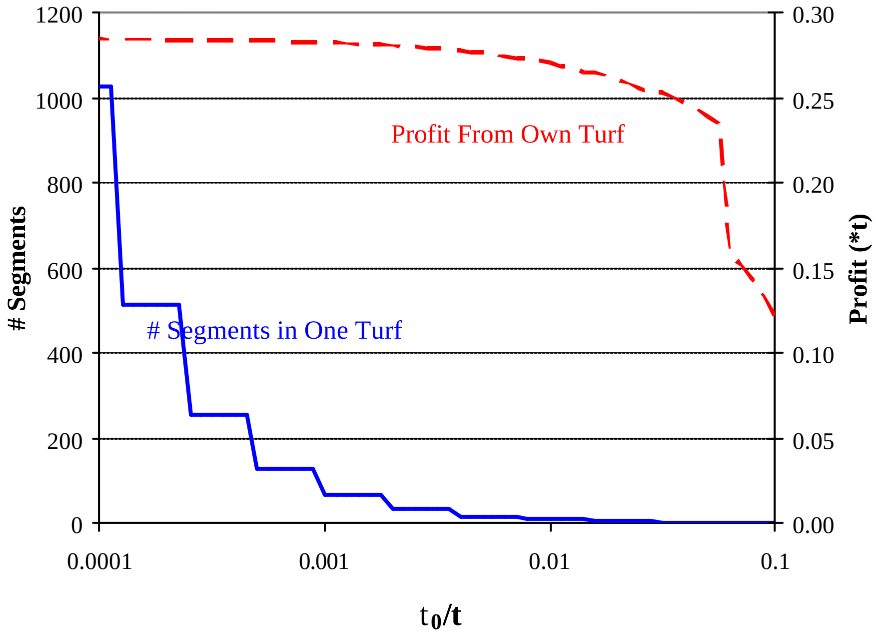


Figure 1.6: The preferred number of segments and the profit of each firm as a function of the ratio of information cost over transportation cost

Figure 1.7 represents each firm's preferred length for shared and loyal segments as a function of the information and transportation costs. Having the results we have seen so far proposition 1 can be rewritten as (it is another interpretation on proposition 1 and equivalent to what we had before):

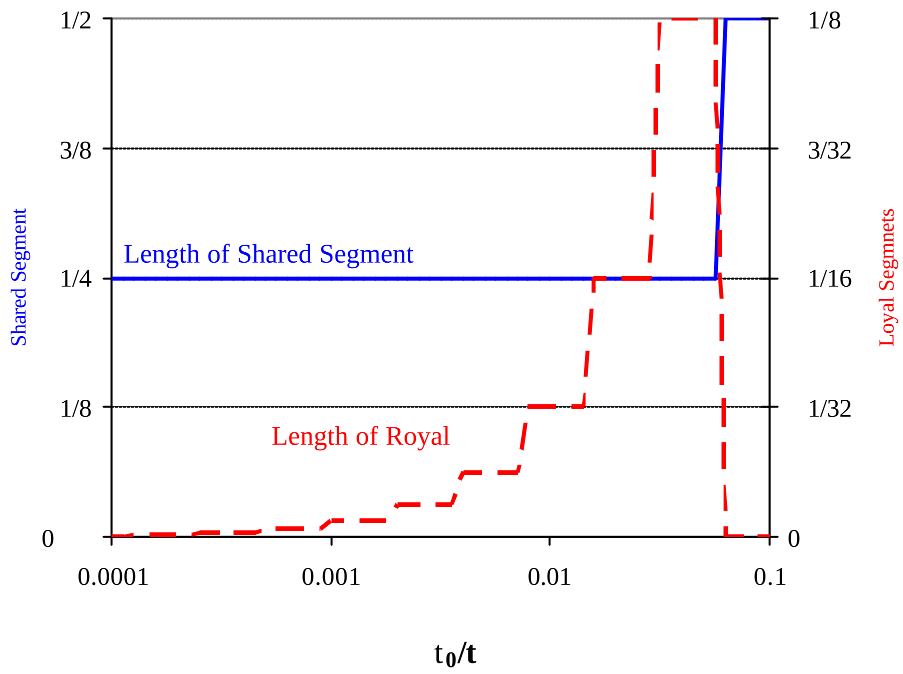


Figure 1.7: The length of shared and loyal segments

as a function of the ratio of information cost over transportation cost

Figure 1.7 also shows that if the cost of first information unit[7] is less than $\frac{t}{16}$ then firm A would be better off by discriminatory pricing in her own turf.

In appendix 1.B we show that proposition 1 is also true for tow other information cost functional forms. However, the upper limit on t_0 and the preferred length of loyal segments are different for each case.

1.3.3. Scenario Three: Only firm A acquires information

This scenario is symmetric with scenario 4 (only firm B acquires information).

Proposition 2: When firm B acquires no information, firm A uses these two rules to acquire information:

2-1. <u>In her own turf:</u> prefers to fully discriminate her own turf (subject to information cost).

2-2. <u>In her rival's turf</u>: acquires no information.

[7] This condition comes from (1.19) and (1.20). If the information cost is higher than this upper limit then firm A decides to acquire no information in her own turf at all.

Proof: See appendix 1.A.

In this case firm B is not able of any discrimination and charges a uniform price for all customers. If $\frac{1}{16} < \frac{t_0}{t} \leq \frac{1}{8}$ then firm A would prefer to acquire just one unit of information in the left hand side [0,0.5] and the unique equilibrium prices are:

$$P_A(x) = \begin{cases} t & x \in [0,0.25] \\ \frac{3t}{4} & x \in (0.25,0.5] \\ \frac{t}{4} & x \in (0.5,1] \end{cases} \qquad \text{and} \qquad P_B(x) = \frac{t}{2}.$$

If $\frac{t_0}{t} \leq \frac{1}{16}$, then the proof of proposition 2 shows that firm B has no share from the left hand side (even in the one next to 0.5 point) and only chooses her unique price to maximize her profit on (0.5,1] interval. On the other hand, firm A would prefer to fully discriminate the left hand side [0,0.5] and the preferred length of the segments are determined by equation (1.20):

$$P_A(x) = \begin{cases} \left(\frac{7}{6} - a_i\right)t & x \in s_i = (a_{i-1}, a_i] \subset [0,0.5] \\ \frac{t}{3} & x \in (0.5,1] \end{cases} \qquad \text{and} \qquad P_B(x) = \frac{2t}{3}.$$

Figure 1.8 shows a possible solution for this sub-game. As it is clear the indifferent customer on [0,0.5] is the customer who is located exactly on 0.5. Then all the left hand side customers buy from firm A. On the right hand side firm A's market share is 1/3 and the rest buy from firm B.

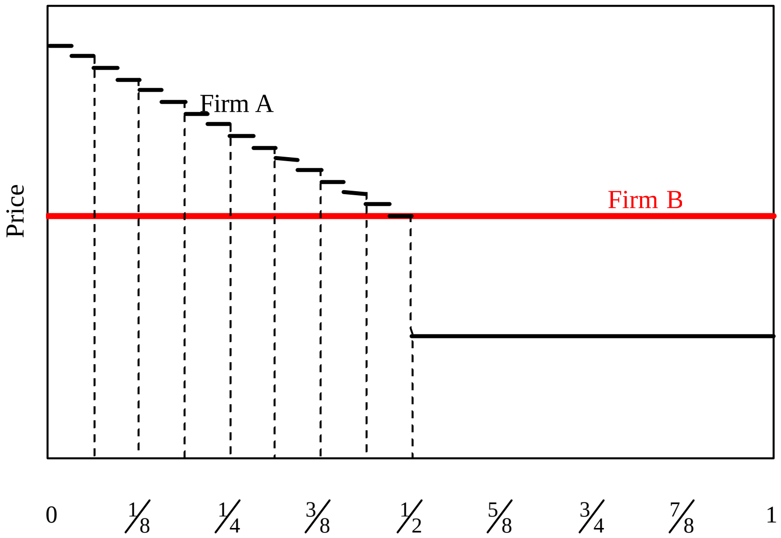


Figure 1.8: An example of the equilibrium strategy for the firms in the third scenario

1.3.4. Outcome of the Two-Stage Game

Figure 1.9 shows the strategic representation of the game when the information cost is insignificant ($t_0 \to 0$). As it can be seen the game is a prisoners' dilemma.

		Firm B: NI	Firm B: I
Firm A	NI	$\frac{t}{2}$, $\frac{t}{2}$	$\frac{2t}{9}$, $\frac{25t}{36}$
Firm A	I	$\frac{25t}{36}$, $\frac{2t}{9}$	$\frac{43t}{144}$, $\frac{43t}{144}$

Figure 1.9: The outcome of the game when $t_0 \to 0$

Figure 1.10 represents firm A's profit as a function of $\frac{t_0}{t}$. In each pair of strategies the first notation refers to firm A's strategy and the second one to firm B's. If firm B acquires information, firm A's best response is to do so, irrespective of the information cost. If the other firm acquires no information, the best response is to acquire information if the information cost is sufficiently low. So if the information cost is sufficiently low, the game becomes a prisoners' dilemma and both firms would have a dominant strategy to acquire information. This threshold is $\frac{t_0}{t} \approx 0.039$.

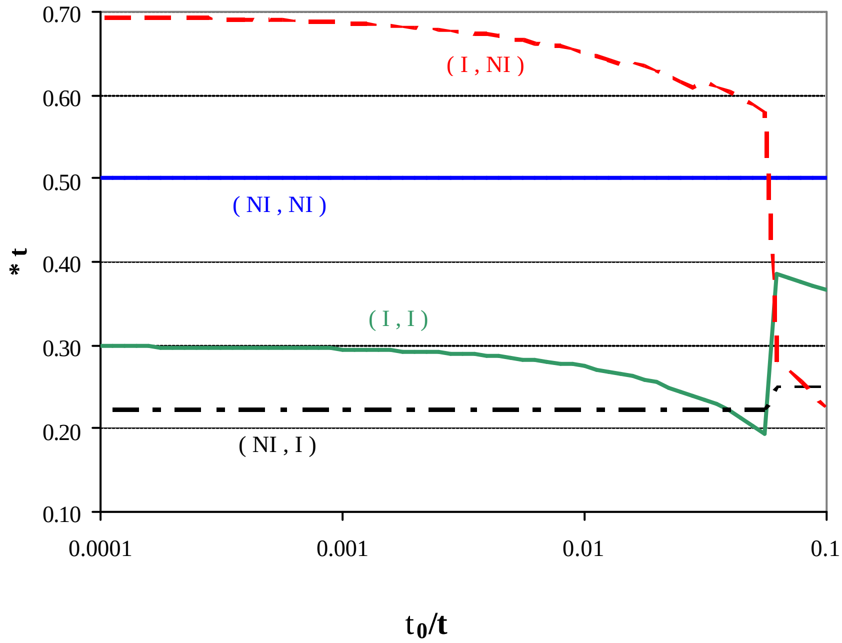


Figure 1.10: Firm A's profit for four different scenarios versus the information / transportation cost ratio

Then if $\frac{t_0}{t} > 0.039$ the game has two Nash equilibria: i) both firms acquire information and ii) neither of the firms acquire information. If $\frac{t_0}{t} \le 0.039$, the game is a prisoners' dilemma where information acquisition is the dominant strategy for both firms. In this case we have excess information acquisition from the firm point of view. Acquiring more information will lead to tougher competition and even in the limit, when $t_0 \to 0$, will lead to about 40% decrease in firm's profits.

Acquiring information has two opposite effects on firm's profit. It enables the firm to price discriminate and on the other hand toughens the competition. The latter effect dominates the former and when both firms acquire information, they both worsen off. Fixing the partitions for both firms, then pricings are strategically complement.

Given the outcome of this game, one might ask why do the firms not freely give each other information about customers on their own turfs? The issue of collusion in sharing the information in this game can be looked at from two different points of view.

Firstly, in the real world situation that our setting might be applied to sharing the customer information with a third party is usually illegal. Fro example, Tescos –the biggest supermarket in the UK with almost one third of the market share- has a huge pool of specific information about its customers via its club-card scheme. However, it is illegal for Tescos to share this information with other supermarkets.

Secondly, as it is showed in this section, information about the customers in the other side of market has no strategic importance for the firm. Then even if the information is available it makes no vital part in pricing decision. Since the outcome of the game shows excessive information acquisition, one possibility for collusion is to collude and not acquire information. However, as it was showed firms have incentive to deviate from this agreement and acquire information.

1.4. The Simultaneous Move Game

In this game, firms cannot observe their rival's information partition. It seems that the two-stage game is able to offer a better explanation of the information acquisition decision in a competitive market. Firms (especially in retailer market) closely monitor their rival's behaviour. Then it seems a reasonable assumption to consider that while competing via prices, they are aware of the information partition chosen by their rival.

We will show that there is no pure strategy equilibrium in this game. Remember that every strategy has two parts, the segmentation scenario and the prices for each segment. To prove non-existence of pure strategy equilibrium, we show that for different cases (regarding the information acquisition decision), at least one of the firms has incentive to deviate from any assumed pure strategy equilibrium.

1.4.1. Case 1: None of the firms acquire information

The proof for the situation that none of the firms acquire information is trivial. When both firms decide to buy no information, the outcome would be charging a uniform price of t for both firms. It is clear that a firm has incentive to deviate from this strategy and acquire some information when t_0 is sufficiently small.

1.4.2. Case 2: Both firms acquire information

Suppose there is a pure strategy equilibrium where both firms acquire some information. Firstly we will show that in this equilibrium firms acquire no information on their rival's turf. Assume firm B acquires some information on [0,0.5]. In the equilibrium every firm can predict her rival's partition accurately. Therefore, based on lemma 2, firm B makes no sale on every interval expect the final right segment on

[0,0.5]. Then the information on this interval is redundant for firm B. She can profitably deviate, acquire no information on [0,0.5], and charge the same price for the entire interval. Then in any pure strategy equilibrium firm B acquires no information on firm A's turf. We will therefore consider all different possibilities for firm A to acquire information on [0,0.5]. Then we will show that in any candidate equilibrium at least one of the firms has incentive to deviate (the fact that in the equilibrium each firm can predict her rival's strategy accurately is used).

i) *No further information in [0,0.5]*: The corresponding equilibrium prices at this interval are

$$P_A(x) = \frac{2t}{3} \quad \text{and} \quad P_B(x) = \frac{t}{3}; \quad \text{for} \quad \forall x \in [0,0.5].$$

It is trivial that firm A has incentive to deviate and acquire some information on the left hand side. The information cost is not a binding constraint here. It has been shown in the proof of proposition 1 that the constraint on whether to acquire some information on [0,0.5) is more relaxed than acquiring any information in the first place (acquiring information on [0,1]).

ii) *Partial discrimination on [0,0.25]*: This means firm A acquires the information which splits [0,0.5] interval to [0,0.25] and (0.25,0.5] and some information (but not fully discrimination) on [0,0.25] (and possibly some information on (0.25,0.5]). In the equilibrium firm A knows that firm B sets a uniform price on the left hand side to maximise her payoff from the very last segment on the right hand side of (0.25,0.5] interval. Responding to this, as shown in proof of proposition 1, firm A has incentive to fully discriminate on [0,0.25]. So a strategy profile like this cannot be an equilibrium.

iii) *Full discrimination on [0,0.25] and no further information on (0.25,0.5]*: As the results of lemma 2 and proposition 1 show, if the information cost is sufficiently low in equilibrium, firm A fully discriminates customers between [0,0.25] (subject to information cost) and charges a uniform price for the section (0.25,0.5], and firm B charges a uniform price for all customers on the left hand side in order to gain the most possible profit from the customers on (0.25,0.5]. Now we want to investigate the players' incentive to deviate from this strategy profile.

Firm A has incentive to deviate from this strategy and acquire more information in the information acquisition stage. Unlike the two-stage game, deviation from this equilibrium and acquiring more information in the very last segment of the left hand side (shared segment) doesn't affect firm B's price for the left hand side. Recalling (1.A17) from the proof of proposition 1, firm A decides to acquire more information in (0.25,0.5] if $\frac{1}{2}-\frac{1}{4}\geq 2\sqrt{\frac{t}{t}}$ or $\frac{t}{t}\leq\frac{1}{64}$. This is exactly the same upper bound for information cost that satisfies firm A's decision to acquire any information in the left hand side in the first instance. That means if information cost is small enough to encourage firm A to acquire some information in [0,0.5] interval, then firm A also has incentive to deviate from the proposed strategy profile.

iv) *Full discrimination on [0,0.5]*: The corresponding equilibrium prices for the left hand side are ((a_{n-1},0.5] is the very last segment on the right where firm A acquires information):

$$P_A(x)=\begin{cases}2t\left(\frac{2}{3}-a_i-\frac{1}{3}a_{n-1}\right) & x\in\left(a_{i-1},a_i\right]\\ \frac{2t}{3}\left(1-2a_{n-1}\right) & x\in\left(a_{n-1},0.5\right]\end{cases}\quad\text{and}\quad P_B(x)=\frac{t}{3}\left(1-2a_{n-1}\right).$$

Firm B has incentive to deviate and acquire some information on the left hand side. If firm B buys one unit of information on the left hand side then she can charge a different price ($\hat{P}_B$) for [0,0.25]. The extra profit which she can achieve will be:

$$\Delta p_B=\left(\frac{1}{4}-\frac{1}{2t}\left(\hat{P}_B-2t\left(\frac{5}{12}-\frac{a_{n-1}}{3}\right)\right)\right)\hat{P}_B-t=\left(\frac{1}{6}-\frac{a_{n-1}}{3}-\frac{\hat{P}_B}{2t}\right)\hat{P}_B-t\ .$$

The first order condition results $\hat{P}_B=\left(\frac{1}{6}-\frac{a_{n-1}}{3}\right)t$ and the corresponding extra profit of $\Delta p=\left(0.5-a_{n-1}\right)^2\frac{t}{18}-t$, which (considering the upper bound on information cost for acquiring information in a firm's own turf) gives firm B incentive to acquire at least one unit of information of the left hand side.

Then the game has no equilibrium when both firms acquire information.

1.4.3. Case 3: Only firm A acquires information

Suppose this case has an equilibrium. In the equilibrium each firm can predict her rival's strategy including preferred partition; so firm A knows that in the equilibrium, her rival can predict her chosen partition. We try to construct the characteristics of this equilibrium. Since in the equilibrium firm B can predict her rival's partition accurately, then we can use some of the results that we had from the first game.

As seen in lemma 2, firm A knows if she acquires information in the right hand side, firm B can prevent her of selling to any customer in the right hand segments except the very first segment. Then firm A has no incentive to acquire information in the right hand side.

As for the left hand side, proposition 2 shows that firm B knows that firm A can gain the most possible profit by fully discriminating. So firm B sets her price to just maximise her profit from the only segment in her turf and firm A fully discriminate the left hand segment.

An equilibrium for this case should have these two characteristics:

1- In the right hand side, firm A (the only firm who acquires information in this scenario) buys no information. Then there is only one segment (0.5,1] and the prices would be $P_A^{RHS} = \frac{2t}{3}$ and $P_B = \frac{4t}{3}$.

2- in the left hand side, firm A fully discriminates subject to information cost given the firm B's uniform price.

Now we want to investigate firm A's incentive to deviate from this equilibrium. Given firm B's uniform price, if firm A deviates and acquires just one unit of information in the right hand side his marginal profit would be the difference between his equilibrium profit over (0.5,1] and the deviation strategy profit over (0.5,0.75] and (0.75,1]. Then the deviation profit can be written as (P_A^L the price charged for the left sub-segment and P_A^R the price for the right sub-segment):

$$p_A^{RHS} = P_A^L\left(\frac{\frac{4t}{3} - P_A^L}{2t}\right) + P_A^R\left(\frac{\frac{4t}{3} - P_A^R}{2t} - \frac{1}{4}\right) - t \ . \qquad (1.21)$$

Solving the FOCs, the first part of (1.21) exactly gives firm A the same profit as the supposed equilibrium. If the second part of the profit is greater than the information cost, then firm A has incentive for deviation. From the FOC $P_A^R = \frac{5t}{12}$, the marginal profit of deviation is:

$$\Delta p_A^{RHS} = \frac{5t}{12}\left(\frac{11}{24} - \frac{1}{4}\right) - t = \frac{25t}{288} - t \ .$$

If $\frac{t}{t} \leq \frac{25}{288} \approx 0.087$ firm A has incentive to deviate and acquire at least one unit of information in the right hand side. This condition is more relaxed than the condition calculated in section 1.3.2 for acquiring information in her turf at all. That means if the information cost is low enough that firm A decides to acquire information in the left hand side, in the first place, she has incentive to deviate from any equilibrium strategy that constructed for this case.

1.4.4. Outcome of the Simultaneous Move Game

The major result of studying the simultaneous move game is the non-existence of equilibrium in pure strategies. Therefore the only possible equilibrium of this game would be in mixed strategies. Considering that each pure strategy consists of an information partition and a pricing function measurable with the chosen information partition, one can imagine that in general there are many possible pure strategies. This makes finding the mixed equilibrium of the game a difficult task. In appendix 1.C, we investigate the existence of a mixed strategy equilibrium through a simple example where the number of possibilities are exogenously restricted.

1.5. Comparing the Two-Stage Game with the Multi-Store Example

In this section we compare our model with the spatial competition among multi-store retailers. The spatial competition model has been studied in several papers (Teitz (1968), Martinez-Girlat & Neven (1988), Slade (1995), Pal & Sarkar (2002)). Consider two retailers, initially each with one store located at the two ends of [0,1] interval. They have the option to open new stores alongside the line. Opening a new store enables the firm to price discriminate, by charging different prices at different stores. In a two stage setting, first each firm decides whether to open their new branch and then firms compete via prices.

Spatial competition models can also be described as introducing new models in a differentiated market where customers have different tastes. Assume there are two brands of car (say Honda and Toyota) and the customers are uniformly located on the interval between these two brands based on their tastes. If a customer's location is closer to Honda, he likes Honda more. The customer who is located at the mid-point is indifferent between two brands.

So the problem for car makers is to produce different models alongside the line to be able to price discriminate. For example, Toyota might want to make some changes to their existing model and making a new model more like Honda products to attract some of Honda customers. Making these changes for the car maker bears a relatively small cost. In a two stage setting, firms first choose their models and then compete via prices.

The information acquisition model is different from this model. In the information acquisition model the products offered to all customers are identical; but in the multi-store model, firm is able to charge different prices by offering different products. In case of considering the model in a spatial context, the difference is the location of stores. In the information acquisition game the pattern of transportation cost was unaffected by the price discrimination practice. In the multi-store model, opening each store potentially reduces the transportation cost for some of the customers who shop at new stores.

In order to demonstrate this we illustrate an example of spatial competition which has similarities to our model. Assume two retailers A and B each with one store located at points 0 and 1 respectively. In the first stage they each might decide whether to open a new store or not. Retailer A has the option to open her new store at 0.25 and retailer B can open her new store at 0.75. After making this decision, both firms observe their rival choice. The game proceeds to the next stage where firms compete in prices. Customers are uniformly distributed on [0,1]. Each customer buys at most one unit of good and her utility is $U = V - P - td$ where V is her reservation price, P is the price she paid, t is the unit cost of transport, and d is the distance to her chosen store. Firms' marginal costs are equal, normalised to zero and the cost of opening a new store is c.

Note that in this game each firm charges a uniform price for all customers at each store. The only option for a firm to price discriminate is to open a new store.

The game has four sub-games as it is shown in figure 1.11. We solve each sub-game and then characterise the sub-game perfect equilibrium.

		Firm B	
		Not Open	Open B_2 @ 0.75
Firm A	Not Open	1^{st} sub-game	4^{th} sub-game
	Open A_2 @ 0.25	3^{rd} sub-game	2^{nd} sub-game

Third and forth Sub-games are symmetric.

Figure 1.11: The multi-store retailer game

1.5.1. First sub-game; None of the firms opens a new store

The equilibrium in this sub-game is trivial. Both firms charge uniform prices ($P_A = P_B = t$), they share the market equally, and each firm's profit is $\frac{t}{2}$.

1.5.2. Second sub-game; Both firms open a new store

Figure 1.12 shows the spatial representation of this sub-game. We call stores located at 0 and 0.25, A_1 and A_2 respectively. Similarly stores located at 1 and 0.75 are called B_1 and B_2.

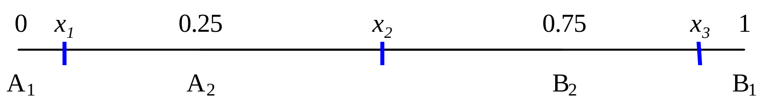


Figure 1.12: The 2^{nd} sub-game of the multi-store retailer game

The utility of the customer who is located at x is (P_i is the price charged by store i):

$$U(x) = \begin{cases} V - P_{A1} - tx & if \;\; she \;\; buys \;\; from \;\; A_1 \\ V - P_{A2} - t\left|x - \frac{1}{4}\right| & if \;\; she \;\; buys \;\; from \;\; A_2 \\ V - P_{B2} - t\left|\frac{3}{4} - x\right| & if \;\; she \;\; buys \;\; from \;\; B_2 \\ V - P_{B1} - t(1-x) & if \;\; she \;\; buys \;\; from \;\; B_1 \end{cases} . \tag{1.22}$$

We restrict our search for equilibrium to symmetric equilibria. In any symmetric equilibria $P_{A1} = P_{B1}$ and $P_{A2} = P_{B2}$. Based on this, we can conclude that in the equilibrium customers in each of the segments ([0,0.25], (0.25,0.75], and (0.75,1]) shop at one of the two stores located at the two ends of that segment. For example customers on [0,0.25] shop either at A_1 or A_2. It is trivial that customers on this interval have no incentive to shop at either of firm B's stores, since it only increases their transportation cost. The same argument is true for interval (0.25,0.75], if in the equilibrium $P_{A1} \geq P_{A2} - \frac{t}{4}$. This condition guarantees that customers located on (0.25,0.75] has no incentive to travel to either of stores located at 0 and 1.

Assume x_1, x_2, and x_3 (see figure 1.12) are the location of indifferent costumers in each segment. Considering our assumption and equations (1.22), the locations of indifferent customers are:

$$x_1 = \frac{1}{8} + \frac{P_{A2} - P_{A1}}{2t}, \tag{1.23}$$

$$x_2 = \frac{1}{2} + \frac{P_{B2} - P_{A2}}{2t}, \text{ and} \tag{1.24}$$

$$x_3 = \frac{7}{8} + \frac{P_{B1} - P_{B2}}{2t}. \tag{1.25}$$

Firm A’s total profit from both stores is:

$$p_A = P_{A1}x_1 + P_{A2}\left(x_2 - x_1\right) - c. \tag{1.26}$$

Substituting from (1.23) and (1.24) into (1.26); and calculating the first order conditions, the best response prices for firm A are[8]:

$$P_{A1} = P_{A2} + \frac{1}{8}t \quad \text{and} \quad P_{A2} = \frac{1}{2}P_{B2} + \frac{t}{2}.$$

Following a Similar procedure for firm B the best responses for firm B are:

$$P_{B1} = P_{B2} + \frac{1}{8}t \quad \text{and} \quad P_{B2} = \frac{1}{2}P_{A2} + \frac{t}{2}.$$

Solving these two set of best responses together, the location of indifferent customers (x_1, x_2, and x_3) are $\frac{1}{16}$, $\frac{1}{2}$, and $\frac{15}{16}$. The equilibrium prices are:

$$P_{A1} = P_{B1} = \frac{9}{8}t \quad \text{and} \quad P_{B2} = P_{A2} = t. \tag{1.27}$$

And the firms’ equilibrium profit is:

$$p_A = p_B = \frac{65}{128}t - c. \tag{1.28}$$

---

[8] The second order condition satisfies the maximum that this solution is a maximum.

Prices in (1.27) satisfy the condition that we need for this equilibrium ($P_{A1} \geq P_{A2} - \frac{t}{4}$). As it can be seen in (1.27) in this sub-game the competition is limited to the middle segment. The competition on this segment has the same pattern as the 1st sub-game and the outcome in this segment is similar to the outcome of the 1st sub-game where the prices are equal to *t* and firms share the market equally.

The possibility of a global deviation by firms should be investigated. The possible deviation strategies for firm A are (given firm B's prices are fixed as (1.27)):

i) Reduce P_{A2} (and consequently P_{A1}) in order to capture a higher share from the right hand side with the possibility of attracting some of the customers on (0.75,1] interval.

ii) Increase P_{A2} (and consequently P_{A1}) in order to increase her profit on [0,0.25] interval.

iii) Ignore A_2 store and try to maximise her profit only through A_1.

It is investigated and none of the above alternative strategies increases firm A's profit. Then the equilibrium discussed here is the unique symmetric equilibrium of this sub-game.

1.5.3. Third sub-game; Only firm A opens a new store

Figure 1.13 shows the spatial representation of this sub-game. In this sub-game firm A has two stores located at 0 and 0.25 and firm B has one store located at 1.

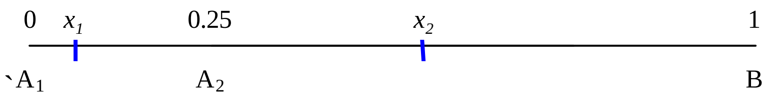


Figure 1.13: The 3rd sub-game of the multi-store retailer game

We assume that in the equilibrium customers in each of the segments ([0,0.25] and (0.25,1]) shop at one of the two stores located at the two ends of that segment. After finding this equilibrium we prove that this is a global equilibrium.

Assume x_1 and x_2 (see figure 1.13) are the location of indifferent costumers in each segment. Considering our assumption and equation (1.22), the locations of indifferent customers are

$$x_1 = \frac{1}{8} + \frac{P_{A2} - P_{A1}}{2t} \text{ and} \tag{1.29}$$

$$x_2 = \frac{5}{8} + \frac{P_B - P_{A2}}{2t}. \tag{1.30}$$

Firm A's total profit has the same form as (1.26). By substituting from (1.29) and (1.30) into (1.26); and calculating the first order conditions, the results are (these are the best response function for firm A)

$$P_{A1} = P_{A2} + \frac{1}{8}t \qquad \text{and} \qquad P_{A2} = \frac{1}{2}P_B + \frac{5}{8}t.$$

Firm B's total profit is:

$$p_B = P_B(1 - x_2). \tag{1.31}$$

Substituting from (1.30) into (1.31); and calculating the first order condition, the result for firm B is

$$P_B = \frac{1}{2}P_{A2} + \frac{3}{8}t.$$

Solving these two set of best responses together, the location of indifferent customers are $\frac{1}{16}$ and $\frac{13}{24}$. The equilibrium prices are:

$$P_{A1} = \frac{29}{24}t, \qquad P_{A2} = \frac{13}{12}t, \quad \text{and} \quad P_B = \frac{11}{12}t. \tag{1.32}$$

And the firms' equilibrium profits are:

$$p_A = \frac{685}{1152}t - c \qquad \text{and} \qquad p_B = \frac{121}{288}t. \tag{1.33}$$

Prices as it can be seen in (1.32) show that in this sub-game, the competition between the firms are limited to [0,0.75].

The deviation possibilities for the firms again fail to improve the profit. Then it is the unique equilibrium of this sub-game.

1.5.4. Outcome of the multi-store game

Figure 1.14 summarises the outcome of the four sub-games. For different values of c the sub-game perfect equilibrium has different characteristics:

i. If $c \le \frac{1}{128}t$, then both players have a dominant strategy to open the new store. But the game is not a prisoners' dilemma. Opening the new stores by both firms improves the profit for both firms.

ii. If $\frac{1}{128}t < c \le \frac{101}{1152}t$, then it is still a dominant strategy to open the new store for both firms; however the game is a prisoners' dilemma.

iii. If $\frac{101}{1152}t < c \le \frac{109}{1152}t$, then the game has two asymmetric equilibria, when one firm opens the new store and her rival does not.

iv. If $\frac{109}{1152}t < c$, then each firm has a dominant strategy not to open the new store.

		Firm B	
		Not Open	Open B_2 @ 0.75
Firm A	Not Open	$\frac{t}{2}$, $\frac{t}{2}$	$\frac{121}{288}t$, $\frac{685}{1152}t - c$
	Open A_2 @ 0.25	$\frac{685}{1152}t - c$, $\frac{121}{288}t$	$\frac{65}{128}t - c$, $\frac{65}{128}t - c$

Figure 1.14: The payoffs in the multi-store retailer game

This game - like the information acquisition game - has a dominant strategy of opening the second store conditional on $c < \frac{101}{1152}t$. However, the game is not a prisoners' dilemma. In fact for different values of c, the game has different characteristics. Note that in the information acquisition game if information cost was less than a threshold, game was a prisoners' dilemma.

We now try to explain intuitively what happens as the number of firms rises in this model.

Assume that firm A can open stores in the interval [0,0.5), while firm B can open stores in the interval (0.5,1]. We define the mid-interval as [*a*,*b*] where *a* and *b* are the location of the two closest stores to the mid-point respectively belonging to firm A and firm B. As our previous example of four stores (two stores for each firm) showed, the pattern of competition on the mid-interval is similar to the game with only one store for each firm. That is, the two stores on both sides of the med-interval compete for customers, just as the two stores located at 0 and 1 did in the original game. Thus, similar intuition suggests that when firms can open many stores, competition is restricted to the mid-interval. Other stores located on other intervals are able to charge a higher price. One can solve a free entry equilibrium in this case where firms can open many stores, but each additional store incurs a fixed cost.

Intuitively, this setup seems different from the information acquisition game. Since stores away from the mid-interval are able to charge a higher price. Therefore in one hand, firms would like to open stores closer to mid-point to push the competition further away from the segments they are constrained monopolist on. On the other hand, firms would like to open stores away from the mid-interval and where they have more monopoly power to increase their profit. The factor that limits the number of stores is the cost of a running new store. Thus opening new stores may allow firms to relax competition, unlike in the information acquisition case, where competition is increased.

1.6. Summary and Conclusion

This chapter has analysed a model of information acquisition by firms, where information allows firms to price discriminate. Our benchmark model is one where information acquisition decisions are common knowledge at the time that firms compete via prices. We show that information acquisition increases price competition and reduces profits, so that we have an outcome similar to a prisoners' dilemma. Our second main finding is that firms acquire less information as compared to a monopoly situation, since this softens price competition.

By introducing information cost (and as a consequence segmentation scenario), the third-degree price discrimination problem can end up neither on fully discrimination policy nor on non-discrimination decision. Depending on the cost of every unit of information, every firm needs to answer two questions: how should I discriminate (what is the preferred length of every segment) and what is the best price to charge for every specified customer. The result would be a partially discrimination policy.

The two-stage game is a prisoners' dilemma which in equilibrium, firms acquire excessive information. Firms also prefer to discriminate partially. Our results show that there is a trade-off in acquiring more information. It improves firms' performances in terms of profit by enabling them to price discriminate. On the other hand, acquiring more information tends to make the competition between the firms more fierce. Tougher competition drives the prices down and ultimately decreases firms' profits.

Our results demonstrate how decreasing marginal profit of information limits firms' willingness to acquire more information. Furthermore, in equilibrium –regardless of the cost of information- firms do not have incentive to acquire information on their rival's turf. Acquiring information in a firm's own turf is also restricted. Extra information in this area makes firms profit to fall as result of tougher competition.

We have also analysed a model where information acquisition decisions are not observed by the rival firm. In this game, there is no pure strategy equilibrium. We solve for a mixed strategy equilibrium for a simple example, where firms have restricted information acquisition possibilities

Appendix 1.A

Proof of lemma 2: Since the firms' profit on $\hat{s}$ can be written as a function of the firms' prices on $\hat{s}$ and the segments associated with that (s_i; $i = 1, 2, \ldots, n$), firms solve the maximization problem for $\hat{s}$ independently of its compliment. We solve the problem for each possible segmentation situation

<u>Case 1:</u>

By solving the first order conditions ($\frac{\partial p_A}{\partial P_A} = 0$, $\frac{\partial p_B}{\partial P_B} = 0$), market shares, prices, and profit of firms is calculated. By applying the FOC to (1.9) and (1.10) and solving them simultaneously, firms' prices are:

$$P_A = \frac{t}{3}\left(2a_1 - 4a_0 + 1\right), \text{ and} \qquad (1.A1)$$

$$P_B = \frac{t}{3}\left(4a_1 - 2a_0 - 1\right). \qquad (1.A2)$$

By substitution the prices from (1.A1) and (1.A2) into (1.5), the location of marginal customer in every segment is derived:

$$x = \frac{1}{6}\left(2a_1 + 2a_0 + 1\right). \qquad (1.A3)$$

In the segments that both firms sell positive quantities, the prices should be non-negative ($P_A \geq 0$, $P_B \geq 0$) and the marginal customer should be located within the segment ($a_0 \leq x \leq a_1$)[9]. From the information acquisition technology at the definition of the model, every two consecutive breaking points (the borders of each segment) have the following form:

$$a_0 = \frac{2k-1}{2^p} \ , \ a_1 = \frac{2l-1}{2^q} \text{ where } k, l, p, q \in \aleph . \qquad (1.A4)$$

And also the length of segment is represented as[10]:

$$a_1 - a_0 = \frac{1}{2^r} \text{ where } r = \max\{p, q\}. \qquad (1.A5)$$

Solving the restrictions, the results are:

i) If $p > q$ then the restrictions hold only for $a_1 = \frac{1}{2}$; both firms sell positive quantities in the segment located exactly at the left hand side of the middle point[11].

ii) If $p < q$ then the restrictions hold only for $a_0 = \frac{1}{2}$; both firms sell positive quantities in the segment located on the right side of the middle point.

iii) $p = q$ is impossible, it is equivalent with a segment of length zero.

In this case, market sharing takes place only for two segments located around $\frac{1}{2}$.

---

9 Obviously, the price restrictions and the location restrictions are equivalent.

10 This definition covers all amounts of a_0 except $a_0 = 0$. That can be solved as: $0 < 2a_1 + 1 < 6a_1$ then $\frac{1}{4} < a_1$. Since $a_1 - a_0 = \frac{1}{2^r} > \frac{1}{4}$ and $a_0 = 0$ then $a_1 = \frac{1}{2}$ is the only possible upper border of a segment with positive demand for both firms.

11 Proof: $a_1 = a_0 + \frac{1}{2^p} = \frac{2k}{2^p}$. Substitute in (1.A1) and (1.A2), and apply in the price restrictions: $k > 2^{p-2} - \frac{1}{2}$, and $k < 2^{p-2} + 1$. Since $k \in \aleph$ then $k = 2^{p-2}$, and $a_1 = \frac{1}{2}$. The proofs of other two cases are quite similar.

Case 2:

In case 2 by solving the first order conditions on $\hat{s}$ ($\frac{\partial p_{iA}}{\partial P_{iA}} = 0$, $\frac{\partial p_B}{\partial P_B} = 0$; $i = 1,2,\cdots,n$) market share, prices, and profit of firms is calculated. By applying the FOC to (1.11) and (1.12) and solving them simultaneously the firms' prices are:

$$P_{iA} = \frac{t}{3}\left(\frac{2a_n + \sum_{i=1}^{n-1} a_i - a_0}{n} - 3a_{i-1} + 1\right) \text{ for } i = 1,2,...,n \text{ and} \qquad (1.A6)$$

$$P_B = \frac{t}{3n}\left(4a_n + 2\sum_{i=1}^{n-1} a_i - 2a_0 - n\right). \qquad (1.A7)$$

The solution is started from the first segment (s_1 which is the first segment in the very left hand side of $\hat{s}$) and shows that the location for indifferent customer does not satisfy $a_0 \le x_1 \le a_1$ then the maximization problems are reduced to n. This procedure continues to the most right hand side segment with a couple of FOCs and problem reduces to the problem solved in case 1.

$$x_1 = \frac{1}{2} + \frac{P_B - P_{1A}}{2t} = \frac{1}{2} + \frac{1}{6n}\left(a_n - a_0 + \sum_{i=1}^{n} a_i + 3na_0 - 2n\right).$$

Define $l_i = a_i - a_0$ then:

$$x_1 = \frac{1}{6} + \frac{2}{3}a_0 + \frac{1}{6n}\left(l_n + \sum_{i=1}^{n} l_i\right).$$

To be credible we should have $x_1 < a_0 + l_1$ and simultaneously $P_B > 0$ then:

$$\frac{1}{6} + \frac{2}{3}a_0 + \frac{1}{6n}\left(l_n + \sum_{i=1}^{n} l_i\right) < a_0 + l_1 , \qquad (1.A8)$$

and from (1.A7): $l_n + \sum_{i=1}^{n} l_i + na_0 - \frac{n}{2} > 0$ (1.A9)

After simplifying (1.A8):

$$\frac{1}{2} - a_0 + \frac{1}{2n}\left(l_n + \sum_{i=1}^{n} l_i\right) - 3l_1 < 0 . \qquad (1.A10)$$

And from (1.A9):

$$l_n + \sum_{i=1}^{n} l_i > n\left(\frac{1}{2} - a_0\right).$$

Define $\frac{1}{2} - a_n = g \geq 0$:

$$\text{RHS of (1.A10)} > \frac{1}{2} - a_0 + \frac{n}{2n}\left(\frac{1}{2} - a_0\right) - 3l_1 = \frac{3}{2}\left(l_n + g\right) - 3l_1.$$

For every *n>1*; $l_n \geq 2l_1$ then (1.A8) and (1.A9) cannot be held simultaneously.

Then we showed for every *n>1* in the first segment firm A is a constrained monopolist. For the *i*th step if *n>i* it is easy to show that these two constraints turn to this form (with $n+2-i$ FOCs):

$$x_i = \frac{1}{2} + \frac{P_B - P_{iA}}{2t} = \frac{1}{2} + \frac{1}{6(n+1-i)}\left(a_n - a_{i-1} + \sum_{j=i}^{n} a_j + 3(n+1-i)a_{i-1} - 2(n+1-i)\right) < a_i,$$

$$\text{and } \; P_B > 0 \Rightarrow a_n + \sum_{j=i}^{n} a_j - a_{i-1} - \frac{n+1-i}{2} > 0.$$

After simplifying:

$$\frac{1}{2} - a_0 + \frac{3}{2}l_i - 3l_{i-1} + \frac{1}{2(n+1-i)}\left(l_n - l_{i-1} + \sum_{j=i}^{n} l_j\right) < 0, \quad (1.A11)$$

$$\text{and } \; l_n - l_{i-1} + \sum_{j=i}^{n} l_j > (n+1-i)\left(\frac{1}{2} - a_0\right). \quad (1.A12)$$

Then

$$\text{The RHS of (1.A11)} > \frac{3}{2}\left(\frac{1}{2} - a_0\right) - \frac{3}{2}\left(2l_i - l_{i-1}\right) = \frac{3}{2}\left(l_n - 2l_i + l_{i-1} + g\right).$$

For *i<n*; $l_i \leq \frac{1}{2}\left(l_n + l_{i-1}\right)$ Then (1.A11) cannot be hold, supposing (1.A12) holds.

This procedure continues until the FOCs reduce to 2 conditions and the problem transforms to the problem has been solved in case 1.

<u>Case 3:</u>

In this case by solving the first order conditions for each segment ($\frac{\partial p_A}{\partial P_A} = 0$, $\frac{\partial p_{iB}}{\partial P_{iB}} = 0$; $i = 1,2,\cdots,n$) market shares, prices, and profit of firms is calculated. By applying the FOC to (1.13) and (1.14) and solving them simultaneously the firms' prices are:

$$P_A = \frac{t}{3n}\left(n + 4a_n - 2\sum_{i=1}^{n} a_i - 4a_0\right) \text{ and } \tag{1.A13}$$

$$P_{iB} = \frac{t}{3}\left(3a_i - 1 + \frac{2a_n - \sum_{i=1}^{n} a_i - 2a_0}{n}\right) \text{ for } i = 1,2,...,n. \tag{1.A14}$$

Again for the first segment:

$$x_1 = \frac{1}{2} + \frac{P_{1B} - P_A}{2t} = \frac{1}{2} + \frac{1}{6n}\left(-2a_n + 2a_0 + \sum_{i=1}^{n} a_i + 3na_1 - 2n\right).$$

Then we should have:

$$x_1 = \frac{1}{6} + \frac{a_1}{2} + \frac{1}{6n}\left(2a_0 - 2a_n + \sum_{i=1}^{n} a_i\right) < a_1.$$

Or equivalently:

$$x_1 = \frac{1}{6} - \frac{a_1}{2} + \frac{1}{6n}\left(2a_0 - 2a_n + \sum_{i=1}^{n} a_i\right) < 0.$$

Again consider $l_i = a_i - a_0$ then:

$$\frac{1}{2} - \frac{3a_0}{2} - \frac{3l_1}{2} + \frac{1}{2n}\left(-2l_n + \sum_{i=1}^{n} l_i + na_0\right) < 0,$$

or:

$$\frac{1}{2} - a_0 - \frac{3l_1}{2} + \frac{1}{2n}\left(-2l_n + \sum_{i=1}^{n} l_i\right) < 0. \tag{1.A15}$$

Now, we show that the minimum amount the right hand side is not negative. It is easy to show that the minimum of $\left(-2l_n + \sum_{i=1}^{n} l_i\right)$ is $-\frac{1}{2^{n-1}} l_n$ and the maximum amount of l_1 is $\frac{l_n}{2}$ then (recall $\frac{1}{2} - a_n = g \geq 0$):

$$\text{The RHS of (1.A15)} \geq \frac{1}{2} - a_0 - \frac{3l_1}{2} - \frac{l_n}{n2^n} = g + l_n\left(\frac{1}{4} - \frac{1}{n2^n}\right).$$

Then as long as $n > 1$ (1.A15) is not valid and in the first segment firm A is a constrained monopolist. For the *i*th step if $n > i$ it is easy to show that firms' preferred price for each section turn to this form:

$$P_A = \frac{t}{3(n-i+1)}\left(n - i + 1 + 4a_n - 2\sum_{k=i}^{n} a_k - 4a_0\right) \text{ and}$$

$$P_{jB} = \frac{t}{3}\left(3a_j - 1 + \frac{2a_n - \sum_{k=i}^{n} a_k - 2a_0}{n-i+1}\right) \text{ for } j = 1,2,...,i.$$

The location of indifferent customer for the last segment could be calculated as follow (with $n + 2 - i$ FOCs):

$$x_i = \frac{1}{2} + \frac{P_{iB} - P_A}{2t} = \frac{1}{2} + \frac{1}{6(n+1-i)}\left(-2a_n + 2a_0 + \sum_{k=i}^{n} a_k + 3(n+1-i)a_i - 2(n+1-i)\right).$$

By following a procedure as before it could be shown that $x_i \geq a_i$ as long as $n > i$ and $g \geq 0$. It means in this case we again end up with a problem similar to case 1 and firms share the market in only the very two extreme segments in the middle. ♦ *QED*

Proof of proposition 1: Firm A's decision to acquire one more unit of information to split the segment between any two already known consequent points can be considered as one of these two cases (note it is already proved that firm A has no incentive to acquire information on the right hand side).

i) Acquisition of one more information unit for dividing one of the first *n-1* segments to two equal sub-segments. Since firm A splits one of her loyal segments to two loyal sub-segments, then the marginal profit of this segmentation for the firm A is ($a_i - a_{i-1} = \left(\frac{1}{2}\right)^k$ where $k > 1$):

$$\Delta p_A = 2t\left(-a_i\left(a_i - \frac{a_i + a_{i-1}}{2}\right) - \left(\frac{a_i + a_{i-1}}{2}\right)\left(\frac{a_i + a_{i-1}}{2} - a_{i-1}\right) + a_i\left(a_i - a_{i-1}\right)\right) - t(k).$$

Where the first two parts are the amounts of extra profit that firm gets from the two sub-segments and the third part represents the similar amount for the original segment that should be subtracted. After simplifying:

$$\Delta p_A = \frac{t}{4}\left(a_i - a_{i-1}\right)^2 - t(k). \qquad \text{(1.A16)}$$

This shows that firm A's demand for more information and consequently more precise price discrimination in this part (the first *n-1* segments) continues as far as the length of pre-final segments satisfies:

$$a_i - a_{i-1} \geq 2\sqrt{\frac{t(k)}{t}}.$$

or equivalently (by substituting $a_i - a_{i-1} = \left(\frac{1}{2}\right)^k$ and $t(k) = \frac{t_0}{2^k}$):

$$k \leq \log_2 \frac{t}{4t_0}. \qquad \text{(1.A17)}$$

This result means the firm has incentive to split a loyal segment, if *k* satisfies this inequality. This is equivalent of minimum length which the firm has incentive to split the interval if the loyal interval is bigger than this minimum length. Therefore, the preferred length of a loyal segment is $\left(\frac{1}{2}\right)^{k+1}$.

We also can conclude that the preferred length for every firm's loyal segment in her turf does not depend on the location of the segment and depends only on the transportation and information costs and considering (1.A17) and the fact that $k \in \aleph \cup \{0\}$ then the preferred length for a loyal segment is:

$$\left(\frac{1}{2}\right)^r \qquad \text{where} \qquad r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor. \qquad \text{(1.A18)}$$

$\lfloor\ \rfloor$ notation represents the floor function (or the greatest integer). It is clear since it is about the length of a loyal segment then the minimum acceptable value for r is 3.

ii) Acquisition of one more information unit for dividing the *n*th segment to two equal sub-segments. Since firm A splits one shared segment to two sub-segments which the left one will be a loyal segment and the right one is a shared segment with her rival, then the marginal profit of such segmentation for the firm A is ($\frac{1}{2}-a_{n-1}=\left(\frac{1}{2}\right)^k$):

$$\Delta p_A=\frac{4t}{3}\left(\frac{\frac{1}{2}+a_{n-1}}{2}-a_{n-1}\right)-\frac{2t}{3}\left(\left(\frac{\frac{1}{2}+a_{n-1}}{2}\right)^2-a_{n-1}^2\right)$$
$$-2t\left(\frac{\frac{1}{2}+a_{n-1}}{2}-a_{n-1}\right)\left(\frac{1}{4}+\frac{a_{n-1}}{2}\right)+\frac{8t}{9}\left(\frac{1}{2}-\frac{\frac{1}{2}+a_{n-1}}{2}\right)^2-\frac{8t}{9}\left(\frac{1}{2}-a_{n-1}\right)^2-t\,(k),$$

$$\text{or}\quad \Delta p_A=\frac{t}{3}\left(\frac{1}{2}-a_{n-1}\right)^2-\frac{t}{6}\left(\frac{1}{2}-a_{n-1}\right)-t_k=\frac{t}{3\times 2^k}\left(\frac{1}{2^k}-\frac{1}{2}\right)-t\,(k).$$

For $\forall k$, this marginal profit is negative and shows the firm A's profit reduces by acquiring one more unit of information in this part regardless of information cost. But we should consider that the left sub-segment created after this information acquisition all are loyal customers now and the possibility of making extra profit by using constrained monopoly power on this sub-segment should be considered. This possibility can be investigated. Consider (1.A18), assume the preferred length of loyal segment is $\left(\frac{1}{2}\right)^r$ where $r=\left\lfloor \log_2\frac{t}{2t_0}\right\rfloor\geq 3$. It is clear acquiring information in this interval is only profitable if $r>k$; however the following result is true for any value of r. By adding the profit of this chain of segmentation the net profit of segmentation in the nth segment, $(a_{n-1},½]$, is:

$$\Delta p_A=\frac{4t}{3}\left(\frac{\frac{1}{2}+a_{n-1}}{2}-a_{n-1}\right)-\frac{2t}{3}\left(\left(\frac{\frac{1}{2}+a_{n-1}}{2}\right)^2-a_{n-1}^2\right)$$
$$-2t\sum_{i=1}^{2^r}\frac{1}{2^r}\left(\frac{1}{4}-\frac{a_{n-1}}{2}\right)\left(a_{n-1}+\frac{i}{2^r}\left(\frac{1}{4}-\frac{a_{n-1}}{2}\right)\right),$$
$$+\frac{8t}{9}\left(\frac{1}{2}-\frac{\frac{1}{2}+a_{n-1}}{2}\right)^2-\frac{8t}{9}\left(\frac{1}{2}-a_{n-1}\right)^2-\Gamma$$

or

$$\Delta\pi_A = \left[t\left(\left(\frac{7}{12} - \frac{1}{2^{r+2}} \right) \left(\frac{1}{2} - a_{n-1} \right)^2 - \frac{1}{6} \left(\frac{1}{2} - a_{n-1} \right) \right) - \Gamma \right];$$

and finally

$$\Delta\pi_A = \left[\frac{t}{2^k} \left(\frac{1}{2^k} \left(\frac{7}{12} - \frac{1}{2^{r+2}} \right) - \frac{1}{6} \right) - \Gamma \right] \qquad (1.19)$$

where the information cost is

$$\Gamma = t(k) + \sum_{i=k+1}^{r-1} 2^{i-(k+1)} t(i) = \frac{t_0}{2^k} + \sum_{i=k+1}^{r-1} \frac{2^{i-(k+1)} t_0}{2^i} = \frac{t_0}{2^k} \left(\frac{r-k+1}{2} \right),\ \frac{1}{2} - a_{n-1} = \left(\frac{1}{2} \right)^k, \text{ and}$$

$$r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor.$$

If the net profit calculated by (1.19) is negative then the segmentation in the nth segment is not profitable for firm A. Then the segmentation in the shared segment in firm A's turf is preferred by her as far as (1.19) is non-negative which because of it is importance is discussed in the main body of paper. ♦ *QED*

Proof of proposition 2:

We know that the firms only share the customers on the two border segments. Suppose Firm A acquires information in her own side such that the last left hand segment is (a,0.5], and as it has been proved in proposition 1 she has no incentive to pay for information in the right hand side. Then the maximization problems that should be solved simultaneously are:

Firm A's profit for (a,0.5]: $\pi_{LA} = P_{LA}\left(\frac{1}{2} + \frac{P_B - P_{LA}}{2t} - a \right).$

Firm A's profit for (0.5,1]: $\pi_{RA} = P_{RA}\left(\frac{P_B - P_{RA}}{2t} \right).$

Firm B's profit for (a,1]: $\pi_B = P_B\left(\frac{1}{2} - \frac{2P_B - P_{LA} - P_{RA}}{2t} \right).$

Solving the FOCs and the results are:

$$P_B = \left(\frac{1}{2} - \frac{a}{3} \right) t, \qquad P_{LA} = \left(\frac{3}{4} - \frac{7a}{6} \right) t, \text{ and} \qquad P_{RA} = \left(\frac{1}{4} - \frac{a}{6} \right) t.$$

And the locations of indifferent customers in these two segments are:

$$x_L = \frac{3}{8} + \frac{5a}{12} \qquad \text{and} \qquad x_R = \frac{5}{8} - \frac{a}{12}.$$

These values should satisfy $P_i > 0$, $a < x_L < \frac{1}{2}$, and $\frac{1}{2} < x_R < 1$.

Since if $a > 0.3$, then x_L will not satisfy its condition. Therefore, for $a > 0.3$, firm B cannot gain from the left hand side. That means if firm A decides to split up (0.25,0.5] then firm B just set her price to gain the most possible profit from the right hand side.

Then we compare the profit of firm A for different possible decisions (the profits are easily calculated similar to the result of lemma 2)[12]:

1- No information in left hand side: $p_A = \frac{5t}{16} - t_0$,

2- Fully discriminate $\left[0, \frac{1}{4}\right]$: $p_A = \left(\frac{241}{576} - \frac{1}{2^{r+2}}\right)t - \frac{(r+3)t_0}{2}$, and

3- Fully discriminate $\left[0, \frac{1}{2}\right]$: $p_A = \left(\frac{25}{36} - \frac{1}{2^{r+2}}\right)t - \frac{(2r+3)t_0}{2}$;

where $r = \left\lfloor \log_2 \frac{t}{2t_0} \right\rfloor$.

If $\frac{t_0}{t} \leq \frac{53}{96r}$ then the third one provides the largest profit for firm A (the profit on the first case exceeds the third one only when $\frac{t}{t} \geq \frac{101}{576}$ which is larger than $\frac{1}{16}$ the upper bound of information acquisition decision calculated in proposition 1); then she prefers to fully discriminate all the left hand side. In this case firm B's profit equals to $\frac{2t}{9}$. ♦ *QED*

Appendix 1.B

In this appendix we replace our assumed form of information cost function with two alternative functional forms. Then we represent the changes to the outcomes of the model as a result of these changes. Note that lemma 1 and lemma 2 are true regardless of the information cost sequence. We focus on how the changes to equation (1.2) changes proposition 1, proposition 2, and the outcome of two-stage game. The result is that firms strategically behave in the same way. Only the length of the loyal segments and the thresholds on information cost calculated in the proofs are different.

Our two alternative information cost functions are:

[12] The length of the loyal segments is calculated with the same rule as equation (1.20).

i) constant information cost: $t(k) = \bar{t}$ for $\forall k$.

ii) information cost with general functional form of:

$$t(k) = a^k t_0, \quad \text{for} \quad \forall k. \qquad (1.B1)$$

The other two information cost functions (equation (1.2) and the constant information cost) are specific cases of (1.C1).[13]

In order to emphasis the changes, we add notations *c* and *g* to each equation number that changes for *constant* and *general* information cost functions respectively.

Constant information cost:

Assume equation (1.2) is replaced by:

$$t(k) = \bar{t} \qquad \text{for} \qquad \forall k.$$

Proposition 1:

The proposition 1 is true for this case. Only because of the change in information cost function to a linear cost function the limit on the first rule is different:

Recall equation (1.A16) the marginal profit of acquiring a unit of information in a loyal segment:

$$\Delta p_A = \frac{t}{4}(a_i - a_{i-1})^2 - t(k). \qquad (1.A16)$$

This equation gives us the limit to the which is now (by substituting $a_i - a_{i-1} = \left(\frac{1}{2}\right)^k$ and $t(k) = \bar{t}$) equation (1.A17) changes to:

$$\left(\frac{1}{2}\right)^k \qquad \text{where} \qquad k \le \frac{1}{2}\log_2 \frac{t}{4\bar{t}}. \qquad (1.A17.c)$$

Then the preferred length for a loyal segment is:

$$\left(\frac{1}{2}\right)^r \qquad \text{where} \qquad r = \left\lfloor \frac{1}{2}\log_2 \frac{t}{\bar{t}} \right\rfloor. \qquad (1.20.c).$$

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[13] We decided to have the special case of $a = \frac{1}{2}$ in the main body of paper, since calculating the closed form of some equations which helps to demonstrate our results is more complicated for the general functional form of (1.3).

The marginal profit of a unit of information on the shared border segment with the length of $\left(\frac{1}{2}\right)^k$ is (note the marginal profit has the same format and only the information cost and the preferred length of the loyal segment are different):

$$\Delta p_A = \left[\frac{t}{2^k}\left(\frac{1}{2^k}\left(\frac{7}{12}-\frac{1}{2^{r+2}}\right)-\frac{1}{6}\right)-2^{r-k}\bar{t}\right]. \qquad (1.19.c)$$

where $\frac{1}{2}-a_{n-1}=\left(\frac{1}{2}\right)^k$, and $r=\left\lfloor\frac{1}{2}\log_2\frac{t}{\bar{t}}\right\rfloor$.

Then the chain of decision statements in table 1.1 changes to table 1.2.

Table 1.2: Firm A's chain of decision statements with a constant information cost

a_{n-1}	a_n	k	Decision statement
0	$\frac{1}{2}$	1	$\left[\frac{t}{16}\left(1-\frac{1}{2^r}\right)-2^r\bar{t}\right]\geq 0$ where $r=\left\lfloor\frac{1}{2}\log_2\frac{t}{\bar{t}}\right\rfloor$
$\frac{1}{4}$	$\frac{1}{2}$	2	$\left[\frac{t}{32}\left(-\frac{1}{6}-\frac{1}{2^r}\right)-2^r\bar{t}\right]\geq 0$ where $r=\left\lfloor\frac{1}{2}\log_2\frac{t}{\bar{t}}\right\rfloor$

As it can be seen the information acquisition rules set out in proposition 1 is still true and only the upper limit on the information cost changes to $\frac{\bar{t}}{t}\leq\frac{1}{64}$.

Proposition 2:

The first part of the proof to proposition 2 is the same. We have to continue the proof form the point where the profits should be compared. We compare the profit of firm A for different possible decisions:

1- No information in left hand side: $p_A=\frac{5t}{16}-\bar{t}$

2- Fully discriminate $\left[0,\frac{1}{4}\right]$: $\quad p_A=\left(\frac{241}{576}-\frac{1}{2^{k+4}}\right)t-(2^k+1)\bar{t}$

3- Fully discriminate $\left[0,\frac{1}{2}\right]$: $\quad p_A=\left(\frac{25}{36}-\frac{1}{2^{k+3}}\right)t-(2^{k+1}+1)\bar{t}$

where $k=\max\left[z,0\,\middle|\,z\in Z,\frac{1}{2}\log_2\frac{t}{t}-3<z\leq\frac{1}{2}\log_2\frac{t}{t}-2\right]$

Obviously the third one provides the largest profit for firm A (the profit on first case exceeds the third one only when $\frac{\bar{t}}{t} \geq 0.14$ that it is larger than the upper bound of information acquisition decision calculated on 3.2); then she prefers to fully discriminate all the left hand side. In this case firm B's profit would be equal to $\frac{2t}{9}$.

If the constant information cost is considered to be equal to the cost of first unit of information in the equation (1.2) ($\bar{t} = t_0$) then switching to a constant information cost increases the information cost and as a result the limit on the information would be tighter to get the same equilibrium outcome.

Outcome of the game:

Again similar to the benchmark functional from in the paper; If firm B acquires information, firm A's best response is to do so, irrespective of the information cost. If the other firm acquires no information, the best response is to acquire information if the information cost is sufficiently low. So if the information cost is sufficiently low, the game becomes a prisoners' dilemma and both firms would prefer to acquire information. This threshold is $\frac{\bar{t}}{t} = 0.024$.

Then if $\frac{\bar{t}}{t} > 0.024$ the game has two Nash equilibria; i) both firms acquire information and ii) neither of the firms acquire information. If $\frac{\bar{t}}{t} \leq 0.024$, the game becomes a prisoners' dilemma where information acquisition is the dominant strategy for both firms. It is clear form the profits that in this case we have excess information acquisition from the firm point of view.

General information cost function:

Assume equation (1.2) is replaced by:

$$t(k) = a^k t_0 \qquad \text{for} \qquad \forall k. \qquad (1.3)$$

The only restriction that we need to impose on a is $a > \frac{1}{4}$ which we will discuss this shortly. Note that if $a = \frac{1}{2}$ then this case is equivalent to (1.2); and if $a = 1$, then this functional form is equivalent to constant information cost.

Proposition 1:

The proposition 1 is true and only because of the change in information cost function to a general cost function the limit on the first rule is different. Recall equation (1.A16) the marginal profit of acquiring a unit of information in a loyal segment:

$$\Delta p_A = \frac{t}{4}\left(a_i - a_{i-1}\right)^2 - t\left(k\right). \qquad (1.A16)$$

Before we go any further, we impose the restriction on this marginal profit to make it a decreasing function on k. It is necessary, because it guarantees that when the firm discovered that the marginal profit of splitting a loyal segment gets to zero, there is no need to investigate the profitability of any finer partition. It can be shown that the sufficient condition for decreasing marginal cost is $\alpha > \frac{1}{4}$.

This equation gives us the limit to the which is now (by substituting $a_i - a_{i-1} = \left(\frac{1}{2}\right)^k$ and $t(k) = \alpha^k t_0$) equation (1.A17) changes to

$$\left(\frac{1}{2}\right)^k \qquad \text{where} \qquad k \le \log_{4\alpha} \frac{t}{4t_0}. \qquad (1.A17.g)$$

Then the preferred length for a loyal segment is

$$\left(\frac{1}{2}\right)^r \qquad \text{where} \qquad r = \left\lfloor \log_{4\alpha} \frac{\alpha\, t}{t_0} \right\rfloor. \qquad (1.20.g).$$

The marginal profit of a unit of information on the shared border segment with the length of $\left(\frac{1}{2}\right)^k$ is (note the marginal profit has the same format and only the information cost and the preferred length of the loyal segment are different)

$$\Delta p_A = \left[\frac{t}{2^k}\left(\frac{1}{2^k}\left(\frac{7}{12} - \frac{1}{2^{r+2}}\right) - \frac{1}{6}\right) - \Gamma\right]. \qquad (1.19.g)$$

where $\frac{1}{2} - a_{n-1} = \left(\frac{1}{2}\right)^k$, $r = \left\lfloor \log_{4\alpha} \frac{\alpha\, t}{t_0} \right\rfloor$, and the information cost is

$$\Gamma = t\left(k\right) + \sum_{i=k+1}^{r-1} 2^{i-(k+1)} t\left(i\right) = \frac{t_0}{2^k} + \sum_{i=k+1}^{r-1} 2^{i-(k+1)} \alpha^i t_0 = \frac{t_0}{2^k}\left(1 + \sum_{i=k+1}^{r-1} 2^{i-1} \alpha^i\right).$$

Then the chain of decision statements in table 1.1 changes as it is demonstrated in table 1.3.

Table 1.3: Firm A’s chain of decision statements with a general information cost function

a_{n-1}	a_n	k	Decision statement
0	$\frac{1}{2}$	1	$\left[\frac{t}{16}\left(1-\frac{1}{2^r}\right)-t_0\left(1+\sum_{i=1}^{r-1}2^{i-1}a^i\right)\right]\ge 0$ where $r=\left\lfloor \log_{4a}\frac{a\ t}{t_0}\right\rfloor$
$\frac{1}{4}$	$\frac{1}{2}$	2	$\left[\frac{t}{32}\left(-\frac{1}{6}-\frac{1}{2^r}\right)-\frac{t_0}{4}\left(1+\sum_{i=2}^{r-1}2^{i-2}a^i\right)\right]\ge 0$ where $r=\left\lfloor \log_{4a}\frac{a\ t}{t_0}\right\rfloor$

As it can be seen the information acquisition rules set out in proposition 1 is still true and only the upper limit on the information cost depends on the value of a .

Proposition 2:

The first part of the proof to proposition 2 is the same. We have to continue the proof form the point where the profits should be compared. We compare the profit of firm A for different possible decisions:

1- No information in left hand side: $p_A=\frac{5t}{16}-t_0$

2- Fully discriminate $\left[0,\frac{1}{4}\right]$: $p_A=\left(\frac{241}{576}-\frac{1}{2^{r+4}}\right)t-t_0\left(\frac{3}{2}+\sum_{i=2}^{r-1}2^{i-2}a^i\right)$

3- Fully discriminate $\left[0,\frac{1}{2}\right]$: $p_A=\left(\frac{25}{36}-\frac{1}{2^{r+3}}\right)t-t_0\left(\frac{3}{2}+\sum_{i=2}^{r-1}2^{i-1}a^i\right)$

where $r=\left\lfloor \log_{4a}\frac{a\ t}{t_0}\right\rfloor$

In order to have a result similar to proposition 2 the following inequality must hold:

$$\frac{t_0}{t}\le\frac{\frac{2}{7}-\frac{1}{2^{r+4}}}{\sum_{i=2}^{r-1}2^{i-2}a^i}\qquad \text{where}\quad r=\left\lfloor \log_{4a}\frac{a\ t}{t_0}\right\rfloor$$

It showed that this inequality holds as long as information cost is small enough that firm acquires some information in the first place.

Appendix 1.C

Example: Suppose that only one unit of information is available for the firms which costs τ. This means the only possible strategies for firms are:

σ_1: No information acquisition and charging a uniform price of P_{i1}, $i = A, B$

σ_2: Acquiring one unit of information and charging P_{i2}^{L} for [0,0.5] and P_{i2}^{R} for (0.5,1], $i = A, B$

We showed that there is no pure strategy equilibrium in general when there was no exogenous limit on the number of information units a firm can acquire. But since in this example we restrict available information units to one, we need to investigate this matter again. Three different cases should be considered.

Case 1: Both firms choose σ_1: In this case (no information acquisition) by solving the first order condition the equilibrium candidate is $P_{A1} = P_{B1} = t$ and the profits are $p_A = p_B = t/2$. Firm A has incentive to deviate and acquire information if

$$p_A^D = P_{A2}^L\left(\frac{1}{2} + \frac{t - P_{A2}^L}{2t}\right) + P_{A2}^R\left(\frac{t - P_{A2}^R}{2t}\right) - t \geq \frac{t}{2}. \qquad (1.C1)$$

The deviation strategy for firm A would be to choose σ_2 and charge $P_{A2}^L = t$ and $P_{A2}^R = t/2$ which gives her the deviation profit of $p_A^D = 5t/8 - t$. Therefore firm A has incentive to deviate in this case if

$$t \leq \frac{t}{8}. \qquad (1.C2)$$

Case 2: One firm (say A) chooses σ_1 and the other chooses σ_2: In this case, by solving the first order condition the equilibrium candidate is $P_{A1} = t/2$ and $P_{B2}^L = t/4$, $P_{B2}^R = 3t/4$ and the profits are $p_A = t/4$ and $p_B = 5t/16 - t$. We will investigate both firms incentive to deviate in this case.

Firm A has incentive to deviate and acquire information if

$$p_A^D = P_{A2}^L\left(\frac{1}{2} + \frac{\frac{t}{4} - P_{A2}^L}{2t}\right) + P_{A2}^R\left(\frac{\frac{3t}{4} - P_{A2}^R}{2t}\right) - t \geq \frac{t}{4}. \qquad (1.C3)$$

The deviation strategy for firm A would be choosing σ_2 and, by solving (1.C3) for the fist order condition, the deviation prices are $P_{A2}^L = 5t/8$ and $P_{A2}^R = 3t/8$ (the boundary conditions will be held for these values) that gives her the deviation profit of $p_A^D = 17t/64 - t$. Therefore firm A has incentive to deviate in this case if:

$$t \leq \frac{t}{64}. \qquad (1.C4)$$

Firm B's incentive to deviate and choosing σ_1 depends on whether the following inequality holds or not:

$$p_B^D = P_{B1}\left(\frac{1}{2} - \frac{P_{B1} - \frac{t}{2}}{2t}\right) \geq \frac{5t}{16} - t\ . \qquad (1.C5)$$

By solving (1.A23) for the first order condition, the deviation price is $P_{B1} = 3t/4$ which gives her the deviation profit of $p_B^D = 9t/32$. Therefore firm B has incentive to deviate in this case if:

$$t \geq \frac{t}{32}. \qquad (1.C6)$$

So if $t/64 \leq t \leq t/32$ this case has a pure strategy equilibrium and for every other value of t at least one of the firms has incentive to deviate. It worth mentioning that in general when there is no external limits on information acquisition (despite this example that only one unit of information is available) these two boundaries move towards each other and there will be no pure strategy equilibrium.

Case 3: Both firms choose σ_2: in this case by solving the first order conditions the equilibrium candidate is $P_{A2}^L = 2t/3$, $P_{A2}^R = t/3$ and $P_{B2}^L = t/3$, $P_{B2}^R = 2t/3$ and the profits are $p_A = p_B = 5t/18 - t$. Firm A has incentive to deviate, acquire no information and charge a uniform price if

$$p_A^D = P_{A1}\left(\frac{1}{2} + \frac{\frac{t}{3} - P_{A1}}{2t} + \frac{\frac{2t}{3} - P_{A1}}{2t}\right) \geq \frac{5t}{18} - t\ . \qquad (1.C7)$$

By solving the first order condition for (1.C7), the deviation price would be calculated as $P_{A1} = t/2$ (the boundary conditions will be satisfied for this value) that gives her the deviation profit of $p_A^D = t/4$; therefore firm A (or firm B) has incentive to deviate in this case if:

$$t \geq \frac{t}{36}. \qquad (1.C8)$$

Summarising our finding ((1.C2), (1.C3), (1.C4), and (1.C8)) from these three cases, we can claim that for this example:

i) If $t > t/8$ then there is a pure strategy equilibrium of acquiring no information. In other words in this case information is too expensive to acquire. The similar condition has been shown for the two-stage game in general.

ii) If $t/36 \leq t \leq t/8$ then there is no pure strategy equilibrium.

iii) If $t < t/36$ then there is a pure strategy equilibrium of acquiring the only unit of information available.

If $t/36 \leq t \leq t/8$ then there is no pure strategy equilibrium. The lower limit on this condition is a result of having an exogenous limit on the number of information unit available. As it has been shown earlier having this limit removed in general case this lower limit will vanish.

Mixed Strategy Equilibrium: If firm B randomises between two strategies with probability b_1 and b_2 respectively then

$$b_1 + b_2 = 1. \qquad \text{(1.C9)}$$

So firm A's profit related to strategies σ1 and σ2 respectively are:

$$p_{A1} = b_1 \cdot P_{A1}\left(\frac{1}{2} + \frac{P_{B1} - P_{A1}}{2t}\right) + b_2 \cdot P_{A1}\left(\frac{1}{2} + \frac{P_{B2}^L - P_{A1}}{2t} + \frac{P_{B2}^R - P_{A1}}{2t}\right), \text{ and}$$

$$p_{A2} = b_1\left[P_{A2}^L\left(\frac{1}{2} + \frac{P_{B1} - P_{A2}^L}{2t}\right) + P_{A2}^R\left(\frac{P_{B1} - P_{A2}^R}{2t}\right)\right] + b_2\left[P_{A2}^L\left(\frac{1}{2} + \frac{P_{B2}^L - P_{A2}^L}{2t}\right) + P_{A2}^R\left(\frac{P_{B2}^R - P_{A2}^R}{2t}\right)\right] - t.$$

So the FOCs are:

$$\frac{\partial p_{A1}}{\partial P_{A1}} = b_1\left(\frac{1}{2} + \frac{P_{B1}}{2t} - \frac{P_{A1}}{t}\right) + b_2\left(\frac{1}{2} + \frac{P_{B2}^L}{2t} + \frac{P_{B2}^R}{2t} - \frac{2P_{A1}}{t}\right) = 0, \qquad \text{(1.C10)}$$

$$\frac{\partial p_{A2}}{\partial P_{A2}^L} = b_1\left(\frac{1}{2} + \frac{P_{B1}}{2t} - \frac{P_{A2}^L}{t}\right) + b_2\left(\frac{1}{2} + \frac{P_{B2}^L}{2t} - \frac{P_{A2}^L}{t}\right) = 0, \text{ and} \qquad \text{(1.C11)}$$

$$\frac{\partial p_{A2}}{\partial P_{A2}^R} = b_1\left(\frac{P_{B1}}{2t} - \frac{P_{A2}^R}{t}\right) + b_2\left(\frac{P_{B2}^R}{2t} - \frac{P_{A2}^R}{t}\right) = 0. \qquad \text{(1.C12)}$$

If we concentrate on the symmetric mixed strategy equilibrium then we have[14]:

$$P_{A1} = P_{B1}, \qquad P_{A2}^{L} = P_{B2}^{R} \text{, and } P_{A2}^{R} = P_{B2}^{L}.$$

Considering these, after some simplifications and solving (1.C10) to (1.C12) simultaneously we will get:

$$P_{A1} = P_{B1} = \frac{2t}{4 - b_1 - b_1^2}, \qquad P_{A2}^{L} = P_{B2}^{R} = \frac{4 - 2b_1}{3 - b_1} P_{A1} \text{, and}$$

$$P_{A2}^{R} = P_{B2}^{L} = \frac{4 - 2b_1}{3 - b_1} P_{A1} - \frac{t}{3 - b_1}.$$

Also the mixed strategy equilibrium should make firm A indifferent between two strategies, this means:

$$p_{A1} = p_{A2}. \qquad (1.C13)$$

By solving these four equations, the mixed strategy of $\left(b_1, P_{A1}, P_{A2}^{L}, P_{A2}^{R}\right)$ can be calculated.[15]

Figure 1.15 shows the value of b_1 for different ratios of information cost over transportation cost. The figure shows that when the information cost is higher, it is significantly more likely for the firms to acquire the information in the mixed strategy equilibrium.

[14] If we want to investigate the existence of asymmetric mixed strategy equilibrium, different probabilities for choosing S_1 and S_2 should be considered for firm A and for this simple example we will end up with 10 equations and 10 unknowns.

[15] To solve for these four equations to find the four unknowns, we use numerical methods and these results are the unique possible outcomes.

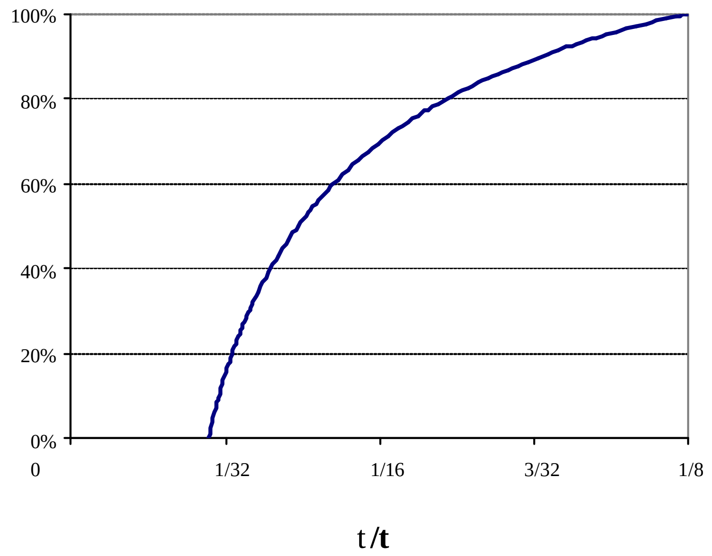

Figure 1.15: The probability of choosing the non-information acquisition strategy in the mixed strategy equilibrium

Figure 1.16 plots the trend of prices and profit as a multiplication of *t*. As it can be seen, the prices are stable for a wide range of information costs; it could be because in this simple example only one unit of information is available. By increasing the information cost all prices tend to increase, this means the lower the information cost, the more intense the competition.

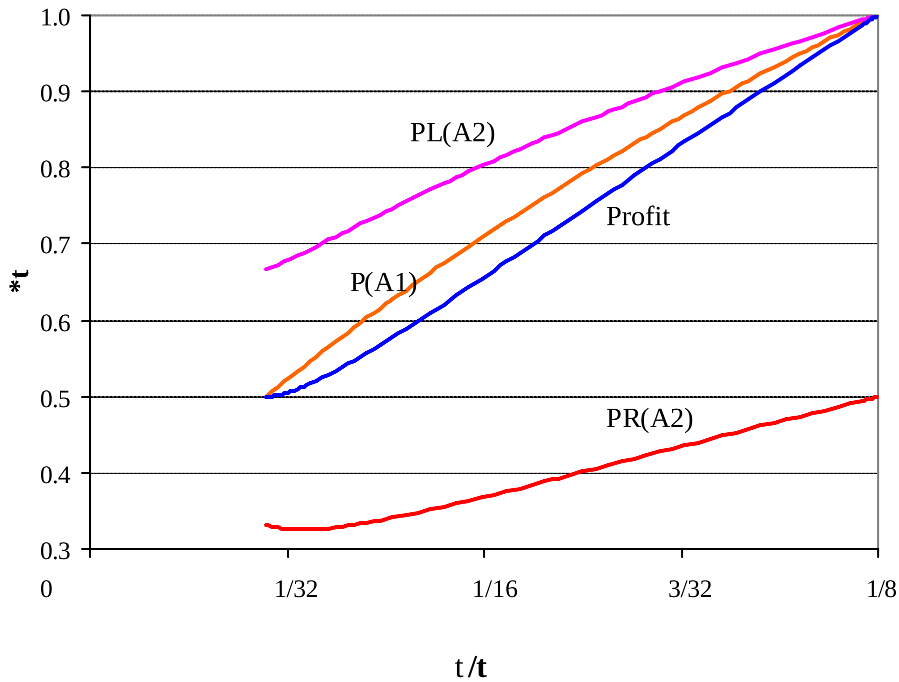

Figure 1.16: The prices and profit in the mixed strategy equilibrium

Chapter 2

National Pricing versus Regional Pricing; An Investigation into the UK Egg Market

2.1. Introduction

The theoretical literature suggests that a firm with monopoly power can increase its profits through price discrimination when it has sufficient information about customers' preferences (Schmalensee, 1981; Varian, 1985; Varian, 1989; Hamilton and Slutsky, 2004; and Armstrong, 2006). Predictions are ambiguous about whether third degree price discrimination is beneficial or detrimental to consumers; and in general there will be some consumers who benefit while others lose out.

Large supermarket chains that operate at the national level may have considerable market power in local markets. Variation in consumer preferences and in the demographics of consumers across regions mean that discriminatory pricing is likely to be profitable for the firm. The profit maximising price in each region will depend on the price and income elasticities of demand in that region, and these may vary substantially. It is not clear whether regionally varying prices will be beneficial or detrimental to consumers. However, competition authorities have frequently viewed price discrimination by firms as detrimental to consumers. For example, in an investigation into the UK supermarket industry in 2000 the Competition Commission (CC) suggested that firms should move to uniform pricing. The largest supermarket chain in the UK - Tesco - received considerable attention in the CC's investigation. Prior to the 2000 investigation Tesco practiced regional pricing policy (CC, 2000). Tesco switched to a uniform national pricing policy (CC, 2008) at least in part to concerns raised by the competition authorities.[1]

In this chapter we consider pricing of a differentiated product, eggs, and estimate the impact that a move from regional to uniform pricing would have on Tesco’s prices, profits and on consumer surplus in different regions. We consider Tesco as a multi-product monopolist over eggs. We estimate the degree of substitution between eggs and other goods, and between categories of eggs using an AIDS model of consumer expenditure, which allows for flexible substitution patterns between different egg products, and we allow these to vary across regions. We use farm gate prices as instruments for retail prices to allow us to control for the possible endogeneity of prices. We hold consumers' choice of supermarket fixed, so assume that it is not influenced by the prices of eggs; this gives the supermarket effective monopoly power over the good.

Our works is related to several lines of research in the literature. Gorman (1980) sets out a framework to study the demand for differentiated products, using eggs as an example. The discriminatory pricing behaviour of a monopolist with differentiated products has also been studied in a number of papers including Pigou (1920), Spence (1976), Schmalensee (1981), Varian (1989), Schulz and Stahl (1996), and Hamilton and Slutsky (2004). Mussa and Rosen (1978) show how the consumer’s choice will be affected by firm’s discriminatory pricing policy.

Another related line of research is the study of effects of regional and national pricing on firm’s profit and consumer welfare and behaviour. This has attracted attention in both the economics and marketing literatures (i.e. Shepard, 1991; Hoch et al, 1995; Slade, 1998; Leslie, 2004; Montgomery, 2004).

This chapter is organised as follows. In the next section we describe the theoretical framework and the econometric model. Section 2.3 contains a description of data and

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[1] Our focus in this paper is on Tesco supermarkets. Tesco also operates a chain of smaller convenience stores - Tesco Metro and Tesco Express. These also operate a national pricing policy, but at a different price level to the supermarkets.

some descriptive analysis. Section 2.4 presents our results and section 2.5 summarises and concludes.

2.2. Theoretical Model

2.2.1. Firm pricing

We consider a supermarket, Tesco, that operates in $r = 1,...,R$ regional markets and offers $j=1,...,J$ different products (types of eggs) in each market.[2] The firm's profits at period $t = 1,...,T$ are given by

$$\Pi_t = \sum_r \sum_j \left(p_{jrt} - mc_{jt}\right) q_{jrt}(P_{rt}) - C_{rt} , \qquad (2.1)$$

where p_{jrt} is the price of product j in region r at period t,

mc_{jt} is the marginal cost of product j at period t,

q_{jrt} is the quantity of product j sold in region r at period t,

P_{rt} $(J\ ´\ 1)$ is the vector of prices in region r (jth element is the price of product j) at period t, and

C_{rt} is the firm's fixed cost in region r at period t.

We assume that the marginal cost of each type of egg is the same across regions. Furthermore, regions are considered as separate markets, where the quantity demanded in each region is a function of only the prices in that region.

National pricing

Tesco currently operates a national pricing policy, which means that $p_{jrt} = p_{jt}$; $\forall r,j$. We consider the firm to act as a monopolist when pricing eggs. The firm sets j prices to solve the first-order condition for each of the J products, given by:

$$\frac{\partial \Pi}{\partial p_j} = \sum_r q_{jr} + \sum_r \sum_k \left(p_k - mc_k\right) \frac{\partial q_{kr}}{\partial p_j} = 0 \quad \text{for} \quad j=1,\dots,J. \qquad (2.2)$$

The economic interpretation of these equations is that an increase in the price of product j affects the firm's profit by (i) decreasing quantity demanded of product j and

---

[2] The number of products offered could differ across regions, but without loss of generality we assume that all products are offered in all regions.

thus decreasing profits, (ii) increasing the profit margin on each unit of product *j* sold and thus increasing profits, and (iii) increasing the demand for other products and thus increasing profits.

Defining $Q_j = \sum_r q_{jr}$ equation (2.2) can be rewritten as

$$Q_j + \sum_k (p_k - mc_k) \sum_r \frac{\partial q_{kr}}{\partial p_j} = 0 \qquad \text{for} \quad j=1,\ldots,J, \qquad (2.3)$$

multiplying both sides by $\frac{p_j}{\sum_k p_k Q_k}$ and defining the expenditure share on product *j* over all regions as $s_j = \frac{p_j Q_j}{\sum_k p_k Q_k}$, we can write

$$s_j + \sum_k \frac{(p_k - mc_k)}{p_k} s_k \sum_r w_{kr} l_{kjr} = 0 \qquad \text{for } j = 1, \ldots, J, \qquad (2.4)$$

where $w_{jr} = \frac{q_{jr}}{Q_j}$ is the quantity share of region *r* between all regions for product *j*, and

$l_{kjr} = \frac{p_j \partial q_{kr}}{q_{kr} \partial p_j}$ is the *j*th price elasticity of demand in region *r* for product *k* .

Given estimates of l_{kjr}, and under the assumption that marginal cost does not vary across regions we can solve these to recover marginal costs for each of the *j* products.

Regional pricing

If the firm can price discriminate across regions, then the firm sets *j*×*r* prices to solve the first-order condition for each of the *j* products in each of the *r* regions, given by:

$$\frac{\partial \Pi}{\partial p_{jr}} = q_{jr} + \sum_k (p_{kr} - mc_k) \frac{\partial q_{kr}}{\partial p_{jr}} = 0 \qquad \text{for} \quad j=1,\ldots,J \text{ and } r=1,\ldots,R. \qquad (2.5)$$

As above, these can be rewritten as:

$$s_{jr} + \sum_k \frac{(p_{kr} - mc_k)}{p_{kr}} s_{kr}\, l_{kjr} = 0 \qquad \text{for} \qquad j = 1,\ldots,J \text{ and } r = 1,\ldots,R \qquad (2.6)$$

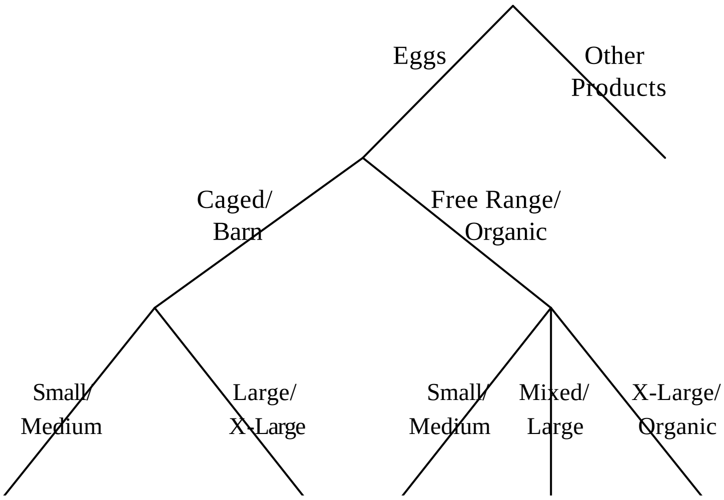
where ($s_{jr} = \dfrac{p_{jr}q_{jr}}{\sum_k p_{kr}q_{kr}}$). We can solve this set of simultaneous equations for the profit maximising prices if the firm operated a regional pricing policy (note that this is possible because we have assumed that marginal cost is constant across regions). In order to do this we need estimates of l_{kjr}, and in particular of $\dfrac{\partial q_{kr}}{\partial p_j}$. We now turn to consider how we obtain estimates of these parameters of consumer demand.

2.2.2. Consumer behaviour

We base our model of consumer demand on the Almost Ideal Demand System (AIDS) (see Gorman, 1980; Deaton and Muellbaeur, 1980; Hausman et al, 1994; Housman and Leonard, 2007). We estimate a demand system using a three-level budgeting model, where the top level corresponds to overall demand for eggs, the middle level represents the choice between the two main categories of eggs, and the bottom level represent the choice of specific type and size of egg (see figure 2.1 and table 2.2). The different categories of eggs are partitioned based on their characteristics.

This structure implies that the utility that consumers get from the two categories of eggs (caged/barn and free-range/organic) are separable, i.e. consumer's demand for eggs within one category is not affected by the level of consumption of eggs within the other category. The substitution between goods in one category depends only on the prices of goods of that category.

The multi-stage budgeting model implies that at the top level, the consumer decides how much to spend on eggs as a function of income and a price index for eggs. At the middle level, the consumer decides how much to allocate to each of two categories as a function of the price indexes for each category. Having decided on the allocation of expenditure on each category, at the bottom level the consumer decides how to allocate this to different eggs in the category as a function the individual prices of all eggs within that category.



Full details of products included in each subcategory is given in table2.2.

Figure 2.1: The three-level budgeting model

We consider the utility of a representative consumer from purchasing eggs as a separable utility function for the two different categories of eggs, indexed by G = caged/barn, free-range[3]

$$U_{rt} = \sum_{G} v_{Grt}(p_{Grt}, E_{Grt}) \qquad (2.7)$$

where U_{rt} is the total utility from eggs for region r at period t,

v_{Grt} is the sub-utility from category G eggs for region r at period t,

E_{Grt} is the overall expenditure on category G eggs for region r at period t, and

p_{Grt} is the price vector for category G eggs for region r at period t.

We start at the bottom level and follow Deaton and Muellbauer (1980) by assuming that consumers' indirect utility within each category (G) takes the form:

$$v_{Grt}(p_{Grt}, E_{Grt}) = \frac{\log E_{Grt} - \log(P_{Grt})}{\log(b_G(p_{Grt}))}, \qquad (2.8)$$

---

[3] Gorman (1959) shows that the functional form consistent with the multi-stage budgeting model is one of the following (assume only two categories):

$$U = F[v_1, f(v_2)] \qquad \text{or} \qquad U = v_1 + f(v_2)$$

Where F and f are general continuous functions and f is homogenous of degree one. Gorman rules out the cases were there are only two categories; Blackorby & Russell (1997) extend Gorman's results on multi-stage budgeting to the two group cases.

where $\log\left(P_{Grt}\right) = a_{0r} + \sum_{j\in G} a_{jr} \log p_{jrt} + \frac{1}{2}\sum_{k\in G}\sum_{j\in G} d^{*}_{jkr} \log p_{jrt} \log p_{krt}$, and

$$\log\left(b_G\left(p_{Grt}\right)\right) = b_{0r} \prod_{j\in G} p_{jrt}^{\,b_{jr}} \ .$$

In order to find the demand equation, we use Roy's identity, which tells us that

$$q_{jrt}(p_{rt}, E_{Grt}) = \frac{\partial E_{Grt}}{\partial p_{jrt}} = -\frac{\partial v_{Grt} / \partial p_{jrt}}{\partial v_{Grt} / \partial E_{Grt}} \ ,$$

and find the uncompensated demand equation for each product *j*. For each product's the expenditure share within the category in each time period and in every region is

$$s_{jrt} = a_{jr} + b_{jr} \log\left(\frac{E_{Grt}}{P_{Grt}}\right) + \sum_{k\in G} d_{jkr} \log(p_{krt}) + e_{jrt}; \qquad " j\ \hat{I}\ G\ \&\ " r = 1,\ldots,R\ , \tag{2.9}$$

where s_{jrt} is the expenditure share of subcategory *j* in category *G* eggs for region *r* at period *t*,

E_{Grt} is the overall expenditure on category *G* eggs for region *r* at period *t*,

p_{jrt} is the average price of subcategory *j* for region *r* at period *t*,

P_{Grt} is the price index of category *G* for region *r* at period *t*,

$d_{jkr} = \dfrac{d^{*}_{jkr} + d^{*}_{kjr}}{2}$,

e_{jrt} is an idiosyncratic error term, and

a_{jr}, b_{jr}, d_{jkr} are parameters to be estimated.

As discussed before, Tesco uses a national pricing policy; however, the regional variations in prices do not arise from differences in the price schedule but instead from differences in consumer choices. We will discuss this issue in more detail later in section 2.3.2.

This equation relates the regional expenditure share for product *j* in a given category to the total expenditure in that category and prices of all goods in the category. The d_{jkr}'s pick up consumers' willingness to substitute between products. a_{jr} differs across products - all else equal, some products will have higher shares than other products as a result of differing consumer preferences for products.

The b_{jr} coefficients allows for non-homotheticity. If b_{jr} = 0 then the preferences are homothetic (as category expenditure increases the share spent on each good remains constant), in which case we can aggregate to the second stage without worrying about the distribution of income. If b_{jr} is positive then the share increases with increased expenditure, and if negative then it decreases. In this case in order to exactly aggregate we would need to account for the distribution of income across individuals.

The indirect utility defined in (2.8) implies symmetry in consumer substitution patterns ($d_{jkr} = d_{kjr}$) which we can test and impose. In addition, the dependent variable is expenditure shares, so for each period they should add up to one ($\sum_j s_{jrt} = 1$ in (2.9)). Consequently, the coefficients are linearly related:

$\sum_j a_{jr} = 1$ the constant coefficients in (2.9);

$\sum_j b_{jr} = 0$ the category expenditure coefficients in (2.9);

$\sum_k d_{jkr} = 0$ the price coefficients in (2.9).

As it is clear from (2.8) to (2.9) that the exact price index is:

$$\log P_{Grt} = a_{0r} + \sum_k a_{kr} \log p_{krt} + \frac{1}{2} \sum_k \sum_j d_{kjr} \log p_{krt} \log p_{jrt} . \quad (2.10)$$

Using the exact price index involves non-linear estimation, because the coefficients appear in the price index. Hausman et al (1994) and others suggest using a Laspeyres price index instead, in order to avoid the non-linear estimation:

$$P_{Grt} = \sum_{j \in G} \hat{q}_{jr} p_{jrt} \text{, where } \hat{q}_j = \frac{q_{jrt_0}}{\sum_{k \in G} q_{krt_0} p_{krt_0}} \qquad (2.11)$$

and t_0 is the index for the base period.

We estimate demand at the bottom level using both the exact price index defined in (2.10) and the Laspeyres approximation defined in (2.11) and show that the results do not differ significantly. To implement the exact price index, we use the iterated linear least square (ILLE) suggested by Blundell and Robin (1999). In this algorithm, the exact price index in each step of iteration is calculated using the coefficients calculated in the previous round. The procedure continues until the coefficients converge. Blundell and Robin (1999) show that the ILLE estimator is consistent and efficient.

In the middle level, demand for each category is modeled in log-log form:

$$\log(Q_{Grt}) = a_{Gr} + b_{Gr}\log(Y_{Ert}) + \sum_{H} j_{GHr}\log(P_{Hrt}) + x_{Grt}, \qquad '' \; r = 1,\ldots,R, \quad (2.12)$$

where Q_{Grt} is the quantity of category *G* eggs for region *r* at period *t*,

Y_{Ert} is the total expenditure on eggs for region *r* at period *t* ,

P_{Grt} is the price index of category *G* for region *r* at period *t*, the Laspeyers price index is used for this level.

x_{Grt} is an idiosyncratic error term, and

a_{Gr}, b_{Gr}, j_{GHr} are parameters to be estimated.

We impose symmetry in the substitution patterns at this level as well ($j_{GHr} = j_{HGr}$).

The separability assumption, used in multi-stage budgeting described in equations (2.9) and (2.11), implies that the expenditure shares within a category depend only on the category's expenditure and the prices in that category. Category expenditure depends on the total expenditure on eggs and the prices for all categories through a price index. Our model allows a very flexible substitution pattern for different egg products in the same category. However, the substitution between categories of eggs in different categories is restricted. A price change for one subcategory of eggs affects the expenditure share on eggs in another category only through the second level demand function. Furthermore, this price change affects the demand for all the eggs in the other category the same way. We will discuss the difference between the cross-price elasticities for products within the same category and products in two different categories in more detail in the next section.

At the top level we use a log-log demand function:

$$\log(Q_{rt}) = a_r + g_r\log(Y_{rt}) + u_r\log(p_{rt}) + z_{rt}, \qquad '' \; r = 1,\ldots,R, \quad (2.13)$$

where Q_{rt} is the total number of eggs sold at region *r* at period *t*,

Y_{rt} is the total expenditure on supermarket goods for region r at period t,

p_{rt} is the price index of eggs for region r at period t with the general form of $p_{rt} = \sum_G \hat{r}_{Gr} P_{Grt}$; we also use a Laspeyres price index.

z_{rt} is an idiosyncratic error term, and

a_r, g_r, u_r are parameters to be estimated.

In this paper we use the total expenditure of households on supermarket goods as proxy for income.

In equation (2.9) the prices of different subcategories of eggs appear on the right hand side. This raises possible concerns about endogeneity - prices may be correlated with shocks to demand ($E[\log(p_{rt}), e_{jrt}] \neq 0$, where p_{rt} is the vector of prices in region r). The correlation between prices and shocks might arise because shocks to expenditure share for j, which are captured in e_{jrt}, may also affect the way that other goods are priced. For example, there might be an advertising campaign to promote j which may also affect the expenditure share of k. If this is the case then OLS estimates of d_{jkr} will not be consistent.

The solution is to find instrumental variables (z_t) that are correlated with p_{rt} ($E[\log(p_{rt}), z_t] \neq 0$) but are not correlated with e_{jrt}, so that $E[z_t, e_{jrt}] = 0$. In other words, we must be able to exclude z_t from equation (2.9), so it has to be the case that it has no direct effect on s_{jrt} and its only effect on s_{jrt} is through p_{rt}.

We use data on the cost of different categories of eggs at the farm gate and time dummies as instruments. We implement this by running a first stage regression relating price to cost and time dummies, of the form:

$$\log(p_{jrt}) = j_{jr} + m_{jr} \log\left(\frac{E_{Grt}}{P_{Grt}}\right) + h_{0jr}\Gamma_t + \sum_i h_{ijr} \log(c_{it}) + V_{jrt}, \qquad (2.14)$$

where p_{jrt} is the average price of subcategory j for region r at period t,

c_{it} is the farm-gate cost of product i at period t,

Γ_t is the vector of seasonal and annual time dummies,

E_{Grt} is the overall expenditure on category *G* eggs for region *r* at period *t*,

P_{Grt} is the price index of category *G* for region *r* at period *t*,

V_{rt} is an idiosyncratic error term, and

$j_{jr}, m_{jr}, h_{0jr}, h_{ijr}$ are parameters to be estimated.

The projected prices are then used in place of actual prices to estimate the lower level demand system.

As mentioned before, for our instruments (the farm-gate prices of eggs and seasonal and annual time dummies) to be valid, we must believe that the expenditure share for eggs – and consequently the error terms on (2.9) – are not correlated to these. It seems reasonable to assume that the expenditure share of different categories of egg does not vary by farm-gate prices but these costs almost certainly affect price. Our data shows that the farm-gate prices on average count for about 35% of final prices.

The instruments that may cause concern are the seasonal and annual dummies. It seems obvious that because of the nature of the poultry industry and storage conditions, egg prices are seasonally affected. However our data does not show a similar correlation between the dependent variable in (2.9) and seasonal and annual dummies. Figure 2.2 shows the expenditure shares for our bottom level products in the London region. A seasonal pattern in these variables is not observed. Furthermore, we also investigated the effect of exclusion of time dummies from (2.12) and including them in (2.9). The coefficients for time dummies were not significant. And our results are robust even by omitting them from our instruments.

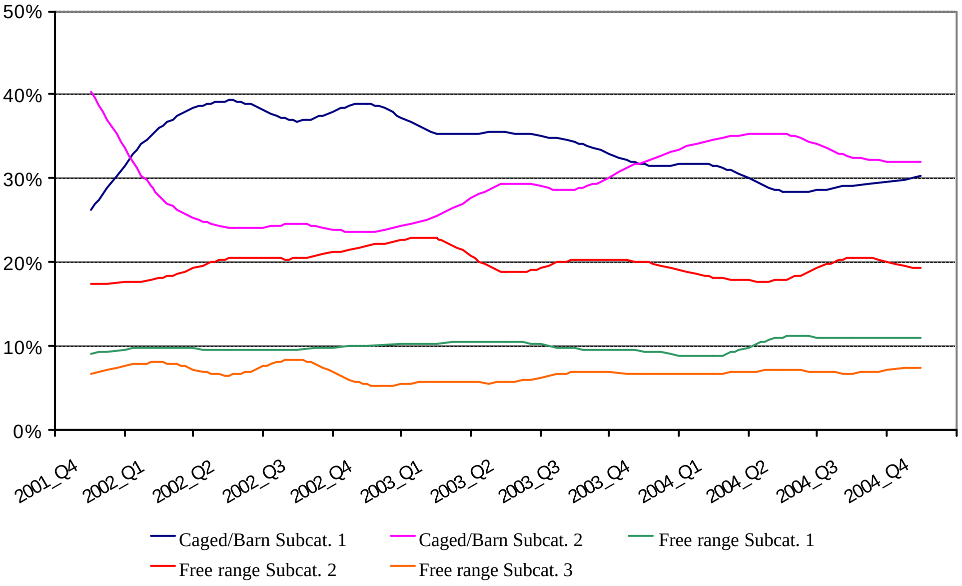


Figure 2.2. Trend of egg categories' expenditure shares over time in the London region

2.2.3. Price Elasticities

We start by considering the conditional (on category expenditure) price elasticities (these are uncompensated or Marshallian price elasticities). We then calculate the unconditional price elasticities, incorporating the parameters from the multi-level demand system described in equations (2.9), (2.12), and (2.13). For simplicity we ignored the index r for all of the parameters and variables in the equations in this section.

Conditional Price Elasticities

We find the conditional (on category expenditure) own-price elasticity from equation (2.9) and it is given by:

$$l_{jj} = \frac{\partial \ln q_j}{\partial \ln p_j} = \frac{d_{jj}}{s_j} - 1, \qquad (2.15)$$

where

$$d_{jj} = \frac{\partial s_j}{\partial \log(p_j)} = \frac{\partial \left({p_j q_j}/{\hat{E}} \right)}{{\partial p_j}/{p_j}} = \frac{p_j}{\hat{E}} \left(\frac{p_j \partial q_j}{\partial p_j} + q_j \right) = \frac{p_j q_j}{\hat{E}} \left(\frac{p_j \partial q_j}{q_j \partial p_j} + 1 \right) = s_j (l_{jj} + 1).$$

Recall that s_j represents the expenditure share of subcategory *j* eggs in the category and $\hat{E}$ is the overall expenditure of the category.

The conditional (on category expenditure) cross-price elasticities within a category is given by (*j* & *kÎ G*) (taking derivative of equation (2.9)):

$$l_{jk} = \frac{\partial \ln q_j}{\partial \ln p_k} = \frac{d_{jk}}{s_j}, \qquad (2.16)$$

$$\text{where } d_{jk} = \frac{\partial s_j}{\partial \log(p_k)} = \frac{\partial \left({p_j q_j}/{\hat{E}} \right)}{{\partial p_k}/{p_k}} = \frac{p_k}{\hat{E}} . \frac{p_j \partial q_j}{\partial p_k} = \frac{p_j q_j}{\hat{E}} . \frac{p_k \partial q_j}{q_j \partial p_k} = s_j \, l_{jk} .$$

Unconditional Price Elasticities

The unconditional own-price elasticity is given (for *j* is a sub-category in the category *G* or *j Î G*) by:

$$l_{jj} = \frac{d_{jj}}{s_j} + \left(s_j + b_j\right) \frac{\hat{q}_j}{d_j} \left(1 + b_G \frac{\hat{w}_G (1+u)}{d_G} + j_{GG} \right) - 1, \qquad (2.17)$$

where $d_j = \frac{q_j}{Q_G}$ is the quantity share of subcategory *j* in category *G*, and

$d_G = \frac{Q_G}{Q}$ is the quantity share of category *G* in total number of eggs.

The unconditional cross-price elasticity within a category is given by (*j* & *kÎ G*):

$$l_{jk} = \frac{d_{jk}}{s_j} + s_k \left(1 + \frac{b_j}{s_j} \right) \frac{\hat{q}_k}{d_k} \left(1 + b_G \frac{\hat{w}_G (1+u)}{d_G} + j_{GG} \right). \qquad (2.18)$$

The unconditional cross-price elasticities between two categories is given by: (*j Î G* & *kÎ H*):

$$l_{jk} = \left(1 + \frac{b_j}{s_j} \right) \hat{q}_j \frac{p_k}{P_H} \left(b_G \frac{P_H}{p} \hat{w}_H (1+u) + j_{GH} \right) \qquad (2.19)$$

The detailed calculations are presented in appendix 2.A.

Equations (2.18) and (2.19) demonstrate the difference between the cross-price elasticities for products within a category and between two categories. Equation (2.18) has two components: the first term has the same form as the conditional cross-price elasticities (equation (2.16)) which represent the flexible pattern of substitution within a category, and the second term, which is made up from the middle and top level coefficients (the income elasticities and the price elasticities from the middle and top level). However, the cross price-elasticity for products in two different categories (equation (2.19)) has only one term, which is similar to the second term of (2.18). More importantly, holding the j index constant, the cross-price elasticity for all k's products have almost the same representation.

2.3. Data

We use data from the TNS Worldpanel[4] on eggs purchased and brought into the home by over 20,000 households in the UK over the period December 2001 to December 2004. The data include the prices paid, quantities purchased, and product characteristics. Participants record purchases using a hand-held scanner in the house. Participants are compensated by vouchers which they can spend on durable items. We consider the variation in demand behaviour across ten regions of the UK - London, the Midlands, the North East, Yorkshire, Lancashire, the South, Scotland, Anglia, Wales and the West, and the South West. Eggs are classified by three characteristics: size, type, and brand.

2.3.1. Characteristics

Size

Four sizes of eggs are sold in the UK: small, medium, large, and extra large. Eggs can be purchased in single sized or mixed size packages. Small eggs weigh less than 53 grams, medium between 53 and 63 grams, large between 63 and 73 grams, and extra large eggs more than 73 grams (BEIS, 2009). There are also mixed size packages which might include eggs from several categories.

Mixed size packages present a difficulty. While consumers are able to compare the size of eggs easily with other eggs available in the store, we do not observe the size of

[4] Described at <http://www.tnsglobal.com/market-research/fmcg-research/consumer-panel>.

eggs in mixed packages. In the data packages of mixed size eggs appear to be very heterogeneous. For example, looking at the price of caged eggs in Tesco, the mixed budget eggs have a price that is similar to the small/medium range, however standard and private brand mixed eggs seems to be more like large/extra large eggs. Figure 2.3 shows prices for these different categories. We use this information to inform the way we categorise eggs.

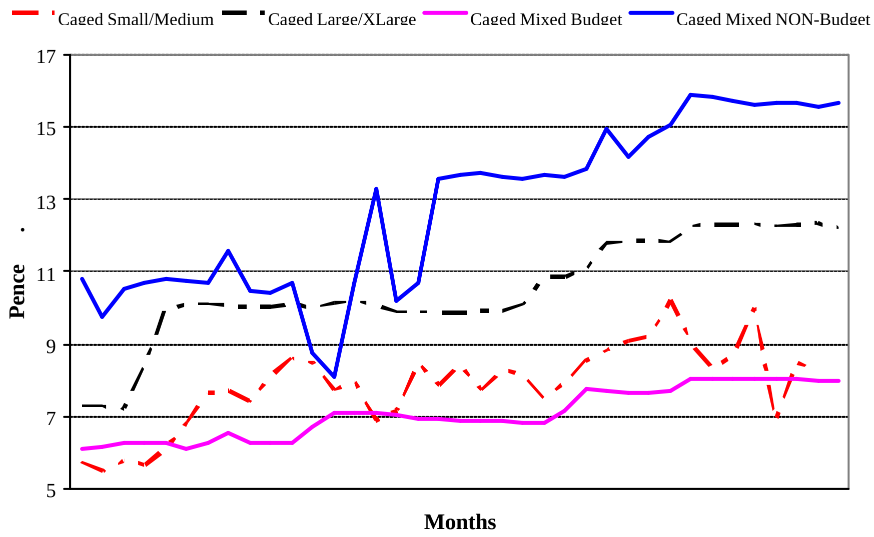


Figure 2.3. Average price of caged eggs at Tesco

Type

One of the main characteristics that defines eggs is the welfare of the chicken and the way they are fed. *Caged* or battery eggs are produced by hens kept in cages. Standards are in place regarding the area of cage per bird, number of tiers, food and water supply equipments, and dropping passes. *Barn* eggs are produced by birds kept in a hen house which has a series of perches and feeders at different levels. *Free range* eggs are laid by hens that have continuous daytime access to runs which are mainly covered with vegetation and with a maximum stocking density of 2,500 birds per hectare. Hens producing *organic* eggs are always *free range*. In addition, hens must be fed an organically produced diet and ranged on organic land.

Budget or Value Brand

In general brand names are not very important in the egg market. However, Tesco offers a *value* private brand of egg alongside its own standard brand and other brands. Branded eggs sold at Tesco account for 18.7% of the total volume and 24% of total value.

Cost

The data on cost of each type of egg comes from the British Egg Association. These data shows the average farm-gate price of each type and size of egg for each quarter. We use these costs as instruments for prices when we estimate the demand system. The marginal cost that we calculate includes not only these costs but also distribution and retail costs.

2.3.2. Descriptive Analysis

We observe over £1m worth of eggs purchased in Tesco in the three years of data that we use. Table 2.1 shows the volume of eggs purchased by type and size. Of all eggs sold in Tesco, by far the largest share are *caged* eggs, followed by free-range, barn and then organic. By size the largest category is the mixed size packages, followed by large, medium and extra large. Small represent a negligible share of eggs purchased.

Table 2.1. Distribution of eggs purchased in Tesco, Dec 2001 – Dec 2004

	Caged	Barn	Free-range	Organic	**Total**	%
Small	65	33	21	0	**119**	0.0%
Mixed	535385	8124	30582	690	**574781**	52.3%
Medium	21605	54393	95609	12404	**184011**	16.7%
Large	25592	63854	100923	13600	**203969**	18.5%
Extra large	129052	7206	564	0	**136822**	12.4%
Total	**711699**	**133610**	**227699**	**26694**	**1099702**	
%	64.7%	12.1%	20.7%	2.4%		

Notes: Data are from TNS Worldpanel and include all households observed. The figures are the number of eggs purchased at Tesco from Dec 2001 to Dec 2004 in TNS data.

Based on the characteristics described above, and an inspection of the average price, we categorise eggs into five categories, as defined in Table 2.2.

Table 2.2. Categories of eggs

Caged and Barn	
1) Small / Medium / Mixed (Value)	Caged-Small, Caged-Medium, Cage-Mixed-Value, Barn-Small , Barn-Medium
2) Large / XLarge / Mixed (Other)	Caged-Mixed-Standard, Caged-Branded, Caged-Large, Caged-XLarge, Barn-Mixed, Barn-Large, Barn-XLarge
Free Range and Organic	
3) Small/Medium (Value)	Free Range-Small, Free Range-Medium-Value, Free Range-Medium-Standard
4) Mixed/Medium (Branded)/ Large	Free Range-Small-Standard, Free Range-Mixed-Standard, Free Range-Medium-Branded, Free Range-Large
5) Branded/XLarge/Organic	Free Range-Mixed-Branded, Free Range-XLarge, Organic all sizes

Table 2.3 shows the regional distribution of purchases of eggs at Tesco. London, Midlands, and the South regions, which are the most populated areas, have the highest level of expenditure on eggs, while the North East has the smallest share with just 1.7% share. Looking at the shares of different categories of eggs purchased in different region we see that there are significant differences in consumer taste for different categories of eggs across the regions. For example, while category 1 eggs (Caged and Barn: Small / Medium / Mixed (Value)) account for 24.8% of expenditure on eggs in the North East, it accounts for more than twice as much in the South West, where the share is 51.4%. For category 5 eggs (Free Range Branded/XLarge and Organic) the expenditure shares vary from 6.1% for the South West to 12.7% for London.

Share

We aggregate the data on egg purchases across households to construct the regional share of each subcategory of egg. The exact expression is

$$s_{jrt} = \frac{\sum_h e_{jrht}}{\sum_{j \in G} \sum_h e_{jrht}}; \qquad \forall j \in G \qquad (2.20)$$

where s_{jrt} is the expenditure share of subcategory j in category G eggs in region r and period t, and

e_{jrht} is expenditure of household *h* on subcategory *j* eggs in region *r* and period *t*.

Table 2.3. The summary of Tesco regional egg sales

Region	Volume (#)	Expenditure (£)	Expenditure share (%)				
			Caged & Barn		Free Range		
			Small / Medium / Mixed (Value)	Large / XLarge / Mixed (Other)	Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic
1 : London	243,767	25,790	33.9%	29.5%	9.1%	14.8%	12.7%
2 : Midlands	168,328	16,829	41.2%	26.1%	8.8%	13.5%	10.3%
3 : North East	17,434	1,932	24.8%	36.8%	11.1%	15.7%	11.5%
4 : Yorkshire	69,103	6,766	42.4%	24.0%	7.7%	18.9%	7.0%
5 : Lancashire	96,270	9,789	39.0%	25.5%	10.1%	14.6%	10.8%
6 : South	156,300	15,614	39.8%	25.5%	9.4%	15.9%	9.4%
7 : Scotland	89,459	8,735	39.5%	25.9%	9.8%	18.2%	6.6%
8 : Anglia	108,725	10,911	40.1%	27.9%	9.1%	12.0%	10.9%
9 : Wales & West	104,721	10,713	38.0%	26.1%	10.5%	16.6%	8.8%
10 : South West	45,595	4,116	51.4%	20.3%	11.0%	11.2%	6.1%
Total	**1,099,702**	**111,195**	**38.7%**	**26.8%**	**9.4%**	**15.0%**	**10.1%**

Price

The average regional price is recovered by dividing the total expenditure on eggs over the number of eggs in each subcategory

$$p_{jrt} = \frac{\sum_h e_{jrht}}{\sum_h q_{jrht}}; \qquad \forall j \in G \qquad (2.21)$$

where p_{jrt} is the average price of subcategory *j* in category *G* eggs in region *r* and period *t*,

e_{jrht} is expenditure of household *h* on subcategory *j* eggs in region *r* and period *t*, and

q_{jrht} is the quantity of eggs purchased by household *h* on subcategory *j* eggs in region *r* and period *t*.

In 3 cases, for one of the subcategories of the free range eggs we do not observe any purchases and we exclude these observations from the sample. Two of these cases are for the North East region and the third one is for the South West.[5]

Since Tesco used a national pricing policy for the period of the study we expect that the price of eggs should be the same across regions. However some small regional variations are observed (see table 2.B1). Variation in prices across regions arises for two main reasons. First, stores in different regions might put eggs on sale at different times or with different frequency. Promotions are rarely used for the eggs, so this first source of variation is not important. Second, each subcategory *j* includes several different types and sizes of eggs, which might also be available in different pack sizes (see table 2.2). We aggregate over these products to measure the average price for each subcategory of eggs. However, the shares of different products in each subcategory vary over the time. One reason for this could be changes in the menu of eggs on offer in Tesco nationwide or in some region. For example, Tesco might decide to replace its own brand of large caged eggs in packs of 15 with a similar egg in packs of 9. Due to non-linear pricing for different pack sizes of eggs this would lead to price variation. The lead to a problem of selection bias: if the price of a certain type of egg changes in a given period, then consumers might buy this product when it is relatively cheaper. In this case, the average price observed in our data is different from the average price of products on shelves. We do not tackle this problem here.

Expenditure

As discussed above, total expenditure of households on supermarket goods is used as proxy for income. In order to calculate this we aggregate all households' expenditure in each region for each period. Table 2.B1 contains summary statistics of all variables used in the regressions.

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[5] The issue of missing observations can be tackled using two different approaches. When no purchase is reported for a subcategory in a region in one period it can be because of one of these two reasons:

i) The subcategory was not available in that region in the given period. Based on this assumption the observation should be excluded.

ii) The product was available but none of the consumer actually preferred that over other products. If this approach was accepted then the observation should be kept in the sample.

In this case, since the aggregation is performed over purchases of a number of households over a month, the first approach seems more reasonable.

2.4. Results

In this section we present the results of the demand system estimation and discuss the application of these to analyse the impact on firm profits and consumer welfare of national and regional pricing policies.

2.4.1. Demand System Estimates

We start with the bottom level results. Table 2.4 presents the estimated coefficients for equations (2.9) (the bottom level of the demand system) for caged and barn eggs in the London region. The estimation is performed twice using two different price indexes. The first estimation is performed using a Laspeyres form approximate price index (as shown in equation (2.10)). For the second estimation an exact price index, as shown in equation (2.11), is used. As discussed above, the second estimation has been performed using the ILLE suggested by Blundell and Robin (1999). The results for the other nine regions are presented in appendix 2.B in tables 2.B2 and 2.B3. The statistical tests show that the results from the two estimations have no significant difference.

Table 2.4. London: bottom level results for Caged and Barn using two different price indexes

Price index used:	approximate price index		exact price index
Dep var: share of expenditure on product	Small / Medium / Mixed (Value)	Large / XLarge / Mixed (Other)	Small / Medium / Mixed (Value)
Constant	-0.991 (0.305)	– –	-0.973 (0.327)
Log (E / P)	0.080 (0.034)	– –	0.080 (0.036)
Log (p_1)	-0.697 (0.178)	– –	-0.726 (0.191)
Log (p_2)	0.358 (0.171)	– –	0.473 (0.189)
Conditional Price Elasticity	-2.316 (0.336)	-1.762 (0.364)	

R^2 = 0.647; adj-R^2 = 0.602; Joint significance; F stat (p-value) = 1.67 (0.192)
Homotheticity test; F stat (p-value) = 5.75 (0.022).
Notes: Numbers in ( ) are standard errors. Each regression includes 37 observations. (E / P) is the total of expenditure caged and barn eggs in each month over the caged and barn price index, p_1 is the average price of Small / Medium / Mixed (Value) for caged and barn eggs in each month, and p_2 is the average price of Large / XLarge / Mixed (Other) for caged and barn eggs in each month.

The standard errors reported in the tables have been corrected for the use of a constructed estimator (the two-stage IV estimation) following Davidson and Mackinnon (2004). The sign and significance of the coefficients are informative, but the coefficients themselves are not easily interpreted. In the last row we report the conditional (on category expenditure) own price elasticities (equation 2.15), which are calculated based on the estimated coefficients. Note that the expenditure elasticity in these tables is the elasticity of expenditure shares (not quantities) and can be negative or positive. The own and cross price elasticities are expected to be negative and positive respectively.

The tests for homotheticity of expenditure shares have been performed and the statistics are reported in table 2.B2 for all regions. The test rejects the null hypothesis of preference homotheticity for four out of ten regions. However, even for these four regions the coefficients are ranged from 7.1% to 9.5%, which are relatively small.

The estimation results of the bottom level for free range eggs (equation (2.9)) in the London region are reported in Table 2.5. Similarly, the estimation is performed twice using the two different price indexes. The results for all ten regions are included in appendix 2.B. The statistical tests show no significant difference between the two models.

Table 2.5. London: bottom level results for Free range

Price index used:	Approximate price index			exact price index	
Dep var: share of expenditure on product	Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic	Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large
Constant	0.145 (0.163)	-0.292 (0.192)	– –	0.101 (0.255)	-0.222 (0.302)
Log (E / P)	-0.092 (0.029)	0.112 (0.028)	– –	-0.072 (0.045)	0.113 (0.043)
Log (p_3)	-1.048 (0.159)	0.093 (0.130)	– –	-1.035 (0.279)	0.090 (0.102)
log (p_4)	0.093 (0.130)	-0.348 (0.320)	– –	0.090 (0.102)	-0.324 (0.536)
log (p_5)	0.955 (0.159)	0.255 (0.320)	– –	0.945 (0.279)	0.234 (0.536)
Conditional Price Elasticity	-5.174 (0.632)	-1.872 (0.803)	-4.457 (0.941)		

R^2 = 0.596; adj-R^2 = 0.560; Joint significance; F stat (p-value) = 10.5 (0.000).
Homotheticity test; F stat (p-value) = 6.06 (0.193) Symmetry test; F stat (p-value) = 1.62 (0.004).
Notes: Numbers in ( ) are standard errors. Each regression includes 37 observations. (E / P) is the total expenditure on free-range and organic eggs in each month over the appropriate free-range and organic price index, p_3 is the average price of Small / Medium (Budget) for free-range eggs in each month, p_4 is the average price of Mixed / Medium (Branded) / Large free-range eggs in each month, and p_5 is the average price of Branded / XLarge for free-range and all Organic eggs in each month. Symmetry in cross-price coefficients is imposed.

The results for homotheticity test are included at the bottom of table 2.B4. Only in three regions the homotheticity assumptions are rejected. In order to perform test of symmetry for cross-price coefficients ($\delta_{jkr} = \delta_{kjr}$) in (2.9), we first estimate this equation without imposing symmetry restrictions. Then the statistical tests are performed to determine whether these coefficients are significantly different or not. The results show that symmetry is rejected only in one out of ten regions, which supports the imposition of symmetry restrictions.

Table 2.6 shows the conditional (on category expenditure) own-price elasticities by region. These elasticities are calculated based on equation (2.15).

Table 2.6. Conditional own price elasticities for bottom level, by region

Region	Caged & barn		Free range		
	Small / Medium / Mixed (Value)	Large / XLarge / Mixed (Other)	Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic
1 : London	-2.316 (0.336)	-1.762 (0.364)	-5.174 (0.632)	-1.872 (0.803)	-4.457 (0.941)
2 : Midlands	-1.624 (0.330)	-2.048 (0.466)	-4.866 (0.935)	-2.099 (1.195)	-4.042 (1.185)
3 : North East	-1.085 (0.582)	-1.714 (0.364)	-5.919 (1.469)	-5.225 (1.577)	-2.740 (1.238)
4 : Yorkshire	-2.305 (0.347)	-2.762 (0.384)	-5.456 (1.253)	-3.138 (0.750)	-5.860 (1.027)
5 : Lancashire	-1.596 (0.384)	-2.730 (0.482)	-1.268 (0.631)	-6.704 (0.932)	-8.720 (1.155)
6 : South	-2.385 (0.358)	-2.590 (0.457)	-2.425 (0.537)	-4.130 (0.910)	-6.680 (0.819)
7 : Scotland	-2.764 (0.356)	-4.004 (0.460)	-1.789 (0.886)	-1.495 (0.438)	-1.527 (0.632)
8 : Anglia	-2.290 (0.405)	-1.582 (0.490)	-2.453 (0.504)	-3.990 (0.983)	-5.034 (0.994)
9 : Wales & West	-1.579 (0.340)	-1.010 (0.504)	-2.605 (0.377)	-2.126 (0.341)	-4.495 (0.605)
10 : South West	-1.433 (0.276)	-1.415 (0.725)	-2.761 (0.934)	-2.095 (1.260)	-4.138 (1.073)

Note: Numbers in ( ) are standard errors.

The results for the middle level (equation (2.12)) in the London region are presented in table 2.7 (the results for other nine region are included in appendix 2.B, table 2.B6). Since a log-log specification is used at this level, the estimated coefficients are directly interpreted as the own and cross-price elasticities for the two categories. The own-price elasticities for caged/barn category are ranged from 0.686 to 1.976 and for free range eggs are ranged from 1.021 to 5.144 across the regions. The own-price elasticities are significantly higher for free range eggs than caged/barn eggs in seven out of ten regions. In the remaining three regions (Yorkshire, Lancashire, and the South West) they are not significantly different.

Table 2.7. London: middle level results

Dep var: log of category's quantity	Caged / Barn	Free Range
Constant	1.421 (0.196)	1.502 (0.206)
Log (Y_E)	1.083 (0.030)	0.906 (0.031)
Log (P_C)	-1.100 (0.091)	0.172 (0.101)
Log (P_F)	0.172 (0.101)	-1.966 (0.254)

R^2 = 0.972; adj-R^2 = 0.969;
Joint significance; F stat (p-value) = 31.04 (0.000)
Homogeneity Test; F stat (p-value) = 8.23 (0.001)
Symmetry Test; F stat (p_value) = 0.86 (0.357)
Notes: Numbers in ( ) are standard errors. Each region's regression includes 37 observations. Y_E is the total expenditure on eggs in each region, P_C is the price index for caged / Barn eggs in each month, P_F is the price for free-range / organic eggs in each month.

The homogeneity test results are included in table 2.B6. The null hypothesis of homogeneity is rejected in three of the ten regions. The symmetry assumptions for the cross-price elasticities can not be rejected for any of the ten regions, which supports the imposition of symmetry restrictions.

Table 2.8 shows the result of the top level regressions (equation (2.12)) for all regions. Since this is a log-log specification the coefficients are directly interpreted as the overall income and price elasticities for eggs. All coefficients at this level are significant. The income elasticities are around one (ranged from 0.973 to 1.257), the null hypothesis of homogeneity is only rejected in one of ten regions (The South West). The price elasticities range from 1.353 (Wales) to 3.281 (South West).

Table 2.8. Income and price elasticities for the top level

Region	Constant	Income elas. log (Y)	Price elas. log(π)	R^2	Adj R^2	Joint significance F stat (p-value)	Homo.; F Stats (p-value)
1 : London	-3.597 (0.632)	1.055 (0.054)	-3.026 (0.201)	0.938	0.935	257.9 (0.000)	1.06 (0.310)
2 : Midlands	-3.362 (0.541)	1.038 (0.048)	-1.928 (0.168)	0.942	0.938	274.3 (0.000)	0.65 (0.426)
3 : North East	-3.336 (0.897)	1.018 (0.096)	-3.024 (0.385)	0.781	0.768	60.7 (0.000)	0.04 (0.843)
4 : Yorkshire	-2.509 (0.673)	0.954 (0.064)	-2.320 (0.199)	0.898	0.892	149.7 (0.000)	0.51 (0.480)
5 : Lancashire	-3.320 (0.505)	1.029 (0.046)	-1.650 (0.156)	0.943	0.941	285.6 (0.000)	0.38 (0.542)
6 : South	-2.661 (0.621)	0.973 (0.055)	-2.187 (0.187)	0.928	0.923	217.7 (0.000)	0.25 (0.620)
7 : Scotland	-3.091 (0.860)	1.011 (0.080)	-2.441 (0.243)	0.863	0.855	107.1 (0.000)	0.02 (0.888)
8 : Anglia	-2.748 (0.536)	0.980 (0.049)	-2.254 (0.183)	0.933	0.929	234.9 (0.000)	0.16 (0.692)
9 : Wales & West	-3.705 (0.503)	1.064 (0.046)	-1.353 (0.172)	0.943	0.940	281.9 (0.000)	1.94 (0.173)
10 : South West	-5.366 (0.992)	1.257 (0.100)	-3.281 (0.350)	0.866	0.858	109.7 (0.000)	6.66 (0.014)

Notes: Numbers in ( ) are standard errors; for the F test results numbers in ( ) are p-values. Each regression includes 37 observations on 10 regions. Dependent variable is the log of quantity of eggs bought in region.

Table 2.9 shows the unconditional own-price elasticities, which are calculated using (2.15). The unconditional own-price elasticities for different categories and different regions vary between -8.756 and -1.113. These seem high, but note that eggs are highly substitutable differentiated products. Two well-known papers studying differentiated product demand systems for food products are Hausman et al (1994) and Nevo (2001). Hausman et al (1994) uses a similar method to study the beer industry and reports unconditional own-price elasticities in the region of -6.205 and -3.763. Nevo (2001) studies the ready-to-eat cereals industry using a discrete choice model. His reported median own-price elasticities vary between -4.252 and -2.277. Our results are slightly higher, but comparable with both papers.

Table 2.9. Unconditional own-price elasticities

Region	Caged & barn Small / Medium / Mixed (Value)	Large / XLarge /Mixed (Other)	Free range Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic
1 : London	-2.559 (0.336)	-1.905 (0.364)	-5.387 (0.632)	-2.478 (0.804)	-4.808 (0.941)
2 : Midlands	-1.520 (0.330)	-1.616 (0.466)	-5.324 (0.935)	-2.715 (1.195)	-5.118 (1.186)
3 : North East	-1.236 (0.582)	-2.052 (0.365)	-6.621 (1.470)	-6.637 (1.578)	-3.204 (1.238)
4 : Yorkshire	-2.139 (0.348)	-2.695 (0.384)	-5.199 (1.254)	-2.427 (0.750)	-5.632 (1.027)
5 : Lancashire	-1.705 (0.384)	-2.796 (0.482)	-1.301 (0.631)	-6.734 (0.932)	-8.756 (1.155)
6 : South	-2.665 (0.358)	-2.716 (0.457)	-2.756 (0.537)	-4.742 (0.910)	-7.109 (0.819)
7 : Scotland	-2.694 (0.356)	-3.961 (0.460)	-2.109 (0.887)	-1.980 (0.438)	-1.613 (0.632)
8 : Anglia	-2.705 (0.405)	-1.777 (0.491)	-3.045 (0.504)	-5.234 (0.983)	-7.833 (0.995)
9 : Wales and West	-1.809 (0.340)	-1.113 (0.504)	-2.926 (0.379)	-2.726 (0.343)	-4.807 (0.606)
10 : South West	-2.512 (0.276)	-1.688 (0.725)	-2.886 (0.935)	-2.375 (1.261)	-4.260 (1.073)

Note: The table contains unconditional price elasticities based on equation (2.17) and parameters estimated for equation (2.9), (2.12), and (2.13). Numbers in ( ) are standard errors.

As an example to compare the own-price elasticities between two categories, we consider the most popular subcategory in each of the two categories. These are the first subcategory (Small / Medium / Mixed (Value)) of caged/barn eggs and the second subcategory (Mixed/ Medium (Branded)/Large) of free-range eggs. The free-range subcategory displays significantly higher own-price elasticities than caged and barn subcategory in five regions (The North East, Lancashire, the South, Anglia, and Wales and the West). In the remaining five regions the own-price elasticities are not significantly different for these two subcategories. A similar pattern of higher own-price elasticities for free range comparing to caged/barn eggs is also observed across other subcategories.

2.4.2. Marginal Costs

In order to compute the regional profit maximizing profits, we first need to find the marginal costs for each category of egg. The marginal costs are assumed to be constant across regions. First the unconditional own and cross-price elasticities for each region have been calculated using (2.17), (2.18), and (2.19). Then, the marginal costs are recovered using equation (2.4).[6]

Table 2.10 summarises the marginal costs that are backed out of the model (averaged over the 37 months of study) and compares them to the farm gate costs.

Table 2.10. Estimated marginal costs and farm gate prices

	Caged & barn Small / Medium / Mixed (Value)	Large / XLarge /Mixed (Other)	Free range Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic
Estimated marginal costs					
Mean	3.24	4.34	7.64	9.15	14.15
SD	0.24	0.24	0.69	0.95	1.39
Min	2.94	3.89	5.08	6.18	12.03
Max	3.62	4.69	9.34	10.04	16.72
Farm gate prices					
Mean	2.28	4.30	4.38	5.73	7.03
SD	0.29	0.25	0.21	0.27	0.33
Min	1.75	3.81	4.07	5.30	6.51
Max	2.74	4.66	4.85	6.21	7.66

Notes: prices are in Pence, data reported for 37 months

The average estimated marginal cost is higher than the farm gate price, which is reassuring. The gap between the estimated marginal costs and the farm gate prices is larger for free range eggs then caged and barn eggs. This may partly be due to the fact that the former are usually offered in smaller pack size, which are made of higher quality packaging materials. Another fact contributing to the gap may be the share of branded eggs in each category. For example, non-Tesco branded eggs count only for 1.4% of sale of Caged & Barn Small/Medium/Mixed, while the same figure for Free Range Branded/XLarge/Organic is 54.7%. It seems reasonable that supermarket pay more for branded products compared to their own brands.

[6] Following (2.4) in order to recover the marginal costs; first assume E_r (5×5) is the price elasticity matrix calculated for region *r*. We define the weighted price elasticity matrix as $E = \sum_r w_r E_r$ (where w_r is a (5×5) matrix and its components are the quantity share of region *r* between all regions for product *j* as $w_r(j,k) = \frac{q_{jr}}{Q_j}$). We calculate the vector $V_t = E^{-1}(E+I)S_t$ where S_t (5×1) is the vector of expenditure shares at period *t*. Define P_t (5×1) as the vector of national prices at time *t*, then the marginal costs of product *j* at period *t* can be written as: $mc_{jt} = V_t(j)\cdot P_t(j)/S_t(j)$.

2.4.3. Profit maximising prices

Using the estimated marginal costs, we turn our attention to equation (2.6), which defines the firm's profit maximisation problem. We solve this equation using numerical methods. Note that as a result of a change in the vector of prices, all quantities demanded will also change. The expenditure share of each category is therefore a function of prices. The price elasticities in (2.6) are also a function of prices and expenditure shares of different categories. In order to find the vector of profit maximizing prices for each region, we use an iterative procedure to maximise regional profits in each period. The iterative procedure is:

Step 1) An initial set of prices is assumed (for quick convergence the vector of average national prices is used).

Step 2) Based on the vector of prices, corresponding price indexes for the middle and top level are constructed.

Step 3) Based on the top level price index, the overall demand and expenditure for eggs are calculated using the coefficients estimated for (2.13).

Step 4) Based on the results of step 3 and the price index for the two middle levels from step 2, the quantity share of each category is calculated, using the coefficients estimated for (2.12).

Step 5) Based on the expenditure on each category and the assumed prices, the bottom level expenditure shares and the quantities are calculated using coefficients estimated for (2.9).

Step 6) Profit is calculated.

Step 7) Repeat steps 2 to 6 to improve the profit until we find the maximum for the profit function.[7]

Figure 2.4 shows the profit maximizing national and regional prices that we calculate for caged and barn small/medium eggs (category one). It is clear that the prices for some of the markets would be lower and some higher under a regional pricing policy compared to prices under national pricing policy. Consumers in Anglia would

[7] While the maximum found using this procedure is not guaranteed to be global; we believe since national prices are used as the initial values, the results here are the best approximate for regional profit-maximising prices.

face the lowest price, just above marginal cost. This is because Anglia has one of the highest price elasticities for this category of eggs, compared to other regions. That means that a marginal increase in price of this category of eggs is likely to decrease the demand for this category in Anglia more than other regions. The negative effect of this on profit is higher than the positive effect of the price rise. At the other extreme consumers in Lancashire, which has a significantly lower price elasticity for this category of eggs, would face substantially higher regional prices.

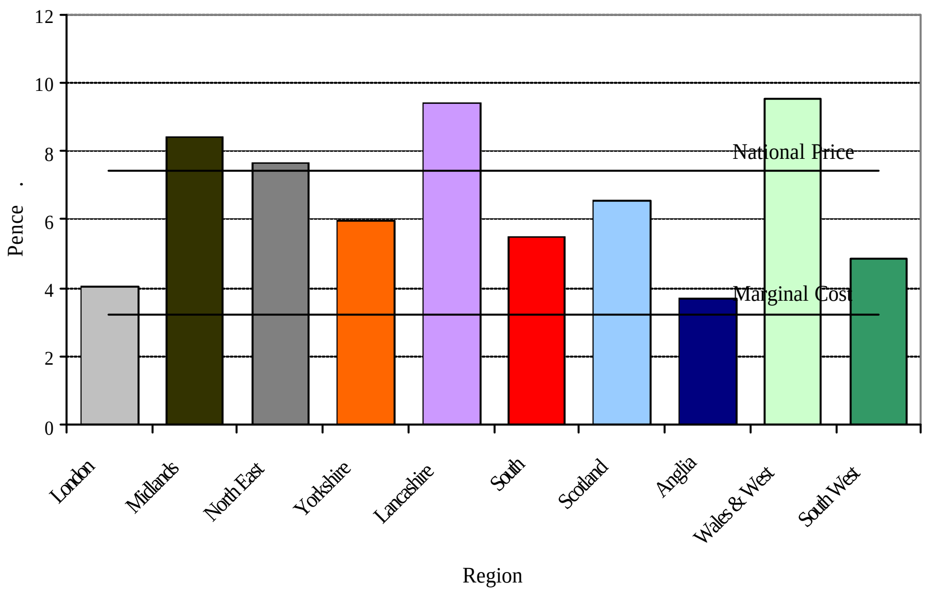

Figure 2.4. The average national and regional profit maximising prices for caged and barn small/medium eggs

Table 2.11 shows the average of profit maximizing national and regional prices for all five subcategories.

Table 2.11. The average national and regional profit maximising prices for all categories

(Unit prices in pence)

Region	Caged & barn Small / Medium / Mixed (Value)	Large / XLarge /Mixed (Other)	Free range Small/ Medium (Budget)	Mixed/ Medium (Branded)/Large	Branded/ XLarge/ Organic
1 : London	4.1	9.0	11.8	14.9	19.5
2 : Midlands	8.4	11.9	10.2	11.5	19.0
3 : North East	7.6	6.6	9.7	14.3	19.7
4 : Yorkshire	6.0	10.5	9.8	12.0	25.8
5 : Lancashire	9.4	8.2	17.5	20.7	27.8
6 : South	5.5	10.8	10.4	12.4	18.1
7 : Scotland	6.6	8.7	11.7	13.9	19.2
8 : Anglia	3.7	12.7	12.4	14.0	17.3
9 : Wales and West	9.6	25.9	15.9	17.5	25.9
10 : South West	4.9	6.8	11.9	13.8	21.1
National prices	7.4	11.7	11.8	14.9	21.9

2.4.4. Impact on Retailer Profits

What impact would a switch from a national to a regional pricing policy have on the retailer's profits? Over the 37 months that we consider moving to a regional pricing policy would have increased Tesco's profit on eggs by about 37%. This figure does not take into the account any extra costs (such as administrative and operational costs) which might occurs as a result of this policy. Figure 2.5 shows a plot of the estimated increase in profits in each month as a result of switching to a regional pricing policy.

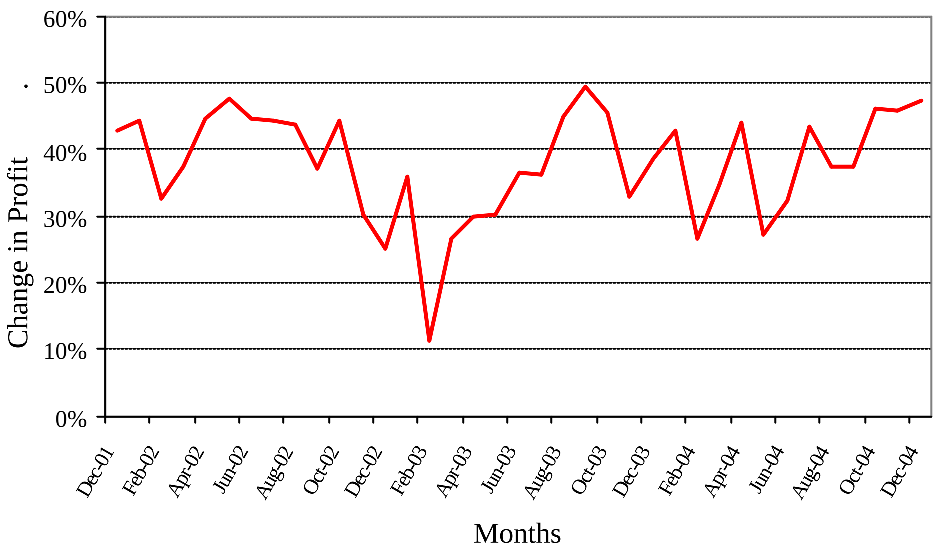

Figure 2.5. The estimated profit gain for Tesco under regional pricing policy

2.4.5. Impact on Consumer Welfare

As mentioned before, the welfare effect of third degree price discrimination is ambiguous. In order to evaluate the level of utility under each pricing policies we use equation (2.7). After substituting sub-utilities from (2.8) in (2.7), the total consumer utility under the national pricing policy is

$$U_{rt}^{N} = \sum_{G} \frac{\log\left(\sum_{j\in G} \hat{p}_{jt}\hat{q}_{jrt}\right) - \log\left(\hat{P}_{Grt}\right)}{\prod_{j\in G} \hat{p}_{jt}^{\,b_{jr}}}, \qquad (2.22)$$

where U_{rt}^{N} is the consumer welfare under national pricing policy in region r and period t,

$\hat{p}_{jt}$ is the national price of subcategory *j* in category *G* eggs in period *t*,[8]

$\hat{q}_{jrt}$ is the regional demand of subcategory *j* in category *G* eggs in region *r* and period *t* under national pricing policy,

$\log\left(\hat{P}_{Grt}\right) = \sum_{j \in G} a_{jr} \log \hat{p}_{jt} + \frac{1}{2} \sum_{j \in G} \sum_{k \in G} d_{jkr} \log \hat{p}_{jt} \log \hat{p}_{kt}$, and

a_{jr}, b_{jr}, and d_{jkr} s, are coefficients estimated from equation (2.9) and reported in tables 2.B2 and 2.B4 for all ten regions.

Similarly the total consumer utility under the regional pricing policy is

$$U_{rt}^{R} = \sum_{G} \frac{\log\left(\sum_{j \in G} \overline{p}_{jrt} \overline{q}_{jrt}\right) - \log\left(\overline{P}_{Grt}\right)}{\prod_{j \in G} \overline{p}_{jrt}^{b_j}}, \qquad (2.23)$$

where U_{rt}^{R} is the total consumer welfare under regional pricing policy in region *r* and period *t*,

$\overline{p}_{jrt}$ is the regional price of subcategory *j* in category *G* eggs in region *r* period *t* (which calculated in section 2.4.3),

$\overline{q}_{jrt}$ is the regional demand of subcategory *j* in category *G* eggs in region *r* and period *t* under regional pricing policy, and

$\log\left(\overline{P}_{Grt}\right) = \sum_{j \in G} a_{jr} \log \overline{p}_{jrt} + \frac{1}{2} \sum_{j \in G} \sum_{k \in G} d_{jkr} \log \overline{p}_{jrt} \log \overline{p}_{krt}$, and

a_{jr}, b_{jr}, and d_{jkr} s, are coefficients estimated from equation (2.9) and reported in tables 2.B2 and 2.B4 for all ten regions.

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[8] As discussed before, Tesco uses a national pricing policy then we expect $\hat{p}_{jt} = p_{jrt}$ for $"r$ where the left hand side is calculated using 2.21. However some regional variations in prices were observed due to consumer choice. For this part we calculate the national prices using $\hat{p}_{jt} = \frac{\sum_r \sum_h e_{jrht}}{\sum_r \sum_h q_{jrht}}$.

So the change in consumer welfare in region *r* and period *t*, after switching to a regional pricing policy is $\Delta U_{rt} = U_{rt}^{R} - U_{rt}^{N}$. Table 2.12 shows a summary result of this change in consumer welfare. Figure 2.6 shows average and range of estimated gain/loss in consumer welfare across ten regions in case of switching to a regional pricing policy. As result of the policy change, London and the South West regions are the biggest winners, and Wales and the west and Lancashire are two biggest losers.

Table 2.12. Summary statistics for the change in consumer welfare as a result of switching to a regional pricing policy

	#	Average	SD	Min	Max
Change in Consumer Welfare	370	4.9%	8.2%	-12.9%	27.0%

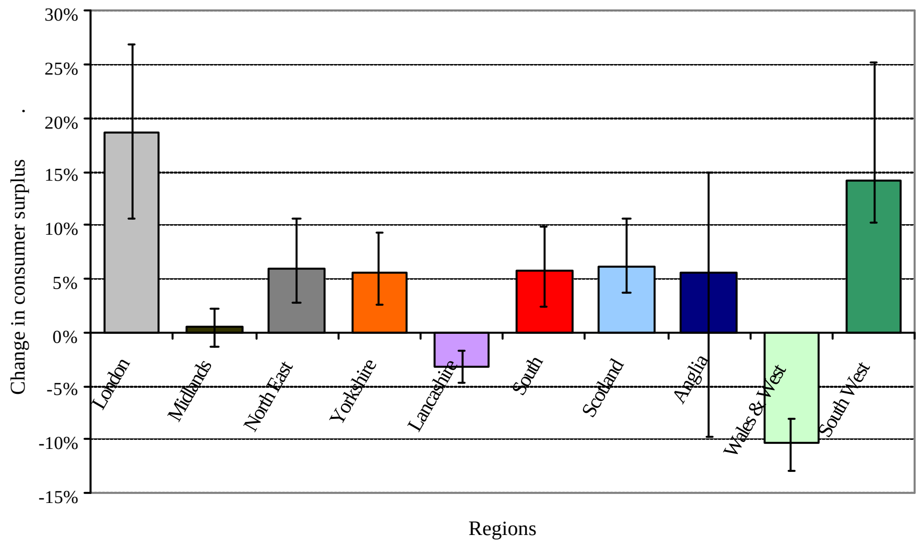

Figure 2.6. The average and range of estimated consumer gain/loss across the regions

2.5. Summary and Conclusion

We have estimated a three-level budgeting demand system for Tesco eggs. Using our estimates of the demand system, we calculated the difference that using a regional pricing policy would make to Tesco's profit on eggs and to consumer surplus. Our estimates suggest that Tesco would substantially increase its profit. The gains to consumers are modest, with some consumers benefiting, but many losing out.

These results lend some support to the attitude taken by the competition authorities in their investigations of the supermarket industry.

Appendix 2.A

Unconditional Own Price Elasticity

From (2.9) we get

$$\frac{\partial s_j}{\partial \log(p_j)} = b_j \frac{\partial \log(E_G)}{\partial \log(p_j)} + d_{jj} = b_j \frac{p_j}{E_G}\frac{\partial E_G}{\partial p_j} + d_{jj}. \qquad (2.A1)$$

The LHS of (2.A1) is

$$\frac{\partial s_j}{\partial \log(p_j)} = p_j \frac{\partial\left(\frac{p_j q_j}{E_G}\right)}{\partial p_j} = p_j \frac{\left(q_j + p_j \frac{\partial q_j}{\partial p_j}\right)E_G - p_j q_j \frac{\partial E_G}{\partial p_j}}{E_G^{\ 2}} = s_j(1 + l_{jj}) - \frac{s_j^{\ 2}}{q_j}\frac{\partial E_G}{\partial p_j};$$

Substituting this into (2.A1) yields

$$s_j(1 + l_{jj}) = d_{jj} + \left(b_j \frac{p_j}{E_G} + \frac{s_j^{\ 2}}{q_j}\right)\frac{\partial E_G}{\partial p_j}. \qquad (2.A2)$$

To calculate the last part of (2.A2) we have

$$\frac{\partial E_G}{\partial p_j} = \frac{\partial P_G}{\partial p_j}\frac{\partial (P_G Q_G)}{\partial P_G} = \hat{q}_j\left(Q_G + P_G \frac{\partial Q_G}{\partial P_G}\right) = \hat{q}_j Q_G\left(1 + \frac{\partial \log Q_G}{\partial \log P_G}\right). \qquad (2.A3)$$

Looking at (2.10)

$$\frac{\partial \log Q_G}{\partial \log P_G} = b_G \frac{\partial \log Y_E}{\partial \log P_G} + j_{GG} = b_G \frac{P_G}{Y_E}\frac{\partial (Y_E)}{\partial P_G} + j_{GG} = b_G \frac{1}{Q_G}\frac{\partial (Y_E)}{\partial P_G} + j_{GG}, \qquad (2.A4)$$

And taking derivative of Y_E with respect to P_G

$$\frac{\partial (Y_E)}{\partial P_G} = \frac{\partial p}{\partial P_G}\frac{\partial (Qp)}{\partial p} = \hat{w}_G\left(Q + p\frac{\partial Q}{\partial p}\right) = \hat{w}_G Q(1+u); \qquad (2.A5)$$

Substituting (2.A5) into (2.A4) and then (2.A3)

$$\frac{\partial E_G}{\partial p_j} = \hat{q}_j Q_G\left(1 + b_G \frac{1}{Q_G}\hat{w}_G Q(1+u) + j_{GG}\right). \qquad (2.A6)$$

Substituting this into (2.A2)

$$s_j(1 + l_{jj}) = \left(\frac{s_j^{\ 2}}{q_j} + b_j \frac{p_j}{E_G}\right)\hat{q}_j Q_G\left(1 + b_G \frac{1}{Q_G}\hat{w}_G Q(1+u) + j_{GG}\right) + d_{jj}.$$

By defining the quantity share of size j in category G as $d_j = \frac{q_j}{Q_G}$ and the quantity share of category G in total number of eggs as $d_G = \frac{Q_G}{Q}$ and reordering we get

$$l_{jj} = \frac{d_{jj}}{s_j} + \left(s_j + b_j\right)\frac{\hat{q}_j}{d_j}\left(1 + b_G \frac{\hat{w}_G\left(1+u\right)}{d_G} + j_{GG}\right) - 1. \qquad (2.17)$$

Unconditional Cross Price Elasticity within a Category:

Differentiating (2.9) with respect to *log(p$_k$)*:

$$\frac{\partial s_j}{\partial \log(p_k)} = b_j \frac{\partial \log\left(E_G\right)}{\partial \log(p_k)} + d_{jk} = b_j \frac{p_k}{E_G}\frac{\partial E_G}{\partial p_k} + d_{jk}. \qquad (2.A7)$$

The LHS of (2.A7) is

$$\frac{\partial s_j}{\partial \log(p_k)} = p_k \frac{\partial\left(\frac{p_j q_j}{E_G}\right)}{\partial p_k} = p_k \frac{p_j \frac{\partial q_j}{\partial p_k} E_G - p_j q_j \frac{\partial E_G}{\partial p_k}}{E_G{}^2} = s_j l_{jk} - \frac{s_j s_k}{q_k}\frac{\partial E_G}{\partial p_k},$$

and then substituting into (2.A7) and rearranging we get

$$s_j l_{jk} - \frac{s_j s_k}{q_k}\frac{\partial E_G}{\partial p_k} = b_j \frac{p_k}{E_G}\frac{\partial E_G}{\partial p_k} + d_{jk}.$$

Using (2.A6): $s_j l_{jk} = \left(\frac{s_j s_k}{q_k} + b_j \frac{p_k}{E_G}\right)\hat{q}_k Q_G \left(1 + b_G \frac{1}{Q_G}\hat{w}_G Q\left(1+u\right) + j_{GG}\right) + d_{jk},$

Reordering the final expression is

$$l_{jk} = \frac{d_{jk}}{s_j} + s_k\left(1 + \frac{b_j}{s_j}\right)\frac{\hat{q}_k}{d_k}\left(1 + b_G \frac{\hat{w}_G\left(1+u\right)}{d_G} + j_{GG}\right). \qquad (2.18)$$

Unconditional Cross Price Elasticity between two Categories:

The unconditional cross price elasticities between two categories are calculated by taking the derivative of (2.9) with respect to *log(p$_k$)*, we get (*jÎ G & kÎ H*) are

$$\frac{\partial s_j}{\partial \log(p_k)} = b_j \frac{\partial \log\left(E_G\right)}{\partial \log(p_k)} = b_j \frac{p_k}{E_G}\frac{\partial E_G}{\partial p_k}. \qquad (2.A8)$$

The LHS of (2.A8) is

$$\frac{\partial s_j}{\partial \log(p_k)} = p_k \frac{\partial\left(\frac{p_j q_j}{E_G}\right)}{\partial p_k} = p_k \frac{p_j \frac{\partial q_j}{\partial p_k} E_G - p_j q_j \frac{\partial E_G}{\partial p_k}}{E_G^{\;2}} = s_j l_{jk} - \frac{s_j p_k}{E_G} \frac{\partial E_G}{\partial p_k}.$$

Substituting into (2.A8) gives us

$$l_{jk} = \left(1 + \frac{b_j}{s_j}\right) \frac{p_k}{E_G} \frac{\partial E_G}{\partial p_k}. \qquad (2.A9)$$

Calculating the last term of (2.A9) we get

$$\frac{\partial E_G}{\partial p_k} = \frac{\partial P_H}{\partial p_k} \frac{\partial (P_G Q_G)}{\partial P_H} = \hat{q}_k P_G \frac{\partial Q_G}{\partial P_H} = \hat{q}_j \frac{P_G Q_G}{P_H} \frac{\partial \log Q_G}{\partial \log P_H}. \qquad (2.A10)$$

Looking at (2.11) $\frac{\partial \log Q_G}{\partial \log P_H} = b_G \frac{\partial \log Y_E}{\partial \log P_H} + j_{GH} = b_G \frac{P_H}{Y_E} \frac{\partial (Y_E)}{\partial P_H} + j_{GH}$,

And substituting from (2.A5)

$$\frac{\partial \log Q_G}{\partial \log P_H} = b_G \frac{P_H}{Y_E} \hat{w}_H Q(1+u) + j_{GH} = b_G \frac{P_H}{p} \hat{w}_H (1+u) + j_{GH}. \qquad (2.A11)$$

Substituting from (2.A10) and (2.A11) into (2.A9), we finally get:

$$l_{jk} = \left(1 + \frac{b_j}{s_j}\right) \hat{q}_j \frac{p_k}{P_H} \left(b_G \frac{P_H}{p} \hat{w}_H (1+u) + j_{GH} \right). \qquad (2.19)$$

Appendix 2.B

Table 2.B1. Summary statistics

	Unit	Mean	Std. Dev.	Min	Max
London					
log (total expenditure)	log(£)	11.795	0.100	11.615	11.965
Log (expenditure on eggs)	Log(£)	6.576	0.073	6.392	6.702
log (total quantity)	#	8.815	0.142	8.501	9.051
log(π)	#	0.013	0.068	-0.089	0.136
Caged / Barn					
log (quantity)	#	8.526	0.152	8.219	8.828
log(P_C)	#	0.009	0.092	-0.176	0.155
s_1	%	52.97%	7.70%	37.54%	64.83%
log (p_1)	Log(£)	-2.586	0.094	-2.729	-2.433
s_2	%	47.03%	7.70%	35.17%	62.46%
log (p_2)	Log(£)	-2.146	0.104	-2.409	-1.995
Free Range					
log (quantity)	#	7.428	0.137	7.097	7.658
log(P_F)	#	0.018	0.041	-0.034	0.101
s_3	%	25.11%	4.21%	14.90%	33.61%
log (p_3)	Log(£)	-2.137	0.081	-2.221	-1.924

	Unit	Mean	Std. Dev.	Min	Max
s_4	%	39.89%	6.19%	24.13%	53.08%
log (p_4)	log(£)	-1.897	0.050	-1.971	-1.807
s_5	%	35.01%	8.11%	18.82%	49.88%
log (p_5)	log(£)	-1.518	0.042	-1.598	-1.447
Midlands					
log (total expenditure)	log(£)	11.383	0.092	11.189	11.563
Log (expenditure on eggs)	log(£)	6.148	0.071	5.991	6.308
log (total quantity)	#	8.449	0.087	8.251	8.618
log(π)	#	0.005	0.069	-0.105	0.119
Caged / Barn					
log (quantity)	#	8.208	0.081	8.033	8.351
log(P_C)	#	-0.004	0.095	-0.194	0.129
s_1	%	60.95%	5.84%	44.54%	69.04%
log (p_1)	log(£)	-2.607	0.094	-2.766	-2.472
s_2	%	39.05%	5.84%	30.96%	55.46%
log (p_2)	log(£)	-2.153	0.109	-2.428	-2.009
Free Range					
log (quantity)	#	6.900	0.160	6.458	7.217
log(P_F)	#	0.018	0.041	-0.030	0.104
s_3	%	26.93%	6.00%	13.99%	35.54%
log (p_3)	log(£)	-2.143	0.089	-2.248	-1.911
s_4	%	41.52%	5.83%	30.38%	53.60%
log (p_4)	log(£)	-1.902	0.058	-1.975	-1.776
s_5	%	31.55%	6.74%	20.91%	50.46%
log (p_5)	log(£)	-1.504	0.069	-1.657	-1.378
North East					
log (total expenditure)	log(£)	9.424	0.201	8.943	9.756
log (expenditure on eggs)	log(£)	3.975	0.166	3.637	4.278
log (total quantity)	#	6.172	0.171	5.903	6.589
log(π)	#	0.028	0.079	-0.145	0.155
Caged / Barn					
log (quantity)	#	5.828	0.202	5.481	6.368
log(P_C)	#	0.027	0.105	-0.248	0.172
s_1	%	40.39%	11.62%	17.21%	56.99%
log (p_1)	Log(£)	-2.594	0.110	-2.871	-2.402
s_2	%	59.61%	11.62%	43.01%	82.79%
log (p_2)	Log(£)	-2.134	0.122	-2.530	-1.967
Free Range					
log (quantity)	#	4.879	0.350	4.277	5.529
log(P_F)	#	0.028	0.063	-0.097	0.136
s_3	%	29.03%	13.00%	6.53%	58.23%
log (p_3)	Log(£)	-2.161	0.098	-2.300	-1.920
s_4	%	42.39%	13.87%	15.36%	80.50%
log (p_4)	Log(£)	-1.901	0.078	-2.139	-1.775
s_5	%	30.17%	14.67%	7.01%	62.42%
log (p_5)	Log(£)	-1.507	0.087	-1.793	-1.354
Yorkshire					
log (total expenditure)	log(£)	10.593	0.109	10.389	10.760
log (expenditure on eggs)	log(£)	5.234	0.092	5.004	5.407
log (total quantity)	#	7.551	0.145	7.138	7.826
log(π)	#	0.021	0.083	-0.120	0.162
Caged / Barn					
log (quantity)	#	7.298	0.147	6.884	7.545
log(P_C)	#	0.015	0.101	-0.196	0.167
S_1	%	63.31%	10.36%	35.11%	82.86%
log (p_1)	log(£)	-2.608	0.089	-2.745	-2.462
S_2	%	36.69%	10.36%	17.14%	64.89%
log (p_2)	log(£)	-2.156	0.146	-2.558	-1.954
Free Range					

	Unit	Mean	Std. Dev.	Min	Max
log (quantity)	#	6.043	0.203	5.598	6.417
$\log(P_F)$	#	0.031	0.062	-0.074	0.185
S_3	%	22.58%	8.76%	6.21%	39.53%
log (p_3)	log(£)	-2.162	0.106	-2.288	-1.873
S_4	%	56.63%	7.69%	37.38%	71.76%
log (p_4)	log(£)	-1.909	0.067	-2.063	-1.766
S_5	%	20.79%	8.01%	5.79%	42.66%
log (p_5)	log(£)	-1.529	0.080	-1.767	-1.419
Lancashire					
log (total expenditure)	log(£)	10.922	0.093	10.707	11.130
log (expenditure on eggs)	log(£)	5.607	0.079	5.417	5.735
log (total quantity)	#	7.891	0.096	7.704	8.105
$\log(\pi)$	#	0.016	0.079	-0.130	0.145
Caged / Barn					
log (quantity)	#	7.616	0.116	7.390	7.891
$\log(P_C)$	#	0.025	0.103	-0.182	0.179
S_1	%	60.20%	9.29%	32.50%	76.01%
log (p_1)	log(£)	-2.586	-1.586	-0.586	0.414
S_2	%	39.80%	9.29%	23.99%	67.50%
log (p_2)	log(£)	-2.159	0.124	-2.464	-1.979
Free Range					
log (quantity)	#	6.450	0.147	6.170	6.775
$\log(P_F)$	#	-0.003	0.045	-0.060	0.096
S_3	%	28.75%	5.88%	17.29%	41.63%
log (p_3)	log(£)	-2.138	0.086	-2.247	-1.945
S_4	%	41.16%	10.07%	21.26%	61.50%
log (p_4)	log(£)	-1.900	0.065	-2.005	-1.746
S_5	%	30.09%	8.68%	13.21%	50.74%
log (p_5)	log(£)	-1.521	0.067	-1.716	-1.416
South					
log (total expenditure)	log(£)	11.384	0.074	11.229	11.526
log (expenditure on eggs)	log(£)	6.072	0.078	5.942	6.272
log (total quantity)	#	8.368	0.135	8.069	8.615
$\log(\pi)$	#	0.021	0.074	-0.112	0.137
Caged / Barn					
log (quantity)	#	8.102	0.143	7.762	8.394
$\log(P_C)$	#	0.022	0.095	-0.190	0.153
s_1	%	60.86%	8.31%	40.37%	72.15%
log (p_1)	log(£)	-2.608	0.093	-2.772	-2.472
s_2	%	39.14%	8.31%	27.85%	59.63%
log (p_2)	log(£)	-2.158	0.123	-2.502	-1.996
Free Range					
log (quantity)	#	6.905	0.167	6.548	7.321
$\log(P_F)$	#	0.019	0.046	-0.028	0.112
s_3	%	27.03%	4.26%	21.01%	37.46%
log (p_3)	log(£)	-2.143	0.091	-2.234	-1.921
s_4	%	45.66%	6.33%	33.55%	64.62%
log (p_4)	log(£)	-1.905	0.051	-1.965	-1.802
s_5	%	27.31%	6.95%	13.13%	42.99%
log (p_5)	log(£)	-1.511	0.040	-1.602	-1.452
Scotland					
log (total expenditure)	log(£)	10.769	0.134	10.523	11.009
log (expenditure on eggs)	log(£)	5.489	0.090	5.325	5.698
log (total quantity)	#	7.808	0.135	7.505	8.160
$\log(\pi)$	#	-0.001	0.083	-0.170	0.126
Caged / Barn					
log (quantity)	#	7.538	0.135	7.204	7.932
$\log(P_C)$	#	0.001	0.108	-0.266	0.135
s_1	%	60.46%	10.85%	32.26%	78.61%

	Unit	Mean	Std. Dev.	Min	Max
log (p_1)	log(£)	-2.617	0.105	-2.840	-2.468
s_2	%	39.54%	10.85%	21.39%	67.74%
log (p_2)	log(£)	-2.188	0.140	-2.583	-2.044
Free Range					
log (quantity)	#	6.360	0.174	6.031	6.649
log(P_F)	#	-0.008	0.059	-0.077	0.111
s_3	%	28.00%	5.75%	17.15%	38.75%
log (p_3)	log(£)	-2.144	0.094	-2.274	-1.920
s_4	%	52.48%	6.28%	38.07%	70.98%
log (p_4)	log(£)	-1.912	0.060	-1.997	-1.813
s_5	%	19.53%	6.31%	4.64%	33.49%
log (p_5)	log(£)	-1.596	0.117	-1.945	-1.392
Anglia					
log (total expenditure)	log(£)	11.049	0.115	10.839	11.255
log (expenditure on eggs)	log(£)	5.715	0.096	5.454	5.895
log (total quantity)	#	8.010	0.108	7.760	8.241
log(π)	#	0.033	0.073	-0.095	0.155
Caged / Barn					
log (quantity)	#	7.772	0.124	7.563	8.108
log(P_C)	#	0.028	0.105	-0.201	0.182
s_1	%	59.02%	9.12%	46.64%	73.59%
log (p_1)	log(£)	-2.610	0.102	-2.775	-2.455
s_2	%	40.98%	9.12%	26.41%	53.36%
log (p_2)	log(£)	-2.148	0.126	-2.508	-1.980
Free Range					
log (quantity)	#	6.434	0.216	5.996	6.805
log(P_F)	#	0.038	0.040	-0.014	0.127
s_3	%	29.04%	6.42%	18.76%	52.72%
log (p_3)	log(£)	-2.140	0.087	-2.227	-1.920
s_4	%	37.39%	7.93%	21.45%	55.10%
log (p_4)	log(£)	-1.903	0.054	-2.013	-1.808
s_5	%	33.57%	8.09%	17.35%	49.02%
log (p_5)	log(£)	-1.504	0.040	-1.583	-1.400
Wales and West					
log (total expenditure)	log(£)	10.991	0.099	10.833	11.242
log (expenditure on eggs)	log(£)	5.693	0.120	5.373	5.934
log (total quantity)	#	7.975	0.086	7.740	8.150
log(π)	#	0.012	0.070	-0.076	0.126
Caged / Barn					
log (quantity)	#	7.689	0.095	7.479	7.916
log(P_C)	#	0.000	0.086	-0.128	0.138
s_1	%	59.10%	5.58%	39.96%	68.47%
log (p_1)	log(£)	-2.608	0.087	-2.749	-2.475
s_2	%	40.90%	5.58%	31.53%	60.04%
log (p_2)	log(£)	-2.135	0.091	-2.261	-1.989
Free Range					
log (quantity)	#	6.576	0.136	6.269	6.848
log(P_F)	#	0.028	0.051	-0.030	0.139
s_3	%	29.59%	4.83%	18.46%	38.78%
log (p_3)	log(£)	-2.148	0.089	-2.251	-1.920
s_4	%	45.91%	7.26%	22.54%	62.18%
log (p_4)	log(£)	-1.899	0.059	-1.991	-1.801
s_5	%	24.49%	7.76%	11.63%	43.55%
log (p_5)	log(£)	-1.527	0.072	-1.745	-1.410
South West					
log (total expenditure)	log(£)	10.025	0.114	9.764	10.279
log (expenditure on eggs)	log(£)	4.740	0.122	4.481	4.941
log (total quantity)	#	7.133	0.195	6.816	7.502
log(π)	#	0.033	0.078	-0.074	0.166

	Unit	Mean	Std. Dev.	Min	Max
Caged / Barn					
log (quantity)	#	6.928	0.222	6.581	7.359
$\log(P_C)$	#	0.058	0.086	-0.064	0.201
s_1	%	70.64%	8.71%	41.75%	87.24%
$\log(p_1)$	log(£)	-2.642	0.093	-2.783	-2.489
s_2	%	29.36%	8.71%	12.76%	58.25%
$\log(p_2)$	log(£)	-2.144	0.088	-2.279	-1.960
Free Range					
log (quantity)	#	5.410	0.249	4.771	5.976
$\log(P_F)$	#	-0.039	0.067	-0.151	0.102
s_3	%	39.95%	11.06%	16.46%	68.49%
$\log(p_3)$	log(£)	-2.150	0.093	-2.349	-1.920
s_4	%	39.25%	11.12%	17.37%	63.19%
$\log(p_4)$	log(£)	-1.912	0.083	-2.067	-1.724
s_5	%	21.38%	10.49%	3.47%	46.44%
$\log(p_5)$	log(£)	-1.570	0.114	-1.839	-1.418

Note: π: the Laspeyres price index for eggs;
P_C: the Laspeyres price index for caged and barn eggs;
s_1: the expenditure share of *Small / Medium / Mixed (Value)* sub-category in caged and barn eggs;
p_1: the price of *Small / Medium / Mixed (Value)* sub-category of caged and barn eggs;
s_2: the expenditure share of *Large / XLarge / Mixed (Other)* sub-category in caged and barn eggs;
p_2: the price of *Large / XLarge / Mixed (Other)* sub-category of caged and barn eggs;
P_F: the Laspeyres price index for free range eggs;
s_3: the expenditure share of *Small / Medium (Budget)* sub-category in free range eggs;
p_3: the price of *Small / Medium (Budget)* sub-category in free range eggs;
s_4: the expenditure share of *Mixed / Medium (Branded) / Large* sub-category in free range eggs;
p_4: the price of *Mixed / Medium (Branded) / Large* sub-category in free range eggs;
s_5: the expenditure share of *Branded / XLarge / Organic* sub-category in free range eggs;
p_5: the price of *Branded / XLarge / Organic* sub-category in free range eggs;

Table 2.B2. Bottom level results for Caged and Barn, coefficients for Small / Medium /Mixed (Value) and conditional own-price elasticities using approximate price index

Dep var: share of expenditure on product	London	Midlands	North East	Yorkshire	Lancashire	South	Scotland	Anglia	Wales & West	South West
Constant	-0.991 (0.305)	0.092 (0.334)	1.321 (0.536)	-0.578 (0.426)	0.904 (0.382)	-0.270 (0.377)	0.467 (0.375)	-1.027 (0.440)	-0.511 (0.303)	-0.778 (0.319)
Log (E / P)	0.080 (0.034)	0.071 (0.034)	-0.029 (0.048)	0.094 (0.049)	0.049 (0.041)	0.004 (0.043)	-0.011 (0.045)	0.027 (0.048)	0.073 (0.027)	0.095 (0.027)
Log (p_1)	-0.697 (0.178)	-0.380 (0.201)	-0.034 (0.235)	-0.826 (0.220)	-0.359 (0.231)	-0.843 (0.218)	-1.066 (0.215)	-0.761 (0.239)	-0.342 (0.201)	-0.306 (0.195)
Log (p_2)	0.358 (0.171)	0.409 (0.182)	0.425 (0.217)	0.646 (0.141)	0.689 (0.192)	0.622 (0.179)	1.188 (0.182)	0.239 (0.201)	0.004 (0.206)	0.122 (0.213)
R^2	0.647	0.720	0.686	0.619	0.807	0.951	0.946	0.913	0.735	0.701
Adj – R^2	0.602	0.685	0.646	0.571	0.783	0.944	0.939	0.902	0.702	0.663
Joint significance, F stat (p-value)	1.67 (0.192)	2.34 (0.091)	1.99 (0.135)	1.48 (0.238)	3.80 (0.019)	17.64 (0.000)	15.93 (0.000)	9.54 (0.000)	2.52 (0.075)	2.13 (0.115)
Homotheticity Test; F stat (p-value)	5.75 (0.022)	4.29 (0.046)	0.36 (0.554)	3.71 (0.063)	1.43 (0.241)	0.01 (0.923)	0.06 (0.812)	0.32 (0.574)	7.08 (0.012)	12.39 (0.001)
Conditional own-price elasticity										
Small / Medium / Mixed (Value)	-2.316 (0.336)	-1.624 (0.330)	-1.085 (0.582)	-2.305 (0.347)	-1.596 (0.384)	-2.385 (0.358)	-2.764 (0.356)	-2.290 (0.405)	-1.579 (0.340)	-1.433 (0.276)
Large/XLarge / Mixed (Other)	-1.762 (0.364)	-2.048 (0.466)	-1.714 (0.364)	-2.762 (0.384)	-2.730 (0.482)	-2.590 (0.457)	-4.004 (0.460)	-1.582 (0.490)	-1.010 (0.504)	-1.415 (0.725)

Notes: Numbers in ( ) are standard errors; for F-test results numbers in ( ) are p-values. Each region's regression includes 37 observations. (E / P) is the total of expenditure caged and barn eggs in each month over the appropriate caged and barn price index, p_1 is the average price of Small / Medium / Mixed (Value) for caged and barn eggs in each month, and p_2 is the average price of Large / XLarge / Mixed (Other) for caged and barn eggs in each month.

Table 2.B3. Bottom level results for Caged and Barn, coefficients for Small / Medium /Mixed (Value) using exact price index

Dep var: share of expenditure on product	**London**	**Midlands**	**North East**	**Yorkshire**	**Lancashire**	**South**	**Scotland**	**Anglia**	**Wales & West**	**South West**
Constant	-0.973 (0.327)	0.093 (0.347)	1.328 (0.568)	-0.557 (0.478)	0.901 (0.412)	-0.266 (0.410)	0.471 (0.356)	-1.022 (0.420)	-0.500 (0.287)	-0.757 (0.318)
Log (E / P)	0.080 (0.036)	0.071 (0.036)	-0.029 (0.051)	0.093 (0.055)	0.049 (0.044)	0.003 (0.047)	-0.012 (0.043)	0.028 (0.047)	0.073 (0.026)	0.095 (0.027)
Log (p_1)	-0.726 (0.191)	-0.369 (0.208)	-0.062 (0.244)	-0.836 (0.247)	-0.329 (0.251)	-0.842 (0.242)	-1.078 (0.214)	-0.764 (0.233)	-0.250 (0.196)	-0.329 (0.194)
Log (p_2)	0.473 (0.189)	0.468 (0.191)	0.426 (0.229)	0.753 (0.166)	0.703 (0.205)	0.625 (0.200)	1.186 (0.173)	0.273 (0.199)	0.012 (0.198)	0.004 (0.216)
Number of iterations	6	5	5	6	5	4	4	5	5	6

Notes: Numbers in ( ) are standard errors. Each region's regression includes 37 observations. (*E / P*) is the total of expenditure caged and barn eggs in each month over the appropriate caged and barn price index, p_1 is the average price of Small / Medium / Mixed (Value) for caged and barn eggs in each month, and p_2 is the average price of Large / XLarge / Mixed (Other) for caged and barn eggs in each month. All simulations started with the initial values of [0.5 0 0 0] for the coefficients; and since the procedure converges quite fast the choice of initial values are not important .

Table 2.B4. Bottom level results for Free Range, coefficients for the three sub-categories and conditional own-price elasticities using approximate price index

Dep var: share of expenditure on product		**London**	**Midlands**	**North East**	**Yorkshire**	**Lancashire**	**South**	**Scotland**	**Anglia**	**Wales & West**	**South West**
Small / Medium (Budget)	Constant	0.145	-0.034	0.013	-0.064	0.454	0.171	0.004	0.733	0.384	0.488
		(0.163)	(0.140)	(0.156)	(0.164)	(0.188)	(0.119)	(0.133)	(0.119)	(0.145)	(0.177)
	Log (E / P)	-0.092	-0.051	-0.042	-0.029	0.043	-0.019	0.049	-0.150	-0.075	-0.123
		(0.029)	(0.031)	(0.063)	(0.041)	(0.034)	(0.026)	(0.038)	(0.032)	(0.029)	(0.042)
	log (p_3)	-1.048	-1.041	-1.428	-1.006	-0.077	-0.385	-0.221	-0.422	-0.475	-0.704
		(0.159)	(0.252)	(0.426)	(0.283)	(0.181)	(0.145)	(0.248)	(0.146)	(0.111)	(0.373)
	log (p_4)	0.093	0.269	1.347	0.603	0.051	0.132	0.189	0.093	0.068	0.231
		(0.130)	(0.257)	(0.426)	(0.303)	(0.013)	(0.189)	(0.229)	(0.019)	(0.011)	(0.389)
	log (p_5)	0.955	0.772	0.081	0.403	0.026	0.253	0.032	0.329	0.407	0.472
		(0.159)	(0.221)	(0.045)	(0.182)	(0.181)	(0.137)	(0.123)	(0.146)	(0.111)	(0.206)
Mixed / Medium(Branded) /Large	Constant	-0.292	0.583	0.478	0.451	-0.187	0.085	0.398	0.267	-0.096	0.274
		(0.192)	(0.138)	(0.234)	(0.171)	(0.185)	(0.130)	(0.133)	(0.118)	(0.143)	(0.170)
	Log (E / P)	0.112	-0.036	0.035	0.009	-0.057	-0.022	0.034	-0.062	0.088	0.031
		(0.028)	(0.037)	(0.065)	(0.041)	(0.036)	(0.026)	(0.035)	(0.043)	(0.029)	(0.042)
	log (p_3)	0.093	0.269	1.347	0.603	0.051	0.132	0.189	0.093	0.068	0.231
		(0.130)	(0.257)	(0.426)	(0.303)	(0.013)	(0.189)	(0.229)	(0.019)	(0.011)	(0.389)
	log (p_4)	-0.348	-0.456	-1.791	-1.211	-2.348	-1.429	-0.260	-1.118	-0.517	-0.430
		(0.320)	(0.496)	(0.669)	(0.425)	(0.384)	(0.415)	(0.230)	(0.367)	(0.157)	(0.495)
	log (p_5)	0.255	0.187	0.444	0.608	2.297	1.298	0.071	1.025	0.449	0.199
		(0.320)	(0.382)	(0.374)	(0.229)	(0.384)	(0.280)	(0.024)	(0.367)	(0.157)	(0.237)
R^2		0.596	0.590	0.284	0.873	0.400	0.798	0.863	0.253	0.771	0.754
Adj – R^2		0.560	0.553	0.220	0.862	0.346	0.780	0.851	0.186	0.750	0.732
Joint significance, F stat		10.50	10.22	2.64	48.86	4.73	28.09	44.77	2.41	23.92	21.09
(p-value)		(0.000)	(0.000)	(0.015)	(0.000)	(0.000)	(0.000)	(0.000)	(0.024)	(0.000)	(0.000)
Symmetry Test; F stat		1.62	1.96	0.60	2.22	0.75	0.66	0.92	1.59	7.12	0.83
(p value)		(0.193)	(0.129)	(0.618)	(0.094)	(0.526)	(0.580)	(0.436)	(0.200)	(0.000)	(0.482)
Homotheticity Test; F stat		6.06	1.95	0.17	0.18	2.69	0.79	1.89	12.62	3.54	2.95
(p-value)		(0.004)	(0.150)	(0.844)	(0.836)	(0.075)	(0.458)	(0.159)	(0.000)	(0.035)	(0.059)

Table continues on the next page

Table 2.B4. (continued)

	London	Midlands	North East	Yorkshire	Lancashire	South	Scotland	Anglia	Wales & West	South West
Conditional own-price elasticity										
Small / Medium (Budget)	-5.174 (0.632)	-4.866 (0.935)	-5.919 (1.469)	-5.456 (1.253)	-1.268 (0.631)	-2.425 (0.537)	-1.789 (0.886)	-2.453 (0.504)	-2.605 (0.377)	-2.761 (0.934)
Mixed/ Medium (Branded)/Large	-1.872 (0.803)	-2.099 (1.195)	-5.225 (1.577)	-3.138 (0.750)	-6.704 (0.932)	-4.130 (0.910)	-1.495 (0.438)	-3.990 (0.983)	-2.126 (0.341)	-2.095 (1.260)
Branded/ XLarge/ Organic	-4.457 (0.941)	-4.042 (1.185)	-2.740 (1.238)	-5.860 (1.027)	-8.720 (1.155)	-6.680 (0.819)	-1.527 (0.632)	-5.034 (0.994)	-4.495 (0.605)	-4.138 (1.073)

Notes: Numbers in ( ) are standard errors; for F-test results numbers in ( ) are p-values. Each region's regression includes 37 observations (except the North East and the South West where there are 35 and 36 observations respectively). (E/P) is the total expenditure on free-range and organic eggs in each month over the appropriate free-range –organic price, index p_3 is the average price of Small / Medium (Budget) for free-range eggs in each month, p_4 is the average price of Mixed / Medium (Branded) / Large free-range eggs in each month, and p_5 is the average price of Branded / XLarge for free-range and all Organic eggs in each month. (Symmetry assumption imposed) The critical values of F distribution at 5% significance level are F(8 , 66) = 2.08, F(3 , 64) = 2.75 & F(2 , 66) = 3.14.

Table 2.B5. Bottom level results for Free Range, coefficients for the three sub-categories using exact price index

Dep var: share of expenditure on product		London	Midlands	North East	Yorkshire	Lancashire	South	Scotland	Anglia	Wales & West	South West
Small / Medium (Budget)	Constant	0.101 (0.255)	-0.011 (0.233)	0.091 (0.229)	-0.044 (0.299)	0.539 (0.340)	0.162 (0.205)	0.010 (0.228)	0.742 (0.206)	0.468 (0.238)	0.556 (0.296)
	Log (E / P)	-0.072 (0.045)	-0.037 (0.057)	0.038 (0.044)	-0.031 (0.073)	-0.038 (0.061)	-0.020 (0.046)	0.042 (0.063)	-0.119 (0.056)	-0.072 (0.049)	-0.135 (0.071)
	log (p_3)	-1.035 (0.279)	-0.955 (0.401)	-1.409 (0.115)	-1.012 (0.455)	0.094 (0.345)	-0.387 (0.228)	-0.269 (0.249)	-0.394 (0.275)	-0.308 (0.194)	-0.701 (0.569)
	log (p_4)	0.090 (0.102)	0.360 (0.402)	1.323 (0.115)	0.627 (0.481)	0.050 (0.000)	0.086 (0.302)	0.195 (0.000)	0.095 (0.000)	0.071 (0.000)	0.296 (0.593)
	log (p_5)	0.945 (0.279)	0.595 (0.206)	0.086 (0.000)	0.385 (0.370)	-0.144 (0.345)	0.300 (0.105)	0.074 (0.249)	0.299 (0.275)	0.237 (0.194)	0.405 (0.596)
Mixed / Medium(Branded) /Large	Constant	-0.222 (0.302)	0.560 (0.231)	0.401 (0.226)	0.452 (0.308)	-0.223 (0.335)	0.107 (0.222)	0.402 (0.226)	0.266 (0.205)	-0.166 (0.235)	0.305 (0.287)
	Log (E / P)	0.113 (0.043)	-0.064 (0.066)	-0.003 (0.041)	0.008 (0.073)	-0.057 (0.065)	-0.022 (0.046)	0.051 (0.054)	-0.089 (0.079)	0.089 (0.048)	0.021 (0.071)
	log (p_3)	0.090 (0.000)	0.360 (0.402)	1.323 (0.115)	0.627 (0.481)	0.050 (0.000)	0.086 (0.302)	0.195 (0.000)	0.095 (0.000)	0.071 (0.000)	0.296 (0.593)
	log (p_4)	-0.324 (0.536)	-1.034 (0.839)	-1.784 (0.133)	-1.259 (0.673)	-2.447 (0.740)	-1.316 (0.695)	-0.319 (0.241)	-1.125 (0.699)	-0.679 (0.270)	-0.552 (0.764)
	log (p_5)	0.234 (0.536)	0.674 (0.595)	0.461 (0.133)	0.632 (0.594)	2.397 (0.740)	1.230 (0.449)	0.124 (0.241)	1.030 (0.699)	0.608 (0.270)	0.256 (0.840)
Number of Iterations		5	5	5	5	5	4	5	6	5	6

Note: Numbers in ( ) are standard errors.

Table 2.B6. Middle level results for all ten regions

Dep var: log of category's quantity		London	Midlands	North East	Yorkshire	Lancashire	South	Scotland	Anglia	Wales & West	South West
Caged & Barn	Constant	1.421 (0.196)	2.149 (0.233)	1.264 (0.473)	1.944 (0.342)	1.616 (0.339)	2.064 (0.261)	1.821 (0.248)	2.057 (0.293)	1.481 (0.263)	1.580 (0.344)
	Log (Y_E)	1.083 (0.030)	0.986 (0.038)	1.152 (0.120)	1.029 (0.066)	1.075 (0.061)	0.998 (0.043)	1.042 (0.046)	1.002 (0.052)	1.089 (0.046)	1.158 (0.073)
	Log (P_C)	-1.100 (0.091)	-0.732 (0.114)	-1.262 (0.395)	-0.595 (0.200)	-1.082 (0.179)	-1.245 (0.127)	-0.686 (0.122)	-1.457 (0.143)	-1.285 (0.215)	-1.976 (0.401)
	log (P_F)	0.172 (0.101)	0.223 (0.151)	0.900 (0.453)	0.723 (0.242)	0.071 (0.234)	0.212 (0.150)	0.281 (0.132)	0.818 (0.171)	0.264 (0.288)	0.653 (0.410)
Free Range & Organic	Constant	1.502 (0.206)	0.751 (0.253)	2.039 (0.511)	0.824 (0.353)	1.230 (0.355)	0.943 (0.278)	1.334 (0.255)	1.577 (0.318)	1.501 (0.264)	1.662 (0.344)
	Log (Y_E)	0.906 (0.031)	1.008 (0.041)	0.730 (0.129)	1.003 (0.067)	0.929 (0.064)	0.987 (0.046)	0.912 (0.047)	0.878 (0.055)	0.902 (0.047)	0.772 (0.074)
	Log (P_C)	0.172 (0.101)	0.223 (0.151)	0.900 (0.453)	0.723 (0.242)	0.071 (0.234)	0.212 (0.150)	0.281 (0.132)	0.818 (0.171)	0.264 (0.288)	0.653 (0.410)
	log (P_F)	-1.966 (0.254)	-2.855 (0.376)	-3.460 (0.835)	-0.428 (0.432)	-1.021 (0.565)	-2.208 (0.351)	-1.703 (0.273)	-5.144 (0.479)	-2.222 (0.498)	-1.319 (0.591)
R^2		0.972	0.953	0.725	0.730	0.903	0.956	0.927	0.935	0.593	0.874
Adj – R^2		0.969	0.949	0.700	0.706	0.895	0.953	0.920	0.929	0.557	0.863
Joint significance, F stat (p-value)		31.04 (0.000)	18.29 (0.000)	2.38 (0.031)	2.45 (0.027)	8.47 (0.000)	19.91 (0.000)	11.43 (0.000)	12.98 (0.000)	1.32 (0.255)	6.27 (0.000)
Homotheticity Test; F stat (p-value)		8.23 (0.001)	0.08 (0.923)	2.77 (0.070)	0.10 (0.905)	1.33 (0.271)	0.04 (0.961)	2.17 (0.122)	2.45 (0.094)	4.05 (0.022)	7.04 (0.002)
Symmetry Test; F stat (p value)		0.86 (0.357)	0.18 (0.673)	0.01 (0.921)	0.29 (0.592)	1.15 (0.287)	0.78 (0.380)	1.02 (0.316)	0.34 (0.562)	0.02 (0.888)	1.16 (0.285)

Notes: Numbers in ( ) are standard errors; for F-test results numbers in ( ) are p-values. Each region's regression includes 37 observations. Y_E is the total on eggs in each region, P_C is the price index for caged / barn eggs in each month, P_F is the price for free-range / organic eggs in each month.

Chapter 3

The Market for Kidneys in Iran

3.1. Introduction

The most effective treatment for End-Stage Renal Disease (ESRD) is a kidney transplant (Renal Replacement Therapy: RRT). The only alternative treatment is dialysis and RRT is the only way for the patient to live without needing dialysis on a regular basis. Some researchers predict that the number of patient with ESRD will reach 2 million worldwide by 2010 (Nwankwo et al., 2005). In the US, it is predicted that more than 40% of patients may die while on the waiting list (Matas, 2006). Xue et al. (2001) predict that more than 95,000 patients will be on the waiting list for a kidney transplant by 2010; the figure was more than 65,000 in 2007.

There are two sources for a kidney transplant, cadaveric kidneys and kidneys from the live donors. Cadaveric kidneys can be harvested either from a brain-dead patient (whose heart is still beating) or cardiacally dead patient; the latter is considered to have a lower quality. Since a normal person can live on just one kidney, she can decide to donate one of her kidneys. The incentive to donate a kidney can be altruistic or obtaining money by selling a kidney. Altruistic kidney donation is mostly a case for emotionally related donors where the donor donates her kidney to either a relative or a close friend.

In order to match a kidney from a donor with a potential recipient, their ABO and RdH blood types as well as tissues should be compatible. The ABO matching should follow the same rules that should be considered for blood transfusion, although some programs are experimenting with ABO-incompatible transplantation (Gloor & Stegall, 2007). Regarding the tissue matching, a higher proportion of tissues matched between the donor and recipient will increase the probability of a successful transplantation.

It is well documented that RRT is cost effective treatment as compared to dialysis. For example the UK national health system (NHS) data reveals that the average cost of dialysis is £30,800 per year while the cost of kidney transplantation is £17,000 following by a £5,000 annual spend on the drugs. That means over a period of 10 year (the median graft survival time: the time that transplanted kidney survives in patient’s body), the average benefit of kidney transplantation, comparing to dialysis, is £241,000 per patient (UK Transplant, 2007).

In order to compare the cost of two alternatives for Iran (all data for 2008); the annual cost of hemodialysis for a patient is about Rials 47.0m[1]. The cost of a transplant operation[2] is about Rials 2.4m following by estimated Rials 40.0m annual expenditure on drugs[3]. That means from the cost of point of view the transplant is preferred and the average benefit over the 10 year period is Rials 67.6m. The higher ratio of drug costs over operation costs in Iran comparing to UK is the result of Iranian system depending on imported drugs.

It is worth mentioning, the above calculations (both for UK and Iran) are only the direct benefit of the transplantation by reducing the treatment costs. Three other factors may also be considered in the cost-benefit analysis i) the opportunity cost of the time,

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[1] By medical standards, every patients should receive thrice weekly dialysis (equivalent to 156 annual sessions), but the reported data in Iran shows that the mean annual sessions per patient is just 142. The tariff for every dialysis session is 92K ("K": medical K; which is determined by the ministry of health each year and for 2008 is Rials 3600). Then the dialysis cost will be 142×92×3600 ˜ 47.0m.

[2] Kidney transplantation tariff is 650K ("K": surgical K; for 2008 is Rials 3700). This value is regardless of kidney source and method of nephrectomy and includes all expenses from admission to discharge (both donor and recipient) except some special drugs that sometimes are used for patients with special conditions or in case of some complications. The costs of initial tests prior to donation or implantation are not included in this. Then the transplant cost will be 650×3700 ˜ 2.4m.

[3] Different immunosuppressive regimens are used for different recipients; therefore, to determine a unique cost is somehow difficult, however considering the governmental subsidy, which these drugs receive, Rials 40m is the estimation. Donors receive no drugs routinely; unless complications happen rarely.

patient spends to get dialysis treatment, ii) the improved quality of life for patient after receiving the transplant, and iii) the risk of death during the surgery for donor. Becker & Elias (2007) reports that based on several studies, the risk of death during surgery for donor is between 0.03% and 0.06%. Matas et al (2003) based on the data from the US transplant centres for period 1993 – 2001 reports the donor's death rate of around 0.03%.

It is also well known that kidneys from the live sources have a better quality as compared to the kidneys harvested from cadavers. Table 3.1 contains a summary of the statistics from US transplants which shows that the kidneys from live donors are more effective (NKUDIC, 2007). While the 10 year graft survival probability for live kidneys are 54.7%, the same figure for a cadaveric kidney is only 39.2%.[4] One issue that should be addressed here is the possibility that these data is affected by selection bias. In reality patients are not randomly matched to kidneys. Terminally ill patients are more likely to receive a cadaveric kidney which becomes available with lower degree of compatibility. On the other hand, patients on better conditions can wait a bit longer to receive a more compatible live donation. Then the cadaveric kidneys may show a lower graft survival not only because of its own condition but also because of the condition of recipients.

Table 3.1: Survival probability for different treatments

	1 year	2 years	5 years	10 years
Patient survival under dialysis	77.7%	62.6%	31.9%	10.0%
Patient survival following cadaveric transplant	94.3%	91.1%	81.2%	59.4%
Patient survival following live-donor transplant	98.2%	95.8%	90.5%	75.6%
Graft survival following cadaveric transplant	89.0%	83.3%	67.4%	39.2%
Graft survival following live-donor transplant	95.2%	91.4%	80.3%	54.7%

Source: NKUDIC (2007)

Harvesting kidneys has been a major concern for health systems all around the world in the last few decades. In order to increase the kidneys available from cadavers, two different systems adopted. The most popular one is the *opt-in system* where people, who wish to donate their organs after their death, sign up to the scheme. For example it is estimated that in the UK one in five people (more than 13 million) signed up to the scheme (Boseley, 2006). This voluntary scheme is run in many countries but usually the

[4] Based on the results of a study in 2001 in Iran (not published officially), the graft survival rate in different intervals for kidney transplants are as follow: 6 months: 90.8%, 12 months: 89.1%, 18 months: 88.2%, 24 months: 87.7%, 30 months: 87.2%, and 36 months: 85.9%.

donor's wish is not enough to guarantee that the donation will take place after the donor's death, since in many cases the consent of next of kin is also required, either by the law or informally. There are campaigns for encouraging organ donations in many countries. However, the shortfall of the number of organs available through this system in recent years is an issue; part of the problem is the decreasing number of deaths among younger people, whose organs are most suitable. For example it is claimed that one of the reasons behind the drop in the UK cadaveric kidney donation in recent years (table 3.2) is seat-belt legislation (Boseley, 2006).

The alternative system is the opt-out system which is practised in some European countries, including Spain and Austria. In this system, the donor's consent is presumed and a person needs to opt out the scheme if she does not want to donate her organs after death. UK also considered switching from opt-in system to this system, where it is under legal and political consideration (Wintour, 2008)[5]. One legitimate argument against this system is that presumed consent means that the state is considered the owner of the body of deceased person. Some consider this to be a problematic assumption (Becker & Elias, 2007). Abadie & Gay (2006) develop an economic model to investigate the effect of presumed consent on the donation rate, their model predicts that the opt-out system may have a positive or negative effect on the rate of donations comparing to opt-in system depending on the model assumptions, however, their empirical analysis for 22 countries over a 10-year period shows after controlling for other determinants, presumed consent legislation has a positive and significant effect on organ donation rates.

Another measure to boost the number of donations is an expansive legal definition of death, such as Spain uses, allowing physicians to declare a patient to be dead at an earlier stage, when the organs are still in good physical condition. This is controversial and has been mentioned as the main reason for individuals not wanting to participate in organ donation schemes. As a result of this procedure, putting extra effort and resources in procurement process, and the presumed consent system, Spain has one of the highest rates of cadaveric donations in Europe. (See Table 3.A1 in appendix 3.A) In summary the high rate of kidney donation in Spain is due to presumed consent policy, enhanced

[5] Recently the government committee has recommended against opt-out.

infrastructure for donation, expansive legal definition of death, and more road accidents. However there has been no study to estimate the contribution of each factor.

Table 3.2: The number of live and cadaveric kidney transplantation 1985 - 2006

Year	Iran			Spain			UK			US		
	Live	Cadaver	Total PMP*	Live	Cadaver	Total PMP	Live	Cadaver	Total PMP	Live	Cadaver	Total PMP
1985	16		0.3									
1986	98		1.6									
1987	158		2.5									
1988	247		4.0									
1989	401		6.4									
1990	498		7.9		1240	32.2	101	1726	31.9	2094	7322	37.3
1991	571		8.9	16	1355	35.5	88	1608	29.6	2394	7281	38.3
1992	689		10.7	15	1477	38.8	101	1622	30.1	2535	7203	38.5
1993	808	8	12.2	15	1473	38.6	142	1555	29.6	2850	8170	43.5
1994	718	2	11.0	20	1613	42.5	135	1588	30.1	3007	8383	44.1
1995	790	8	11.8	35	1765	46.8	155	1615	30.8	3221	8598	46.3
1996	743	12	11.3	22	1685	44.3	183	1499	29.3	3389	8560	46.7
1997	1078	4	16.3	20	1841	46.9	179	1487	29.1	3597	8577	47.7
1998	1193	2	17.8	19	1976	50.3	252	1330	26.8	4017	8938	50.7
1999	1214	14	18.3	17	2006	50.9	270	1311	26.8	4511	8016	49.5
2000	1389	32	20.5	19	1919	48.7	348	1323	28.3	5311	8087	52.5
2001	1550	70	24.0	31	1893	46.7	358	1333	28.7	5989	8212	49.8
2002	1585	96	24.5	34	1998	48.5	372	1286	28.1	6178	8508	50.9
2003	1474	167	23.9	60	2069	49.8	451	1246	28.7	6464	8665	52.0
2004	1563	207	26.0	61	2125	50.5	463	1367	30.8	6644	9349	54.5
2005	1721	209	27.4	88	2049	48.3	543	1197	29.5	6541	9827	55.3
2006	1615	243	26.4	102	2055	48.3	671	1240	31.7	6434	10659	57.3
2007	1600	311	27.1	137	2074	49.5	804	1207	33.5	6037	10587	54.7
Ave. annual growth rate (1996-06)	8.1%	35.1%		16.6%	2.0%		13.9%	-1.9%		6.6%	2.2%	
Ave. annual growth rate (2001-06)	0.8%	28.3%		26.9%	1.7%		13.4%	-1.4%		1.4%	5.4%	

* PMP: total number of organ donations per million population — Source: IRODaT (2009)

There is the argument of conflict of interest in medical teams who should either declare the death or try to save the badly injured patients. For example in US, in one case a medical official was accused of trying to end somebody's life in order to harvest their organs. In another case a doctor said she was under pressure by organ procurement team, to declare a patient dead sooner than medically advisable (Stein, 2007).[6]

If the donor is a close relative or emotionally related to the recipient, live donation is legal in most of the countries around the world. The sale of organs is forbidden in all countries except in Iran, which has a regulated system for selling kidneys. However, there is evidence of the abuse of the system in many other countries. Organ trafficking in India is an example where there are reports of removing the kidneys without donor's consent (Patel, 1996)[7]. Also, there are reports that patients from wealthy countries travel to poorer countries in order to buy a kidney (Boseley, 2006) which in some cases removed from donor's body without their knowledge (Patel, 1996).

In Iran a regulated system for kidney donation with monetary compensation was introduced in 1980s. Under this regime the donor receives a monetary compensation from the recipient and enjoys additional monetary and non-monetary bonuses from the government. The system has been criticised harshly (i.e. Harmon & Delmonico, 2006 and Zargooshi, 2001) as well as receiving some warm support (i.e. Daar, 2006 and Mahdavi-Mazdeh et al., 2008) both inside Iran and internationally. Ghods & Savaj (2006) is one of the most recent papers which tries to reason in support of the system by highlighting the benefits and answering some of the critics. Data show that in 2006 1858 kidney transplantation took place in Iran. 13% and 12% of these transplants were harvested from cadaveric and emotionally related live sources respectively and the other 75% was from unrelated live donations (Pondrom, 2008).

There has been no discussion on how the system works by economists. While there were a lot of discussion in medical journals on the Iranian system (for some of the most recent ones look at Ghods & Savaj (2006), Griffin (2007), and Mahdavi-Mazdeh et al. (2008)), the lack of publication in economics journals leads to misleading quotes in other researches. For example Becker & Elias (2007) mention that Iranian government opposes the cadaveric donation on religious grounds which in not true. On contrary, as figures in table 3.2 show the Iranian government tries hard to replace the live donation

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6 China has also been under pressure for selling the organs of executed individuals (Kram, 2001) where Chinese transplant centres openly advertise for business from foreigners (Boseley, 2006).

7 Kidney sale was legal in India in 1980s and early 1990s and then became illegal in mid 1990s.

with harvesting kidneys from cadavers and the number of other cadaveric organ donations is also growing fast (Pondrom, 2008).[8]

Another issue that should be addressed is the compatibility issue. There are two major considerations regarding the compatibility, blood type and tissues. Blood type of the donor and the recipient is needed to have the general compatibility rule for the blood types (which is being depicted in table 3.3). Even with medical achievements in recent years to overcome the compatibility issue still incompatibility raises the rejection probability in transplant. Finding an exact blood type match between recipient and donor significantly increases the possibility of success. Tissue matching is performed by testing whether a number of antigens (normally 6 antigens) are matched between recipient and donor. Higher number of matches in tissues also increases the chance of success in transplant.

Table 3.3: The compatibility rule for blood and organ donation

		Donor							
		O+	A+	B+	AB+	O-	A-	B-	AB-
Recipient	O+	↵				↵			
	A+	↵	↵			↵	↵		
	B+	↵		↵		↵		↵	
	AB+	↵	↵	↵	↵	↵	↵	↵	↵
	O-					↵			
	A-					↵	↵		
	B-					↵		↵	
	AB-					↵	↵	↵	↵

In this paper we try to establish clearly how the Iranian regulated system works, find facts using the data collected from one of procurement centres in Tehran, and explain the welfare effect of this market on all parties involved. Our finding shows the average waiting time in Iranian system is around 5 months. This can be considered a great success compared to average waiting time in other countries.

[8] Research grants are also allocated by the Iranian government for research on cloning in order to be used in organ procurement. There is no significant opposition from religious leaders or other social pressure groups, but it is very unlikely that these researches lead to a significant breakthrough for organ procurement in the next decade, not only in Iran but also worldwide (Ghods & Savaj, 2006).

Following we start with a brief review on the economics literature on organ donation in section 3.2. In section 3.3 and 3.4 we demonstrate Iran's case and present the data collected from one of the procurement centres. In section 3.5 a theoretical model will be introduced following by conclusion in section 3.6 which includes our findings and policy implications.

3.2. Literature Review

Economists have made contribution to the organ donation literature in two fields. First, the kidney market and issues associated with that. The other is designing a mechanism to resolve the compatibility issues where donor and recipient are selected.

3.2.1. Kidney Market

Discussion on buying and selling organs or parts of human body (including blood) can be done on four grounds: medical, moral, legal, and economic grounds. Top medical experts do not agree on whether the organ market can be implemented or should be banned.[9]

From the medical point of view, the evidence as presented in introduction shows that live donation is efficient and cost effective. Furthermore, if it is safe to be performed on an emotionally related donor, there should be no medical concern for a kidney market on the medical grounds. The only point would be to ensure the system puts the donor's welfare before the recipient's; the same rule which should be considered for an emotionally related pair.

We are not going to discuss moral issues surrounding the kidney sales in full details in this paper. Roth (2007) explains how the ethical and moral belief of majority of a society may affect the market as repugnance.

The legal discussions usually concentrate on answering the question of whether an individual has the right to sell one of her organs or not. For an economist, it might seems quite a reasonable assumption that one's body can be considered as their own property, but defining a property framework for the human body is one of the fresh lines of research in *medical ethics*. (i.e. Quigley, 2007)

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9 Some of the most recent arguments for and against the idea can be found respectively in Reese et al. (2006) and Danovitch & Leichtman (2006).

The early discussion on the economics of a market for human body parts goes back to 1970 when Titmuss argued that buying and selling blood has an adverse effect on the quality of the blood (Titmuss, 1997). Titmuss compares the data from the British system (where paying for the blood was illegal) with the American system (where blood donors got paid) and argues that the latter had a lower quality of denoted blood. Titmuss points out that a significant fraction of the American blood came from individuals with hepatitis and other diseases that could not be screened out, and the blood given under the British system tended to be healthier. Titmuss also argued that monetary compensation for donating blood might reduce the supply of blood donors. This hypothesis often referred to as *crowding out* effect. Titmuss predicts that people will give blood mainly for altruism and introducing money compensation into the system is going to diminish their incentives for blood donation.

Becker (2006) argues that even if Titmuss was right about the quality of the blood, the American system provides more blood per capita than British system. This means that the crowding out effect is not present. However, the quality of blood is not a major problem now, since the modern screening methods can guarantee the blood is not contaminated. In case of kidneys, one can argue that medical developments can determine the well-being of the donor and recipient. On the other hand, since kidney transplant is a more complicated and costly procedure comparing to blood transfusion, the initial test for the donor in order to assess the quality of the kidney, as well as the donor's safety and welfare, would be more justifiable.

Mellström & Johannesson (2008) ran a field experiment on the blood transfusion system in Sweden to examine whether the crowding out effect can be determined. They designed three treatments. In the first one, subjects are given the opportunity to become blood donors without any compensation. In the second treatment subjects receive monetary compensation (SEK 50 ~ $7), and in the last one subjects can choose to receive the payment or donating it to charity. Their experiment shows evidence for the crowding out effect only on some part of population (women) which will be eliminated if the monetary payment made to charity rather than the individual.

Cohen (1989), Epstein (1993), and Kaserman & Barnett (2002) discuss the monetary compensation for cadaveric organ donations but Becker & Elias (2007) are the first to calculate a price for live kidneys. They calculate a price of a kidney (and a liver) based on three monetary compensations i) compensation for the risk of death as a result of donation, ii) compensation for the time lost during recovery, and iii) compensation for the risk of reduced quality of life. They suggest a price of $15,200 for a kidney. They also point out that if the market for cadaveric kidneys established alongside the live kidney market, most kidneys will come from cadavers and live kidney prices works as a benchmark for the market equilibrium price for cadaveric kidneys.[10]

3.2.2. Kidney Exchange Mechanisms

One of the main restrictions for emotionally related organ donations is the compatibility issue, where the donor's kidney cannot be transplanted for their intended recipient. But it might be compatible with another patient who also has a non-compatible donor.

Roth et al. (2004) introduce a kidney exchange mechanism which efficiently and incentive compatibly, can increase the number of transplants within existing constraints. Their model resembles some of the housing problems studied in the mechanism design literature for indivisible goods (i.e. Shapley & Scarf, 1974 and Abdulkadiroglu & Sönmez, 1999). Modified versions of their model, in order to limit the number of simultaneous operations needed, with constraint on the maximum number of donor-patient pairs to two or three, has been developed in later papers (Roth et al., 2005b; Roth et al., 2007; and Saidman et al., 2006). Roth et al. (2005a) provides evidence from the experiment of opening a kidney clearinghouse in New England, US.

In an exceptional case a 6 way exchange performed in the US on April 2008 (BBC, 2008). However, because of practical issues (the exchange operations should be done simultaneously and most possibly at the same hospital) as well as incentive issues (where medical teams should work together and it is most likely doctors in small hospitals should refer almost all of their patients to other centres) the exchange mechanism cannot provide enough kidneys to overcome the shortage.

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[10] If Becker & Elias (2007) suggestion for paying for cadaveric kidneys and livers is going to be practiced; one issue, which should be addressed, is its effect on health costs of other transplantations from cadaveric sources, like hearts and corneas. Currently no payment has been made for harvesting these organs which under the new system it seems plausible to assume they should be priced as well. One argument can be since the demand for these organs are not as high as kidney and liver the equilibrium price will not be significantly high and the altruistic donation may be enough to cover the demand. However, this issue can be subject of a separate research.

3.3. Iran's Case

3.3.1. Background

The 1979 revolution in Iran was followed in 1980 by an eight year war with Iraq. Dialysis equipment was scarce because of economic sanctions and lack of funds for imports (Nobakht & Ghahramani, 2006). As a result of these events, nephrologists were encouraged to perform kidney transplants. At the beginning, the process relied on few cadaveric kidneys available, along with emotionally related donors. But the large number of patients on the waiting list forced the authorities to establish a regulated market for living unrelated donations. The efforts of charities, established and managed by dialysis patients and their close relatives, helped to develop the market. Table 3.2 shows a clear picture of the development of kidney transplantation in Iran. It is notable that over a period of 10 year (1996-2006) the rate of cadaveric and live donation increased by 35.1% and 8.1% annually. Cadaveric transplants accounted for 1.6% of total number of transplantation in 1996, this figure reached 13.1% in 2006.

3.3.2. Institutions

There are several bodies involved in kidney procurement for patients in need of a kidney transplant in Iran:

1) *Kidney Foundation of Iran* (or *Dialysis and Transplant Patients Association* (DATPA)) is a charity founded by some of kidney patients and their relatives about 20 years ago. The foundation is a non-governmental organisation and helps kidney patients with their problems. With 138 branches around the country, they help kidney patients with medical, financial, and other problems. In about 10 centres they have kidney donation offices. Their main and busiest office is located in Tehran. The foundation also has official support of the *Charity Foundation for Special Diseases*.

2) *Office of the Governor of Tehran* (Ostan-dari) has also an office for kidney donation which has limited activities comparing to the Kidney Foundation. There are similar offices in some other provinces located in the governors' headquarters.

3) *Management Centre for Transplantation and Special Diseases* which is part of the *Ministry of Health and Medical Education* and is responsible for cadaver transplant. This centre has different waiting lists for patients in need of various organs for transplantation and is the main (and only) centre involved in procurement of organs

from cadavers. The centre's database ran nationally. When cadaveric organs of a deceased patient become available, the centre allocates the organs (including kidneys) to transplant centres around the country considering different factors including distance and waiting time.

In summer 2007, there were around 1000 patients on their waiting list for kidney transplant. As it can be seen in table 3.2, in 2005 from 1854 kidney donation, 243 cases were from cadavers. That means around 13% of the kidneys come from cadaver sources. Religious and traditional views are a major barrier for cadaveric donations, however, in recent years the numbers of cadaveric of transplants is increasing. A scheme of donor registry (opt-in system) is designed and some individuals, especially young educated Iranians, have shown interest in signing to the scheme. But in practice the relatives of the dead person have veto power and they can overrule the original decision made by the person herself, as it is the case in many other countries with the opt-in system (Abadie & Gay, 2006).

3.3.3. How Does Unrelated Kidney Donation in Iran Work?[11]

The Kidney Foundation keeps waiting lists for kidney patients with different blood types in each of its procurement offices. There are eight different lists for different blood types (see table 3.3). A kidney patient, who wishes to be added to the waiting list, needs to present a letter from his doctor. Since the foundation does not run any initial tests on patients, some patients may enter the list when they are not medically ready for a transplant. This may cause unintended delays in the matching process. A patient should be at a certain stage of the kidney failure disease to be considered ready for the transplant; and his general physical conditions (for example strength or minimum weight) also play a significant part in increasing the probability of success in operation. A patient is given priority in the waiting list, if he either is medically in an emergency situation (as assessed by his doctor) or is a disabled soldier[12].

There is no centralised waiting list and each centre has its own waiting list. Patients are asked by foundation to book in their nearest centre but some patients enter several waiting lists (including the cadaveric waiting list) in order to minimise their waiting

[11] This section is based on our interviews with the foundation staff, other sources and some published papers.

[12] Mostly injured in the eight year war with Iraq (1980-88).

time. However, the centres coordinate with each other in case of imbalances (especially for emergency cases) of demand and supply for kidneys with a particular blood type.

Medical staff including the members of the transplantation team have no role in identifying potential donors. When a donor (aged between 22 and 35)[13] turns up to donate her kidney, she needs to provide certain documents; including a formal consent from either her spouse or her father (in case of un-married donors)[14]. After the initial official paperwork, she will be referred to a clinic for the initial medical tests. The foundation office in Tehran has its own clinic which is used in order to offer medical support for kidney patients. Using this clinic speeds up the initial process. These tests determine whether the potential donor has any sort of kidney problem as well as a simple blood test and whether her kidney has two renal arteries[15]. If the transplantation team suspected any possible harm to the donor either now or for the future, the donation will be cancelled. The costs of these tests, which are not high, have to be paid by the donor herself. Since the cost of these tests (estimated around Rials 50k) is not significantly high comparing to the monetary compensation, it does not seem to have an adverse effect on donors' decision.

After the donor passes the initial tests, the administrators contact the first patient in the same waiting list as the donor's blood type. In this stage the staff also has in their mind to match the physical build of the donor and the patient or at least make sure that they are not extremely different. This also raises the issue of finding a suitable match for child patients which is difficult. Matches cross different blood types are rare and they

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[13] The reason for the age cap is considered to be a higher chance of the graft survival. Some researches on live donation do not support that the lower the age of the donor has a significant relationship with higher graft survival period. For example El-Agroudy et al (2003) shows that the average age for the live donor when kidney survived for more than 15 years was 30 ± 8.6 while for the graft survival rate less than 15 years was 35 ± 10.7. Another research (El-Husseini et al., 2006) reports for a 10 year graft surviving period, these figures as 37.1 ± 9.4 and 36.2 ± 8.5 respectively. However, it always will be the case that any operation (like being a kidney donor) is considered with a substantial risk after an age threshold.

[14] In Absence of next of kin, to make sure the donor is aware of her action and its consequences, she will be referred to a chartered psychologist at the coroner's office for a psychic test.

[15] Most patients are not happy to have a kidney transplant from this type, since it reduces the chance of successful transplant. However, some researches show no difference regarding this (Makiyama et al., 2003).

try to match the blood type of the donor and the recipient. Since having the same blood type is going to increase the possibility of a successful transplant (comparing to alternative transplants between compatible blood types), usually the doctors also advise their patients to wait for an exact match.

If the patient who is on the top of the waiting list at the moment is not ready for the transplant at that moment, the next patient will be called, and so on, until a ready patient will be found. Then a meeting between the two parties is arranged (they are provided with a private area within the foundation building if they want to reach a private agreement) and they will be sent for tissue tests. If the tissue test gives the favourable result[16], a contract between the patient and the donor will be signed and they will be provided with a list of the transplant centres and doctors who perform surgery. When the patient and the donor are referred to transplant centre, a cheque from the patient will be kept at the centre to be paid to the donor after the transplant takes place. The guide price has been 25m Rials (≈ \$2660) until March 2007 for 3 years and at this time[17] it has been raised to 30m Rials (≈ \$3190).[18] This decision has been made because the foundation was worried of a decreasing trend in number of donors. In some cases, the recipient will agree to make an additional payment to the donor outside the system; it is not certain how common this practice is, but according to the foundation staff the amount of this payment is not usually big and is thought to be about 5m to 10m Rials (≈ \$530 to \$1060). The recipient also pays for the cost of tests, two operations, after surgery cares, and other associated costs (like accommodation and travel costs if the patient travels from another city). Insurance companies cover the medical costs of the transplant and the operations are also performed free of charge in state-owned hospitals.

In addition, the government pays a monetary gift to the donor for appreciation of her altruism (currently, 10m Rials), as well as automatic provision of one year free health insurance[19], and the opportunity to attend the annual appreciation event dedicated

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[16] According to administrators of the foundation less than 10% of the tests have a positive cross-match which effectively rules out transplantation. It should be noted that the more tissue matching factor leads to a higher probability of success.

[17] The Iranian new year starts at 20 March. The adjustment happened at the start on new year.

[18] The exchange rate for 20 Feb 2008: \$1 ≡ Rials 9410; £1 ≡ Rials 18400.

[19] Nobakht & Ghahramani (2006) claim that the donors are provided with a free life-long insurance which is in contrary with our findings, after interviews with the foundation staff.

to donors[20]. The *Charity Foundation for Special Diseases* also provides the donors with a free annual medical test and high level of support, in case that the donor develops kidney problems in the future, regardless of whether this is due to the transplant or not.

Emotionally related donors also enjoy these monetary and non-monetary bonuses as well as exemption of paying hospital costs, and it gives them a good incentive to register in the foundation offices.

The minimum monthly legal wage for 2007 was Rials 1,830k (later raised to 2,200k for 2008). The minimum payment of Rials 45m is around 2 years of minimum wage.[21]

The minimum current payment (45m Rials) by using PPP exchange rate[22] is equivalent to $14,000 which is interestingly close to Becker & Elias (2007) suggestion for the market value of a kidney at $15,200 for the US. In 1980s when the sale of kidney was legal in India, donors were paid $1,603. After making this illegal in 1990s the average payment dropped to $975 (Goyal et al., 2002). Based on this paper and other researches, Becker & Elias (2007) estimate that the equivalent cost of a kidney in Indian market to US dollar in 2005 is in region of $17,078 to $17,665. However, they even report a price of around 50,000 Rupees in 1980s which with their calculations will be equivalent to $81,510 in the US market for 2005.

The government decision to ease the process by legislation and monetary and non-monetary bonuses seems reasonable. The social negative effect of losing ESRD patients who are usually at working age and most possibly parents of underage children is quite significant. This decision is also justifiable on economic grounds, from the government and insurers point of view. A patient, who is going under constant dialysis, is going to spend a lot of time out of the job. Adding up to this opportunity cost, the financial burden for the dialysis on the patient, his family, social services, and the government

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[20] This event is an event to celebrate the altruism of family of cadaver organ donors as well as living kidney donors. Among the guests are also all the organ recipients. The events gather a very good publicity in media; usually to emphasis the importance of cadaveric donors.

[21] This figure is the minimum wage which is well below the minimum cost of living. The Iranian Central Bank reports the monthly average cost of living for a family of four to be Rials 8.7m for Tehran and Rials 6.64m for other urban areas. This makes the minimum compensation equivalent to 5.2 to 6.7 months of average cost of living in urban areas.

[22] For PPP exchange rate an average of indexes suggested by IMF, and World Bank is used.

and considering a higher probability of death while in the waiting list, having no option for live transplant; shows the high alternative cost for the society.

Advertising for kidney donors is banned. However, some patients manage to find donors from other informal channels in order to avoid the waiting list. The foundation handle these cases with due care and such cases need to be reviewed by the foundation managing director. However, since the bonus payment appreciation and other protections by the government are in place for donors, then any donation that takes place is registered in one of the foundation offices around the country. This includes most of donations from family members which recipient and donor do not involve in any financial transactions.

In order to prevent international kidney trade, the donor and recipient are required to have the same nationality. That means an Afghan patient, who is referred to the foundation, should wait until an Afghan donor with appropriate characteristics turns up. This is to avoid transplant tourism. Transplant tourism seems to be a problem in India (Patel, 1996). Another issue can be Iranian nationals residing abroad and travel to Iran to buy a kidney, which is allowed under current legislation.[23]

Although the insurance companies will not cover the donor's compensation, poor recipients can get help in order to provide the cost from different charities. The foundation staff also have an informal list of generous volunteers, who are eager to help poor patients financially.

By the foundation's procedure to keep 8 different waiting lists, if one assumes that the blood type distribution is the same between patients and potential donors then the waiting time would be fairly similar for all waiting lists, furthermore there will be no significant social benefit in matching between blood groups.

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[23] Official statistics show that around 1m refugees live in Iran mostly with Afghan and Iraqi origins (Some claim the actual figure is far more and in some stages over the past 20 years has even reached to around 3 million). Ghods and Savaj (2006) refer to a study on nationality of transplant recipients and kidney donors. From 1881 kidney transplants, 19 (1%) recipients were refugees, and 11 (0.6%) were other foreign nationals who received kidneys from living-related donors or from living-unrelated donors of the same nationality. Of 1881 recipients, 18 (0.9%) also were Iranian immigrants (residing abroad for years) who came and received kidneys from Iranian paid donors. The scale of transplant tourism is very small in Iran.

One of the concerns about employing the Iranian system would be the possible welfare effect on the minorities because of the different pattern of the blood type distribution in their blood types. Table 3.A2 shows the blood type distribution of blood donors in different provinces. This data shows only the geographical distribution of the blood donors and usually is biased in favour O and negative blood types, since usually blood transfusion centres encourage these types of blood types to be donated more. However, looking at these data one line of the fresh research in Iranian system would be to investigate the proportion of different ethnic and race minorities in the pool of kidney donors and recipients. Walter et al. (1991) summarises the result of few other researches in Iranian ethnic variability of blood type frequencies based on ABO alleles (Their finding can be found on table 3.A3). Since their divisions in Iran population is neither consistent (have some geographical division and some ethnic minorities) nor inclusive (do not show a clear picture of the whole country) their findings can be addressed as another source of concern for this issue. They specially point out that Assyrian, Armenians, Zoroastrians, Jews, Turkmans, and Arabs, all religious and ethnic minorities, show a significant different pattern of ABO frequencies, however, they report a significantly lower percentage of O alleles for all of these minority groups than the Iranian average.

There are two major papers which address the donors' satisfaction issue. Zargooshi (2001) surveys 300 of kidney donors. They donated between 6 to 132 months ago. He finds that the majority of donors either did not receive or did not attend follow-up visits. Many of them regretted their original decision. On contrary Malakoutian et al (2007) report a 91% satisfaction between living kidney donors. However, the latter survey is asked the donors at the point of discharge from hospital.

3.4. Data

Our data contains 598 transplantations recorded in Tehran office of the Kidney Foundation between April 2006 and December 2008. In fact, this is the number of patients who withdrew from the waiting list with a kidney transplant in these 21 months. Of these, 549 were live kidney donations of which 539 were traded kidney and 10 emotionally related donations. The remaining 49 transplantations took place with a cadaveric donation. In theory the waiting lists for live and cadaveric kidneys run independently; and the coverage of our data from cadaveric transplant is not complete.

While our data shows a 8.2% share for the cadaveric transplantations, which is slightly lower than around 13% on average from table 3.2. Having in mind that our data is only a subset of total transplants, this can be addressed by the number of patients who only sign in the cadaveric lists and not in the living waiting lists.

The number of traded kidneys only includes the matches that the recipient and the donor both were registered in Tehran office. Since for other matches were either patient or the donor are found by other offices they did not have a complete profile of both parties. The foundation office in Tehran does not have a computerised database at the moment, and the data was produced by going through the files of every individual match, that has been made.

We now demonstrate our findings from the data. It is clear that our finding can not be a good image of what is happening in terms of emotionally related donations, because of the small number of this type of donations in our sample.

Table 3.4 shows the ABO and RhD blood types distribution of recipients.

Table 3.4: The ABO and RhD blood types distribution of recipients

	Blood Type									
	O+	A+	B+	AB+	O-	A-	B-	AB-	**Total**	
Traded	150	165	110	38	27	34	10	5	**539**	90.1%
Non-Traded	3	2	2	1	0	1	1	0	**10**	1.7%
Cadaver	15	15	11	2	1	3	2	0	**49**	8.2%
Total	**168**	**182**	**123**	**41**	**28**	**38**	**13**	**5**	**598**	

In Order to check whether the traded kidneys are biased in favour of AB blood type and are disadvantageous for O type, table 3.5 demonstrates the ABO blood type distribution of recipients. Although the share of AB recipients is higher in traded cases but there is no significant difference for the share of O recipients in traded and cadaveric cases.

Table 3.5: The ABO blood type distribution of recipients

	Blood Type				
	O	A	B	AB	**Total**
Traded	32.8%	36.9%	22.3%	8.0%	**100%**
Non – Traded	30.0%	30.0%	30.0%	10.0%	**100%**
Cadaver	32.7%	36.7%	26.5%	4.1%	**100%**
Total	**32.8%**	**36.8%**	**22.7%**	**7.7%**	**100%**

Another concern could be discriminating against women in receiving kidneys. Traditionally in Iran, men are referred as breadwinner of the family. Although the sex pattern of labour force has been changed, but it is still biased towards a higher proportion of male workers. Since in this view, the economic value of a man is considered to be higher, one consequence in our argument can be a higher likelihood for a male patient receiving a kidney from traded sector. Table 3.6 shows the number and percentage of male and female recipients. The figures do not support any negative effect on female patients in our data.

Table 3.6: The sex of recipients of each type of kidney

	Male	Female	Total
Traded	350 (64.9%)	189 (35.1%)	539 (100.0%)
Non-Traded	5 (50.0%)	5 (50.0%)	10 (100.0%)
Cadaver	33 (67.3%)	16 (32.7%)	49 (100.0%)
Total	**388**	**210**	**598**

On the other hand the donors are mostly men (Table 3.7). This can be because of the two facts. Firstly, the ages between 22 and 35; when the donation is accepted; is the fertility age; and women are less likely to be considered as potential donors. Secondly, as we mentioned before since men are supposed as the main breadwinner of the family, it is more likely that they sell their kidneys in order to overcome financial difficulties. Female donors count for around 18% of traded kidneys in our data; it is in contrary with the Indian case where 71% of the sold kidneys were from female donors (Goyal et al. 2002).[24]

Table 3.7: The sex of donors of each type of kidney

	Male	Female	Total
Traded	446	93	539
Non-Traded	4	6	10
Total	**450**	**99**	**549**

Table 3.8 demonstrates the age distribution of recipients and donors of traded kidneys. It shows that 10.9% of the recipients are under the age of 20. Finding kidneys

[24] Indian data needs to be treated very carefully, since the kidney sale is illegal. However, the difference between two figures is quite significant.

for child patients is one of their main problems. The kidneys for these children should be small in size, and usually women donors are the best to match for these patients. The high number of transplants needed for relatively young patients (42.9% under the age of 40 and 65.3% under the age of 50), shows the economic and social value of these transplants. Although the foundation's policy is to limit the donors' age to 35, 10.4% of the donors are older than 35.

The joint blood type distribution of recipients and donors can be seen at table 3.9. On average 94.8% of kidneys are matched to an exact blood type. In total 28 cases out of 539 are matches between different blood types. The reason behind this can be emergency cases, matches found by patients themselves out of the formal system, and especial cases (like children recipients when the size of kidney plays an important rule).

Table 3.8: Age distribution of recipients and donors

Age	Recipients		Donors	
5 – 9	12	2.2%		
10 – 14	19	3.5%		
15 – 19	28	5.2%		
20 – 24	36	6.7%	148	27.5%
25 – 29	50	9.3%	216	40.1%
30 – 34	42	7.8%	119	22.1%
35 – 39	44	8.2%	51	9.5%
40 – 44	59	10.9%	5	0.9%
45 – 49	62	11.5%		
50 – 54	58	10.8%		
55 – 59	65	12.1%		
60 – 64	40	7.4%		
65 – 69	16	3.0%		
70 – 74	7	1.3%		
75 – 79	1	0.2%		
Total	**539**	**100.0%**	**539**	**100.0%**

Table 3.9: Joint ABO and RdH frequency of transplants for recipients and donors

		Donor									
		O+	A+	B+	AB+	O-	A-	B-	AB-	**Total**	
Recipient	O+	149				1				**150**	27.8%
	A+	2	163							**165**	30.6%
	B+	4		104				2		**110**	20.4%
	AB+		1	1	36					**38**	7.1%
	O-	7				20				**27**	5.0%
	A-	1	4			3	26			**34**	6.3%
	B-							10		**10**	1.9%
	AB-				2				3	**5**	0.9%
Total		**163**	**168**	**105**	**38**	**24**	**26**	**12**	**3**	**539**	100.0%
		30.2%	31.2%	19.5%	7.1%	4.5%	4.8%	2.2%	0.6%	100.0%	
Own type		91.4%	97.0%	99.0%	94.7%	83.3%	100.0%	83.3%	100.0%	94.8%	

The average waiting time for patients who receive a live kidney is 149 days (Table 3.10). By waiting time, we mean the time gap between signing into the waiting list and the operation date. This includes the time needed for the tests and preparation before the transplant when a match initially introduced.

Assuming a similar distribution in donors and recipients population over the blood types, waiting time is expected to be the same for all waiting lists. However, the waiting time for a given waiting list is going to be affected by the following:

- Not enough donors from that blood type turn up comparing to other blood types; it can be serious when one blood type is rare; like AB- for the Iranian population.
- When kidneys from a blood group is offered to other matching blood groups. In our data, type O+ recipient is likely to be slightly affected by this, as the waiting time for them 171 days (22 days more than the average). 8.6% of this type of kidney is allocated to other blood groups.
- When a patient enters before he is medically ready for the transplant; we cannot check for this in our data.
- When a mismatch arises in testing procedure which means a 2-4 weeks is added to waiting time of the next recipient of this kidney. However, we can assume this has a similar effect on all waiting lists.

- As mentioned before the guideline price increased by 20% on March 2007. But our data shows no significant change in the waiting time or the number of donation. It could because of two reasons; firstly this increase has almost no significant effect in real term because of inflation[25]. In fact considering the inflation the official level of payment has been decreased over the 3 years when it has been capped prior to March 2007. Secondly the price that actually paid in each case can be different from this benchmark by two parties' negotiation process and it can also make that increase less significant.

Table 3.10: Average waiting time for recipients based on the blood type of both parties

		Donor								
		O+	A+	B+	AB+	O-	A-	B-	AB-	**Average**
Recipient	O+	169				461				**171**
	A+	110	138							**137**
	B+	85		138				214		**138**
	AB+		104	32	128					**125**
	O-	163				117				**129**
	A-	92	205			249	177			**184**
	B-							124		**124**
	AB-				218				144	**174**
Average		**163**	**165**	**139**	**137**	**133**	**148**	**177**	**139**	**144**

Considering all of the mentioned factors, having a waiting list of around 5 months in Iranian system comparing to more than 3 years for some other countries seems a significant achievement. One question that may arise (also by looking at tables 3.2 and 3.A1) is that the overall rate of kidney transplantation in Iran is not particularly higher than its European and north American counterparts, then why the Iranian waiting lists is much shorter. The fact is that the rate of ESRD patients in Iranian population is lower as well. One of the main reasons behind this can be the Iranian population structure, in 2006 (latest census) 60.5% are below 30 and 86.1% are below 50 years old (SCI, 2007). It is estimated that in 2005, 1505 per million population (pmp) in North America, 585 pmp in Europe, and 370 pmp in Iran suffered from ESRD. (Grassmann et al., 2005)

Following, we list the possible policy considerations:

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25 The reported rate inflation for 2006-07 is 18.4%.

- Since the donors might be subject to exploitation because of their social status; it needs to be guaranteed that they make an informed decision and are aware of all risks attached to their decision.
- After donation networks needs to be strengthened in order to make sure the donors receive the best support possible.
- Considering the Iranian population structure, it is expected that the demand might rise for kidneys in coming years and decades. Then, more efforts need to be put on other sources of kidneys. Cadaveric kidneys can be utilised more effectively. Unlike some developed countries, Iran faces no social barrier in new frontiers in medical research, e.g. cloning. Investing in this area may help to eliminate the demand for live donation in the future.
- A national waiting list can reduce the waiting time as well as improving pre- and post- surgery support for both donors and recipients.

3.5. Model

Suppose we have a continuum population with the total mass normalised to one. Let there be two blood types X and Y, with shares of a and $1\text{-}a$ of the population respectively. The probability of a person being in need of a kidney is r regardless of her blood type, however a shock of d is considered for demand of type X kidneys; which can be positive or negative.[26] We assume that the demand for each type of kidney can be written as:

$$q_X^D = (1+d)ra\ g(P_X) \qquad \text{and} \qquad q_Y^D = r(1-a)\ g(P_Y) \qquad (3.1)$$

$$\text{where} \qquad 0 < a < 1\ ;$$

$$0 \text{ £ } r << 1 \quad ; \quad -1 \text{ £ } d << 1/r - 1\ ;$$

$$g' < 0 \quad ; \text{and} \quad g(0) = 1$$

[26] The shock is only considered for type X kidneys. From the overall welfare point of view analysis of a positive (negative) shock to demand for type Y kidney is equivalent to a negative (positive) shock to type X. However, the effect in welfare on each market can be different which is not important for our discussion here.

Assume that type X kidney cannot be donated to type Y, but type Y kidneys can be donated to type X recipients. Suppose the income distribution is independent of blood types, so the supply has the same functional form for both types. Then the supplies can be written as:

$$q_X^S = a \; f(P_X) \qquad \text{and} \qquad q_Y^S = (1-a) \; f(P_Y) \tag{3.2}$$

$$\text{where} \quad f' > 0$$

In the absence of the shock ($d = 0$), the equilibrium price for both markets is the same $f(\hat{P}) = r\,g(\hat{P})$.

We assume that the regulator observes all the parameters of the market except the shock. Furthermore the regulator is able to allocate the kidneys efficiently. That means even if the market price is less than market clearing price, patients with the highest priority (highest willingness to pay) will receive kidney and the maximum feasible consumer surplus will be achieved. The regulator sets a uniform price for both markets. This price is equal to the market clearing price in the absence of the shock. The regulator is now faced with the problem whether to allow trade between the markets or not.

Negative shock ($d < 0$*):*

At the price set by the regulator ($\hat{P}$) there is now excess supply of type X kidneys. Since type Y cannot receive type X kidneys, the equilibrium in the Y market remains unchanged. In the X market the quantity reduces. Figure 3.1 shows this situation where D and D' are the original demand and demand in presence of a negative shock, respectively. Allowing the intra-trade is making no difference on the outcome and social welfare in this case. However, since the regulatory price is now higher than the market-clearing price, total welfare is reduced. The highlighted area in figure 3.1 shows this loss.

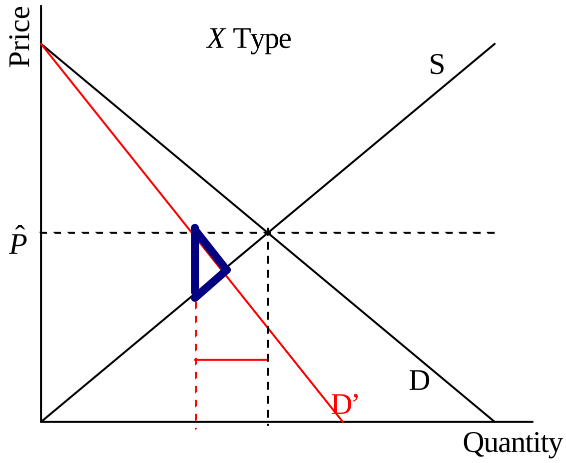

Figure 3.1: Demand and supply in *X* type markets in presence of a negative shock to demand for *X*

Positive shock ($d > 0$):

At the price set by the regulator $\hat{P}$ there is now excess demand for type *X* kidneys. If intra-trade between the two markets is allowed, some of type *Y* kidneys will be sold in type *X* market. In order to achieve the maximum welfare in this case some of the *Y* kidneys should be allocated to *X* patients. *Y* kidneys should be allocated to *X* recipients until the marginal willingness became the same in both markets (dashed red line in figure 3.2). Figure 3.2 compares the gain and loss in consumer surplus in *X* and *Y* market. The graph to the left demonstrates type *X* market where D and D' representing demand in absence and presence of a shock respectively. The right graph presents the case for type *Y*. The two arrows show the welfare-improving shift in supply after a positive shock to demand for *X*. The two marked areas shows the gain and loss resulted by intra-trade.

Allowing the intra-trade has no effect on the supplier surplus. The consumer surplus gained by type *X* patients overweighs the loss in type *Y* patients' consumer surplus. Overall patients' welfare improves as a result of intra-trade in case of a positive shock to demand for *X*.

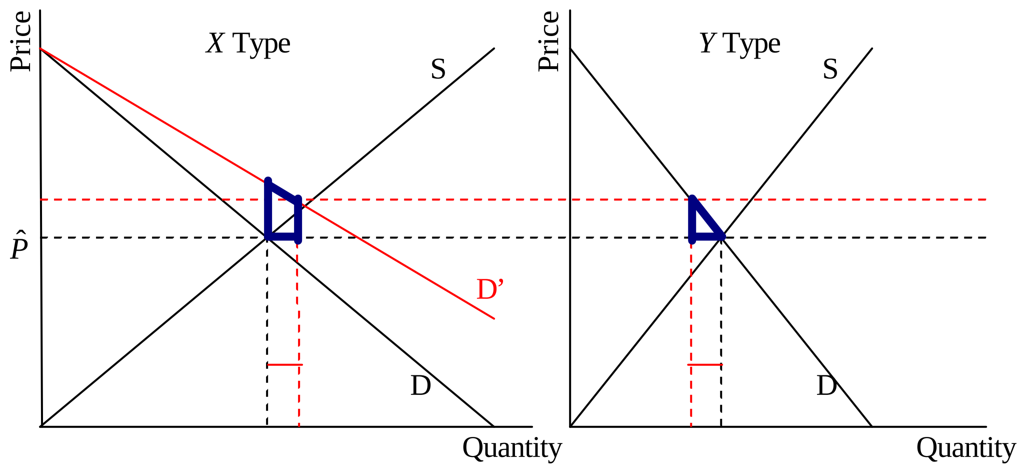

Figure 3.2: Demand and supply in two blood-type markets in presence of a positive shock to demand for *X*

It is worth mentioning even if the regulator sets a price different from the equilibrium price; still this welfare analysis is true. In presence of a positive shock to demand for *X*, Whatever the price set by the government, allowing intra-trade reduces the consumer surplus for type *Y* and consumer surplus for type *X* increases. The latter always dominates and the outcome is a higher social welfare resulted by intra-trade.

3.6. Summary and Conclusion

In this paper, we investigate how the Iranian kidney market works. Our focus was not on the moral and ethical issues surrounding the discussions. The effect of the Iranian system on reducing the waiting time for patients is significant, which based on our data it is around 5 months. One should be careful in advising to ban the sale at all. The alternative solution practiced in other developing countries, e.g. black market for organs, might have dramatic consequences. This may result lower standards on medical conditions, as well as leaving the donors who can be vulnerable without any official support.

We showed that allowing intra-trade between different blood types although has a negative effect on the welfare of some patients, but is going to improve the social welfare.

Appendix 3.A

Table 3.A1: Number of kidney transplants per million population for some countries in 2006

PMP (per million people)

Country	Live	Cad.	Total	Country	Live	Cad.	Total
Cyprus	54.3	11.4	65.7	Poland	0.5	23.5	24.0
US	21.6	35.7	57.3	Slovenia	0.0	24.0	24.0
Austria	7.0	41.5	48.5	Argentina	4.9	16.7	21.6
Spain	2.3	46.0	48.3	Israel	7.7	12.4	20.1
Norway	17.1	28.1	45.2	New Zealand	11.3	8.4	19.7
Belgium	4.0	40.6	44.6	South Korea	14.1	4.9	19.0
Uruguay	2.5	41.8	44.3	Greece	5.7	13.1	18.8
France	4.0	38.0	42.0	Puerto Rico	3.5	15.3	18.8
Malta	10.0	30.0	40.0	Mexico	13.7	4.6	18.3
Netherland	17.1	22.1	39.2	Lebanon	16.0	2.0	18.0
Finland	0.6	38.3	38.9	Brazil	9.6	8.2	17.8
Portugal	3.8	33.2	37.0	Lithuania	1.8	15.9	17.7
Canada	15.0	21.5	36.5	Colombia	1.9	13.4	15.3
Czech Rep.	3.2	33.1	36.3	Pakistan	15.1	0.0	15.1
Switzerland	15.7	19.9	35.6	Estonia	0.7	13.4	14.1
Ireland	1.0	32.4	33.4	Turkey	10.1	4.0	14.1
Denmark	10.7	22.1	32.8	Brunei	13.4	0.0	13.4
Latvia	0.0	32.6	32.6	Cuba	0.7	9.9	10.6
Germany	6.3	25.8	32.1	Romania	7.9	1.9	9.8
UK	11.2	20.6	31.8	Hong Kong	1.9	7.6	9.5
Hungry	1.3	29.6	30.9	Qatar	2.6	4.0	6.6
Jordan	30.5	0.0	30.5	Guatemala	6.0	0.4	6.4
Australia	13.3	16.0	29.3	Trinidad & Tobago	6.2	0.0	6.2
Italy	1.5	27.6	29.1	South Africa	2.1	3.0	5.1
Iran	23.0	3.4	26.4	Bulgaria	0.3	4.6	4.9
Iceland	26.0	0.0	26.0	Ukraine	1.4	1.1	2.5
Slovak Rep.	5.4	20.4	25.8	Malaysia	0.9	1.0	1.9
Saudi Arabia	9.3	16.4	25.7	Gerogia	1.8	0.0	1.8
Croatia	4.5	20.3	24.8	Moldova	0.6	0.0	0.6

Source: IRODaT (2008)

Table 3.A2: The ABO and RdH blood type distribution of Iran provinces *

	ABO				RdH		
	O	A	B	AB	+	-	
Azarbayejan Gharbi	37.4%	20.9%	32.9%	8.8%	90.2%	9.8%	**1.62%**
Azarbayejan Sharghi	37.3%	20.9%	33.9%	7.9%	88.6%	11.4%	**7.08%**
Booshehr	27.2%	27.2%	40.1%	5.4%	92.5%	7.5%	**0.10%**
Chahar Mahal & Bakhtiari	32.1%	19.5%	43.9%	4.5%	88.8%	11.2%	**0.32%**
Fars	28.8%	24.9%	39.0%	7.2%	90.4%	9.6%	**2.02%**
Gilan	30.5%	22.1%	41.0%	6.4%	89.2%	10.8%	**4.90%**
Hamedan	32.9%	23.7%	35.8%	7.6%	91.0%	9.0%	**3.85%**
Hormozgan	19.9%	28.1%	46.2%	5.8%	91.8%	8.2%	**0.06%**
Ilam	37.3%	23.6%	32.3%	6.8%	91.6%	8.4%	**0.09%**
Isfahan	32.9%	22.9%	37.4%	6.9%	89.5%	10.5%	**4.77%**
Kermanshah	32.2%	23.8%	36.2%	7.8%	91.0%	9.0%	**1.72%**
Kerman	27.0%	28.5%	37.1%	7.4%	89.0%	11.0%	**1.15%**
Khoozestan	29.7%	24.9%	38.8%	6.6%	91.2%	8.8%	**2.44%**
Khorasan	29.9%	26.8%	35.0%	8.2%	89.5%	10.5%	**4.37%**
Kohkilooyeh & Boyer Ahmad	31.9%	13.3%	50.4%	4.4%	88.5%	11.5%	**0.04%**
Kurdestan	31.6%	24.6%	36.5%	7.3%	90.9%	9.1%	**0.75%**
Lorestan	34.1%	21.6%	37.6%	6.7%	91.9%	8.1%	**1.28%**
Markazi	31.8%	24.0%	36.9%	7.3%	89.2%	10.8%	**8.74%**
Mazandaran	29.0%	24.8%	39.2%	7.0%	90.1%	9.9%	**5.08%**
Semnan	30.6%	25.8%	34.5%	9.0%	89.4%	10.6%	**3.63%**
Sistan & Baloochestan	26.5%	28.7%	38.4%	6.4%	89.4%	10.6%	**0.19%**
Tehran	32.4%	23.5%	35.9%	8.2%	89.6%	10.4%	**43.29%**
Yazd	26.7%	32.4%	31.0%	9.9%	87.2%	12.8%	**1.33%**
Zanjan	34.0%	21.8%	35.9%	8.3%	90.2%	9.8%	**1.20%**
Iran	**32.1%**	**23.7%**	**36.4%**	**7.8%**	**89.6%**	**10.4%**	

* The data is arranged based on an older version of national divisions which currently is changed and consist of 30 provinces.

Source: IBTO (2000)

Table 3.A3: ABO allele frequencies in 21 Iranian population groups

	p (A)	q (B)	r (O)
Tehranis	22.74%	16.85%	60.41%
Gilanis	20.54%	15.43%	64.03%
Mazandaranis	20.02%	17.35%	62.63%
Azaris	25.06%	16.16%	58.78%
Kurds	22.48%	17.10%	60.42%
Lurs	22.05%	14.55%	63.40%
Khorasanis	20.61%	18.10%	61.29%
Isfahanis	21.91%	16.87%	61.22%
Farsis	19.76%	16.91%	63.33%
Yazdis	20.21%	24.20%	55.59%
Kermanis	21.48%	16.89%	61.63%
Baluchis	18.59%	19.15%	62.26%
Bandaris	15.70%	18.05%	66.25%
Khoozestanis	19.44%	17.17%	63.39%
Turkomans	21.12%	24.81%	54.07%
Ghashghaais	20.07%	14.30%	65.63%
Arabs	17.23%	22.34%	60.43%
Assyrians	37.06%	11.69%	51.25%
Armenians	37.78%	10.92%	51.30%
Zoroastrians	16.38%	29.94%	53.68%
Jews	26.63%	18.56%	54.81%
Total	**22.23%**	**16.95%**	**60.82%**

Source: Walter et al. (1991)

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