TESIS DOCTORAL

Determinación de la Estructura del Mercado y de las Características del Producto: Tres Ensayos

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A mi Familia

Prefacio

Elaborar la lista de agradecimientos ha sido una de las tareas más placenteras de la realización de esta tesis. Al hacerla me he dado cuenta del gran número de personas que ha contribuido a que esta tesis llegase a ser una realidad, y que ha influido, en mayor o menor grado, en la forma y contenido que presenta hoy.

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Iván José Barreda Tarrazona

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Contenido

Capítulo 1

Determinación de la Estructura del Mercado y de las Características del Producto: Tres Ensayos

1.1 Introducción

Esta tesis es la culminación de mis estudios en el Doctorado en Economía Internacional e Industrial del Departamento de Economía de la Universitat Jaume I de Castellón. En consonancia con el proceso de especialización que viene sufriendo la disciplina económica en las últimas épocas, yo me he decantado por la Economía Industrial.

En la elaboración de esta tesis nos[1] hemos marcado como objetivo que los distintos trabajos que en ella se presentan sean potencialmente publicables (es decir, susceptibles de ser enviados a revistas para su evaluación) sin necesidad de transformaciones importantes. Es por ello que hemos seguido criterios de publicabilidad para decidir qué incluir en el documento de la tesis y qué dejar en nuestros papeles de trabajo. También es esta la razón de que, aparte de este primer capítulo, la tesis esté escrita en inglés. En lugar de

[1]A lo largo de la tesis sólo hablaré en primera persona del singular en algunos puntos de esta introducción, donde me corresponde hacerlo, en el resto, como reflejo del trabajo en conjunto realizado por mi director y yo, todo aparece expresado en primera persona del plural.

hacer aparecer hasta el último cálculo y hasta el último dato, y hacer una presentación exhaustiva de la literatura previa, sólo hemos incluido aquello que considerábamos imprescindible, o al menos, muy interesante, para que un lector (economista) pueda seguir los razonamientos que aquí se presentan. Este lector debería considerar que tiene entre sus manos un documento que pretende ser un libro monográfico de recopilación de tres artículos originales de investigación sobre un tema, llevados a cabo por el mismo equipo de investigación, que pueden ser leídos independientemente uno de otro, y no una obra magna en la que se recopila todo el saber acumulado sobre la cuestión y se propone una extensión.

El más claro punto de unión de la tesis es su objeto de estudio: los mercados de productos horizontalmente diferenciados bajo competencia imperfecta.

El término diferenciación horizontal hace referencia al hecho de que, si dos productos se ofrecieran a la venta al mismo precio, encontraríamos algunos consumidores dispuestos a comprar cualquiera de ellos, es decir, no existiría unanimidad en cuanto a cuál es la variedad preferida.

El enfoque de competencia imperfecta asume que, al menos algunos de los agentes que intervienen en el mercado, son conscientes de que pueden influir en el precio que se establezca en el mismo mediante su comportamiento, pero tienen también en cuenta que el comportamiento de los demás agentes va a interactuar estratégicamente con el suyo. Además, la competencia no se va a ver limitada a los precios, sino que el grado de diferenciación de los productos, u otras variables estratégicas, van a ser cruciales para la determinación de los resultados que a posteriori obtendrán los participantes en el mercado.

El planteamiento adoptado para la realización de esta tesis es teórico-empírico. Claro que a economistas que hacen estudios empíricos en otras ramas de la economía les puede parecer que la economía experimental no es lo que ellos entienden por trabajo empírico. Sin embargo, la diferencia fundamental radica en que en lugar de buscar los datos en bases de datos, periódicos, y publicaciones diversas, enviar cuestionarios, ... , en economía experimental, los datos se obtienen realizando sesiones experimentales con personas. Una vez obtenidos los datos, su análisis es muy similar al que se haría en otros campos.

La metodología utilizada para los tres ensayos de esta tesis es la que viene empleándose en los últimos años en la Economía Industrial.

En la parte teórica del trabajo, fundamentalmente en los Capítulos 2 y 4, para construir los modelos, y resolverlos, se utilizan las herramientas que proporciona la Teoría de Juegos no cooperativos.

En la parte empírica del trabajo, en concreto en el segundo ensayo (Capítulo 3), utilizamos la metodología de la Economía Experimental[2]. Esta es una línea de trabajo relativamente nueva y que hace poco que empezó a recibir un reconocimiento y aceptación amplios, aunque Maschler, Nash, Schelling, Shubik y Selten ya realizaron trabajos experimentales en los años cincuenta y sesenta.

1.2 Estructura de la Tesis

La organización de la tesis refleja el enfoque de tres ensayos de investigación distintos que hemos adoptado.

En el primer ensayo, que presentamos en el Capítulo 2, estudiamos la actuación óptima de las autoridades de política de la competencia frente a distintos tipos de restricciones verticales en la distribución que pueden convenir a un fabricante monopolista. En el segundo ensayo, que constituye el Capítulo 3, presentamos un modelo de diferenciación horizontal de producto de corte clásico y hacemos un estudio experimental sobre el mismo para contrastarlo. En el tercer ensayo, Capítulo 4, proponemos un modelo de competencia monopolística que permite estudiar la intervención pública óptima en este tipo de mercados, considerando distintos pesos en la función de coste social, costes de entrada endógenos, inversión pública en infraestructuras, y regiones con distintas características.

1.2.1 Regulating Vertical Relations in the presence of Retailer Differentiation Costs

En este primer ensayo, hemos pretendido ofrecer una herramienta útil para el análisis a realizar por parte de las autoridades de política de la competencia sobre los efectos en el bienestar social de distintos tipos de acuerdos de distribución (relaciones verticales) que el fabricante de un producto horizontalmente diferenciado puede tratar de imponer a sus distribuidores, independientemente del efecto que estos acuerdos tengan en la competencia entre marcas, que es el criterio habitualmente utilizado para juzgar estos casos.

[2]También hemos utilizado el estudio de casos reales de política de la competencia en el Capítulo 2, pero sólo a modo de ilustración de posibilidades de aplicación de nuestro modelo, no como lo haría un jurista.

Elementos innovadores de nuestro análisis son la representación de la variedad producida por el fabricante en el mismo espacio en el que representamos las variedades distribuidas por los detallistas, y la introducción del concepto de costes de diferenciación horizontal del producto, entendidos como unos costes en los que deben incurrir los detallistas para vender una variedad distinta de la que les proporciona el fabricante.

La conclusión que obtenemos de nuestro estudio teórico es que la intervención de las autoridades de política de la competencia, en pro de la misma, estarían justificadas desde el punto de vista del aumento del bienestar social en el momento presente y para los agentes implicados en el mercado, cuando se establecen sistemas de distribución que imponen a los detallistas el mantenimiento de territorios exclusivos, el mantenimiento del precio de reventa, o que otorgan el monopolio a un solo detallista. Mientras que, si los costes de diferenciación del producto tienen cierta importancia en relación a los costes de transporte, las autoridades deberían permitir sistemas de distribución como las franquicias, o las subsidiarias, aunque estos restrinjan la competencia dentro de la marca, incluso en ausencia de competencia entre marcas.

Este ensayo, en su estado actual, invita por un lado a la consideración de la competencia entre marcas en el modelo, es decir, a la inclusión de un segundo fabricante. Esto requeriría cambios bastante importantes en el modelo y probablemente nos pondría delante de discontinuidades que harían el problema muy poco tratable. Otro punto de extensión interesante sería el diseño de algún estudio empírico para identificar la relación entre costes de diferenciación y de transporte en casos reales.

1.2.2 Experiments on Location and Pricing

En este segundo ensayo, nuestra intención ha sido construir un test empírico para un modelo de diferenciación horizontal de producto basado en el modelo clásico de Hotelling (1929). El resultado de este test no sirve para confirmar o rechazar el modelo, o aquellos similares, sino que su utilidad es la de aportar ideas que permitan mejorar el modelo, incorporando aspectos previamente omitidos y que, a la luz del experimento, se revelan importantes.

El uso de los métodos experimentales para el estudio de la diferenciación horizontal de producto resulta aún bastante novedoso[3]. Y es completamente

[3]Véase Brown-Kruse y Schenk (2000), y Collins y Sherstyuk (2000).

original el diseño de un experimento en que las variables de decisión sean tanto el precio como la variedad a vender.

Nuestra conclusión en este tercer capítulo es que la racionalidad de los agentes, que supone el razonamiento en términos de equilibrio de Nash perfecto en subjuegos, no es suficiente para describir el comportamiento de las personas en nuestro entorno experimental. Posibles cuestiones a tener en cuenta para el enriquecimiento de los modelos teóricos de diferenciación horizontal de producto, de la misma clase que el nuestro, serían las dificultades de coordinación o selección del equilibrio, las dificultades de aprendizaje, y sobre todo, la aversión al riesgo de los agentes.

La continuación de nuestro trabajo en esta línea está pendiente únicamente de la obtención de los fondos necesarios para ello. Tenemos la intención de añadir varios tratamientos que podrían resultar interesantes para tratar de identificar mejor las causas de nuestros resultados empíricos, aunque no esperamos resultados muy distintos a los ya obtenidos.

1.2.3 Optimal State Intervention in Monopolistically Competitive Markets

En el tercer ensayo, nuestro objetivo ha sido construir un modelo de competencia monopolística que ponga de manifiesto la subjetividad de las conclusiones sobre el bienestar realizadas en base a pesos implícitos ignorados de los distintos componentes del coste social, y la inefectividad de la intervención estatal mediante la regulación de la entrada de empresas en el mercado cuando los costes de entrada dejan de ser un coste fijo para convertirse en una variable estratégica. También hemos pretendido ofrecer resultados susceptibles de contrastación empírica para el caso de inversión en la infraestructura de dos regiones distintas.

En el trabajo presentado en el cuarto capítulo resulta original tanto el hecho de considerar explícitamente los pesos de los distintos componentes del coste en la función de coste social, como la consideración de la inversión en infraestructura como un 'sunk cost' endógeno; de parte *de las empresas y el estado.*

Una de las conclusiones que obtenemos en el cuarto capítulo es que, en función de los pesos que asignemos a los distintos componentes del coste en la función de coste social, el conocido resultado de proliferación de marcas en competencia monopolística se produce o no. Y más importante, mostramos que la intervención estatal mediante el control de la entrada resulta inútil en términos de mejorar el bienestar social, si la decisión de invertir en la infraestructura necesaria para participar en el mercado es estratégica para el estado y las empresas. En este caso, la intervención estatal sería efectiva por medio de la inversión en infraestructura que reduzca el coste de transporte.

Este capítulo podría ser susceptible de algún tipo de contrastación empírica disponiendo de datos de dos regiones geográficas para alguna industria adecuada. Ya que desde el punto de vista teórico obtenemos que la inversión pública en infraestructuras debería ser mayor en aquella región más densamente poblada y con peores condiciones de partida en sus infraestructuras o en sus dificultades naturales.

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Chapter 2

Regulating Vertical Relations in the presence of Retailer Differentiation Costs

2.1 Introduction

Following textbook economic theory, intense competition among firms is associated with more efficient market outcomes. However, this belief does not automatically carry over in the case of competition among retailers. In fact, competition legislation in the EC and the United States calls for a relatively sympathetic treatment of vertical restraints (leading to substantially less intra-brand competition) provided that manufacturers are exposed to a sufficiently competitive environment (inter-brand competition)[1].

The reasoning behind this attitude is straightforward: If competition among manufacturers (upstream firms or brands) is sufficiently strong, private gains from less intra-brand competition (more vertical coordination) will be interpreted in a more efficient outcome in the downstream market. However, following the analysis reported here, a sufficiently competitive environment at the manufacturers' level may be an excessively demanding condition in order for a given vertical restraint leading to less intra-brand competition to qualify as a socially desirable firm strategy.

[1]See Whish *et al.* (1993).

We argue that efficiency gains from a more coordinated and, thus, less competitive environment in the downstream market may lead to a more efficient (privately and socially) market configuration even in the absence of inter-brand competition. Therefore, policy making should allow for the possibility of socially efficient vertical instruments even when competition at the manufacturers' level is not enhanced by restrictions in intra-brand competition.

An important feature of our framework is that we model and study both price and non price competition among retailers. Following our assumptions and results, vertical restrictions may aim at reducing price and/or non price competition in the downstream market. We model non price retail competition as investment undertaken by retailers in order to differentiate themselves from the basic product manufactured by an upstream monopolist. Following standard IO literature, such a strategy would aim at relaxing price competition in the downstream market. Alternatively, the sales promotion strategy may be decided by the manufacturer in order for total (integrated) profit to be maximised.

Therefore, when addressing the social desirability of certain types of contracts and vertical restrictions, we will focus on the role of costs paid, depending on the distribution mode, by either individual retailers or the vertical structure (manufacturer-retailers) in order to relax competition in the downstream market and/or expand the market potential of the distributed product. As we argue in the following pages, the possibility of endogenisation of this differentiation cost by a vertically integrated structure plays an important role in determining the extent of the retail network, the degree of interdependence among upstream and downstream firms and the desirability of certain types of vertical contracts in terms of competition policy.

In the presence of vertical relations it has been shown [Tirole (1988)] that a manufacturer would either distribute his products by means of a unique retailer, or he would use several retailers, making the horizontal externality disappear in the retail market by imposing an 'exclusive territories' regime on them. According to this, sufficient differentiation among retailers is needed for the configuration to be optimal for the manufacturer[2].

[2] An important line of research on vertical relations [Rey and Tirole (1986), and Mathewson and Winter (1984)] considers the transmission of information among the parties

Interpreting the models of spatial competition à la Hotelling (1929) as models of product characteristics choice, we assume that the quality of the product offered by the manufacturer constitutes a standard variety from which differentiation by the retailers is the result of a costly process. For instance, a car dealer could differentiate himself from another dealer of the same brand by advertising on the local television channel, or by offering special post-sale services. In this case, the final product is a variety which is different from the car as it comes out of the production process. We could find another example in computer retailers who differentiate from each other and from the same basic product with respect to sale conditions, services and software configuration. In this sense, the disappearance of the horizontal externality among retailers should not be studied without taking into account the costs of differentiating from the standard variety produced by the manufacturer. Throughout the text, we will often adopt the terminology used in the geographical interpretation of the product characteristics space. That is, a firm's 'location' will be taken to mean the firm's choice for its product's characteristics.

Let us move now to another feature of vertical market foreclosure, which is also a main concern of this chapter and most of the literature on vertical market structure. That is, the divergence between socially optimal and privately profitable configurations of the retail network. Some legislations[3] force manufacturers to distribute their products through as many retailers as possible. Therefore, it could be interesting to study in which cases the manufacturer will allow competition among retailers, rather than establishing rules (exclusive territories, resale price maintenance, retail monopoly, etc.) in order to avoid the horizontal externality at the distribution level. The comparison of these alternatives from a social welfare point of view will help us to reach policy oriented conclusions. A general conclusion is that the vertical structure arranged by the invisible hand may be different from the socially optimal one, so intervention will be needed to reach the first best in

involved, the key factor determining the mode of distribution and the clauses which will govern the vertical contract. The results obtained there, have been established under the hypothesis that differentiation among retailers is exogenous, and consequently, does not entail any cost. Besides, the existence of the manufacturer is not related to any specific point in the product characteristics space on which final (differentiated) commodities are represented. In this paper, we will not deal with the issue of information transmission which, as we see, has inspired a large part of the literature on vertical market structure.

[3]For example: The Danish Competition Act, Section 12, in Albaek *et al.* (1997).

some cases.

We consider a three stage game. In the first stage, the manufacturer designs the optimal contract [Bonanno and Vickers (1988)] according to which the number of retailers[4] and the mode of distribution is determined. In the second stage, the retailers differentiate from the standard variety produced by the manufacturer, subject to a sunk cost, which is proportional to the degree of differentiation chosen. In the third stage, retail prices are set. In some distribution modes the manufacturer, rather than the retailers, will make some of the decisions.

Our results predict intermediate degrees of retailer differentiation. Besides, in our study, distribution by two retailers does not necessarily imply that an *exclusive territories* regime is the most profitable contract for the manufacturer. Thus, competition among retailers may be preferred to an exclusive territories regime, although the latter always ranks below the former in terms of social welfare. Complete vertical integration is the first best from both the private and the social perspective, except if retailer differentiation is not too costly, in which case no restriction to retailer competition should be allowed in order for social welfare to be maximised.

The contribution of our theoretical framework to the literature on economic policy towards vertical market structure is twofold: 1) the upstream firm's product is represented on the same space as that on which the varieties of the final product are represented, 2) the cost associated with the differentiation between manufactured products and distributed (final) varieties is studied as the result of the decision by either individual retailers or the integrated vertical structure.

The chapter is organised as follows: the model is described in detail in Section 2.2. Then, in Section 2.3, we solve the game for the different distribution modes available to the manufacturer. In Section 2.4, we present a summary of the most relevant results for each distribution mode considered and we compare them. In Section 2.5 we apply our theoretical results to two European competition policy cases.

[4] For simplicity, we consider a maximum of two retailers.

2.2 The Model

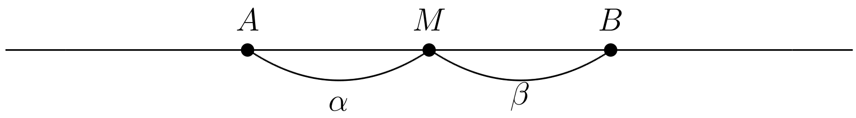

Figure 2.1: M Manufacturer, A and B Retailers.

We consider a linear city (or space of characteristics) of infinite length in which there is a manufacturer of a (potentially) differentiated product who is located on a point M which is considered the 'location' of the *standard variety.* We assume that two potential retailers A and B can locate at distances $\alpha \in [0, +\infty[$ and $\beta \in [0, +\infty[$ from the manufacturer. The manufacturer's unit production cost is zero. The differentiation costs incurred by the retailers are a quadratic function of their distance to the manufacturer:

$$K_A(\alpha) = c \cdot \alpha^2, \tag{2.1}$$

$$K_B(\beta) = c \cdot \beta^2. \tag{2.2}$$

Consumers are uniformly distributed along the market. Consumer i buys a maximum of one unit of the good in order to maximise her utility function:

$$U_{iJ} = \max \{R - n - p_J - t \cdot x_{iJ} \, , \, 0\} \, . \tag{2.3}$$

Where $J \in \{A, B\}$ is the retailer from whom consumer i buys the product, R is the consumer's positive and finite reservation price, n is the intermediate price charged by the manufacturer, p_J is the commercial margin of retailer J, t is the transportation cost parameter, and x_{iJ} is the 'distance' on the characteristics space between consumer i's ideal variety and retailer J's product. Furthermore, consumer i will buy the product from firm J as long as:

$$R - n - p_J - t \cdot x_{iJ} \geq R - n - p_I - t \cdot x_{iI} \geq 0, \tag{2.4}$$

where $\{I, J\} = \{A, B\}$, or equivalently:

$$p_J + n + t \cdot x_{iJ} \leq p_I + n + t \cdot x_{iI} \leq R. \tag{2.5}$$

The left hand side of (2.5) will be referred to as *generalised price.* The consumer will buy a unit from the retailer whose generalised price is lower, as long as this price does not exceed her reservation price, otherwise, the consumer will prefer not to buy the good. We assume that $c \geq t$.[5]

We define q_A and q_B as the units of the good bought by the consumers from each retailer. We also assume that the retailers sell all the units they purchase from the manufacturer: $q_M = q_A + q_B$.

The model can be considered as a three stage game:

- In the first stage, the manufacturer can choose the distribution mode he wants for his product among the following alternatives[6]: a regime of *Retail Competition* (COMP) among the retailers, applying *Resale Price Maintenance* (RPM), *Image Maintenance* (IM), *Complete Control* (CC), or giving *Exclusive Territories* (ET). Another possibility would be for him to distribute his product establishing a *Retail Monopoly* (MON). In the regime of Exclusive Territories, each retailer monopolises the demand on a part of the line, without competing with the other retailer. In the Retail Competition regime, the upstream firm gives the retailers freedom to locate as near, to each other and/or to the standard variety, as they want, and compete in prices. The same happens in the RPM regime, but their retail prices will be decided by the manufacturer. In the IM regime, retailers are free to set their prices, but the degree of differentiation between final varieties and the variety sold by the upstream firm is directly set by the manufacturer. In the CC regime the manufacturer sets both prices and locations of the retailers. The Retail Monopoly is the only non symmetric treatment for the retailers that we have considered in this chapter. Furthermore, once he has decided the distribution mode, the manufacturer chooses the type of compensation that the retailers have to give him, and the amount of the compensation. The manufacturer can charge either a price n on each unit of product sold to the retailers, or a fixed compensation F, or a combination of both. We assume that the retailers are

[5] In Section 2.3.3 we will see why we need this assumption.

[6] In Section 2.3, we will give a detailed description of each one of them.

going to accept the contract if their profits are non negative: $\Pi_J \geq 0$, $J \in \{A, B\}$.

- In the second stage, the retailers or the manufacturer (depending on the regime chosen by M) choose their location in the line.
- In the third stage, the retailers or the manufacturer (depending on M's choice of distribution mode) set final retail prices in the product market.

We look for *subgame perfect equilibria*.

2.3 Manufacturer Strategies

We are going to consider that the manufacturer can benefit from the dominant position he enjoys, as the monopolist producer of the standard product, by imposing on the retailers one out of six vertical contracts:

- Retail Competition (COMP): Each retailer freely chooses his differentiation from the standard variety and his price.
- Resale Price Maintenance (RPM): Each retailer chooses his differentiation from the standard variety, but the manufacturer sets retail prices.
- Image Maintenance (IM): The manufacturer chooses retailers' differentiation, and each retailer chooses his retail price.
- Complete Control (CC): The manufacturer decides on both downstream strategic variables: differentiation and retail price.
- Exclusive Territories (ET): Each retailer monopolises a part of the territory on either side of the manufacturer.
- Retail Monopoly (MON): The manufacturer sells to only one of the two retailers.

In this section, we will present the results of solving the game for every distribution mode. The mathematical calculations are presented in detail in the Appendix. We will leave the comparison of the most relevant results for Section 2.4.

2.3.1 Retail Competition

We begin by solving the price competition stage for COMP distribution mode. And then we proceed to compute the results of the precedent retailers' location stage and manufacturer's pricing stage.

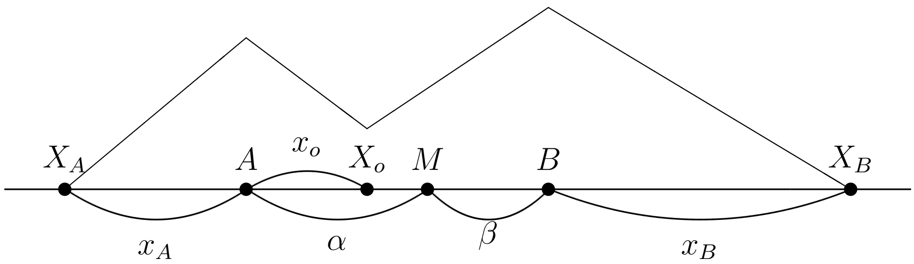

Figure 2.2: Consumer Surplus under Retail Competition.

Given a pair of commercial margins (p_A, p_B) which are not too different from each other[7], there will be a consumer who is *indifferent* between buying from one retailer or the other, located at a distance x_o from firm A, where, following (2.5) as equality:

$$x_o = \frac{p_B - p_A + t(\alpha + \beta)}{2t}. \tag{2.6}$$

Observe that, when prices are equal the retailers share equally the consumers located between them. The one with the highest price has a lower

[7] In fact, in order that the discontinuity in demand and profit functions observed by D'Aspremont *et al.* (1979) for the Hotelling model with linear transportation costs does not happen here, we must have that $p_I \geq p_J^* - t(\alpha^* + \beta^*)$, for $\{I, J\} = \{A, B\}$. That is, we assume that the manufacturer will include a *non drastic price cuts* clause in the Retail Competition and the Image Maintenance contracts, so that no retailer tries to force the other one out of the market by means of price undercutting. This is a reasonably realistic assumption, given the market power of the manufacturer, who, in case he wanted to have only one retailer, would directly choose the Retail Monopoly distribution mode, which is always the most profitable if distribution is undertaken by one retailer alone (due to the absence of differentiation costs).

share of the consumers between them. Besides, the captive markets of the retailers are:

$$x_A = \frac{R - n - p_A}{t}, \qquad x_B = \frac{R - n - p_B}{t}. \tag{2.7}$$

With these expressions, we can set up the profit functions of the retailers, considering the case in which the manufacturer charges a positive price n on each unit of the standard good and a fixed franchise fee F:

$$\Pi_A = p_A \left(\frac{2\,(R-n) - 3p_A + p_B + t(\alpha+\beta)}{2t} \right) - c\alpha^2 - F, \tag{2.8}$$

$$\Pi_B = p_B \left(\frac{2\,(R-n) - 3p_B + p_A + t(\alpha+\beta)}{2t} \right) - c\beta^2 - F. \tag{2.9}$$

From these equations, after some straightforward calculations, we obtain the equilibrium results under the Retail Competition (COMP) distribution mode:

- Retailers' profit margins: $p_A^* = p_B^* = \frac{25Rc}{3(25c-4t)}$.
- Retailers' sold quantities: $q_A^* = q_B^* = \frac{25Rc}{2t(25c-4t)}$.
- Retailers' location and distance to the indifferent consumer:
  $\alpha^* = \beta^* = x_o^* = \alpha^* + \beta^* - x_o^* = \frac{5R}{2(25c-4t)}$.
- Retailers' captive territories: $x_A^* = x_B^* = \frac{5R(5c-t)}{2t(25c-4t)}$.
- Retailers' profits: $\Pi_A^* = \Pi_B^* = 0$.
- Manufacturer's intermediate price: $n^* = \frac{R(25c-9t)}{6(25c-4t)}$.
- Manufacturer's franchise fee: $F^* = \frac{25cR^2(50c-3t)}{12t(25c-4t)^2}$.
- Manufacturer's profit: $\Pi_M^* = \frac{25cR^2}{2t(25c-4t)}$.

2.3.2 Resale Price Maintenance

In this subsection we assume that the manufacturer can directly impose the retail prices to the downstream firms. The retailers will only choose their final varieties location in the space of characteristics.

The indifferent consumer between buying from one retailer or the other, located at a distance x_o on the right of firm A, for whom the generalised prices[8] of the retailers are equal will be as in equation (2.6). And the captive markets of the retailers will be:

$$x_A = \frac{R - p_A}{t}, \qquad x_B = \frac{R - p_B}{t}. \tag{2.10}$$

Where p_A and p_B are the final retail prices fixed by the manufacturer. Now, we can set up the profit functions of the retailers:

$$\Pi_A = p_A \cdot q_A - c \cdot \alpha^2 - F = p_A \left(\frac{2R - 3p_A + p_B + t\,(\alpha + \beta)}{2t} \right) - c\alpha^2 - F, \tag{2.11}$$

$$\Pi_B = p_B \cdot q_B - c \cdot \beta^2 - F = p_B \left(\frac{2R - 3p_B + p_A + t\,(\alpha + \beta)}{2t} \right) - c\beta^2 - F. \tag{2.12}$$

From them we get the equilibrium results under Resale Price Maintenance (RPM) distribution mode:

- Retail prices: $p_A^* = p_B^* = \frac{4cR}{8c-t}$.
- Retailers' sold quantities: $q_A^* = q_B^* = \frac{4cR}{(8c-t)t}$.
- Retailers' location and distance to the indifferent consumer: $\alpha^* = \beta^* = x_o^* = \alpha^* + \beta^* - x_o^* = \frac{R}{8c-t}$.
- Retailers' captive territories: $x_A^* = x_B^* = \frac{R(4c-t)}{(8c-t)t}$.
- Retailers' profits: $\Pi_A^* = \Pi_B^* = 0$.

[8] In RPM, the generalised price does not include n (it is zero), because the retail price is directly chosen by the manufacturer. Now, p_A and p_B will be final prices, not only commercial margins.

- Manufacturer's intermediate price: $n^* = 0$.
- Manufacturer's franchise fee: $F^* = \frac{cR^2(16c-t)}{t(8c-t)^2}$.
- Manufacturer's profit: $\Pi_M^* = \frac{2cR^2(16c-t)}{t(8c-t)^2}$.

2.3.3 Image Maintenance

In this section we assume that the retailers will choose their profit margins, taking into account the intermediate price n charged by the manufacturer. So, the regime of IM can be solved as the Retail Competition one until we get to the location decision. But then, the manufacturer will choose the location of the retailers under this mode of distribution.

The equilibrium results under Image Maintenance (IM) distribution mode are[9]:

- Retailers' profit margins: $p_A^* = p_B^* = \frac{4cR}{3(4c-t)}$.
- Retailers' sold quantities: $q_A^* = q_B^* = \frac{2cR}{t(4c-t)}$.
- Retailers' location and distance to the indifferent consumer:
  $\alpha^* = \beta^* = x_o^* = \alpha^* + \beta^* - x_o^* = \frac{R}{4c-t}$.
- Retailers' captive territories: $x_A^* = x_B^* = \frac{R(2c-t)}{t(4c-t)}$.
- Retailers' profits: $\Pi_A^* = \Pi_B^* = 0$.
- Manufacturer's intermediate price: $n^* = \frac{2cR}{12c-3t}$.
- Manufacturer's franchise fee: $F = \frac{cR^2(8c-3t)}{3t(4c-t)^2}$.
- Manufacturer's profit: $\Pi_M^* = \frac{2cR^2}{t(4c-t)}$.

[9] Note that with the assumption $c \geq t$ all the results are positive, and $x_A \geq x_o$. With $c < t$, we would have $x_A < x_o$, and we cannot accept this in our model. That is the reason why we have adopted the assumption $c \geq t$ throughout the analysis.

2.3.4 Complete Control

In this section we give the manufacturer the possibility of choosing both retail prices and locations of the retailers. So, the regime of CC can be solved as the RPM one until we get to the location decision, which will also be made by the manufacturer.

Now, we present the equilibrium results under Complete Control (CC) distribution mode:

- Retail prices: $p_A^* = p_B^* = 2R\frac{c}{4c-t}$.
- Retailers' sold quantities: $q_A^* = q_B^* = \frac{2cR}{t(4c-t)}$.
- Retailers' location and distance to the indifferent consumer:

  $\alpha^* = \beta^* = x_o^* = \alpha^* + \beta^* - x_o^* = \frac{R}{4c-t}$.
- Retailers' captive territories: $x_A^* = x_B^* = \frac{R(2c-t)}{t(4c-t)}$.
- Retailers' profits: $\Pi_A^* = \Pi_B^* = 0$.
- Manufacturer's intermediate price: $n^* = 0$.
- Manufacturer's franchise fee: $F = \frac{cR^2}{t(4c-t)}$.
- Manufacturer's profit: $\Pi_M^* = \frac{2cR^2}{t(4c-t)}$.

Notice that, due to the existence of the intermediate price n, which acts as an indirect way of controlling the final retail prices for the manufacturer (instead of directly using RPM), the IM case is equivalent to the CC one.

2.3.5 Exclusive Territories

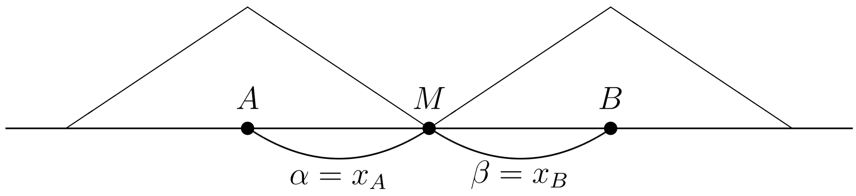

Figure 2.3: Consumer Surplus under Exclusive Territories.

Another way in which the manufacturer can prevent the retailers from competing with each other is by giving them exclusive territories. In order that there is no competition between the two monopolists, they will have to exhaust the reservation price of the consumer who is indifferent between them. Under this distribution mode p_A and p_B are final retail prices. The manufacturer is not interested in imposing the intermediate price n, since each retailer is monopolising its half of the market and extracting the maximum profit, which he can appropriate by means of the franchise fee F. As the situation is symmetric for A and B we are going to carry out the analysis for firm A only. This time, as there is no competition, the retailers' location is, from the beginning, equal to the distance to the indifferent consumer[10], and to the retailer's captive market:

$$R - p_A - t \cdot x_A = 0 \qquad \Longrightarrow \qquad x_A = \frac{R - p_A}{t}. \tag{2.13}$$

And the profit function of the retailer with exclusive territory will be:

$$\Pi_A = p_A \cdot q_A - c \cdot (x_A)^2 = \frac{2p_A t \left(R - p_A\right) - c\left(R - p_A\right)^2}{t^2}. \tag{2.14}$$

[10]The retailer does not have any incentive to locate further away than this distance, as he would incur in unnecessary differentiation costs.

After the calculations in Appendix 2.7.1 we get the equilibrium results under Exclusive Territories (ET) distribution mode:

- Retail prices: $p_A^* = p_B^* = \frac{R(c+t)}{c+2t}$.
- Retailers' sold quantities: $q_A^* = q_B^* = \frac{2R}{c+2t}$.
- Retailers' location, distance to the indifferent consumer and captive territories:

$$\alpha^* = \beta^* = x_o^* = \alpha^* + \beta^* - x_o^* = x_A^* = x_B^* = \frac{R}{c+2t}.$$

- Retailers' profits: $\Pi_A^* = \Pi_B^* = 0$.
- Manufacturer's intermediate price: $n^* = 0$.
- Manufacturer's franchise fee: $F^* = \frac{R^2}{c+2t}$.
- Manufacturer's profit: $\Pi_M^* = \frac{2R^2}{c+2t}$.

Note that an alternative way of modeling exclusive territories exists: the manufacturer could guarantee that neither retailer actively[11] sells out of its assigned territory. In that case, it is interesting to note that the results coincide with those under IM and CC. This contrasts with the usual distinction by competition law between CC and ET. Thus, in the comparison of the modes studied we will refer to ET under the definition at the beginning of the subsection, rather than to the case in which ET and CC coincide. However, it is also important to observe that seemingly different measures of vertical control may yield identical results.

[11]'Actively' is used here in the sense of promoting sales out of the established territory. On the contrary, a retailer is usually forced by law to serve a consumer, if the latter asks for it.

2.3.6 Retail Monopoly

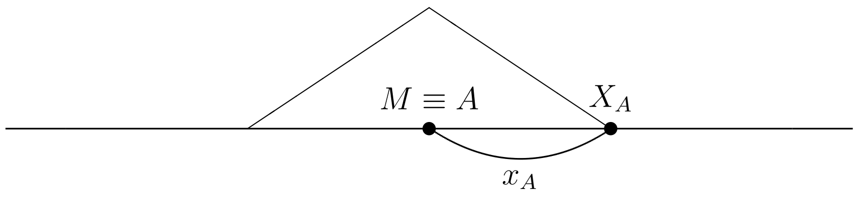

Figure 2.4: Consumer Surplus under Retail Monopoly.

Finally, we are going to consider the distribution using a single retailer who monopolises the whole line. Given that consumer density is the same along the line, this retailer will locate with the manufacturer so as to minimise the differentiation cost. Again, the price p_A will be the final retail price, and the manufacturer will not impose an intermediate price n on the monopolist retailer. He will extract all the retailer's profit by means of the franchise fee F. For each $p_A \leq R$ there will be an indifferent consumer between buying and not buying:

$$R - p_A - t \cdot x_A = 0 \qquad \Longrightarrow \qquad x_A = \frac{R - p_A}{t}. \tag{2.15}$$

And the monopolist retailer's profit function will be:

$$\Pi_A = p_A \cdot q_A = \frac{2p_A\,(R - p_A)}{t}. \tag{2.16}$$

The equilibrium results under Retail Monopoly (MON) distribution mode are:

- Retail price: $p_A^* = \frac{R}{2}$.
- Retailer's sold quantity: $q_A^* = \frac{R}{t}$.
- Retailer's location: $\alpha^* = 0$.

- Retailer's captive territory: $x_A^* = \frac{R}{2t}$.
- Retailer's profit: $\Pi_A^* = 0$.
- Manufacturer's intermediate price: $n^* = 0$.
- Manufacturer's franchise fee and manufacturer's profit: $F^* = \Pi_M^* = \frac{R^2}{2t}$.

2.4 Analysis of the Results

In this section, we discuss the main results of our analysis. We present, first, a summary table with the most relevant results, which are those on the degree of retailer differentiation, manufacturer's private profits, and the social welfare under each distribution mode.

Then, we will compare the retailer's product choice decision under every distribution mode in order to find any regularities. We will also compare manufacturer's profits in order to decide which distribution mode will be optimal for him. Finally we will compare the preferred vertical contracts for the manufacturer with the social welfare maximising ones, which should be preferred by the economic authorities.

Distrib. Mode	**Location (α)**	**Manuf. Profit**	**Social Welfare**
COMP	$\frac{5R}{2(25c-4t)}$	$\frac{25cR^2}{2t(25c-4t)}$	$\frac{25R^2\left(75c^2-8tc-2t^2\right)}{4t(25c-4t)^2}$
RPM	$\frac{R}{8c-t}$	$\frac{2cR^2(16c-t)}{t(8c-t)^2}$	$\frac{2R^2\left(24c^2-tc-t^2\right)}{t(8c-t)^2}$
IM	$\frac{R}{4c-t}$	$\frac{2cR^2}{t(4c-t)}$	$\frac{2R^2\left(6c^2-tc-t^2\right)}{t(4c-t)^2}$
CC	$\frac{R}{4c-t}$	$\frac{2cR^2}{(4c-t)t}$	$\frac{2R^2\left(6c^2-tc-t^2\right)}{(4c-t)^2t}$
ET	$\frac{R}{c+2t}$	$\frac{2R^2}{c+2t}$	$\frac{2R^2(3t+c)}{(c+2t)^2}$
MON	0	$\frac{R^2}{2t}$	$\frac{3R^2}{4t}$

Table 2.1: Summary of the Results (Social Welfare results are derived in Section 2.4.3).

2.4.1 Equilibrium Locations

In Figure 2.5, we can graphically observe the equilibrium degree of differentiation incurred by retailer A under the different distribution modes[12].

In the case of ET the retailers will be more differentiated than in any other distribution mode, only if $c = t$ the equilibrium location under IM and CC will be equal to that of ET. After IM and CC we have still less differentiation with RPM, and a little less with COMP. Finally we have minimum differentiation for all t under MON.

Another characteristic which can be easily observed in the graph is that, as c goes to infinity the equilibrium location under every mode of distribution goes to zero.

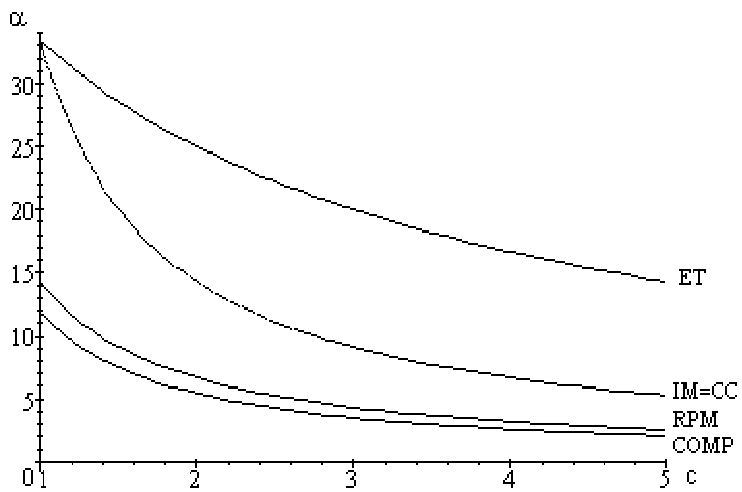

Figure 2.5: Retailer A Equilibrium Location under the Different Distribution Modes.
($R = 100$, $t = 1$, $\alpha_{MON} = 0$)

We can summarise these results in the following propositions:

[12]In order to be able to represent we have chosen an arbitrary finite reservation price of $R = 100$, but the results would be similar for any other finite value. We have also normalised $t = 1$.

Proposition 2.1 *In COMP, RPM, IM, and CC distribution modes, the differentiation cost parameter relates negatively with the degree of differentiation, and the unit transportation cost relates positively. In the ET distribution mode, both parameters relate negatively with the degree of differentiation.*

Proof: See Table 2.1.

Proposition 2.2 *The equilibrium location of retailers A and B implies always more differentiation under Exclusive Territories than under the other distribution modes considered as long as $c > t$. For $c = t$ Image Maintenance and Complete Control produce the same degree of differentiation as Exclusive Territories.*

Proof: See Appendix.

Except for the case of a Retail Monopoly, if the differentiation cost parameter is not too high in comparison with the transportation cost parameter, we will always find intermediate differentiation location equilibria, rather than the extreme cases of maximum or minimum differentiation.

2.4.2 Distribution Mode Selection

In Figure 2.6, we have represented manufacturer's profit under the different distribution modes. We can see that the most profitable distribution modes for the manufacturer are Image Maintenance and Complete Control. Only if $c = t$ Exclusive Territories are equally profitable. RPM is less profitable than IM and CC, but a bit more profitable than COMP. If differentiation costs are not relatively high, every distribution mode yields substantially more profit for the manufacturer than the Retail Monopoly. The Exclusive Territories regime profit is the most penalised by a relative increase in differentiation costs, and it yields very low profits for relatively high values of c, while profits from the other distribution modes converge to the Retail Monopoly profit.

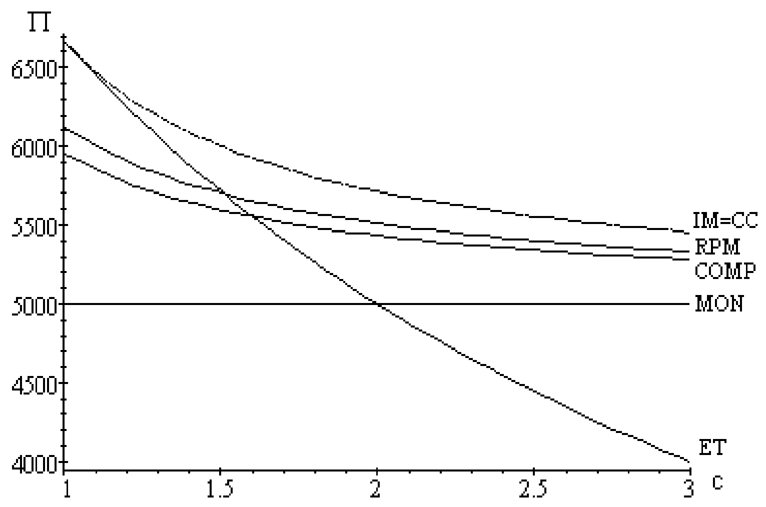

Figure 2.6: Manufacturer Equilibrium Profits under the Different Distribution Modes.
$(R = 100,\, t = 1)$

Stating this result in a more formal way we obtain the following proposition:

Proposition 2.3 *If $c > t$, Image Maintenance and Complete Control distribution modes will be chosen by the manufacturer. If $c = t$ the Exclusive Territories regime yields profits equal to those of the aforementioned modes.*

Proof: See Appendix.

If differentiation costs are relatively low as compared to transportation costs, we can expect to find any of the three distribution modes: Image Maintenance, Complete Control or Exclusive Territories. If differentiation costs are relatively high, we will observe the first two only. In any case, *it is very unlikely that the manufacturer allows competition among the retailers.* This could only happen if differentiation costs were sufficiently high and the manufacturer was not allowed to adopt his most preferred distribution modes (IM, CC or RPM).

2.4.3 Social Welfare Comparison

In order to study our results from the social welfare point of view, we take into consideration that the manufacturer price n and the commercial margins of the retailers p_A and p_B are internal transfers. We set up the social welfare function by calculating the integral of reservation price less transportation cost for all the consumers who buy the good and subtracting the differentiation costs incurred by the retailers:

$$W = 2 \cdot \left(\int_0^{x_A} (R - t \cdot x)\ dx + \int_0^{\alpha} (R - t \cdot x)\ dx \right) - 2 \cdot c \cdot \alpha^2. \tag{2.17}$$

The retailers' captive market x_A and the retailers' location α will be different under each distribution mode[13], but the social welfare function is the same for Retail Competition, Resale Price Maintenance, Image Maintenance and also Complete Control.

The social welfare function under Exclusive Territories is slightly different:

$$W = 4 \cdot \int_0^{x_A} (R - t \cdot x)\ dx - 2 \cdot c \cdot (x_A)^2. \tag{2.18}$$

In the Retail Monopoly case, the social welfare function does not include any differentiation costs:

$$W = 2 \cdot \int_0^{x_A} (R - t \cdot x)\ dx. \tag{2.19}$$

The results of the calculations above can be found in Table 2.1. In Figure 2.7 we use the same normalisation in order to represent the social welfare obtained under each distribution mode. We can observe that, if the differentiation cost parameter is not high relative to the unit transportation cost, the socially optimal distribution mode will be Retail Competition, whereas for larger differentiation costs, Image Maintenance and Complete Control will lead to higher levels of social welfare. Resale Price Maintenance is dominated by Retail Competition. Exclusive Territories are dominated by all the rest, and besides, they are heavily penalised when differentiation costs grow in relation to transportation costs. All the other distribution modes converge to the Retail Monopoly social welfare, as c grows relative to t, while social welfare under Exclusive Territories decreases gradually to zero.

[13]Except for CC and IM where they are the same.

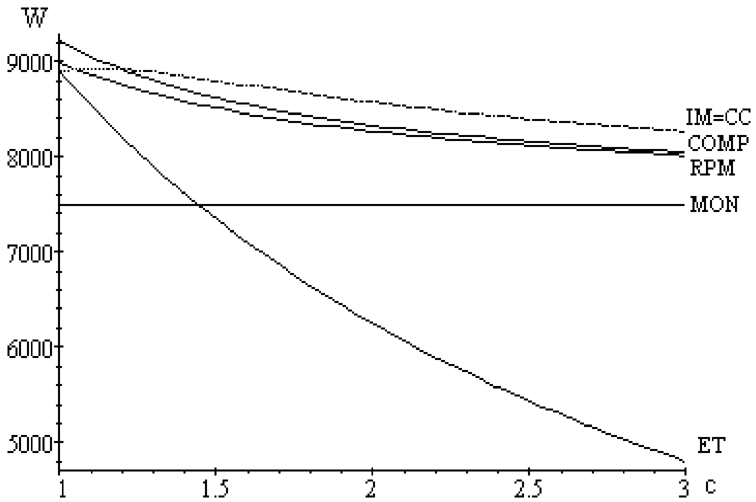

Figure 2.7: Social Welfare under the Different Distribution Modes.
$(R = 100,\, t = 1)$

Proposition 2.4 *If $c < 1.193 \cdot t$, the social welfare maximising distribution mode is Retail Competition. If $c > 1.193 \cdot t$, the socially optimal modes of distribution are: Image Maintenance and Complete Control.*

Proof: See Appendix.

Mathewson and Winter (1986) warn us that the contracts which maximise the integrated profit for the manufacturer will not necessarily be those which maximise social welfare. The manufacturer's interest in imposing vertical restraints is not a sign of their social efficiency, given that this interest takes into account only the manufacturer's profit, and not consumer's surplus.

According to Proposition 2.3, the manufacturer has strong incentives to impose Image Maintenance or exercise Complete Control, or even, grant Exclusive Territories, if differentiation costs are relatively small. If the first two distribution modes were prohibited, he would still prefer Resale Price Maintenance to allowing competition between the retailers.

These incentives are partially opposed to those of social welfare maximising authorities, which are presented in Proposition 2.4. If differentiation costs are not small, the authorities can allow Image Maintenance or Complete Control, which would correspond, in the real world, to franchising and subsidiaries, respectively. However, if differentiation costs are small, the authorities will prefer Retail Competition over the former two distribution systems. In any case, Retail Competition will be preferred in terms of social welfare over Resale Price Maintenance, Monopoly, or Exclusive Territories.

2.4.4 Output and Social Efficiency

If we compare the total output sold under the distribution modes studied, we obtain the following ranking: $Q^{IM} = Q^{CC} > Q^{COMP} > Q^{RPM} > Q^{MON}$. Concerning the output sold in the ET mode, we find that in the range of the parameter values assumed, it holds that $Q^{IM} = Q^{CC} \geq Q^{ET}\ \forall c$, and $Q^{ET} \geq Q^{COMP}$, if $t \leq c \leq 1.6t$, but $Q^{COMP} \geq Q^{ET} \geq, Q^{RPM}$, if $1.6t \leq c \leq 1.705t$, $Q^{RPM} \geq Q^{ET} \geq Q^{MON}$, if $1.705t \leq c \leq 2t$ and $Q^{ET} \leq Q^{MON}$, if $c > 2t$.

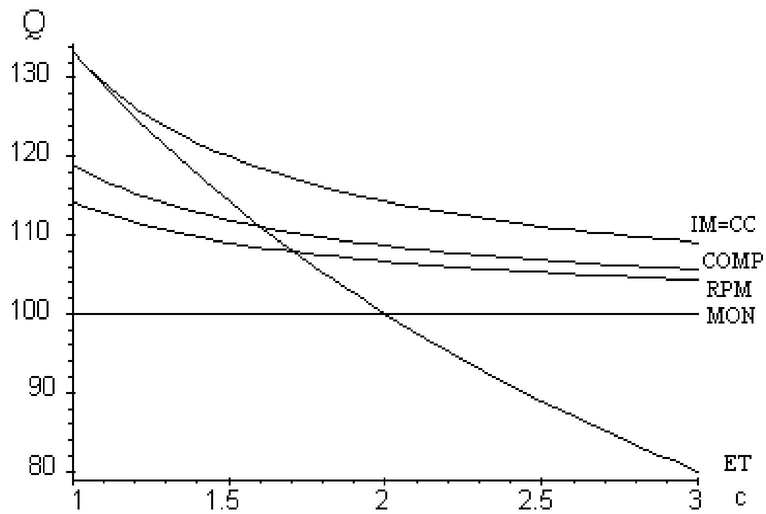

Figure 2.8: Total Output under the Different Distribution Modes. ($R = 100$, $t = 1$)

Looking at the social efficiency of the distribution modes considered (Figure 2.7), we can easily see that the output criterion (Figure 2.8) ranks all alternatives in the same way as social welfare analysis would do with three exceptions: First, according to our social welfare analysis, for very low values of the differentiation cost parameter, both RPM and COMP dominate (in terms of social efficiency) practices leading to a tighter vertical control (IM and CC), while the output criterion would lead to the inverse conclusion. Second, for slightly higher values of the differentiation cost parameter, COMP (but not RPM) still dominates IM and CC, while the output criterion would yield the contrary conclusion. Third, the ET mode, which is dominated by almost all modes (except for MON in the case of low differentiation costs) would rank above them or most of them, according to the output criterion, as long as differentiation costs are not too high.

Therefore, on one hand, the output criterion might underestimate the benefits from retailer competition, as opposed to complete vertical control, if differentiation costs are low. On the other hand, the output criterion may overestimate the benefits from granting exclusivity to a retailer, protecting him from competition by other retailers, as opposed to other price or non-price vertical restraints. With respect to this observation, we would like to point out that, despite the lack of inter-brand competition, our analysis is easily applicable to cases in which more than one brands exist. In such a case, like in standard Cournot oligopolies, output expansion is usually associated with more competitive behaviour by firms. However, in the presence of vertical relations, more coordination among different levels of the production-distribution chain and control of different types of competition (price and non-price) among retailers may produce benefits which can be studied independently from competition among brands. Much of the theoretical analysis and antitrust legislation agree in that restrictions in intra-brand competition should be tolerated as a necessary strategy adopted by manufacturers in order to motivate retailers in their promotional effort.

Our analysis has illustrated how the desire for a more efficient distribution may lead to a more favourable treatment of socially inefficient vertical restraints and how a totally permissive attitude towards tight vertical control may ignore the benefits from a more competitive environment in the downstream market. Such an erroneous assessment of the social costs of vertical restrictions is more likely to happen if differentiation costs in the downstream market are ignored. At the same time, our analysis shows that an integrated control of both price and non-price decisions may be privately and socially efficient if it aims at internalising costs associated with promotion of the products and differentiation of retailers in the downstream market.

2.5 Two Real World Examples

The theoretical predictions of the last section are approximately matched by the European Union Competition Policy inspired in Articles 81 and 82 of the Treaty of Rome[14].

According to Goyder (1992), European competition law always fights certain anti-competitive agreements among firms (such as: price fixing[15], banning exports[16], banning parallel imports[17], etc.), and the abuse of a firm's dominant position (a producer refusing to supply a given retailer, etc.).

Some agreements can be authorised if they fall under block exemptions[18] or in a case by case basis if they provide sufficient economic advantages, but not normally those that we have enumerated. These exemptions allow for a certain degree of territorial protection in some well-defined types of contract, though without ever permitting a complete ban on sales outside any given territory.

Vertical agreements that can be permitted thanks to block exemptions are for instance some of exclusive distribution[19], franchising[20], etc. For the exemption to apply automatically the manufacturer's market share must be less than 30%. In our model we do not consider the existence of other brands, so we analyse cases were this share could be much higher, even 100%.

Therefore, regarding the theoretical contracts that we have analysed in our model, we can affirm that their corresponding real-world counterparts should normally be allowed only in the cases of Complete Control (manufacturer subsidiaries dedicated to sales), Image Maintenance (franchising), and Retail Competition (independent retailers), whereas Resale Price Maintenance (price fixing agreements), Exclusive Territories (absolute territorial exclusivity[21]), or Retail Monopoly (monopoly in all the market), should be

[14] Numbers 85 and 86 before the Amsterdam Treaty.

[15] Resale Price Maintenance.

[16] The distribution contract provides that goods are not to be sold outside a particular territory.

[17] Arrangements giving absolute territorial exclusivity for distributors.

[18] See EC Regulation 2790/1999.

[19] Those that are not made between competitors and that allow for passive sales to be made outside the assigned territory.

[20] Clauses necessary for the maintenance of the identity and reputation of the franchise network should be valid.

[21] This means that the dealer is assured that customers within the contract territory have no available source of the contract good apart from him.

prohibited.

Having in mind our analysis so far, let us consider two real world examples: the *Newitt-Dunlop*, and the *Hinkens-Montedison* cases[22].

2.5.1 Newitt *v.* Dunlop Slazenger International

We will analyse first the case *Newitt-Dunlop.* The products involved were first grade tennis balls produced by DSI and distributed by his network of exclusive retailers for each country of the European Union.

Newitt was a wholesaler and retailer of sport equipment who decided to buy Dunlop Fort tennis balls in the English market and take them to the Dutch market, where he could sell them at higher prices.

All Weather Sports BV (AWS) was DSI's exclusive retailer for the Benelux, and he was facing strong competition by the parallel imports of Newitt, so he complained to DSI. AWS and DSI decided to provide AWS absolute territorial protection (Exclusive Territories in our framework) by adopting certain measures against Newitt: more expensive pricing for the parallel importers, negative to supply Newitt, use of codes to identify the parallel imports and purchase of them, and also the payment of a lump sum to the Dutch Federation of Tennis in order to be able to stamp 'KNLTB official' in the balls exported to Holland by DSI. The Commission declared that these practices were against Article 81, forced DSI and AWS to allow the competition of Newitt and fined them with 5 million ecus.

We can apply our framework to the study of this case. Following our theoretical models results and terminology we can affirm that the differentiation costs, in this case, were relatively small. In fact, such costs were limited to a small lump sum payment which empowered DSI to stamp in its tennis balls a label guaranteeing that they were the only officially approved and recommended by the Dutch Federation of Tennis.

Under these circumstances, the regime of Exclusive Territories resulted very profitable for DSI, much more than allowing competition by Newitt. But we have seen that, if differentiation costs are relatively small, Retail Competition is welfare maximising, and socially much more desirable than Exclusive Territories.

[22]Some other similar cases which could be seen in the light of our framework are: *Tretorn* (1994), *Basf* (1995), *Adalat* (1996), *Novalliance-Systemform* (1996), and *Audi-VW* (1998).

2.5.2 Zera and Hinkens *v.* Montedison and Stäler

Now, let us consider the *Hinkens-Montedison* case. The product concerned was the herbicide Digermin. Montedison, the manufacturer, obtained the authorisation of the product for its sale in Germany from the Federal Institute of Biology using a different formula than that used in the other European countries. Thus, it resulted impossible for the parallel importer Hinkens to introduce Digermin in Germany which was purchased at lower prices in other European countries and, thus, compete with Stäler, which was Montedison's exclusive retailer in Germany. Thanks to the payment of a relatively low cost for the authorisation of a different formula for Germany, Montedison was able to provide Stäler with absolute territorial protection (Exclusive Territories in our framework). The Commission declared that these practices had been against Article 81.

Using our framework to study this case we get to similar conclusions. Again, differentiation costs which were relatively small (a payment of around 2.000 DM) made it legally impossible for any potential downstream competitor to introduce the product in Germany under a different formula from the one authorised. Again, the regime of Exclusive Territories resulted much more profitable for Montedison than allowing downstream competition. But, as we have shown, Retail Competition would have been preferred in terms of social welfare to Exclusive Territories.

2.6 Conclusions and Policy Implications

We have studied the choice made by a manufacturer with regard to the optimal distribution mode and pricing policy for his products at two different vertical levels. An innovative aspect of the theoretical framework adopted is the introduction of some differentiation costs incurred by the retailer when he differentiates his final product (service) from the standard good supplied by the manufacturer as it comes off the production lines. Such an investment also represents the effort made by the retailer to expand the market potential (promote) the distributed product.

The hypothesis about the existence of a maximum of two retailers simplifies the analysis, allowing us to obtain endogenously the vertical structure. We show that three of the six possible distribution modes, involving tight vertical control or retailer exclusivity, can be observed in an unregulated equilibrium. Firstly, the distribution mode which uses two retailers who do not compete with each other at all in the final product market (Exclusive Territories) will be preferred by the manufacturer when the differentiation costs are low enough for this configuration to yield maximum profits due to appropriation of a higher consumer surplus. Besides, the manufacturer may prefer a situation in which retailer competition is reduced via Image Maintenance or Complete Control contracts.

We have also shown that the degree of differentiation of the retailers with respect to the central variety will depend on the relative size of the differentiation cost compared with the unitary transportation cost. This result implies, in general, intermediate degrees of differentiation between the two extreme cases of minimum and maximum differentiation.

The theoretical framework proposed is particularly relevant when studying vertical relations with a view to making recommendations to the institutions in charge of competition policy, given that it presents a reasoning which is complementary to the usual arguments about the role of information in determining the distribution terms of a differentiated product. In our model, depending on the relative size of transportation and differentiation costs, we obtain that Retail Competition, or Image Maintenance and Complete Control, may be welfare maximising. Then, if the invisible hand led to Exclusive Territories, Resale Price Maintenance, or Retail Monopoly, being implemented by the manufacturer, state intervention would be needed in order to reach the social welfare first best, by means of imposing one of the social welfare maximising vertical structures.

2.7 Appendix

2.7.1 Mathematical Computations in Section 2.3

Retail Competition

Retailers' Pricing Stage: From equations (2.8) and (2.9), we set up the first order conditions for firms A and B:

$$\frac{\partial \Pi_A}{\partial p_A} = \frac{2\,(R-n) - 6p_A + p_B + t(\alpha+\beta)}{2t} = 0, \tag{2.20}$$

$$\frac{\partial \Pi_B}{\partial p_B} = \frac{2\,(R-n) - 6p_B + p_A + t(\alpha+\beta)}{2t} = 0. \tag{2.21}$$

From them we obtain the system of best response functions [23]:

$$p_A = \frac{1}{3}\left(R - n + \frac{p_B + t(\alpha+\beta)}{2}\right), \tag{2.22}$$

$$p_B = \frac{1}{3}\left(R - n + \frac{p_A + t(\alpha+\beta)}{2}\right). \tag{2.23}$$

Whose solution gives us the equilibrium commercial margins:

$$p_A^* = p_B^* = \frac{1}{5}\left[2\left(R-n\right) + t\left(\alpha+\beta\right)\right]. \tag{2.24}$$

And the corresponding equilibrium quantities:

$$q_A^* = q_B^* = \frac{3}{10t}\left[2\left(R-n\right) + t\left(\alpha+\beta\right)\right]. \tag{2.25}$$

In equilibrium, the indifferent consumer's location will be at a distance from A:

$$x_o^* = \frac{\alpha+\beta}{2}, \tag{2.26}$$

and:

$$x_A^* = x_B^* = \frac{3\left(R-n\right) - t\left(\alpha+\beta\right)}{5t}. \tag{2.27}$$

Equilibrium profits of the two retailers are then:

$$\Pi_A^* = \frac{3\left[2\left(R-n\right) + t\left(\alpha+\beta\right)\right]^2}{50t} - c\alpha^2 - F, \tag{2.28}$$

$$\Pi_B^* = \frac{3\left[2\left(R-n\right) + t\left(\alpha+\beta\right)\right]^2}{50t} - c\beta^2 - F. \tag{2.29}$$

[23] We check the second order conditions: $\frac{\partial^2 \Pi_A}{\partial p_A^2} = -\frac{3}{t} < 0$, and $\frac{\partial^2 \Pi_B}{\partial p_B^2} = -\frac{3}{t} < 0$.

Retailers' Location Stage: We obtain the derivatives of the profit functions with respect to the corresponding location variables α and β and we set up the F.O.C. of the location stage:

$$\frac{\partial \Pi_A}{\partial \alpha} = \frac{3\left[2\left(R-n\right)+t\left(\alpha+\beta\right)\right]}{25} - 2c\alpha = 0, \tag{2.30}$$

$$\frac{\partial \Pi_B}{\partial \beta} = \frac{3\left[2\left(R-n\right)+t\left(\alpha+\beta\right)\right]}{25} - 2c\beta = 0. \tag{2.31}$$

Which give us the following system of best response functions:

$$\alpha = 3\frac{2R-2n+t\beta}{50c-3t}, \qquad \beta = 3\frac{2R-2n+t\alpha}{50c-3t}. \tag{2.32}$$

Whose solution gives us the equilibrium locations of the retailers[24].

$$\alpha^* = \beta^* = \frac{3\left(R-n\right)}{25c-3t}. \tag{2.33}$$

The equilibrium locations of A and B require $c > \frac{3t}{25}$ in order for α and β to be positive. It is very difficult that retail competition produces *minimum differentiation* ($\alpha^* = \beta^* = 0$), in fact, it requires that $c \to \infty$. Furthermore, given our assumption $c \geq t$, *maximum differentiation* ($\alpha^* = \beta^* = +\infty$) is impossible (only if $c = \frac{3t}{25}$). Therefore, we find a continuum of interior equilibria depending on the relationship between the differentiation cost parameter and the transportation cost parameter. The greater the differentiation cost parameter, as compared to the transportation cost parameter, the less differentiation we have in equilibrium.

With the values obtained for α^* and β^* we can substitute in the functions (2.24), (2.25), (2.28), and (2.29) calculated before:

$$p_A^* = p_B^* = \frac{10c(R-n)}{25c-3t}, \tag{2.34}$$

$$q_A^* = q_B^* = \frac{15c\left(R-n\right)}{\left(25c-3t\right)t}, \tag{2.35}$$

[24]Let's check that the S.O.C. hold: $\frac{\partial^2 \Pi_A}{\partial \alpha^2} = \frac{3}{25}t - 2c < 0$, and $\frac{\partial^2 \Pi_B}{\partial \beta^2} = \frac{3}{25}t - 2c < 0$, require $c > \frac{3t}{50}$.

$$\Pi_A^* = \Pi_B^* = \frac{3c\,(R-n)^2\,(50c-3t)}{(25c-3t)^2\,t} - F. \tag{2.36}$$

Manufacturer's Pricing Stage: Now we can solve for M's optimisation problem concerning n and F, which is described as:

$$\begin{aligned} \max_{n,F} \quad \Pi_M &= n\cdot(q_A^* + q_B^*) + 2F \\ s.t. \quad \Pi_A^* &\geq 0\,,\ \Pi_B^* \geq 0. \end{aligned} \tag{2.37}$$

The manufacturer will choose $F = \frac{3c(R-n)^2(50c-3t)}{(25c-3t)^2 t}$, so that $\Pi_A^* = \Pi_B^* = 0$. And then he will maximise with respect to the standard product intermediate price n the resulting function:

$$\Pi_M = \frac{6c\,(R-n)\,(50Rc+75nc-3tR-12tn)}{(25c-3t)^2\,t}. \tag{2.38}$$

The optimal n will satisfy:

$$\frac{\partial \Pi_M}{\partial n} = \frac{6c\,(25Rc-150nc-9tR+24tn)}{(25c-3t)^2\,t} = 0, \tag{2.39}$$

whose solution gives[25]:

$$n^* = \frac{R\,(25c-9t)}{6\,(25c-4t)}. \tag{2.40}$$

Resale Price Maintenance

Manufacturer's Retail Price Decision: The manufacturer can obtain, thanks to the fixed payment F, all the profits of the retailers. Besides, instead of charging the intermediate price n, the manufacturer will, under the RPM distribution mode, choose the retail price.

$$\begin{aligned} \max_{p_A,p_B} \quad \Pi_M &= F_A + F_B \\ s.t. \quad \Pi_A^* &\geq 0\,,\ \Pi_B^* \geq 0. \end{aligned} \tag{2.41}$$

[25] The S.O.C. $\frac{\partial^2 \Pi_M}{\partial n^2} = 36c\frac{-25c+4t}{(3t-25c)^2 t} < 0$ holds if $c > \frac{4t}{25}$.

The manufacturer will choose $F_A = p_A\left(\frac{2R-3p_A+p_B+t(\alpha+\beta)}{2t}\right) - c\alpha^2$ and $F_B = p_B\left(\frac{2R-3p_B+p_A+t(\alpha+\beta)}{2t}\right) - c\beta^2$, so that $\Pi_A^* = \Pi_B^* = 0$. So, now he will maximise with respect to the retail prices his profit function[26].

$$\frac{\partial \Pi_M}{\partial p_A} = \frac{2(R-3p_A+p_B)+t(\alpha+\beta)}{2t} = 0, \tag{2.42}$$

$$\frac{\partial \Pi_M}{\partial p_B} = \frac{2(p_A+R-3p_B)+t(\alpha+\beta)}{2t} = 0. \tag{2.43}$$

From them we obtain the best response functions [27]:

$$p_A = \frac{1}{6}\left[2(R+p_B)+t(\alpha+\beta)\right], \qquad p_B = \frac{1}{6}\left[2(R+p_A)+t(\alpha+\beta)\right]. \tag{2.44}$$

Then we obtain the equilibrium prices:

$$p_A^* = \frac{1}{4}\left[2R+t(\alpha+\beta)\right], \qquad p_B^* = \frac{1}{4}\left[2R+t(\alpha+\beta)\right]. \tag{2.45}$$

The equilibrium profits of A and B as function of α and β are:

$$\Pi_A^* = \frac{\left[2R+t(\alpha+\beta)\right]^2}{16t} - c\alpha^2 - F, \qquad \Pi_B^* = \frac{\left[2R+t(\alpha+\beta)\right]^2}{16t} - c\beta^2 - F. \tag{2.46}$$

Retailers' Location Stage: The retailers will independently make the location decision under the distribution mode of RPM:

$$\frac{\partial \Pi_A}{\partial \alpha} = \frac{1}{8}\left[2R+t(\alpha+\beta)\right] - 2c\alpha = 0, \tag{2.47}$$

$$\frac{\partial \Pi_B}{\partial \beta} = \frac{1}{8}\left[2R+t(\alpha+\beta)\right] - 2c\beta = 0. \tag{2.48}$$

From the F.O.C. we obtain the best response functions:

$$\alpha = \frac{2R+t\beta}{16c-t}, \qquad \beta = \frac{2R+t\alpha}{16c-t}. \tag{2.49}$$

[26] See equations (2.11) and (2.12).

[27] We check the second order conditions: $\frac{\partial^2 \Pi_M}{\partial p_A^2} = -\frac{3}{t} < 0$,and $\frac{\partial^2 \Pi_M}{\partial p_B^2} = -\frac{3}{t} < 0$.

And the equilibrium locations of the retailers are[28]:

$$\alpha^* = \frac{R}{8c-t}, \qquad \beta^* = \frac{R}{8c-t}. \tag{2.50}$$

In the case of Resale Price Maintenance, as in that of Retail Competition, it is very difficult to observe the extreme differentiation results (we will have minimum differentiation only if $c \to \infty$, and maximum differentiation only if $c = \frac{t}{8}$, which is not possible under our assumptions). The equilibrium locations of the retailers are quite close in both distribution modes, only in RPM the retailers will incur in a little more differentiation than under COMP.

Image Maintenance

The profit functions of COMP depending on α and β were (2.28) and (2.29). And, the profit function that the manufacturer will maximise is:

$$\begin{aligned} \max_{\alpha,\beta} \quad \Pi_M &= n \cdot (q_A^* + q_B^*) + F_A + F_B \\ s.t. \quad \Pi_A^* &\geq 0\,,\ \Pi_B^* \geq 0. \end{aligned} \tag{2.51}$$

The manufacturer will choose his franchise fee so that $\Pi_A^* = \Pi_B^* = 0$, so $F_A = \frac{3[2(R-n)+t(\alpha+\beta)]^2}{50t} - c\alpha^2$ and $F_B = \frac{3[2(R-n)+t(\alpha+\beta)]^2}{50t} - c\beta^2$. And then he will maximise with respect to the retailers' locations α and β his profit function:

$$\Pi_M = \frac{3\left[2\left(R-n\right)+t\left(\alpha+\beta\right)\right]^2 - 25ct\left(\alpha^2+\beta^2\right) + 15n\left[2\left(R-n\right)+t\left(\alpha+\beta\right)\right]}{25t}. \tag{2.52}$$

Manufacturer's Location Decision: The F.O.C. of the manufacturer's problem are:

$$\frac{\partial \Pi_M}{\partial \alpha} = \frac{3}{25}\left[4R+n+2t\left(\alpha+\beta\right)\right] - 2c\alpha = 0, \tag{2.53}$$

[28]The S.O.C. hold if we consider our assumption that $c \geq t$, $\frac{\partial^2 \Pi_A}{\partial \alpha^2} = \frac{1}{8}t - 2c < 0$ and $\frac{\partial^2 \Pi_B}{\partial \beta^2} = \frac{1}{8}t - 2c < 0$.

$$\frac{\partial \Pi_M}{\partial \beta} = \frac{3}{25}\left(4R + n + 2t\left(\alpha + \beta\right)\right) - 2c\beta = 0. \tag{2.54}$$

From them we get the best response functions:

$$\alpha = \frac{3\left(4R + n + 2t\beta\right)}{2\left(25c - 3t\right)}, \qquad \beta = \frac{3\left(4R + n + 2t\alpha\right)}{2\left(25c - 3t\right)}. \tag{2.55}$$

And the equilibrium locations under the IM mode of distribution[29]:

$$\alpha^* = \frac{3\left(4R + n\right)}{2\left(25c - 6t\right)}, \qquad \beta^* = \frac{3\left(4R + n\right)}{2\left(25c - 6t\right)}. \tag{2.56}$$

Manufacturer's Pricing Decision: The manufacturer also chooses the price of the standard product in this regime in order to maximise his profits:

$$\Pi_M = \frac{3\left(4Rnc + 3n^2t + 8R^2c - 12n^2c\right)}{2t\left(25c - 6t\right)}. \tag{2.57}$$

The F.O.C. is:

$$\frac{\partial \Pi_M}{\partial n} = \frac{3\left(2Rc + 3nt - 12nc\right)}{t\left(25c - 6t\right)} = 0. \tag{2.58}$$

And the optimal intermediate price[30]:

$$n^* = \frac{2cR}{12c - 3t}. \tag{2.59}$$

Complete Control

The profit functions of RPM depending on α and β were those in equation (2.46). Let us remind that in CC and in RPM, p_A and p_B are final retail prices, not profit margins, so the manufacturer will not charge any intermediate price ($n = 0$). The manufacturer will optimise with respect to locations:

[29] The S.O.C. hold under our assumptions: $\frac{\partial^2 \Pi_M}{\partial \alpha^2} = \frac{6}{25}t - 2c < 0$, and $\frac{\partial^2 \Pi_M}{\partial \beta^2} = \frac{6}{25}t - 2c < 0$.

[30] The S.O.C. holds: $\frac{\partial^2 \Pi_M}{\partial n^2} = -9\frac{4c-t}{t(25c-6t)} < 0$.

$$\begin{aligned}\max_{\alpha,\beta} \quad \Pi_M &= F_A + F_B \\ s.t. \quad \Pi_A^* &\geq 0\,,\ \Pi_B^* \geq 0.\end{aligned} \tag{2.60}$$

The manufacturer will choose $F_A = \frac{[2R+t(\alpha+\beta)]^2}{16t} - c\alpha^2$ and $F_B = \frac{[2R+t(\alpha+\beta)]^2}{16t}$ $-c\beta^2$, so that $\Pi_A^* = \Pi_B^* = 0$. And then he will maximise with respect to the retailers' locations α and β his profit function:

$$\Pi_M = \frac{[2R + t\,(\alpha+\beta)]^2}{8t} - c\left(\alpha^2 + \beta^2\right). \tag{2.61}$$

Manufacturer's Location Decision: The F.O.C. of the manufacturer's location choice for the retailers are:

$$\frac{\partial \Pi_M}{\partial \alpha} = \frac{1}{2}R + \frac{1}{4}t\,(\alpha+\beta) - 2c\alpha = 0, \tag{2.62}$$

$$\frac{\partial \Pi_M}{\partial \beta} = \frac{1}{2}R + \frac{1}{4}t\,(\alpha+\beta) - 2c\beta = 0. \tag{2.63}$$

And the best response functions:

$$\alpha = \frac{2R + t\beta}{8c - t}, \qquad \beta = \frac{2R + t\alpha}{8c - t}. \tag{2.64}$$

So, the manufacturer's profit maximising locations are[31]:

$$\alpha^* = \frac{R}{4c - t}, \qquad \beta^* = \frac{R}{4c - t}. \tag{2.65}$$

Note that these location equations are identical to those in IM. The locations under IM and CC produce more differentiation in equilibrium than RPM or COMP.

[31] The S.O.C. hold: $\frac{\partial^2 \Pi_M}{\partial \alpha^2} = \frac{1}{8}\frac{2t^2 - 16ct}{t} < 0$ and $\frac{\partial^2 \Pi_M}{\partial \beta^2} = \frac{1}{8}\frac{2t^2 - 16ct}{t} < 0$.

Exclusive Territories

Retailer's Pricing Decision: When choosing his retail price the retailer is also determining his captive market, and in the ET distribution mode, this is equivalent to his location.

The first order condition of the maximisation problem is:

$$\frac{\partial \Pi_A}{\partial p_A} = \frac{2\left[R\left(t+c\right) - p_A\left(2t+c\right)\right]}{t^2} = 0.$$

From where we extract the maximising[32] price for the retailer:

$$p_A^* = p_B^* = \frac{R\left(c+t\right)}{c+2t}. \tag{2.66}$$

With these prices, the locations will be:

$$\alpha^* = \beta^* = \frac{R}{c+2t}. \tag{2.67}$$

This time both differentiation and transportation costs play against differentiation. But the degree of differentiation attained under ET is greater than for any of the other distribution modes considered until now. Only for $c = t$ it will coincide with IM and CC.

Retail Monopoly

Retailer's Pricing Decision: The monopolist retailer only has to decide his retail price, because his location will obviously be zero, given that consumer density is the same along the line and the retailer does not need to incur in any differentiation cost to reduce competition. We set up the F.O.C. of the maximisation problem:

$$\frac{\partial \Pi_A}{\partial p_A} = \frac{2\left(R - p_A\right)}{t} = 0. \tag{2.68}$$

The maximising price is[33]:

$$p_A^* = \frac{R}{2}. \tag{2.69}$$

[32] We check that the second order condition holds: $\frac{\partial^2 \Pi_A}{\partial p_A^2} = -2\frac{2t+c}{t^2} < 0$.

[33] Let us check that the S.O.C. holds $\frac{\partial^2 \Pi_A}{\partial p_A^2} = -\frac{4}{t} < 0$.

2.7.2 Proof of Proposition 2.2

Let us compare the equilibrium retailers' locations under every distribution mode:

$\alpha_{ET} - \alpha_{IM=CC} = \frac{R}{2t+c} - \frac{R}{4c-t} = \frac{3R(c-t)}{(2t+c)(4c-t)}$. This difference is always positive, remember our assumption $c \geq t$, it can only be zero when $c = t$.

$\alpha_{IM=CC} - \alpha_{RPM} = \frac{R}{4c-t} - \frac{R}{8c-t} = \frac{4cR}{(4c-t)(8c-t)}$. This difference is always positive.

$\alpha_{RPM} - \alpha_{COMP} = \frac{R}{8c-t} - \frac{5R}{2(25c-4t)} = \frac{R(10c-3t)}{2(8c-t)(25c-4t)}$. This difference is always positive.

Besides, as $c \to \infty$ the denominators of all the location expressions go to infinity, so location goes to zero. Furthermore, this happens gradually, as c grows in terms of t. **QED**

2.7.3 Proof of Proposition 2.3

Let us compare the manufacturer's equilibrium profit under every distribution mode:

$\Pi_{IM=CC} - \Pi_{ET} = \frac{2cR^2}{t(4c-t)} - \frac{2R^2}{2t+c} = \frac{2R^2\left(c^2-2ct+t^2\right)}{t(4c-t)(2t+c)}$. This difference is always positive, remember our assumption $c \geq t$, it can only be zero when $c = t$.

$\Pi_{IM=CC} - \Pi_{RPM} = \frac{2cR^2}{t(4c-t)} - \frac{2cR^2(16c-t)}{t(8c-t)^2} = \frac{8R^2c^2}{(4c-t)(8c-t)^2}$. This difference is always positive, so $\Pi_{IM=CC} > \Pi_{RPM}$ $\forall c$.

If $c < 1.511 \cdot t$ we have that $\Pi_{ET} > \Pi_{RPM}$, while if $c > 1.511 \cdot t$ then $\Pi_{ET} < \Pi_{RPM}$.

$\Pi_{RPM} - \Pi_{COMP} = \frac{2cR^2(16c-t)}{t(8c-t)^2} - \frac{25cR^2}{2t(25c-4t)} = \frac{cR^2(44c-9t)}{2(8c-t)^2(25c-4t)}$. This difference is always positive, so $\Pi_{RPM} > \Pi_{COMP}$ $\forall c$.

If $c < 1.6 \cdot t$ we have that $\Pi_{ET} > \Pi_{COMP}$, while if $c > 1.6 \cdot t$ then $\Pi_{ET} < \Pi_{COMP}$.

$\Pi_{COMP} - \Pi_{MON} = \frac{25cR^2}{2t(25c-4t)} - \frac{R^2}{2t} = \frac{2R^2}{25c-4t}$.This difference is always positive, so $\Pi_{COMP} > \Pi_{MON}$ $\forall c$.

If $c < 2 \cdot t$ we have that $\Pi_{ET} > \Pi_{MON}$, while if $c > 2 \cdot t$ then $\Pi_{ET} < \Pi_{MON}$.

Finally, we can see, by calculating the limits, that Π_{COMP}, $\Pi_{CC} = \Pi_{IM}$, and $\Pi_{RPM} \longrightarrow \Pi_{MON} = \frac{R^2}{2t}$ when $c \longrightarrow \infty$. **QED**

2.7.4 Proof of Proposition 2.4

Let us compare social welfare under every distribution mode:

$$W_{COMP} - W_{IM=CC} = \frac{25R^2\left(75c^2-8tc-2t^2\right)}{4t(25c-4t)^2} - \frac{2R^2\left(6c^2-tc-t^2\right)}{t(4c-t)^2} =$$

$$= \frac{3R^2\left(1769c^2t-1200c^3-424t^2c+26t^3\right)}{4(-25c+4t)^2(4c-t)^2}$$

This difference is positive if $c < 1.1932803 \cdot t$ and it is negative if $c > 1.1932803 \cdot t$.

$$W_{COMP} - W_{RPM} = \frac{25R^2\left(75c^2-8tc-2t^2\right)}{4t(25c-4t)^2} - \frac{2R^2\left(24c^2-tc-t^2\right)}{t(8c-t)^2} =$$

$$= \frac{R^2\left(2203c^2t+600c^3-872t^2c+78t^3\right)}{4(-25c+4t)^2(8c-t)^2}$$

This difference is always positive, remember our assumption $c \geq t$, so $W_{COMP} > W_{RPM}$ $\forall c$.

If $c < 1.049 \cdot t$ we have that $W_{RPM} > W_{CC} = W_{IM}$, while if $c > 1.049 \cdot t$ we have: $W_{RPM} < W_{CC} = W_{IM}$.

$$W_{RPM} - W_{ET} = \frac{2R^2\left(24c^2-tc-t^2\right)}{t(8c-t)^2} - \frac{2R^2(3t+c)}{(2t+c)^2} = \frac{2R^2\left(31c^3t+24c^4+39t^3c-7t^4-85c^2t^2\right)}{t(8c-t)^2(2t+c)^2}.$$

This difference is always positive, so $W_{RPM} > W_{ET}$ $\forall c$.

$W_{RPM} - W_{MON} = \frac{2R^2\left(24c^2-tc-t^2\right)}{t(8c-t)^2} - \frac{3R^2}{4t} = \frac{R^2(40c-11t)}{4(8c-t)^2}$. This difference is always positive so $W_{RPM} > W_{MON}$ $\forall c$.

If $c = t$ we have that $W_{CC} = W_{IM} = W_{ET}$, while if $c > t$ we have: $W_{CC} = W_{IM} > W_{ET}$.

If $c < 1.44 \cdot t$ we have that $W_{ET} > W_{MON}$, while if $c > 1.44 \cdot t$ we have: $W_{ET} < W_{MON}$.

Finally, we can see, by calculating the limits, that W_{COMP}, $W_{CC} = W_{IM}$, and $W_{RPM} \longrightarrow W_{MON} = \frac{3R^2}{4t}$ when $c \longrightarrow \infty$. **QED**

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Chapter 3

Experiments on Location and Pricing

3.1 Introduction

Product differentiation has been broadly studied by economists. However, while numerous theoretical models have been used to explain a large number of phenomena related with product differentiation[1], empirical work aimed at formally testing theoretical predictions represents only a very small part of the literature. This lack of systematic empirical testing of product differentiation theory is often explained as a result of the difficulties faced by economists to successfully represent the product differentiation variable by proxies based on real world data[2]. Furthermore, in empirical work in which product differentiation is accounted for, the latter is treated as an explanatory variable of other economic phenomena. Therefore, in a strict sense, product differentiation theory remains an empirically unexplored field of our discipline.

[1]An exhaustive list of such phenomena falls out of the scope of this paper. As representative examples, we mention minimal differentiation and variety clustering [like in Hotelling (1929) and Eaton and Lipsey (1975)], maximal differentiation [like in D'Aspremont *et al.* (1979)], predation [Judd (1985)] and multiproduct activity [Aron (1993)] or the lack of it [Martínez-Giralt and Neven (1988)], *etc.*

[2]Along this line, an assumption which seems to be broadly accepted by economists is that RD expenses are a good proxy for vertical product differentiation and advertising levels can be used as a proxy for horizontal differentiation. For a critical review of some of these assumptions and other similar ones, see Greenaway (1984).

Like in the case of many other phenomena for which real world data leave little space for empirically testing economic theories, product differentiation models have been tested in the laboratory. Brown-Kruse and Schenk (2000), Collins and Sherstyuk (2000), and Huck *et al.* (2000), study experimental spatial markets with 2, 3 and 4 firms, respectively. All three articles report experiments with subjects whose only decision variable is location. Like in earlier work by Brown-Kruse *et al.* (1993), prices were taken to be exogenously given. Minimal product differentiation predicted by theory as the non-cooperative equilibrium for the framework used in Brown-Kruse *et al.* (1993) and Brown-Kruse and Schenk (2000), as well as 'intermediate'[3] differentiation predicted as the collusive outcome of the framework when communication among subjects is allowed were given support by their experimental results. The assumption of non-price competition in the experimental studies of spatial competition reviewed above, makes the results obtained directly applicable to the voting literature[4].

However, a standard intuition which has motivated most of the theoretical work on the economics of product differentiation is that a firm may want to differentiate its product from products sold by rival firms in order to relax price competition. Our aim in this chapter is to experimentally test the predictions of a location-and-price competition model of horizontal product differentiation. The experiment we design has three essential characteristics: (a) it is a two-stage location and price game with two sellers, (b) there is a small number of location and price choices which leads to high risk in subject's decision making, and (c) the design allows to compare individual and group decision making, and also the results with an odd or even number of possible varieties. As we will see in Section 3.4, the repetition of the two stage location-then-price competition game asks for an experimental design which solves the problem of representing short- (pricing) and long-term (design)

[3]We use this term to refer to a product differentiation that lies between minimal (both firms locate in the middle of the segment) and maximal (each firm occupies one of the two extremes of the line) differentiation. In fact, the degree of product differentiation which corresponds to the joint profit-maximising solution is shown to require the firms to locate on the quartiles of the segment.

[4]Since Downs' (1957) work, non-price competition by competitors choosing locations on a closed linear segment along which a population of consumers (voters) are uniformly distributed is often adopted by theoretical political scientists to model electoral competition between political parties. For a more detailed review of this literature see Collins and Sherstyuk (2000).

decisions in an efficient way.

Apart from considering price competition, in our study we introduce several changes in the original Hotelling (1929) model of product differentiation. Most of these changes, which are described in detail in the following section, are motivated by real world situations and a few of them are inspired in the findings of previous experimental results.

The resulting theoretical model highlights the importance of using discrete variables as the strategic space of players. Another feature which emerges as a determinant factor of observed behaviour is a subject's attitude towards risk. Interestingly but not surprisingly, this is also pointed out by Collins and Sherstyuk (2000) for the non-price competition version of the framework. Finally, unlike the framework adopted in the three aforementioned articles, our framework allows for incomplete market coverage, which is, though, observed in a much smaller number of occasions than we would have initially thought.

Despite important differences between our framework and the Hotelling (1929) model, our subject's aggregate behaviour confirms to some extent the principle of minimum product differentiation and almost competitive price levels. But, this is only the most frequent result, several other situations with intermediate differentiation degrees and higher prices are also obtained. A treatment with collective players indicates that groups are less successful than individual players in adopting product differentiation strategies. However, given a high degree of product differentiation, groups are more successful in establishing higher prices than individuals are. Finally, a treatment with an even number of possible locations indicates that, in such a setting, price and variety competition is less intense than in one with odd locations, where there exists a unique central variety.

The remaining part of the chapter is organised in the following way: Section 3.2 offers a detailed description of the theoretical framework and a brief discussion of theoretical problems and considerations which should be taken into account in order to explain our experimental subjects' behaviour. In Section 3.3, we describe the market situation our subjects are faced with and we present the theoretically probable outcomes of the situation. In Section 3.4, the experimental design and results are discussed. Section 3.5 concludes. In the Appendix we present the tables which summarise the Nash equilibria in the pricing subgames.

3.2 Framework

The aim of this chapter is to study human behaviour in economic situations which deviate in one or more ways from the ideal environments implied by the assumptions of theoretical economic models. A simple example of such an assumption, which is too often considered to be innocuous by theorists, is coordination by firms locating on a linear segment. Experimental results show that the lack of implicit coordination possibilities may yield frustration among subjects which fail to differentiate from each other in a successful way (for example, firm A on the left and firm B on the right of the segment). One could argue that this is a minor issue in terms of intuition for decision making and economic policy in real world markets, but there is no doubt that ignoring coordination problems altogether might yield misleading conclusions concerning the benefits from explicit communication among firms[5].

In the framework proposed here, a number of standard assumptions in product differentiation models are modified in order to analyse the difficulties faced by experimental subjects when acting in a more realistic environment than that assumed in existing product differentiation theory. The main modification introduced is motivated by the fact that, in the real world, product prices are chosen from a discrete space of values (dictated by each country's monetary units and other factors related with the buyer's capacity of calculation and comparison of available alternatives). Furthermore, product differentiation itself may be subject to technological restrictions which limit the possible varieties of a differentiated product which can be supplied by the manufacturers to the consumers. The latters' ideal varieties may also be dictated by the technologically feasible options available to manufacturers.

Following these observations, we propose a theoretical model which is a discretised version of the Hotelling (1929) model of product differentiation. That is, in our setup, locations and prices are chosen by firms from finite strategic spaces (with a finite number of elements each). In the location strategic space, feasible firm locations are chosen to coincide with a number of (discrete) locations on which (a finite number of non-zero mass) consumers are assumed to be.

A number of theoretical results indicate the possibility of non existence of equilibrium in economic games with discontinuous payoff functions. A fa-

[5]Brown-Kruse and Schenk (2000) have already experimentally studied horizontal product differentiation under different communication regimes, so we will not treat this important question in our experiments.

mous example is the proof by D'Aspremont *et al.* (1979) concerning non existence of a pure-strategy equilibrium in the price-setting stage of the Hotelling (1929) model of product differentiation. It can be easily verified that, in our framework, the stage price-setting game will, in general fail to have a pure-strategy equilibrium. Despite the fact that both the price-setting as well as the location-then-price competition games are repeated a finite number of periods, the non existence of pure strategy equilibria in some of the price-setting subgames is not necessarily translated into non-existence of a pure-strategy equilibrium of the supergame considered here. In the case of our framework, in which not only payoffs but, also, action spaces are discontinuous and (thus) discontinuity points do not satisfy the property of a negligible probability (Dasgupta and Maskin (1986a, 1986b)) or, even the weaker version of the property required by Simon (1987)[6], a mixed strategy equilibrium may also fail to exist. However, it can be shown that, in the special case considered here under the assumption of *risk-neutrality*, backward induction by substitution of subgames with their corresponding mixed strategy equilibria in prices leads to a pure strategy equilibrium for the supergame, in both prices and locations.

A discrete consumer location framework is also used by Collins and Sherstyuk (2000), but their number of consumer locations is much larger than ours (100 against 7), so that, in our framework, the possibility of a 'draw' on a consumer location is far more important for a firm's profits. This, together with the fact that, in the experiments reported here, 'draws' are solved in a probabilistic -rather than a deterministic- way (by tossing a coin) exposes our subjects to a far more significant risk than that faced by Collins and Sherstyuk's (2000)[7] subjects. Therefore, consumers are not treated as zero-mass particles of a population whose individual ideal varieties are distributed according to a continuous distribution function along the relevant product characteristics space. Rather, they are treated as individuals (or, generally speaking, clusters of individuals) with unit demand (potentially) for the product supplied by the manufacturers.

It is important to note the difference between our basic and even treatments. In the basic treatment we have considered an odd number of equally

[6]The author requires that only some (even one) of the discontinuity points satisfies the negligible probability property.

[7]In that work, the authors assume that 10 units are demanded at each location and, in the case in which a 'draw' occurs, 5 units are purchased from each of the two firms involved.

spaced locations, and in the even one an even number of consumers and feasible firm locations exist. Our interest in the odd number case is that, together with some difficulties which are explained below, a further difficulty seems to arise when an attraction point (which does not necessarily coincide with a theoretical equilibrium of the game) of subjects' strategies implies an *ex post* asymmetric outcome following an *ex ante* symmetric initial situation.

In the real world design decisions concern a number of people organised in a group representing a firm's interest. However, this issue has not been (and, probably, cannot be) addressed by product differentiation theory. Accordingly, between our basic and collective treatments there is no difference from a theoretical point of view, but we can expect that groups are more reluctant to take risky options than individuals. This should be reflected in differences between the two treatments results. Differences in the consistency of individual and group decision making have been experimentally studied by Bone *et al.* (1999). And experimental results obtained by Bornstein and Yaniv (1998) support the hypothesis that groups are more rational players than individuals.

The experimental design is such that the two stage (location-then-price competition) game is modified in order to gain in realism by introducing finite sets of periods during which firms can only modify their prices, taking product design as given. The repetition of this sequence (product design, price, price, price...) over a finite number of times does not modify the theoretical equilibrium predictions and constitutes a useful way of implementing the usual multistage representation of (more) long-run and (more) short-run economic variables in experimental environments.

As far as learning is concerned, our experimental design requires far less complex calculations by subjects than the continuous (in locations, prices and consumer tastes) framework. Therefore, players are not only fully informed on the market conditions, but also, they are exposed to a minimum level of complexity when calculating the consequences of their decisions. García-Gallego (1998) and García-Gallego and Georgantzís (2001) report the results from experiments in which subjects had no information on the true demand model. The estimation of a firm-specific demand model by O.L.S. (available to firms) was shown to be of little use to subjects who seemed to lack incentives to learn or capacity to calculate their optimal strategies. Implicit learning with trial-and-error algorithms were not found to guarantee convergence to the theoretical predictions. Contrary to these findings, we would not expect that divergence between predicted behaviour and that obtained from our experiments could be only due to the aforementioned limitations in our subjects' learning possibilities. Rather, we will argue that such divergence is mainly due to the differences between our subjects' attitude towards risk and that assumed in the predicted theoretical equilibrium. This observation closely relates to a special feature of the *discrete* model presented here. That is, when individual (rather than zero-mass) consumers are considered, the probability of a 'draw' on a given consumer location has nonnegligible probability of occurring. We assume that 'draws' are solved by a random mechanism (tossing a coin). Then, the attitude of firms towards risk emerges as an important determinant factor of observed behaviour and this may be used to explain the divergence between our initial theoretical predictions, under risk-neutrality, and our subjects' observed behaviour. As stated before, a solution of the theoretical model is presented, assuming a very weak version of risk aversion (we refer to it as *risk-neutrality*) which makes a subject prefer a certain payoff to an expected gain of the same size, but prefer any expected gain to a certain one of a lower size. That is, subjects' risk aversion is assumed to motivate their preference for the least risky among a number of equal payoffs, whereas subjects are never sufficiently risk averse to prefer a lower payoff to a higher one, no matter how high the risk implied in the latter may be. As we will see, our results indicate that, in reality, our subjects may have been much more conservative than the theoretical model has assumed them to be. In fact, our results are more compatible with a demand maximising behaviour (or *maximin* playing), which may emerge from subjects' strong aversion towards low-demand outcomes. This result is compatible with a similar observation in Collins and Sherstyuk (2000) whose theoretical foundation is Osborne's (1993) result that the characterisation of mixed strategy equilibria may vary according to assumptions concerning a player's attitude towards uncertainty.[8]

3.3 A Model

Let two firms, A and B, play a two-stage game. In the first stage, firm $i \in \{A, B\}$ chooses a location $L_i \in \{1, 2, ...n\}$ (in the experiments, $n = 7$ in the Basic and Collective Treatments and $n = 8$ in the Even Treatment) among n

[8]In fact, in Harsanyi (1967), it is argued that a mixed strategy equilibrium can, under certain circumstances, be viewed as a pure strategy equilibrium in a game of incomplete information.

equally spaced points along a unit-length linear segment, as shown in Figure 3.1. In the second stage, after the location choices are known by both firms, each firm chooses a price $P_i \in \{0, 1, 2, ...P^{\max}\}$ (given the assumptions stated below, $P^{\max} = 10$).[9] In each stage, decisions are simultaneously made by the two firms, whose aim is to maximise individual profits. Firms sell their product to n consumers, each one located on each one of the equally spaced points on the linear segment.

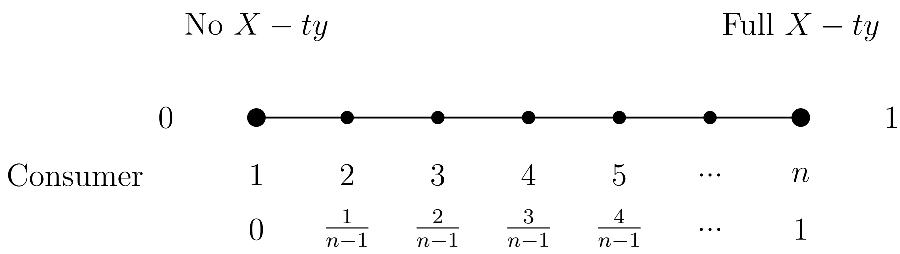

Figure 3.1: Linear city with discrete locations.

A consumer $j \in \{1, 2, 3...n\}$ (here $n = 7$ or 8, depending on the treatment, as stated above) buys a maximum of *one* unit of the product from firm $i \in \{A, B\}$ in order to maximise her utility given by:

$$U_{ji} = \max\{10 - p_i - t \cdot x_{ji}, 0\},$$

where x_{ji} is the 'distance' on the product characteristics space between j's ideal variety and the one actually offered by firm i, and t (here $t = 6$ for the Basic and Collective Treatments, and $t = 7$ for the Even Treatment) is a unit-transportation cost parameter (disutility suffered for each unit of 'distance' between a consumer's ideal and consumed varieties). The decision of the consumer to purchase the good from i implies that $U_{ji} \geq U_{jk}$,with $k \neq i$. In fact, if $U_{ji} = U_{jk}$ holds, the consumer will randomly choose one of the two firms (with a probability of 1/2 for each firm).

[9] As we will see in the experimental design section, we have made the game last for 25 periods. In periods 1, 5, 10, 15, 20, and 25, both the location and the pricing decision are taken. In the rest of the periods, the subgame has only one stage, the pricing one, location remains fixed until the next location and price decision period. As the repetition of the game is finite, the equilibrium we obtain for the one shot game can easily be adapted in order to describe the equilibrium of the whole supergame.

3.3.1 Optimal and Equilibrium Strategies

As stated before, a pure strategy equilibrium does not exist for all combinations of firm locations. Before calculating the equilibrium, we propose and discuss some combinations of location and pricing strategies that can be thought of as globally optimal solutions. Although these are not predicted as equilibria of the game considered, they offer a useful benchmark for the analysis of globally ideal behaviour. As can be observed from the comments in the lines below, not even the optimal strategies can be obtained without specific assumptions concerning players' attitude towards uncertainty.

Basic and Collective Treatments

Tacit Collusion A *global maximum* in the two firms' joint profit is obtained with firms locating on locations 2 and 6 and prices $(P_i, P_k) = (8, 9)$, for $(i, k) = (A, B)$. Then, all consumers are served and the joint profit is given by $8 \cdot 4 + 9 \cdot 3 = 32 + 27 = 59$. A main problem associated with this optimum as a target of subjects acting individually and in the lack of any communication and tacit coordination possibilities is asymmetry. It is very unlikely that one of two *ex ante* symmetric inequity averse players will accept the role of the low-profit (the one whose price is 9 earns 27 monetary units against 32 earned by his 'rival') firm, especially when side payments are impossible. A more complex coordination mechanism could be used by firms in order to change roles over subsequent periods as a profit-sharing device, but this, given our experimental results seems a rather unrealistic scenario.

A *symmetric* joint profit-maximising solution is obtained if firms (who are now assumed to restrict their strategy profiles to those with symmetric prices) choose the same locations, but set a price $P = 8$. Joint profits are, now, given by $8 \cdot 7 = 56$. A problem which is associated with this solution is that each firm's expected demand is 3.5 which is the result of a 'draw' on the *central* consumer location. This implies that each firm's *ex post* profits will be either $8 \cdot 4 = 32$ or $8 \cdot 3 = 24$ (each firm's expected profits are, then, given by 28).

A *risk-averse* joint profit-maximising solution could be the symmetric strategy profile $P = 9$. Then, given firm locations 2 and 6, the consumer in the middle (location 4) will prefer not to buy the good at all. Firms earn certain profits of $9 \cdot 3 = 27$ monetary units each (joint profits are 54). This strategy would be chosen by tacitly colluding firms if they were sufficiently risk averse to prefer a certain payoff that is one unit less than an expected gain implying a 50% probability of earning three units less than the certain payoff guarantees.

A final remark concerns the optimality of multi-location (-plant) operation. It can be easily checked that locating in the middle of the segment (one or two plants) can at most yield (for the optimal price $P = 7$) 49 monetary units of profit, which is far below the multi-location optima above.

Non-cooperative Equilibria It can be checked that none of the solutions discussed above can be sustained as an equilibrium of the game, given that individual deviations from them are profitable. In order to discuss the Subgame Perfect Equilibrium of the game, we will, first, have to calculate equilibrium prices for all firm location combinations. A pure strategy equilibrium in prices exists for some of the location combinations. In fact, it is straightforward to check that pure strategy Nash equilibria exist in the price-setting subgame for all firm locations for which the distance between firms x_{ik} satisfies $x_{ik} \notin [2/6, 3/6]$. For location combinations implying differences in the interval $[2/6, 3/6]$, we have computed mixed strategy equilibria of the price-setting stage[10]. We provide here the (expected) payoff matrix corresponding to price-equilibrium for all possible location combinations.

	1	2	3	4	5	6	7
1	(3'5, 3'5)^e	(1, 6)	(4'5, 13'6)*	(10, 22'3)*	(18, 28)	(21, 28)	(24'5, 24'5)^e
2	(6, 1)	(3'5, 3'5)^e	(2, 5)	(10, 16'9)*	(20, 23'6)*	(24'5, 24'5)^e	(28, 21)
3	(13'6, 4'5)*	(5, 2)	(3'5, 3'5)^e	(6, 8)	(18'2, 18'2)*	(23'6, 20)*	(28, 18)
4	(22'3, 10)*	(16'9, 10)*	(8, 6)	(3'5, 3'5)^e	(8, 6)	(16'9, 10)*	(22'3, 10)*
5	(28, 18)	(23'6, 20)*	(18'2, 18'2)*	(6, 8)	(3'5, 3'5)^e	(5, 2)	(13'6, 4'5)*
6	(28, 21)	(24'5, 24'5)^e	(20, 23'6)*	(10, 16'9)*	(2, 5)	(3'5, 3'5)^e	(6, 1)
7	(24'5, 24'5)^e	(21, 28)	(18, 28)	(10, 22'3)*	(4'5, 13'6)*	(1, 6)	(3'5, 3'5)^e

Table 3.1: Mixed (*) and pure strategy price equilibrium (expected(^{e})) payoffs for the Basic and Collective Treatments.

Following this payoff matrix, it is easy to see that *risk-neutral* players' equilibrium location and pricing equilibrium for the supergame is that given in Table 3.2:

[10] In the Appendix we provide the tables which summarise the mixed and pure strategy price equilibria for each location combination.

Locations	Prices	Expected Demands	Expected Profits
(2, 6)	(7, 7)	(3’5, 3’5)	(24’5, 24’5)

Table 3.2: Location and price equilibrium of the supergame for the Basic and Collective Treatments.

As stated above, in the calculation of the subgame perfect equilibrium of the game we have assumed risk-neutrality, according to which only in the case of equality between a certain and an expected payoff subjects prefer certainty. However, it is worth noting that this assumption may be stronger than what one would think. An alternative solution in which strong risk aversion is assumed can be sketched in the following lines.

From textbook game theory, we know that playing *maximin strategies* does not only fail to give a Nash equilibrium of a non-cooperative game, but, in the case of nonzero-sum games, may be an irrational strategy. However, we can imagine that a very risk averse player may want to guarantee a minimum payoff independently from the other players’ strategies. Ignoring the other player’s rationality may lead a subject to treat strategic interaction and uncertainty in the same way. In any case, strong risk aversion may be interpreted as an extreme fear that the worst outcome will emerge, including the case of an opponent who is irrational enough to pursue minimum rival payoffs rather than own utility maximisation. We will use the *maximin strategy* $(L_i, P_i) = (4, 1)$ as a benchmark (and extreme) behaviour for strongly risk averse (or pessimistic) players.

We can summarise the predictions corresponding to the theoretical solutions above in the following way.

Theoretical predictions:

3.1) *In the basic and collective treatments, the joint profit-maximising and the risk-neutral players’ non-cooperative equilibrium locations are given by* $(L_i, L_k) = (2, 6)$*. The prediction for the corresponding prices ranges from* 7 *to* 9*, depending on the intensity of price competition, the symmetry requirement and the degree of players’ risk aversion.*

3.2) *However, more central locations leading to lower prices (more intense price competition) are expected in the case of stronger risk aversion, up to the extreme case of* maximin playing *by strongly risk averse players choosing the central location* $L_i = 4$ *and the minimum positive price* $P_i = 1$.

Even Treatment

Tacit Collusion Now a *global maximum,* which besides is *risk-averse*, in the two firms' joint profit is obtained with firms locating on 2 and 6 and prices $(P_i,P_k) = (9,8)$, for $(i,k) = (A,B)$. Then, all consumers are served and the joint profit is given by $9 \cdot 3 + 8 \cdot 5 = 27 + 40 = 67$. Or with firms locating on 3 and 7 and setting prices $(P_i,P_k) = (8,9)$, for $(i,k) = (A,B)$. Profits are $8 \cdot 5 + 9 \cdot 3 = 40 + 27 = 67$. A problem associated with these optima is, as in the other two treatments, the lack of symmetry.

A *symmetric*, and *risk-averse*, joint profit-maximising solution is obtained if firms locate on $(L_i,L_k) = (3,6)$ or $(L_i,L_k) = (2,7)$, for $(i,k) = (A,B)$, and set a price $P = 8$. Joint profits are, now, given by $8 \cdot 8 = 64$. And firms will share them equally. These could be good attraction points for collusion.

Finally, locating only one plant near the middle of the segment, in 4 or 5, can at most yield (for the optimal price $P = 7$) 49 monetary units of profit, which is less than the multi-location optima.

Non-cooperative Equilibria The Subgame Perfect Equilibrium of the supergame is calculated in the same way as for the other two treatments. Now, pure strategy Nash equilibria exist in the price-setting subgame for all firm locations for which the distance between firms x_{ik} satisfies $x_{ik} \notin [2/7, 3/7]$. For location combinations implying differences in the interval $[2/7, 3/7]$, we have computed mixed strategy equilibria[11]. The payoff matrix corresponding to price-equilibrium for all possible location combinations is:

	1	2	3	4	5	6	7	8
1	(4, 4)	(1, 7)	$(4, 12)^*$	$(9, 22)^*$	(18, 35)	$(24'5, 36)^e$	(28, 32)	(28, 28)
2	(7, 1)	(4, 4)	(2, 6)	$(9, 16)^*$	$(18, 28)^*$	(28, 32)	(32, 32)	(32, 28)
3	$(12, 4)^*$	(6, 2)	(4, 4)	(6, 10)	$(17, 18)^*$	(28, 28)	(32, 28)	$(36, 24'5)^e$
4	$(22, 9)^*$	$(16, 9)^*$	(10, 6)	(4, 4)	(12, 12)	$(18, 17)^*$	$(28, 18)^*$	(35, 18)
5	(35, 18)	$(28, 18)^*$	$(18, 17)^*$	(12, 12)	(4, 4)	(10, 6)	$(16, 9)^*$	$(22, 9)^*$
6	$(36, 24'5)^e$	(32, 28)	(28, 28)	$(17, 18)^*$	(6, 10)	(4, 4)	(6, 2)	$(12, 4)^*$
7	(32, 28)	(32, 32)	(28, 32)	$(18, 28)^*$	$(9, 16)^*$	(2, 6)	(4, 4)	(7, 1)
8	(28, 28)	(28, 32)	$(24'5, 36)^e$	(18, 35)	$(9, 22)^*$	$(4, 12)^*$	(1, 7)	(4, 4)

Table 3.3: Mixed (*) and pure strategy price equilibrium (expected(^{e})) payoffs for the Even Treatment.

[11] In the Appendix we provide the tables.

According to this payoff matrix, one can check that *risk-neutral* players' Pareto superior non-cooperative equilibrium in location and prices is that given in Table 3.4:

Locations	Prices	Demands	Profits
(2, 7)	(8, 8)	(4, 4)	(32, 32)

Table 3.4: Location and price equilibrium of the supergame for the Even Treatment.

Observe that the Nash equilibrium coincides with one of the symmetric and risk-averse joint profit maximising strategies.

In the even treatment we have two possible *maximin strategies:* $(L_i, P_i) = (4, 1)$ and $(L_i, P_i) = (5, 1)$, both offering a minimum expected payoff of 4 experimental units.

We can make the following predictions according to the theoretical solutions for the even treatment:

Theoretical predictions:

3.3) *In the even treatment, the joint profit-maximising and the risk-neutral players' non-cooperative equilibrium locations range from* 2 *to* 3 *for one firm and from* 6 *to* 7 *for the other. The prediction for the corresponding prices ranges from* 8 *to* 9, *depending on the symmetry requirement and the degree of players' risk aversion.*

3.4) *However, more central locations leading to lower prices are expected in the case of stronger risk aversion, up to the extreme case of* maximin playing *by strongly risk averse players choosing the nearest to the center location,* $L_i = 4$ *or* 5, *and the minimum positive price* $P_i = 1$.

3.4 Experimental Design and Results

3.4.1 Experimental Design

Three treatments were organised in 18 experimental sessions each. In the basic treatment (BT) and in the even treatment (ET), the two players were individual subjects, whereas in the collective treatment (CT) each player consisted of a group of 10 to 15 subjects. So, we have had 36 individual subjects playing in the basic treatment, 36 more in the even treatment, and 36 collective subjects playing in the collective treatment. No individual has participated in more than one experimental session in any treatment, or in more than one treatment. The experiments were not computerised. Thanks to the simplicity of the calculations needed to obtain the payoffs, the experimentalist immediately presented the different decisions and results in a blackboard which both players could see. The players were sitting in the same room, but they were separated and surveyed by the experimentalist, so that they could not talk, or see each other[12]. Within each group (forming a collective player) communication and any other type of spontaneous organisation of collective decision was permitted. No communication between rival firms was allowed. Apart from the written set of instructions[13], the organiser of each session gave detailed explanation of how demands and profits should be calculated given any strategic profile chosen by fictitious subjects. The simplicity of the discrete version of the model was found to be a very appropriate environment for full understanding of the consequences of all possible strategies. In fact, no calculus is needed, and any optimisation exercise (when necessary) can be performed using simple arithmetic operations.

Subjects were Economics students from three Universities (Universitat Jaume I in Castellón, University of Valencia and University of Zaragoza). In fact, collective players were students (and groups were formed by classmates) of the undergraduate IO, Game theory, Public Enterprise Economics and Economics of Technical Change courses.

Players were paid at the end of each session according to an exchange rate of 10 Spanish Pesetas for each experimental monetary unit. In the basic and collective treatments a maximum profit of 6750 Pesetas (approximately, 40.5 Euros) could be earned by each subject in firms which would collude during the 25 periods, setting the risk averse optimal price (9). The risk-neutral subjects playing equilibrium strategies during the 25 periods of a session would earn 6125 Pesetas (approximately 36.8 Euros), whereas 875 Pesetas (5.2 Euros) would be earned by a strongly risk averse subject conforming with the *maximin* strategy over the whole experimental session. In the even treatment a maximum profit of 8000 Pesetas (approximately, 48 Euros) could be earned by each subject in firms which would collude during the 25 periods, setting the risk averse optimal price (8). The risk-neutral sub-

[12]The subjects knew that the session would end automatically with zero profits for both if they tried to communicate in any way.

[13]See Appendix.

jects playing equilibrium strategies during the 25 periods of a session could earn the same amount, whereas 1000 Pesetas (6 Euros) would be earned by a strongly risk averse subject conforming with the *maximin* strategy over the whole experimental session. Therefore, our experiments were designed to be worth participating in. Furthermore, subjects were given strong incentives to abandon the conservative (*maximin*) attitude (central locations and unit prices) guaranteeing the minimum payoff.

Each session consists of the repetition of the same basic structure for a total of 25 periods. The duration of each session is known by subjects at the beginning of the game. The basic structure contains product design and pricing decisions. On periods 1, 5, 10, 15, 20 and 25, which we will call 'product design' periods, firms simultaneously choose, first, locations on the line and, then, after their location decisions are known by both, they simultaneously set prices. Following a 'product design' period, firms can only modify prices in the next four 'pricing periods', taking their last location decision as given until the next 'product design' period. The 'location-price...price' sequence is repeated over and over until the 25th period is reached. The last (25th) period of the session is a 'location period', so a location-price sequence is played. We have opted for this strategy as a way to isolate possible end-game behaviour in both location and price strategies.

3.4.2 Aggregate Results from Basic *v.* Collective Treatment

Our aggregate results indicate (Figures 3.2 and 3.3) that collective players have differentiated significantly[14] less than individual players did. Also, their prices have been significantly lower[15]. Average earnings from subjects in the basic treatment have been of 2.631 pts., ranging from 360 pts. to 5510 pts. Whereas, in the collective treatment, they have averaged 2.394 pts., ranging from 820 pts. to 4.610 pts.

[14] A Kolmogorov-Smirnov test has indicated ($KS = 3.67$ against the theoretical value of 1.36) that the difference in the distribution of degrees of differentiation observed in aggregate data from the two treatments is statistically significant at the 0.05 level. It is also significant at the 0.01 level but we will use the 0.05 level throughout the paper for consistency. A Mann-Whitney test can also be used to show that, on average, locations from the collective treatment are more central and less differentiated than those from the basic treatment ($MW = -4.492$ and $MW = -6.303$ against 1.96 respectively).

[15] $KS = 1.4613$ against 1.36 and $MW = -2.581$ against 1.96.

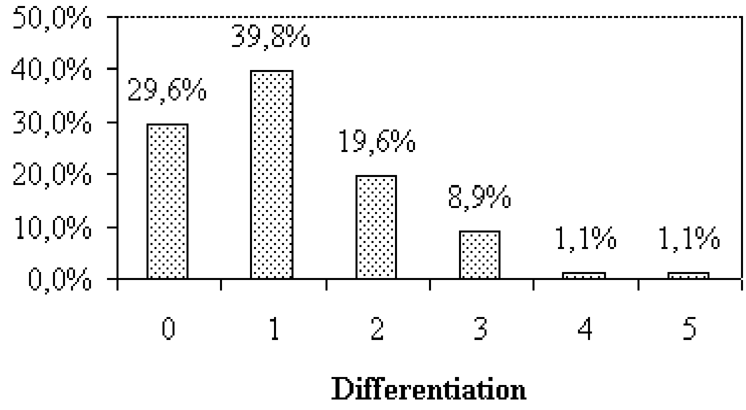

Figure 3.2: Percentages of differentiation in the basic treatment (BT). (*Differentiation* refers to the distance between the two firm's locations measured in sixths of the segment).

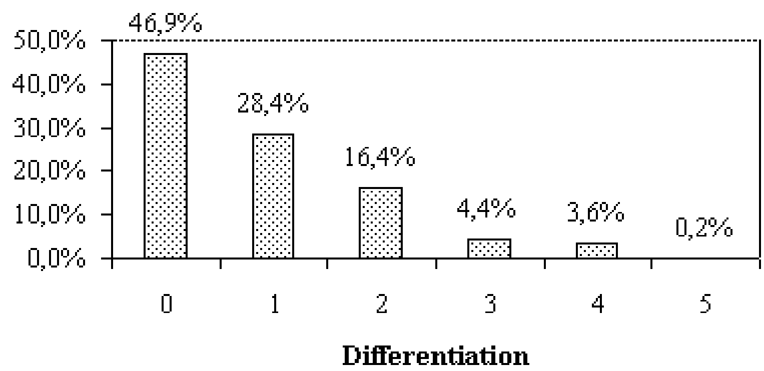

Figure 3.3: Percentages of differentiation in the collective treatment (CT).

For the degrees of differentiation between pairs of firm locations for which a sufficiently large number of observations were obtained, we can affirm the following[16]:

[16]We have performed the analysis taking into account the achieved degree of differentiation, and not the absolute location pairs because, there are so many location combinations that, for most of them, we end up having very few observations on which to base our analysis.

In the absence of product differentiation[17] (zero distance between competing firm locations) the distribution of prices in sessions with collective and individual subjects present no significant[18] differences (Figure 3.4). Average price is only slightly higher in the BT (2.81) than in the CT (2.77). In fact, the most frequent result is the pure strategy Nash equilibrium prediction for the corresponding price subgames ($P = 1$).

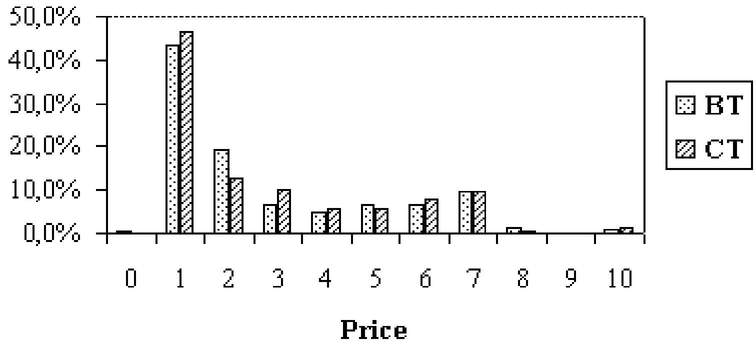

Figure 3.4: Price distribution when differentiation is 0.

With a unit difference between firm locations[19], we find that the distributions of prices obtained from the two treatments are significantly[20] different (Figure 3.5). More specifically, in both treatments subjects have used prices whose distribution has a peak on 2, but average prices are higher (3.54) for the basic treatment than for the collective treatment (2.61). Individual players have managed to set significantly higher prices with a low degree of differentiation. On average, the equilibrium prediction of prices equal to 1 or 2 (depending on the locations on which unit-differentiation takes place) is exceeded by observed behaviour.

[17] 266 observations in the basic treatment and 422 in the collective treatment.
[18] $KS = 0.5$ against 1.36 and $MW = -0.336$ against 1.96.
[19] 358 observations for the BT and 256 for the CT.
[20] $KS = 2.47$ against 1.36 and $MW = -5.24$ against 1.96.

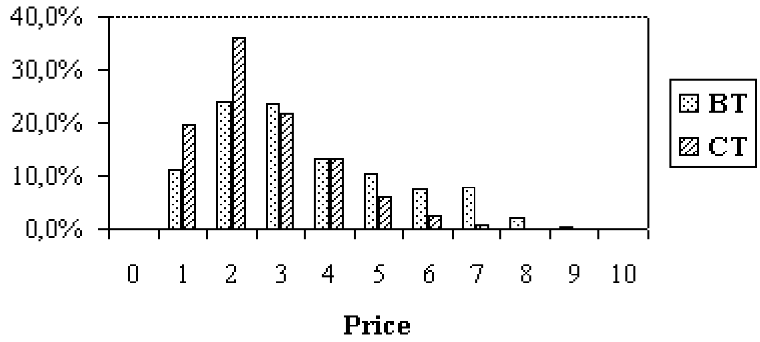

Figure 3.5: Price distribution when differentiation is 1.

When firm locations differ by two[21], the distributions of prices from the two treatments do not present significant[22] differences (Figure 3.6). A peak is observed for a price of 3 in both cases, and collective prices only have a slightly higher average (4.24) than individual ones (3.85). A higher price dispersion may reflect the fact that a pure strategy equilibrium in the pricing stage does not exist. Mixed strategy equilibria prices range from 1 to 6, which seems roughly compatible with our subjects' behaviour.

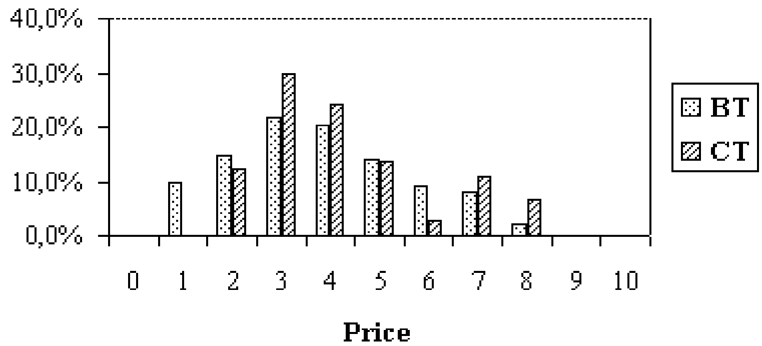

Figure 3.6: Price distribution when differentiation is 2.

[21] 176 observations in the BT and 148 in the CT.
[22] $KS = 1.14$ and $MW = -1.31$.

Locations differing by 3 sixths of the segment[23] present price distributions which significantly[24] vary across treatments (Figure 3.7). Individuals have set lower prices on average than collective players (respectively, peaks on 3 and 5 are observed and respective average prices are 3.30 and 4.55). The mixed strategy equilibrium prediction of prices ranging from 2 to 7 is compatible with the behaviour of both types of players, although individuals have set some prices below the minimum of the aforementioned interval. Finally, location differences of more than 3 (4 or 5) were observed in very few occasions and any conclusions based on this evidence would lack statistical significance.

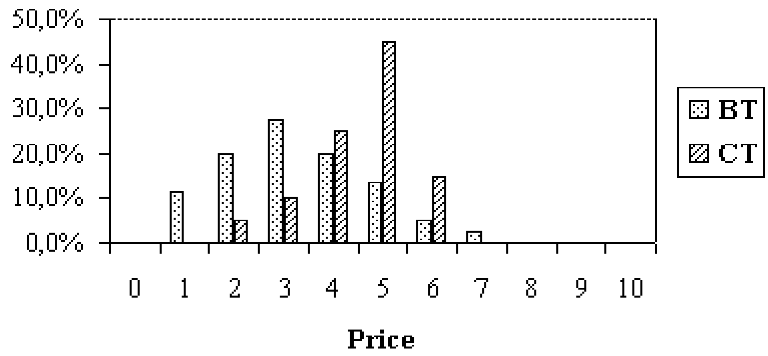

Figure 3.7: Price distribution when differentiation is 3.

On aggregate, a positive relationship between product differentiation and prices is observed (Figure 3.8) and this relationship is stronger for collective subjects. Apart from the aforementioned differences across treatments, our results indicate that our subjects have differentiated much less and they have set much lower prices than those of the risk-neutral perfect equilibrium $((L_i, L_k, P_i, P_k) = (2, 6, 7, 7))$. In fact, the predicted outcome occurred only in two periods of one of the sessions in the collective treatment. The global, the symmetric and the risk-averse joint profit maximum occurred only once each. We have only had incomplete market coverage in one case out of 450 in each treatment. And implicit coordination (having each firm in a different

[23] 80 observations for the BT and 40 for the CT.
[24] $KS = 2.26$ and $MW = -4.76$.

half of the market) has occurred in less than 10 % of the cases in the BT, and in less than 20% of the cases in the CT.

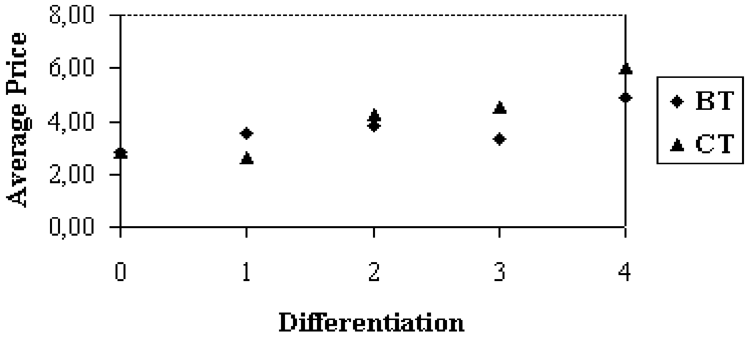

Figure 3.8: Relationship between differentiation and average prices.

Far more support is offered for predicted behaviour under strong risk aversion for location decisions. For example, the central location was chosen in more than half of the 'product design' periods, as can be seen from the aggregate data on locations (Figure 3.9), which were found to exhibit significant differences across treatments[25].

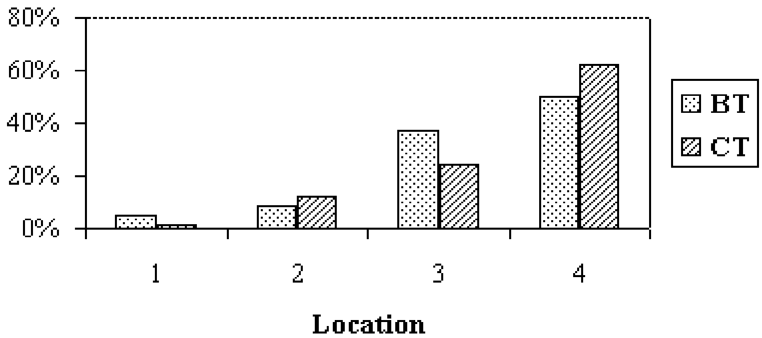

Figure 3.9: Aggregate location distribution.[26]

[25] $KS = 2.61$.

[26] We have considered that location 1=7, 2=6, and 3=5.

Along the same line, aggregate price data, which, as we have already noted, significantly vary across treatments, give more support to the strong risk-averse players' prediction of unit prices (it is the most frequent price), than to a price of 7, predicted under the assumption of risk-neutrality (Figure 3.10). Anyway, we observe too a high price dispersion to be able to support any unique result in aggregate terms. Prices have been, more or less, close to the equilibrium prediction for their corresponding price subgames.

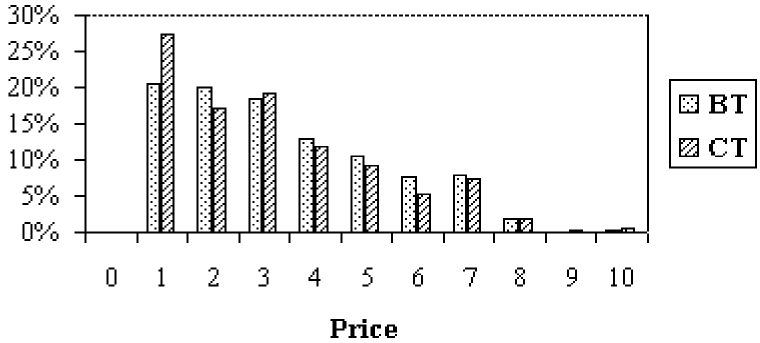

Figure 3.10: Aggregate price distribution.

We can summarise our partial conclusions up to this point in the following results:

Result 3.1: *On aggregate, our subjects' behaviour has yielded less product differentiation than would be the non-cooperative equilibrium prediction under risk-neutrality. In both treatments, more than half of the observed locations are compatible with* maximin *playing. Comparison across treatments shows that individual players differentiate significantly more than collective players do.*

Result 3.2: *Subjects seem to have realised the benefits from locating apart from each other, given that observed prices are higher, the higher is the distance between firm locations. In fact, collective subjects have exploited product differentiation more, even if they have used it less, than individual players did, given that the formers' prices have exceeded prices charged by the latter, and also the theoretical levels predicted for the corresponding degrees of differentiation, when differentiation was high.*

Result 3.3: *In the case of locations leading to pure strategy equilibria, prices have been close to them, even if there is high dispersion. In the case of locations leading to mixed strategy equilibria, price dispersion is observed over intervals that are compatible with theoretical predictions.*

3.4.3 Dynamic Results from Basic *v.* Collective Treatment

The repetition of the same structure ('product design-price-price...') over several periods gives rise to a number of dynamic phenomena which could not have been predicted by our theoretical solutions of the two-stage game analysed in Section 3.3. We briefly refer here to the most interesting of these phenomena.

A first observation is that within each 'product design-price-price...' sequence of periods, in a vast majority of the cases, prices have exhibited two different trends: A declining and a constant one. In order to formalise this observation, we have run one linear model of the type:

$$P_t = \beta \cdot P_{t-1},$$

for price sequences under each degree of differentiation ranging from 0 to 4[27]. The declining trend is represented by $\beta < 1$ and constant prices are implied by $\beta = 1$. A total of 5 such regressions were estimated for each treatment. On aggregate, a moderately declining trend was observed[28]. However, the most interesting phenomenon associated with declining prices relates to product differentiation.

As can be seen in Figure 3.11, in both treatments, we find a positive relationship between product differentiation and the corresponding β's, which tend to (and may even slightly exceed) unity (constant prices) when product differentiation is high.

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[27] As we do not have many observations with differentiation levels of 4 or higher (less than 30 prices), any conclusions based on those regressions might be misleading.

[28] The average β estimate for the 14 regressions estimated (in the three treatments) is 0.937.

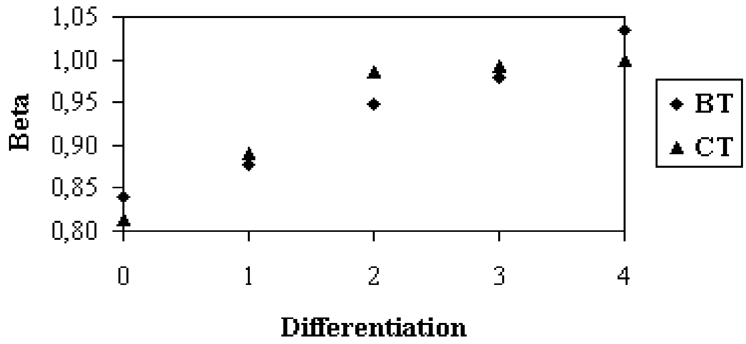


Figure 3.11: β estimates as a function of differentiation.

The positive relationship between differentiation degree and estimated β is virtually identical for both treatments. So, we obtain the following conclusion.

Result 3.4: *Lower (higher) degrees of product differentiation, together with lower (higher) prices also imply declining (constant) prices.*

This result can be the logical consequence of the fact that equilibrium prices in the pricing subgames in which differentiation is low are lower than in those with high differentiation.[29] So, when subjects try to support high prices, the pressure to decrease them is much stronger in the low differentiation cases.

Another interesting result relates with end-game behaviour. While the equilibrium of a static game that is repeated a finite number of periods coincides with the equilibrium of the stage game, it is reasonable to think that subjects may have incentives to signal friendly behaviour in order to encourage cooperation.

In the framework adopted here, both non-cooperative equilibrium and collusive behaviour could have lead risk-neutral subjects to differentiate from each other as implied by Theoretical Prediction 3.1. However, we have also argued that such a high degree of (or any) product differentiation may never occur if subjects are sufficiently risk averse.

[29]See Appendix.

Therefore, a friendly attitude by one player is not only a signal of cooperative behaviour but, also, a guarantee that the other player should not fear the worst of all outcomes. Therefore, during each session we would expect such a friendly attitude to be more likely observed in intermediate periods. That is locating and pricing in a less aggressive way (as specified in the collusive solution in Section 3.3.1.1) makes less sense in the last period of the game in which no future profits exist to compensate possible short run losses.

In our experiment 8 out of 36 individual subjects decide to locate in the middle of the segment (location 4) at the end of the game, not being located there the period before the last. The same event occurred in 8 out of the 36 possible occasions in the collective subjects treatment. However, the same kind of behaviour can be found with similar frequencies in periods: 5, 10, 15, or 20. So, we cannot find clear evidence of an end game behaviour.

Result 3.5: *No significant end-game behaviour is exhibited by subjects in the basic and collective treatments.*

Finally, the degree of product differentiation does not seem to significantly[30] vary during each experimental session, although subjects have significantly[31] changed their 'central' first period strategies with less central ones in periods 5, 10, 15 and 20. We are not able to identify any other trend in the locations over time, there is no convergence to the locational equilibrium.

The central location in the first period could be justified as an equilibrium selection problem, given that if one player assigns a probability of $\frac{1}{2}$ to the other playing any of the two possible location equilibrium strategies, his best response will be to play center. But after one player has seen that the other has chosen a given strategy this belief will no longer be valid, and best response dynamics could take him to the equilibrium in few steps.

The rather paradoxical observation that firms choose, over time, less central locations without achieving a significantly higher degree of product differentiation relates to coordination problems faced by firms which are simultaneously trying to differentiate from each other. Locating far from the center cannot guarantee success in a firm's effort to differentiate with respect

[30]Mann-Whitney tests showed that differentiation in each 'product design' period is not significantly different from that obtained in the same period for the other treatments and from that in previous and subsequent periods.

[31]$MW = -2.25$ for the basic treatment and $MW = -2.246$ for the collective treatment.

to its rival, if the latter decides, at the same time to do the same on the same direction (with respect to the center). This may indicate that, although subjects are faced with a problem of low complexity, in which simple arithmetic operations are required, coordination requires more and better learning than can be achieved by our subjects in the six 'product design' periods of a session. One could argue that, with more such periods in a session, coordination and/or trust by one firm in its rival's capacity to differentiate in the 'right' way would be more likely to observe. However, we would like to point out that, in many real world cases, firms' possibilities of re-designing a product are not as many as theory would like them to be either.

Result 3.6: *Subjects moved away from the middle in periods 5-20, but that did not lead to a higher differentiation.*

3.4.4 Aggregate Results from Basic *v.* Even Treatment

Our aggregate results indicate (Figures 3.12 and 3.13) that players in the even treatment have differentiated significantly[32] less than players in the basic treatment did. But, their prices have paradoxically been significantly higher[33]. This could be a consequence of the fact that it is much easier to accommodate a situation in which there are two equally central locations which provide strategic advantage from a risk-averse point of view, instead of only one. If both firms want a central location, differentiation will not necessarily be zero in the even treatment, so there will be less competitive pressure on prices.

Average earnings in the even treatment have been 3.304 pts., ranging from 1.030 pts. to 6.540 pts. Taking into account the three treatments, the global average earnings have been of 2.777 pts., ranging from a minimum of 360 pts. to a maximum of 6.540 pts.

[32] $KS = 3.15$. A Mann-Whitney test can also be used to show that, on average, locations from the even treatment are more central and less differentiated than those from the basic treatment ($MW = -12.949$ and $MW = -5.026$ respectively).

[33] $KS = 1.649$ and $MW = -2.809$.

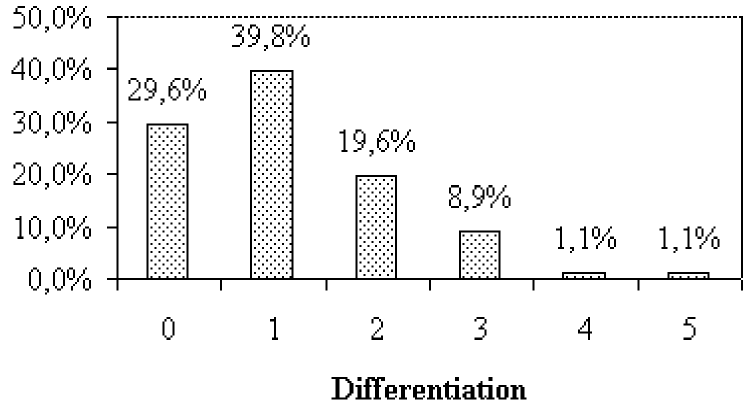


Figure 3.12: Percentages of differentiation in the basic treatment (BT). (*Differentiation* refers to the distance between the two firm's locations measured in sixths of the segment).

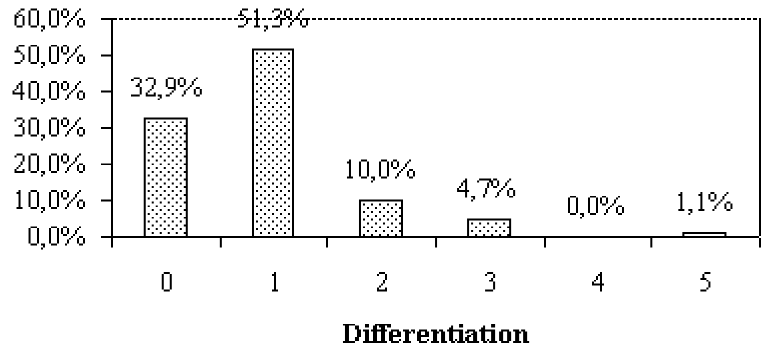


Figure 3.13: Percentages of differentiation in the even treatment (ET). (*Differentiation* refers to the distance between the two firm's locations measured in sevenths of the segment).

For the degrees of differentiation between pairs of firm locations for which a sufficiently large number of observations were obtained, we can affirm the following:

In the absence of product differentiation[34] prices have been on average significantly higher in the even treatment[35] (Figure 3.14). Average price in the even treatment has been 3.25, against 2.81 in the basic treatment. The pure strategy Nash equilibrium prediction for the corresponding price subgames ($P = 1$) which can be supported for the basic treatment is a bit harder to believe for the even treatment. The even treatment must have provided a more favourable environment for collusion.

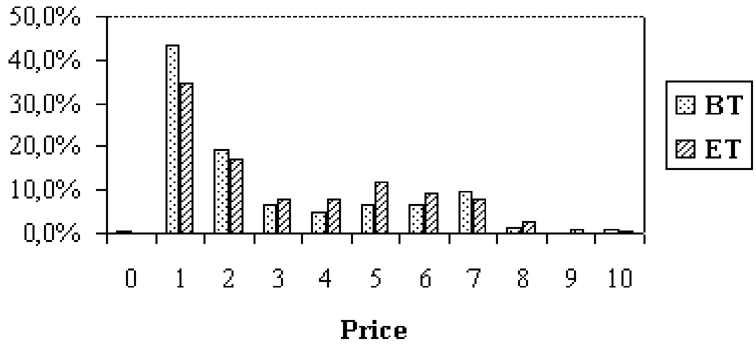


Figure 3.14: Price distribution when differentiation is 0.

With a unit difference between firm locations[36], we also find that the distributions of prices obtained from the two treatments are significantly[37] different (Figure 3.15). More specifically, in both treatments subjects have used prices whose distribution has a peak on 2, but average prices are higher (4.14) for the even treatment than for the basic treatment (3.54). On average, the equilibrium prediction of prices equal to 1 to 2 for the basic treatment and 1 to 3 for the even treatment (depending on the locations on which unit-differentiation takes place) are exceeded by observed behaviour.

[34] 296 cases in the ET.

[35] $KS = 1,36$ against 1.36 and $MW = -2.44$ against 1.96.

[36] 462 observations in the even treatment, more than half of the total.

[37] $KS = 2.16$ and $MW = -3.41$.

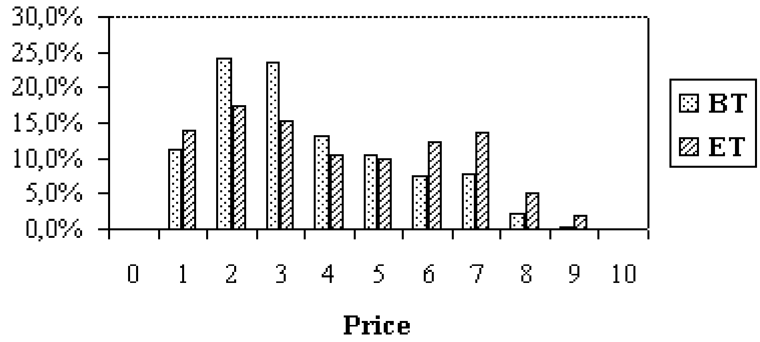


Figure 3.15: Price distribution when differentiation is 1.

When firm locations differ by two[38], the distributions of prices from the two treatments do not present significant[39] differences (Figure 3.16). A peak is observed for a price of 3 in the basic treatment and three peaks on 2, 3 and 4, in the even treatment. Prices in the basic treatment only have a slightly higher average (3.85) than in the even one (3.44). Mixed strategy prices range from 1 to 6 in the basic treatment and from 1 to 5 in the even one, which seems roughly compatible with our subjects' behaviour.

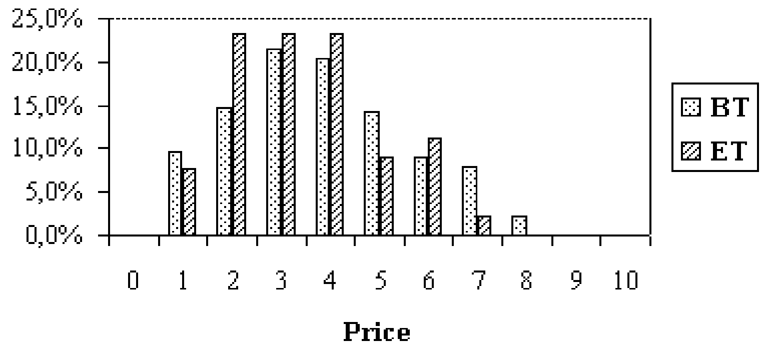


Figure 3.16: Price distribution when differentiation is 2.

[38]90 observations in the even treatment.
[39]$KS = 0.87$ and $MW = -1.68$.

Locations differing by three[40] present price distributions which do not significantly[41] vary across treatments (Figure 3.17). Individuals in the even treatment have set lower prices on average than players in the basic one (a peaks on 3 is observed for both treatments and respective average prices are 2.80 and 3.30). The mixed strategy equilibrium prediction of prices ranging from 2 to 7 for both treatments is compatible with the behaviour of both types of players, although some players have set prices below the minimum of the aforementioned interval. Finally, differentiation higher than 3 was observed in very few occasions and any conclusions based on this evidence would lack statistical significance.

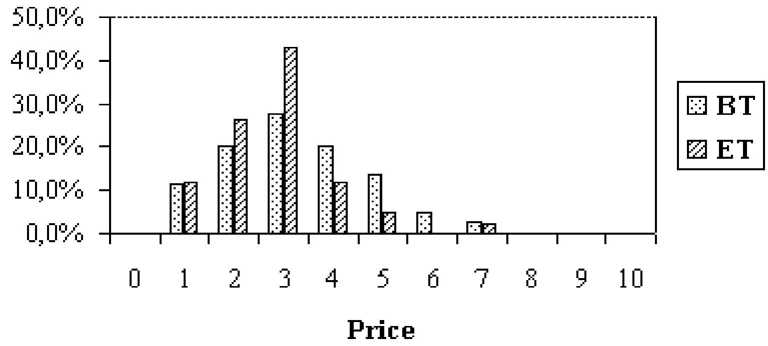


Figure 3.17: Price distribution when differentiation is 3.

On aggregate, a positive relationship between product differentiation and prices is observed (Figure 3.18). But when differentiation is higher than 2 this relationship seems to reverse. However, it is more likely that this phenomenon is due to insufficient data, than to a true reversal of the relationship.

Apart from the aforementioned differences across treatments, our results indicate that our subjects have differentiated far less than we would have expected if they were playing the risk-neutral perfect equilibrium ((L_i, L_k, P_i, P_k) $= (2, 7, 8, 8)$). In fact, the predicted outcome never occurred. Neither occurred the global and the symmetric risk-averse joint profit maxima. In the even treatment we have had incomplete market coverage in 24 out of 450

[40] 42 observations in the ET.
[41] $KS = 1.16$ and $MW = -1.83$.

cases. And implicit coordination (having each firm in a different half of the market) has occurred in less than 20 % of the cases in the ET.

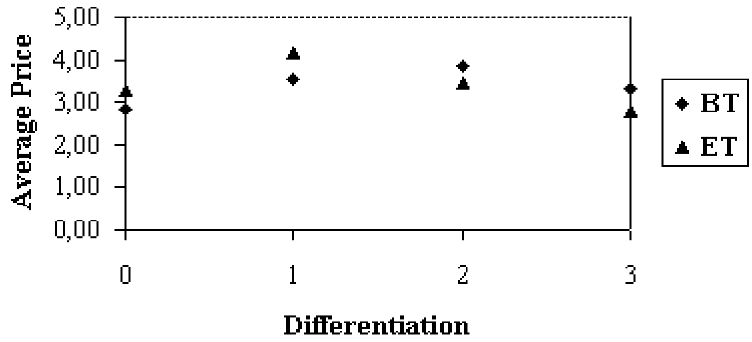


Figure 3.18: Relationship between differentiation and average prices.

Far more support is offered for predicted behaviour under strong risk aversion. For example, the central locations were chosen in more than half of the 'product design' periods in the basic treatment and in nearly 80% of the cases in the even treatment, as can be seen in Figure 3.19. Besides, there were significant differences across treatments[42].

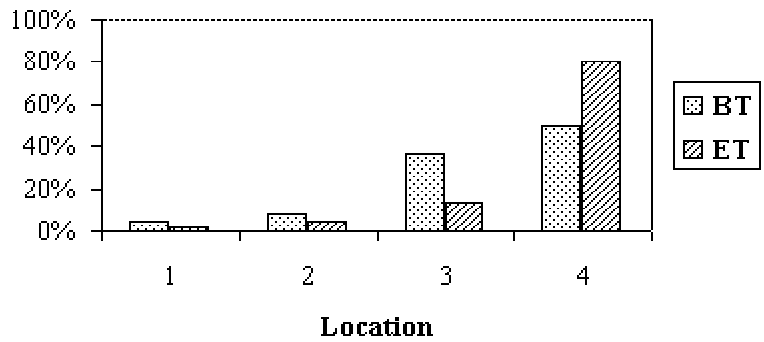


Figure 3.19: Aggregate location distribution.[43]

[42] $KS = 6.41$.

[43] We have considered that location 1=7, 2=6, and 3=5 for the basic treatment, and that location 1=8, 2=7, 3=6 and 4=5 for the even one.

Aggregate price data significantly vary across treatments, as we have already noted. We have more support to the strong risk-averse players' prediction of unit prices, than to a price of 7 predicted under the assumption of risk-neutrality for the basic treatment, and of 8 for the even one (Figure 3.20). But most of the times, prices have been higher than one and lower than 7, so the only general conclusion we can draw from these results is that depending on the concrete location situation, prices have differed greatly, as they have been taking values near the pricing equilibria of the corresponding subgames.

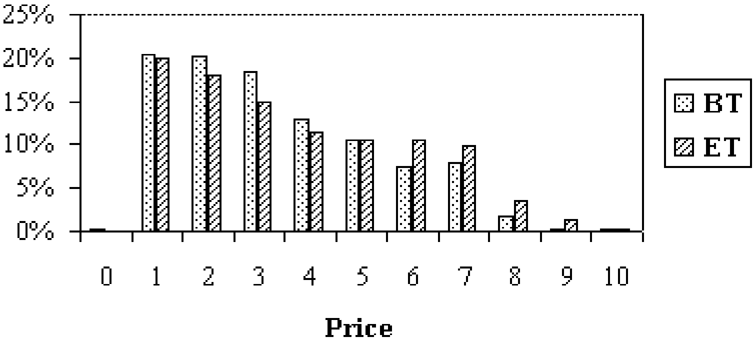


Figure 3.20: Aggregate price distribution.

We can summarise our partial conclusions up to this point in the following results:

Result 3.7: *In aggregate, our subjects' behaviour has yielded less product differentiation than would be the non-cooperative equilibrium prediction under risk-neutrality. In both treatments, more than half of the observed locations are compatible with* maximin *playing. This result reinforces Result 3.1. Comparison across treatments shows that players in the even treatment differentiate significantly less and take more central locations than players in the basic treatment.*

Result 3.8: *Subjects seem to have realised the benefits from locating apart from each other, given that observed prices are generally higher, the higher is the distance between firm locations. This result reinforces Result 3.2. In fact, subjects in the basic treatment have exploited product differentiation* *more than those in the even one, given that the formers' prices have exceeded prices charged by the latter when differentiation was high, but for low levels of differentiation players in the even treatment have been able to set higher prices.*

Result 3.9: *In the case of locations leading to pure strategy equilibria, prices have been near them, even if there is high dispersion. In the case of locations leading to mixed strategy equilibria, price dispersion is observed over intervals that are compatible with theoretical predictions. As in Result 3.3.*

3.4.5 Dynamic Results from Basic *v.* Even Treatment

Again, prices have exhibited two different trends: A declining and a constant one.

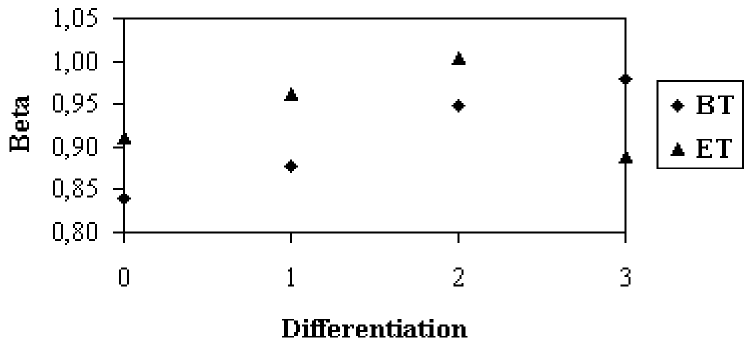


Figure 3.21: β estimates as a function of differentiation.

As seen in Figure 3.21, in both treatments, we find a positive relationship between product differentiation and the corresponding β's, which tend to (and may even slightly exceed) unity (constant prices) when product differentiation is high[44]. A price war is less likely in the even treatment for any differentiation degree. Then, we reach the following conclusion:

Result 3.10: *Lower (higher) degrees of product differentiation, together with lower (higher) prices also imply declining (constant) prices. Same as Result 3.4. And price wars are less likely in the even treatment.*

[44]The decrease in β when differentiation is 3, for the even treatment, does not change our result, as it is based on a regression with only 35 prices.

In the even treatment we have observed end game behaviour only in 3% of the cases. As such, we consider the decision of a firm to locate in 4 or 5 at the end of the game, provided that the firm was not located there the period before the last. The tendency to move to more central locations was much greater in previous location periods, mainly in period 10, with 22% of the cases.

Result 3.11: *No end-game behaviour is observed in the subjects' play in the even treatment. Same as Result 3.5.*

Finally, the degree of product differentiation and the centrality of the locations does not seem to significantly[45] vary during each experimental session. We have not observed any definite trend in locations.

We have already argued in previous sections that we do not think that the subjects could not calculate the consequences of their actions, and we will also argue now that, even if six product design periods are not too many, some kind of learning should already have taken place. Even if the subjects took the central locations as a focal point or due to a equilibrium selection problem, that is not an equilibrium, and they could perfectly move away from this situation after the first period and reach the equilibrium by best response dynamics after two product design periods. It seems as if our subjects have not dared to try anything different from keeping their defensive central locations.

Result 3.12: *We have not found any evidence of learning in locations in the even treatment. Contrary to Result 3.6 where at least locations were less central in subsequent periods after the beginning.*

3.5 Conclusions

The principle of minimum differentiation is revisited using experimental methods. Unlike previous experimental work on spatial competition, we study endogenous prices and allow for incomplete market coverage. The basic framework is a version of the Hotelling (1929) game with discrete location and price variables. The calculation of a subgame perfect equilibrium requires specific assumptions concerning firms' attitude towards risk. As a

[45]Mann-Whitney tests showed that differentiation in each 'product design' period is not significantly different from that obtained in the same period for the other treatment and from that in previous and subsequent periods. Besides locations do no significantly vary their proximity to the center in subsequent location periods.

result, two extreme cases are used as benchmark theoretical predictions. On one hand, intermediate differentiation and high prices are predicted as the non-cooperative equilibrium with risk-neutral firms. On the other hand, minimum differentiation and minimum prices are predicted as the result of *maximin* strategies played by strongly risk averse (or pessimistic) firms. Thus, the principle of minimum differentiation is far from being the unique subgame perfect equilibrium prediction of theory for the case considered here. Instead, a variety of theoretical predictions between the two aforementioned extreme cases (intermediate and minimum differentiation) correspond to different levels of risk aversion. Pure strategy equilibria fail to exist for a broad range of location combinations, which makes the calculation of an equilibrium to be a complex task for our subjects, despite the simplicity of the discrete framework used. The locational non-cooperative equilibrium coincides with that of the joint-profit maximising pair of locations but lower prices are predicted to emerge from price competition in the basic and collective treatments. In the even treatment the non-cooperative equilibrium and the joint-profit maximising strategies in location and prices can coincide. This may imply a further complication for the problem with which our subjects are faced on their way to 'learning' the equilibrium of the supergame.

Despite the aforementioned modification of the original framework proposed by Hotelling (1929) and the resulting cognitive difficulties for subjects competing in a two-variable repeated strategic situation, the principle of minimum differentiation is shown to be the most frequently observed among all possible outcomes. However, observed price levels are higher than the maximin prediction. The relationship between product differentiation and price levels is confirmed. Collective players' behaviour is more conservative in locations (they differentiate less) and less conservative in prices (given a high differentiation prices are higher) than behaviour observed in the basic treatment. This observation may indicate that collective players make a more systematic effort to calculate the consequences of their strategies than individual players do, but groups are more reluctant to pre-commit to a risky option than individuals are. On the other hand, players in the even treatment have differentiated significantly less than those in the basic treatment, however, they have managed to set higher prices, possibly due to the more collusion friendly setting in the even treatment. In the case of location combinations for which a pure strategy equilibrium exists, price distributions present peaks near the equilibrium prediction. When mixed strategy equilibria correspond to a certain location combination, price dispersion along the predicted interval is observed.

Our dynamic results indicate that low degrees of product differentiation do not only relate to lower prices but also to declining ones. Some learning dynamics are observed. However, despite the fact that, from the beginning of each session, subjects can calculate the consequences of any strategic profile using simple arithmetic operations, learning how to differentiate is not found to be an easy task. This can be explained as a result of the fact that learning not to play 'central' locations fails to be translated in learning to *coordinate* and successfully differentiate between firms. No significant end-game behaviour is obtained for any treatment.

Despite the evidence in favour of the principle of minimum differentiation which is rather easy to accommodate in existing textbook economic theory, we feel that some of the phenomena reported above deserve further study both in experimental economics laboratories and in theoretical work in the future. A rather systematic evidence seems to exist for more 'competitive' like results than those predicted by the theory. This finding seems to go on the same direction as results obtained from experiments conducted within non-expected utility frameworks in which strong risk aversion is associated with less cooperative outcomes (Sabater-Grande and Georgantzís, 2001). The basic model should be extended with generalisations, which do not necessarily go on the direction of more complex functional forms, but rather, which are inspired in simple situations in which clear-cut theoretical predictions fail to exist and standard simplifying assumptions (e.g. coordination, learning, and risk neutrality) are less innocuous than is usually thought.

3.6 Appendix

3.6.1 Basic and Collective Treatments Pricing Stage Equilibria

In order to obtain the pricing-stage Nash equilibria we have calculated a table for each of the possible location combinations with the expected payoffs for every price combination. When locations were differentiated by less than two or more than three, a pure strategy Nash equilibrium was easy to obtain. But when differentiation was two or three we have looked for mixed strategy Nash equilibria, considering all the plausible price supports,[46] and we have chosen the Pareto superior one in case of multiplicity. Below we present a summary of the pricing equilibria which have been used to build Table 3.1.

Locations	Prices	Demands	Profits
(1, 1)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(2, 2)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(3, 3)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(4, 4)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(5, 5)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(6, 6)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)
(7, 7)	(1, 1)	(3'5, 3'5)	(3'5, 3'5)

Table 3.A1: Both firms are located on the same point.

Locations	Prices	Demands	Profits
(1, 2)	(1, 1)	(1, 6)	(1, 6)
(6, 7)	(1, 1)	(6, 1)	(6, 1)
(2, 3)	(1, 1)	(2, 5)	(2, 5)
(5, 6)	(1, 1)	(5, 2)	(5, 2)
(3, 4)	(2, 2)	(3, 4)	(6, 8)
(4, 5)	(2, 2)	(4, 3)	(8, 6)

Table 3.A2: Firms differentiate their products $1/6$ of the segment.

Locations	Prices	Probabilities	Demands	Profits
(1, 3)	([1, 3], [3, 4])	([0'31, 0'68],[1, 0])	(2'45, 4'54)	(4'5, 13'6)
(5, 7)	([3, 4], [1, 3])	([1, 0],[0'31, 0'68])	(4'54, 2'45)	(13'6, 4'5)
(2, 4)	([2, 4, 5], [4, 5, 6])	([0'23, 0'12, 0'64],[1, 0, 0])	(2'76, 4'24)	(10, 16'9)
(4, 6)	([4, 5, 6], [2, 4, 5])	([1, 0, 0],[0'23, 0'12, 0'64])	(4'24, 2'76)	(16'9, 10)
(3, 5)	([4, 5, 6], [4, 5, 6])	([0'1, 0'47, 0'41],[0'1, 0'47, 0'41])	(3'5, 3'5)	(18'2, 18'2)

Table 3.A3: Firm's products are differentiated in $2/6$ of the segment.

[46]That is, all prices which could have a positive probability of being played in an equilibrium strategy.

Locations	Prices	Probabilities	Demands	Profits
(1, 4)	([2, 4, 5], [5, 6, 7])	([0'16, 0'07, 0'76],[1, 0, 0])	(2'53, 4'47)	(10, 22'3)
(4, 7)	([5, 6, 7], [2, 4, 5])	([1, 0, 0],[0'16, 0'07, 0'76])	(4'47, 2'53)	(22'3, 10)
(2, 5)	([4, 6], [6, 7])	([0'06, 0'93],[0'33, 0'66])	(3'43, 3'56)	(20, 23'6)
(3, 6)	([6, 7], [4, 6])	([0'33, 0'66],[0'06, 0'93])	(3'56, 3'43)	(23'6, 20)

Table 3.A4: Firms differentiate their products $3/6$.

Locations	Prices	Demands	Profits
(1, 5)	(6, 7)	(3, 4)	(18, 28)
(3, 7)	(7, 6)	(4, 3)	(28, 18)
(2, 6)	(7, 7)	(3'5, 3'5)	(24'5, 24'5)

Table 3.A5: Firms differentiate their products $4/6$.

Locations	Prices	Demands	Profits
(1, 6)	(7, 7)	(3, 4)	(21, 28)
(2, 7)	(7, 7)	(4, 3)	(28, 21)

Table 3.A6: Differentiation is $5/6$.

Locations	Prices	Demands	Profits
(1, 7)	(7, 7)	(3'5, 3'5)	(24'5, 24'5)

Table 3.A7: The products are maximally differentiated $(6/6)$.

3.6.2 Even Treatment Pricing Stage Equilibria

Similarly we have obtained the pricing equilibria corresponding to the even treatment, which have been summarised in Table 3.3.

Locations	Prices	Demands	Profits
(1, 1)	(1, 1)	(4, 4)	(4, 4)
(2, 2)	(1, 1)	(4, 4)	(4, 4)
(3, 3)	(1, 1)	(4, 4)	(4, 4)
(4, 4)	(1, 1)	(4, 4)	(4, 4)

Table 3.A8: Both firms are located on the same point.

Locations	Prices	Demands	Profits
(1, 2)	(1, 1)	(1, 7)	(1, 7)
(2, 3)	(1, 1)	(2, 6)	(2, 6)
(3, 4)	(2, 2)	(3, 5)	(6, 10)
(4, 5)	(3, 3)	(4, 4)	(12, 12)

Table 3.A9: Firms differentiate their products 1/7 of the segment.

Locations	Prices	Probabilities	Demands	Profits
(1, 3)	([1, 3], [2, 3])	([0'64, 0'36],[0'33, 0'66])	(3'05, 4'95)	(4, 12'7)
(2, 4)	([2, 4], [3, 4])	([0'44, 0'56],[0'33, 0'66])	(3'37, 4'63)	(9'3, 16'6)
(3, 5)	([3, 5], [4, 5])	([0'29, 0'71],[0'14, 0'86])	(4'10, 3'90)	(17'1, 18'8)

Table 3.A10: Firm's products are differentiated in 2/7 of the segment.

Locations	Prices	Probabilities	Demands	Profits
(1, 4)	([2, 4], [4, 5])	([0'31, 0'69],[0'33, 0'66])	(3'10, 4'90)	(9'3, 22'7)
(2, 5)	([3, 6], [6, 7])	([0'11, 0'89],[1, 0])	(3'33, 4'66)	(18, 28)
(3, 6)	(7, 7)	(1, 1)	(4, 4)	(28, 28)

Table 3.A11: Firms differentiate their products 3/7.

Locations	Prices	Demands	Profits
(1, 5)	(6, 7)	(3, 5)	(18, 35)
(2, 6)	(7, 8)	(4, 4)	(28, 32)

Table 3.A12: Firms differentiate their products 4/7.

Locations	Prices	Demands	Profits
(1, 6)	(7, 8)	(3'5, 4'5)	(24'5, 36)
(2, 7)	(8, 8)	(4, 4)	(32, 32)

Table 3.A13: Differentiation is 5/7.

Locations	Prices	Demands	Profits
(1, 7)	(7, 8)	(4, 4)	(28, 32)

Table 3.A14: Differentiation is 6/7.

Locations	Prices	Demands	Profits
(1, 8)	(7, 7)	(4, 4)	(28, 28)

Table 3.A15: The products are maximally differentiated (7/7).

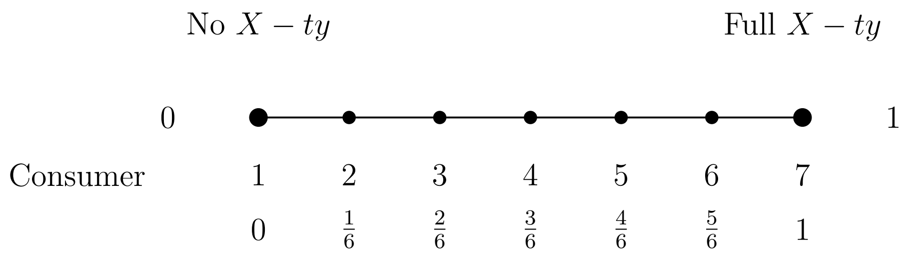
3.6.3 Instructions (Basic and Collective Treatments)[47]

Consider a market for a product which can be differentiated according to a characteristic that we will call 'X-ty'. There are 7 potential consumers, each of them with different preferences regarding their ideal product's 'X-ty' degree. Each consumer wants to buy a unit of the product, if his utility in doing so is not negative. He will buy his unit from the firm which makes the most interesting offer to him, in terms of price plus the monetary quantification of the 'non-consumption' of his ideal variety, according to the following utility function:

$$U = 10 - p - 6x,$$

where x is the distance between the consumer's ideal variety and the one actually consumed.

You are one of the two firms which sell the product in this market. The different consumer preferences are represented in the following graph:



where the points coincide with the 'X-ty' degree preferred by each one of the seven consumers, and besides, they are the only location points available for you and your rival.

You are in the following situation:

- The market functions for a total of 25 periods (years).

[47] The instructions for the Even treatment are very similar, only the utility function changes to $U = 10 - p - 7x$, and the graph presents eight possible locations with a consumer in each one of them.

- Every **five** periods (starting in period 1) you can 'redesign' your product with regard to the offered degree of 'X-ty'.

- Every period you will set the price of your product, taking into account that your variable costs are: $C = 0$.

- Your goal is getting as much profit as you can after the 25 periods (you will get 10 pts. for each experimental monetary unit you win).

- Every consumer is always rational and decides to buy or not to buy according to his utility function. So, he will buy (if he decides to buy) to the firm which is less expensive for him after considering price and transportation costs (because he obtains a higher utility in this way).

- If you are in a draw with your rival (a consumer is indifferent between buying from you or from your rival) regarding a consumer or a group of them, the final decision will be reached by tossing a coin for each consumer for which there is a draw.

- Some time after the beginning of each period, your product design and price decisions will be communicated to the experimentalist, simultaneously to those of your rival. **The period in which you must make both decisions, you will communicate first your location on the segment and, then, after the experimentalist has written your decision and that of your rival on the board, you will make and communicate your price decision.**

- The information on the location and pricing decisions, and the results, in the past periods, will appear in the board for you and your rival to see. But we suggest that you write them down too.

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Chapter 4

Optimal State Intervention in Monopolistically Competitive Markets

4.1 Introduction

The monopolistic competition framework has been the basis for most partial equilibrium analysis of welfare in markets with endogenous market structure. In the spatial version of the framework, each consumer has his own tastes, even if all of them have a similar utility function. In this utility function the disutility reporting items are: the price which the consumer has to pay in order to obtain a good, and the value lost from not consuming his ideal variety.

The main conclusion of these models in terms of social welfare relates to variety proliferation in the case of a free entry long run equilibrium with respect to the social optimum[1]. That is, the zero profit condition leads to there being more firms in the long run than the socially optimal number would be. So entry control (or choice of optimal variety number) by a central authority would be justified.

A common feature of the framework is that social welfare is calculated accounting for two sources of social costs. Namely, (1) the sunk cost paid by firms in order to enter into the market, and (2) the disutility suffered by the consumer due to the divergence between his ideal variety and that actually

[1]See Salop (1979) and Dixit-Stiglitz (1977).

purchased in equilibrium (transportation costs in the spatial interpretation of the model).

With respect to this assumption, we will argue that, although (dis)utility, profits and costs are expressed in monetary terms, the two components of social costs may be qualitatively different. For example, while investing a fixed sum F in order to enter into a market may benefit some sector providing production machinery to the firms, the disutility suffered by a consumer due to divergence between his ideal variety and that actually purchased, does not benefit any economic agent. Therefore, in a more general framework, the two components of social disutility should be treated in different ways.

Along a different strand in the literature, monopolistic competition models[2] have been used to study situations in which firms build an infrastructure which makes them easier to access by their potential customers. This is the literature on differentiated product markets with endogenous transportation costs (*disutility* in the terminology of spatial competition models as models of product differentiation). In Hendel and Neiva (1997), transportation costs are endogenously obtained as the result of a strategic decision by oligopolists who enter into a spatial market until the zero profit condition is satisfied. The authors consider that the decision of a firm to reduce the unit transportation costs faced by its clients is equivalent to the decision of designing a more *general purpose* product. The reduction is assumed to be costless or, alternatively, to be reflected on higher unit production costs. The same interpretation is adopted in an earlier article by Von Ungern-Sternberg (1988), in which the design of a general purpose product makes unit production costs higher. In all cases, state intervention is restricted to a costless choice of the number of firms (varieties) or the level of private strategies such as advertising expenditure, in order for a social utility (loss) function to be maximised (minimised).

We have opted for a modification of this framework assuming that investing in transportation infrastructure is both *costly* and *necessary* and must be supported by *both* private and public investment. We introduce a stage which precedes the usual entry/private investment/price competition structure. In this first stage, the policy maker decides on the level of the investment in a public infrastructure which will be used by firms at an endogenously deter-

[2] Hendel and Neiva (1997), Weitzman (1994), Von Ungern-Sternberg (1988), and Grossman and Shapiro (1984), are the most representative examples of the aforementioned literature.

mined sunk cost.

Therefore, our chapter can be framed within two different strands in the literature. One, in which the only entry costs firms face are exogenous, and another one, in which firms entry costs are endogenously determined by them in order to reduce the transportation cost their products face. The main contribution of the chapter concerns government intervention through public investment in a transportation cost reducing infrastructure.

In fact, we consider that firms invest in installing or improving the infrastructure which is required for the transportation of economic goods from the place of production to the place of consumption. Both the state and private investors are involved in such an effort. For example, a highway may be the result of public investment, but firms have to invest in their own transportation infrastructure if they want to use the highway. Communication networks could be another example. In such a framework, transportation cost-reducing investment leads to both a process and a product innovation, because transportation is an input of economic activity and, at the same time, a determinant factor of the intensity of competition among producers.

Our results clearly deviate from the standard clear-cut conclusion on variety proliferation as compared to the social optimum. The relationship between the optimal and the equilibrium number of firms in the long run may vary depending on the relative weights of the components of the social cost function. Our results also indicate that, in the endogenous entry costs setting, a government policy addressed to entry control is ineffective in terms of rising social welfare. Instead, public investment in transportation cost reducing infrastructure is found to play an important role as a policy instrument by a social planner who acts as a leader with respect to the rest of the agents in the market. We also find that the market equilibrium is such that private investment in transportation infrastructure depends negatively on public investment. This property concerning strategic substitutability between private and public investment makes public investment an effective policy instrument which can be used to minimise social costs.

It is worth observing at this point that both our results and those obtained in the aforementioned articles have many common features with results obtained (or possible to obtain) from long-run equilibrium in oligopolistic markets with endogenous sunk costs (Smalensee, 1992; and Sutton, 1991). The main difference between our model and the ones used in the literature is found in the way in which the public sector is assumed to act.

Finally, another strand in the literature, the one related to international industrial location, also considers topics which can be addressed by means of our framework. That is the case of Martin and Rogers (1995) who study the incentives for firms to relocate in a given region depending on its publicly financed domestic infrastructure. Along a different line, Yamano and Ohkawara (2000) study the trade-off between efficiency and equity the central authority is faced with when deciding its investment in a developed, or in a more depressed region. Coughlin and Segev (2000) find that higher levels of economic size and transportation infrastructure are associated with a larger number of new foreign-owned plants being opened in a region in the United States. We extend our framework to the case of endogenous entry costs and two regions with different characteristics. Our results show that there will be incentives for more firms to locate in a region with higher population density, or with worse underlying geographical conditions, while public investment in infrastructure will also be higher in this kind of region.

The remaining part of this chapter is organised in the following way: Section 4.2 presents the basic framework which we will apply in the subsequent sections, Section 4.3 studies entry policy in the case of exogenous entry costs. Public investment optimality and its implications, in the case of endogenous entry costs, are treated in Section 4.4. In Section 4.5, we extend the case of endogenous entry costs to unconstrained and constrained public investment in two different regions. Section 4.6 concludes.

4.2 Framework

Consider the following version of the monopolistic competition model in its spatial form, as proposed by Salop (1979). Let n firms be equidistantly located around a unit periphery circle. A continuum of consumers is uniformly distributed around the circle with density equal to d. Each one of them is willing to buy one unit of the good from the firm whose generalised price (price plus transportation costs) at the consumer location is lower, unless the consumer's surplus were negative, in which case zero consumption would be preferred to consuming one unit.

We summarise the preceding assumptions stating that a consumer j purchasing a unit of the good at firm i maximises her utility U_{ji} as long as $U_{ji} \geq 0$ and

$$U_{ji} \geq U_{jh} \Rightarrow R - p_i - T_i(x_{ji}) \geq R - p_h - T_h(x_{jh}), \tag{4.1}$$

where firm h is firm i's adjacent firm as we move (anti-)clockwise on the circle ($h \in \{i-1,\ i+1\}$) and p_i denotes the price charged by firm i. We will consider that equilibrium prices charged by the firms are low enough, or (which is equivalent) that the income of consumers - denoted by R in expression (4.1) - is high enough[3] for each one of them to buy a unit of the good from the firm whose generalised price at the consumer location is lower. Then, the market is fully covered by the sales of the firms. We will also consider that marginal production costs are 0.

Transportation costs, paid by consumer j buying from firm $i \in \{1, 2, ...n\}$, are a linear function of the distance x between the locations of production (where i is located) and consumption (where j is located) of the good, respectively. This is expressed by:

$$T_i(x_{ji}) = \tau_i \cdot x_{ji} = \frac{t}{k_i} \cdot x_{ji} = \frac{w}{k_i \cdot I} \cdot x_{ji}, \tag{4.2}$$

where k_i and I are, respectively, the levels of *individual* (firm-specific) and *public* investments in the aforementioned infrastructure. The product of private and public investment in the denominator of the firm-specific unit transportation cost coefficient, τ_i, implies a positive interaction between private and public investment in the transportation cost-saving capacity of the infrastructure.

Given that consumers are uniformly distributed around the circle with a constant density d, firm i's demand coincides with the size of the segment whose population buys from the firm multiplied by d. Let p_i, p_{i+1}, p_{i-1} be, respectively, the prices of firm i, and the firm $i+1$ ($i-1$), which is the first as we move clockwise (anti-clockwise) from it. Then, given an equidistant arrangement of firms, there will be a consumer at a distance x_i ($\frac{1}{n} - x_{i-1}$) as we move clockwise (anti-clockwise) on the circle from firm i, who will be indifferent between buying from firm i and buying from firm $i+1$ ($i-1$).

In fact, using these two locations as the extremes of the segment supplied by firm i, we can write firm i's demand: $q_i = d \cdot (x_i + (\frac{1}{n} - x_{i-1}))$.

Given an equidistant arrangement of the firms, and following (4.1) as equality: $p_i + \tau_i \cdot x_{ji} = p_{i+1} + \tau_{i+1} \cdot (\frac{1}{n} - x_{ji})$,we can obtain the distance from firm i of the indifferent consumer between firm i and $i+1$:

[3]In the Appendix, we define the exact expression for this restriction in terms of the parameters of the model.

$$x_i = \frac{p_{i+1} - p_i}{\tau_i + \tau_{i+1}} + \frac{\tau_{i+1}}{n(\tau_i + \tau_{i+1})}. \tag{4.3}$$

So, firm i's demand will be:

$$q_i = d \cdot \left(\underbrace{\frac{p_{i+1} - p_i}{\tau_i + \tau_{i+1}} + \frac{\tau_{i+1}}{n(\tau_i + \tau_{i+1})}}_{x_i} + \underbrace{\frac{p_{i-1} - p_i}{\tau_i + \tau_{i-1}} + \frac{\tau_{i-1}}{n(\tau_i + \tau_{i-1})}}_{\frac{1}{n} - x_{i-1}} \right). \tag{4.4}$$

This expression indicates that unit transportation costs paid by firm i's clients have an unambiguously negative effect on the firm's demand.[4]

It can also be concluded that the effect of unit transportation costs paid by rival firms' clients have a positive effect on firm i's demand, unless rival prices are much higher than firm i's own price and the number of firms is sufficiently high.[5]

Finally, the effect of price differences on firm i's demand depends negatively on the sum of firm-specific unit transportation cost coefficients.[6]

We will now proceed to modify this framework applying it, first, to the case of exogenous entry costs, then, to the case of endogenous entry costs,

[4] Observe that, as long as the firm's price is not too much higher than the price charged by the firm's adjacent rivals in the presence of a sufficiently low number of firms for firm i to have a positive share, the following conditions are satisfied:

$$\frac{\partial x_i}{\partial \tau_i} = \frac{n(p_i - p_{i+1}) - \tau_{i+1}}{n(\tau_i + \tau_{i+1})^2} < 0,$$

given that a positive market share is guaranteed for firm i if $p_i - p_{i+1} < \frac{t_{i+1}}{n}$.

[5] Observe that, as long as the price charged by the rival firm is not too much higher than firm i's own price and with a sufficiently low number of firms in the market, explicitly if $p_{i+1} - p_i < \frac{\tau_i}{n}$, then

$$\frac{\partial x_i}{\partial \tau_{i+1}} = \frac{n(p_i - p_{i+1}) + \tau_i}{n(\tau_i + \tau_{i+1})^2} > 0.$$

[6] Note that:

$$\frac{\partial x_i}{\partial (p_{i+1} - p_i)} = \frac{n(p_{i+1} - p_i) + \tau_{i+1}}{n\left(p_{i+1} - p_i\right)\left(\tau_i + \tau_{i+1}\right)}.$$

and finally, to the case of two regions with different natural and population characteristics.

4.3 Exogenous Entry Costs

Following Tirole (1988) the standard result of variety proliferation is obtained assuming a monopolistically competitive market in which the free entry equilibrium is calculated for any exogenous entry cost f.

In order to have a model similar to the one presented in Tirole we will introduce the following simplifying assumptions in the framework: $\tau_i = \tau_{i+1} = \tau_{i-1} = \tau$, and they are exogenous, we will also consider that $d = 1$. Rewriting (4.3) with these assumptions we get:

$$x_i = \frac{(p_{i+1} - p_i)n + \tau}{2n\tau}. \tag{4.5}$$

And, firm i's demand will be:

$$q_i = \underbrace{\frac{(p_{i+1} - p_i)n + \tau}{2n\tau}}_{x_i} + \underbrace{\frac{(p_{i-1} - p_i)n + \tau}{2n\tau}}_{\frac{1}{n} - x_{i-1}}. \tag{4.6}$$

Thus, firm i's profit function in the case of an exogenous entry cost f can be written as:

$$\Pi_i = p_i \left(\frac{(p_{i+1} + p_{i-1} - 2p_i)n + 2\tau}{2n\tau} \right) - f. \tag{4.7}$$

From the first order conditions for maximisation of the profit function above with respect to p_i, we obtain the best price-response of firm i.

$$p_i = \frac{(p_{i+1} + p_{i-1})n + 2\tau}{4n}. \tag{4.8}$$

This expression of firm i's reaction function implies a system of n equations with n unknown variables, which should be solved simultaneously.[7] Setting $p_i = p_{i+1} = p_{i-1} = p$, we can obtain the symmetric solution:

$$p^* = \frac{\tau}{n}. \tag{4.9}$$

[7] Second order conditions for maximum are satisfied: $\frac{\partial^2 \Pi_i}{\partial p_i^2} = -\frac{2}{\tau}$.

We can substitute this expression in the profit function:

$$\Pi_i^* = \frac{\tau}{n^2} - f. \tag{4.10}$$

In the long run, firms will enter into the market until profits fall to zero. So the equilibrium number of firms in the market with free entry will be:

$$n^* = \sqrt{\frac{\tau}{f}}. \tag{4.11}$$

Each one charging a price:

$$p^{*'} = \sqrt{\tau \cdot f}. \tag{4.12}$$

The generalised way of doing the welfare analysis assumes the existence of a benevolent social planner who would choose a particular number of firms in the market so as to minimise the sum of entry costs and transportation costs:

$$SC = EC + TC = f \cdot n + 2 \cdot n \cdot \int_0^{\frac{1}{2n}} \tau \cdot x \, dx = fn + \frac{\tau}{4n}. \tag{4.13}$$

Social cost is minimised when:

$$n' = \frac{1}{2}\sqrt{\frac{\tau}{f}}. \tag{4.14}$$

And each firm will charge a price:

$$p^{'} = 2\sqrt{\tau \cdot f}. \tag{4.15}$$

That is, social cost is minimised when the number of firms is half the one in the free entry equilibrium. The variety proliferation result is a more general property of monopolistic competition models rather than a special characteristic of the spatial interpretation adopted here (Dixit and Stiglitz, 1977).

However, if we assume that the policy maker considers that transportation and entry costs should have different weights on social costs, by using a parameter $\lambda \in (0, 1)$, the function to be minimised is:

$$SC(\lambda) = \lambda \cdot EC + (1 - \lambda) \cdot TC = \lambda f n + \frac{(1-\lambda)\tau}{4n}. \tag{4.16}$$

The optimal number of firms is:

$$n^o = \frac{1}{2\lambda f}\sqrt{(\lambda f\,(1-\lambda)\,\tau)}. \tag{4.17}$$

Proposition 4.1 *The free entry equilibrium contains too many firms as compared to the socially optimal number if* $\lambda > \frac{1}{5}$.

Proof: We can obtain the condition under which the optimal number of firms with weight λ coincides with the free entry equilibrium number:

$$n^* - n^o = \sqrt{\frac{\tau}{f}} - \frac{1}{2\lambda f}\sqrt{(\lambda f\,(1-\lambda)\,\tau)} = 0, \quad \textit{when} \quad \lambda = \frac{1}{5}.$$

Therefore, for $\lambda = \frac{1}{5}$, the free entry equilibrium number of firms is optimal. Depending on the value of λ the optimal number of firms in our approach can range from 0, if transportation costs are not important ($\lambda = 1$), to ∞, if only transportation costs matter ($\lambda = 0$). The implicit weights in the standard approach are equivalent to $\lambda = \frac{1}{2}$, thus the result concerning product proliferation is conditioned by this perception of the relative importance of the social costs.

Following this result, the optimal policy may be to encourage, or impede entry, depending on the relative importance of the two components of the social cost function.

4.4 Endogenous Entry Costs

Instead of a fixed and exogenous entry cost f, let us consider, now, an endogenous entry cost, the cost k_i faced by firm i in order to decrease its transportation cost parameter τ_i. We substitute τ_i with t/k_i in firm i's demand (4.4) and we get[8]:

$$q_i = \frac{d}{n \cdot t}\left(\frac{n(p_{i-1}-p_i) + \frac{t}{k_{i-1}}}{\left(\frac{1}{k_{i-1}} + \frac{1}{k_i}\right)} + \frac{n(p_{i+1}-p_i) + \frac{t}{k_{i+1}}}{\left(\frac{1}{k_{i+1}} + \frac{1}{k_i}\right)}\right). \tag{4.18}$$

[8]Note that we no longer use the simplifying assumptions of the previous section that $d = 1$, and that $\tau_i = \tau_{i+1} = \tau_{i-1} = \tau$ and exogenous.

We can now write individual profits:

$$\Pi_i = \frac{p_i \cdot d}{n \cdot t}\left(\frac{n(p_{i-1}-p_i)+\frac{t}{k_{i-1}}}{\left(\frac{1}{k_{i-1}}+\frac{1}{k_i}\right)} + \frac{n(p_{i+1}-p_i)+\frac{t}{k_{i+1}}}{\left(\frac{1}{k_{i+1}}+\frac{1}{k_i}\right)}\right) - k_i. \tag{4.19}$$

From the first order conditions for maximisation of the profit function above with respect to p_i, we obtain the best price-response[9] of firm i. Then, $\frac{\partial \Pi_i}{\partial p_i} = 0 \Rightarrow p_i(p_{i+1}, p_{i-1}) =$

$$p_i = \frac{n(k_{i-1}(k_i+k_{i+1})p_{i-1} + k_{i+1}(k_i+k_{i-1})p_{i+1}) + t(k_{i-1}+k_{i+1}+2k_i)}{2n(k_{i-1}k_i + 2k_{i-1}k_{i+1} + k_{i+1}k_i)}. \tag{4.20}$$

This expression of firm i's reaction function implies a system of n equations with n unknown variables, which should be solved simultaneously together with the system of the following first order conditions satisfied by equilibrium entry costs: $\frac{\partial \Pi_i}{\partial k_i} = 0 \Rightarrow$

$$\frac{d \cdot p_i}{n \cdot t} \cdot \left(\frac{k_{i-1}(k_{i-1}n(p_{i-1}-p_i)+t)}{(k_i+k_{i-1})^2} + \frac{k_{i+1}(k_{i+1}n(p_{i+1}-p_i)+t)}{(k_i+k_{i+1})^2}\right) = 1, \tag{4.21}$$

in order for an equilibrium with respect to investment levels k_i and prices p_i to be determined *simultaneously*.[10]

[9] Which does not depend on population density (d).

[10] It is relatively easy to check that second order conditions for maximum are also satisfied:

$$\frac{\partial^2 \Pi_i}{\partial p_i^2} = -\frac{2d \cdot k_i}{t}\left.\frac{2k_{i+1}k_{i-1}+k_ik_{i-1}+k_ik_{i+1}}{(k_{i-1}+k_i)(k_{i+1}+k_i)}\right|_{(p^0,k^0)} = -\frac{d\cdot\sqrt{2dt}}{n \cdot t} < 0.$$

$$\frac{\partial^2 \Pi_i}{\partial k_i^2} = \frac{2d\cdot p_i}{nt}\left(\frac{n(p_{i-1}-p_i)+\frac{t}{k_{i-1}}}{\left(\frac{1}{k_{i-1}}+\frac{1}{k_i}\right)^3 k_i^4} - \frac{n(p_{i-1}-p_i)+\frac{t}{k_{i-1}}}{\left(\frac{1}{k_{i-1}}+\frac{1}{k_i}\right)^2 k_i^3}\right) +$$

$$+\frac{2d\cdot p_i}{nt}\left.\left(\frac{n(p_{i+1}-p_i)+\frac{t}{k_{i+1}}}{\left(\frac{1}{k_{i+1}}+\frac{1}{k_i}\right)^3 k_i^4} - \frac{n(p_{i+1}-p_i)+\frac{t}{k_{i+1}}}{\left(\frac{1}{k_{i+1}}+\frac{1}{k_i}\right)^2 k_i^3}\right)\right|_{(p^0,k^0)} = -\frac{n\sqrt{2dt}}{dt} < 0.$$

$$\frac{\partial^2 \Pi_i}{\partial p_i \partial k_i} = \frac{d}{nt}\left(\frac{n(p_{i-1}-p_i)+\frac{t}{k_{i-1}}}{\left(\frac{1}{k_{i-1}}+\frac{1}{k_i}\right)^2 k_i^2} + \frac{n(p_{i+1}-p_i)+\frac{t}{k_{i+1}}}{\left(\frac{1}{k_{i+1}}+\frac{1}{k_i}\right)^2 k_i^2}\right) +$$

$$+p_i\frac{d}{nt}\left.\left(-\frac{n}{\left(\frac{1}{k_{i-1}}+\frac{1}{k_i}\right)^2 k_i^2} - \frac{n}{\left(\frac{1}{k_{i+1}}+\frac{1}{k_i}\right)^2 k_i^2}\right)\right|_{(p^0,k^0)} = 0.$$

Setting $k_i = k$ and $p_i = p$, we can obtain the symmetric solution, which reduces to the solution of the following system:

$$p_i = \frac{t}{n \cdot k}, \tag{4.22}$$

and

$$k_i = \frac{d \cdot p}{2n}, \tag{4.23}$$

whose solution gives[11]:

$$p^* = \sqrt{\frac{2t}{d}}, \tag{4.24}$$

and

$$k^* = \frac{1}{n} \cdot \sqrt{\frac{d \cdot t}{2}}. \tag{4.25}$$

The expressions for p^* and k^* in (4.24) and (4.25) can be substituted into the profit function in (4.19), in order for the individual short-run profit to be determined:

$$\Pi_i^* = \frac{1}{n} \cdot \sqrt{\frac{d \cdot t}{2}}. \tag{4.26}$$

Observe that, following (4.26), the zero-profit condition requires that infinitely many firms enter into the market. We summarise the straightforward but important long-run implication of this result in the following proposition:

Proposition 4.2 *The free-entry equilibrium industry structure contains $n = \infty$ firms, each one investing $k = 0$ in transportation infrastructure. Unit transportation costs τ are infinite, while total transportation costs are zero.*

The proof is straightforward, so we omit it. Proposition 4.2 implies that the long-run (free-entry) equilibrium is only achieved when infinitely many firms enter the market, investing $k = 0$ each, in order to monopolise an infinitely small part of the market. Therefore, as long as fixed costs are treated as a strategic variable of potential entrants, which is directly related

[11] These results have also been derived in a simpler version in Barreda *et al.* (2000).

with the market potential that each one of them covers in equilibrium (note from (4.25) the inverse relation between k^* and n) infinitely many firms will enter the market. In that case, each firm's market area is zero which also determines that, in the long run, no investment in transportation-reducing infrastructure (or, in terms of Grossman and Shapiro, 1984, informative advertising) will take place.

The fact that unit transportation costs are infinite for zero individual investment is responsible for the result according to which the infinitely large number of firms results in a monopoly-like situation rather than in a more competitive market. A higher number of firms results in less investment in transportation infrastructure, which implies more market power for each oligopolist. Furthermore, short-run individual profit, which in this particular model equals individual investment, is a decreasing function of the number of firms. Therefore, the higher the number of firms is, the stronger are the incentives for individual firms to make their products less substitutable with the varieties offered by their rivals.

Substituting $\tau = \frac{t}{k^*}$, where $k^* = \frac{1}{n} \cdot \sqrt{\frac{d \cdot t}{2}}$, in the social cost function:

$$SC(\lambda) = \lambda \cdot k^* \cdot n + (1 - \lambda) \cdot 2 \cdot d \cdot n \cdot \int_0^{\frac{1}{2n}} \tau \cdot x \, dx, \tag{4.27}$$

we get that social cost does not depend on the number of firms (n):

$$SC(\lambda) = \frac{(\lambda + 1)\sqrt{dt}}{\sqrt{2^3}}. \tag{4.28}$$

Hence, in this model, *state intervention by setting an optimal number of firms is not an effective policy.* Social costs will be higher, the higher the importance of entry costs in the social cost function, the higher the population density, and the higher the infrastructure deficiencies reflected in t.

Following this rather extreme result, we will consider any exogenous number of firms $\bar{n}$ in order for the optimal public policy to be determined with respect to public investment in infrastructure (I).

We minimise the following social cost function, which assigns, as in the previous section, different weights to entry costs and transportation costs by means of a parameter $\lambda \in (0, 1)$:

$$SC(\lambda) = EC + TC = \lambda \cdot (I + k^* \cdot \bar{n}) + (1-\lambda) \cdot 2 \cdot d \cdot \bar{n} \cdot \int_0^{\frac{1}{2\bar{n}}} \tau \cdot x \, dx, \quad (4.29)$$

where we have substituted t by $\frac{w}{I}$ so that $k^* = \frac{1}{\bar{n}} \cdot \sqrt{\frac{d \cdot w}{2I}}$ and $\tau = \frac{w}{k^* \cdot I}$. The expression we obtain is:

$$SC(\lambda) = \frac{4\lambda I\sqrt{(dwI)} + \lambda dw\sqrt{2} + dw\sqrt{2}}{4\sqrt{(dwI)}}. \quad (4.30)$$

Minimising (4.30) with respect to public investment we get that the optimal public investment is[12]:

$$I^o = \frac{1}{4\left(\sqrt[3]{\lambda}\right)^2} \sqrt[3]{2 \cdot d \cdot w} \left(\sqrt[3]{\lambda} + 1\right)^2. \quad (4.31)$$

The optimal public investment depends positively on the population density (d) and on the toughness of natural conditions (w). It will coincide with the result of the non-weighted minimisation when $\lambda = \frac{1}{2}$, it will increase as the relative importance of entry costs (λ) decreases to 0, until it attains an infinite value, and it will decrease to a minimum of $\frac{1}{2}\sqrt[3]{d \cdot w}$, as λ grows to 1.

Substituting the optimal public investment in the social cost function we get the optimal social cost:

$$SC(\lambda)^o = \frac{3}{4}\sqrt[3]{2\lambda dw}\left(\sqrt[3]{(\lambda+1)}\right)^2. \quad (4.32)$$

This function depends positively on the relative importance of entry costs (λ), population density (d), and geographical difficulties (w)[13].

Similarly, substituting the optimal public investment in the equilibrium individual price, investment, and profit of each firm we get that their values are:

$$p^o = \sqrt{\frac{2w}{dI^o}} = \frac{2}{d}\sqrt{\left(\frac{\left(\sqrt[3]{2\lambda dw}\right)^2}{\left(\sqrt[3]{(\lambda+1)}\right)^2}\right)}. \quad (4.33)$$

[12] We check that the S.O.C. for minimum holds: $\frac{\partial^2 SC}{\partial I^2} = \frac{3\sqrt{2dw}(\lambda+1)}{16\left(\sqrt{I}\right)^5} > 0$.

[13] $\frac{\partial SC(\lambda)^o}{\partial \lambda} = \frac{\sqrt[3]{2dw}(3\lambda+1)}{4\sqrt[3]{(\lambda+1)}\left(\sqrt[3]{\lambda}\right)^2} > 0$.

$$k^o = \Pi^o = \frac{1}{n}\sqrt{\frac{dw}{2I^o}} = \frac{1}{n}\sqrt{\left(\frac{\left(\sqrt[3]{2\lambda dw}\right)^2}{\left(\sqrt[3]{(\lambda+1)}\right)^2}\right)}. \tag{4.34}$$

Proposition 4.3 *In the case of endogenous entry costs (k_i) and optimal public investment (I^o), equilibrium prices depend positively on the relative importance of entry costs (λ), and the toughness of natural conditions (w), and negatively on population density (d). The equilibrium individual investment and profit, which are equal, depend positively on λ, w, and d, and negatively on the number of firms (n).*

Proof: See Appendix.

If both the central authority and the firms invest in transportation cost reducing infrastructure, private and public investment increase with the population density and the toughness of natural conditions, but public investment decreases with increases in the relative weight of entry costs, while private investment increases with them in order to compensate the decrease in public investment, and decreases with the number of firms in the market, because all of them share equally the burden of private investment. Social costs increase with increases in population density, natural difficulties and in the relative importance of entry costs. The firms' prices increase with the relative importance of entry costs and with an increase in the natural difficulties, while they decrease with an increase in population density. Let us observe this in a numerical example in which density is expressed in terms of inhabitants per km^2, and natural difficulties are expressed in a scale ranging from 1 (very low) to 5 (very high):

$(\mathbf{n}, \mathbf{w}, \mathbf{d}, \lambda)$	$\mathbf{I}^o$	$\mathbf{SC}(\lambda)^o$	$\mathbf{p}^o$	$\mathbf{k}^o = \mathbf{\Pi}^o$
$(10, 2, 100, 0.25)$	5.3861	4.0396	0.0861	0.43089
$(20, 2, 100, 0.25)$	5.3861	4.0396	0.0861	0.21544
$(10, 4, 100, 0.25)$	6.786	5.0895	0.1085	0.54288
$(10, 2, 200, 0.25)$	6.786	5.0895	0.0542	0.54288
$(10, 2, 100, 0.50)$	3.8315	5.7473	0.1021	0.51087
$(20, 4, 200, 0.50)$	6.0822	9.1233	0.0810	0.40548

Table 4.1: Numerical example of the case of endogenous entry costs.

4.5 Optimal Public Investment in two Regions

Now, we are going to consider that there are two regions with different geographic difficulties (w_1 and w_2) and different population densities (d_1 and d_2), in which a central authority has to decide how much to invest in transportation infrastructure (I_1 and I_2), apart from the quantity privately invested by firms (k_{1i} and k_{2i}).

First, we will obtain the social cost minimising public investment for the two regions as an interior solution in the absence of a budget constraint:

$$\begin{aligned} TSC &= SC_1 + SC_2 = \frac{4\lambda I_1\sqrt{(d_1 w_1 I_1)} + \lambda d_1 w_1\sqrt{2} + d_1 w_1\sqrt{2}}{4\sqrt{(d_1 w_1 I_1)}} + \\ &+ \frac{4\lambda I_2\sqrt{(d_2 w_2 I_2)} + \lambda d_2 w_2\sqrt{2} + d_2 w_2\sqrt{2}}{4\sqrt{(d_2 w_2 I_2)}}. \end{aligned} \tag{4.35}$$

From the F.O.C. $\frac{\partial TSC}{\partial I_1} = 0$ and $\frac{\partial TSC}{\partial I_2} = 0$ we obtain the candidates for an unconstrained optimal investment[14]:

$$I_1^o = \frac{1}{4\left(\sqrt[3]{\lambda}\right)^2}\sqrt[3]{2\cdot d_1\cdot w_1}\left(\sqrt[3]{(\lambda+1)}\right)^2, \tag{4.36}$$

$$I_2^o = \frac{1}{4\left(\sqrt[3]{\lambda}\right)^2}\sqrt[3]{2\cdot d_2\cdot w_2}\left(\sqrt[3]{(\lambda+1)}\right)^2. \tag{4.37}$$

Proposition 4.4 *The central authority will invest more in the region in which population density is higher and geographical conditions are worse.*

Proof: Observe that optimal public investment in infrastructure in each region is just the same than in the one region case. This is not surprising, as

[14] And we check that the S.O.C for minimum hold:
$\frac{\partial^2 TSC}{\partial I_1^2} = \frac{3\sqrt{2\cdot d_1\cdot w_1}(\lambda+1)}{16\left(\sqrt{I_1}\right)^5} > 0.$
$\frac{\partial^2 TSC}{\partial I_2^2} = \frac{3\sqrt{2\cdot d_2\cdot w_2}(\lambda+1)}{16\left(\sqrt{I_2}\right)^5} > 0.$
$\frac{\partial^2 TSC}{\partial I_1 \partial I_2} = \frac{\partial^2 TSC}{\partial I_2 \partial I_1} = 0.$

the social cost function is separable. The only differences in public investment and individual prices, will arise from differences in population densities and natural conditions between regions. Differences in individual investment and individual profits will also depend on the number of firms in each region.

The optimal total investment by the central authority will be:

$$I_T^o = I_1^o + I_2^o = \frac{1}{4}\sqrt[3]{2}\left(\sqrt[3]{(\lambda+1)}\right)^2 \frac{\sqrt[3]{(d_1 \cdot w_1)} + \sqrt[3]{(d_2 \cdot w_2)}}{\left(\sqrt[3]{\lambda}\right)^2}. \tag{4.38}$$

As in the one region case, total public investment depends positively on the population densities and on the toughness of natural conditions and negatively on the relative importance of entry costs.

With this optimal investment, the total social cost will be:

$$TSC(\lambda)^o = \frac{3}{4}\sqrt[3]{2\lambda}\left(\sqrt[3]{(\lambda+1)}\right)^2 \left(\sqrt[3]{d_1 \cdot w_1} + \sqrt[3]{d_2 \cdot w_2}\right), \tag{4.39}$$

which depends positively on natural difficulties and population densities in both regions, and on the relative importance of entry costs, as in the one region setting.

In the case of two regions with no budget constraints everything works in the same way as in the endogenous entry costs case for one region. And changes in the population density, the natural difficulties, or the number of firms, in one region, will not affect in any way the other region. This can be observed in the following example:

$(\lambda, \mathbf{n}_1, \mathbf{n}_2, \mathbf{w}_1, \mathbf{w}_2, \mathbf{d}_1, \mathbf{d}_2)$	$\mathbf{I}_1^o$	$\mathbf{I}_2^o$	$\mathbf{SC}^o$	$\mathbf{p}_1^o$	$\mathbf{p}_2^o$	$\mathbf{k}_1^o$	$\mathbf{k}_2^o$
(0.25,10,10,2,2,100,100)	5.38	5.38	8.07	0.086	0.086	0.43	0.43
(0.50,10,10,2,2,100,100)	3.83	3.83	11.49	0.102	0.102	0.51	0.51
(0.25,20,10,2,2,100,100)	5.38	5.38	8.07	0.086	0.086	0.21	0.43
(0.25,10,10,4,2,100,100)	6.78	5.38	9.12	0.108	0.086	0.54	0.43
(0.25,10,10,2,2,200,100)	6.78	5.38	9.12	0.054	0.086	0.54	0.43
(0.50,20,10,4,2,200,100)	6.08	3.83	14.8	0.081	0.102	0.40	0.51

Table 4.2: Numerical example of the case of two regions and no budget constraints.

But this would be the case of no budgetary constraints. Let us now study the case in which the budget is less than the unconstrained optimal public investment ($B < I_T^o$).

Binding Budget Constraint

Let us now consider the following budget constraint: $I_1 + I_2 = B$. In order to obtain the optimal public investment in this case, we set up the Lagrangian using (4.35):

$$L = TSC - \mu(I_1 + I_2 - B). \tag{4.40}$$

Again, from the F.O.C. $\frac{\partial L}{\partial I_1} = 0$, $\frac{\partial L}{\partial I_2} = 0$, and $\frac{\partial L}{\partial \mu} = 0$, we obtain the candidates for the constrained optimal investment:

$$I_1' = \frac{1}{4\left(\sqrt[3]{(\lambda - \mu)}\right)^2} \sqrt[3]{2 \cdot d_1 \cdot w_1} \left(\sqrt[3]{(\lambda + 1)}\right)^2, \tag{4.41}$$

$$I_2' = \frac{1}{4\left(\sqrt[3]{(\lambda - \mu)}\right)^2} \sqrt[3]{2 \cdot d_2 \cdot w_2} \left(\sqrt[3]{(\lambda + 1)}\right)^2. \tag{4.42}$$

The only change with respect to (4.36) and (4.37) is the Lagrange multiplier μ, which decreases optimal public investment as compared to the unconstrained case. Using the third equation, which is the budget constraint, we can obtain the optimal public investment in each of the two regions[15]:

$$I_1^o = \frac{\sqrt[3]{d_1.w_1}}{\sqrt[3]{d_1.w_1} + \sqrt[3]{d_2.w_2}} B, \tag{4.43}$$

$$I_2^o = \frac{\sqrt[3]{d_2.w_2}}{\sqrt[3]{d_1.w_1} + \sqrt[3]{d_2.w_2}} B. \tag{4.44}$$

Observe that the optimal investments are expressed as percentage shares of the budget, and they do not depend on λ. The critical magnitudes in order to decide the sharing of the budget will be the product between density and natural difficulties in each region. It could even be the case that a region with low natural difficulties and high population density should receive a lower share of the budget than a region with low population density and

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[15]We check that the S.O.C for minimum hold:
$\frac{\partial^2 L}{\partial I_1^2} = \frac{3\sqrt{2 \cdot d_1 \cdot w_1}(\lambda+1)}{16\left(\sqrt{I_1}\right)^5} > 0.$
$\frac{\partial^2 L}{\partial I_2^2} = \frac{3\sqrt{2 \cdot d_2 \cdot w_2}(\lambda+1)}{16\left(\sqrt{I_2}\right)^5} > 0.$
$\frac{\partial^2 L}{\partial I_1 \partial I_2} = \frac{\partial^2 L}{\partial I_2 \partial I_1} = 0.$

very high natural difficulties. Although, with the parameter values used, this is rather difficult to happen[16].

In this case, the investment of public money in one or the other region depends on the differential characteristics between them, regarding population densities and natural difficulties, and *not on the relative importance of entry costs*, which we assume equal in both regions, or on the number of firms in each region, which, as we already know, is ineffective in order to affect social welfare.

Proposition 4.5 *Optimal public investment in infrastructure in the case of endogenous entry costs and two different regions, depends positively on own region density, own natural difficulties, and the budget, and negatively on the other region ones.*

Proof: See Appendix.

The central authority will invest the whole budget in the two regions but it will attain a higher social cost than in the unconstrained case, given that the total investment is lower than the unconstrained social optimum. Social cost will behave as in the unconstrained case, it will increase with increases in the relative importance of entry costs, natural difficulties and population densities of the regions. Besides, it will decrease with increases in the budget, until the unconstrained optimum is reached.

Regarding the firm's decisions in each region, we will report here the socially optimal individual prices, investment and profits of each firm in Region 1[17]:

$$p_1^o = \sqrt{\frac{2w_1}{d_1 I_1^o}} = \sqrt{\frac{2\left(\sqrt[3]{(d_1 w_1)}\right)^2 \left(\sqrt[3]{(d_1 w_1)} + \sqrt[3]{(d_2 w_2)}\right)}{B d_1^2}}. \tag{4.45}$$

[16]Let us take for instance the extreme cases of Valencia and Aragón. Valencia has an average population density of 173 inhabitants per square kilometer (higher than 1000 in/km^2 in the big cities, 350 in/km^2 near the sea, and only 10 in/km^2 in the interior), and Aragón has an average population of only 25 in/km^2. Even if we assigned a weight of 5 to the natural difficulties in Aragón (which are in fact similar to those found in the interior part of Valencia) and of only 1 to those of Valencia, the budget share to be invested would still be higher on average in Valencia, and much higher in the coastal cities.

[17]If we want to get the equivalent expressions for firms in Region 2, we only have to change subindex 1 by 2, and vice versa. If all the variables where equal for both regions, public investment would be lower, and private investment, profits and prices higher than in the unconstrained case.

Proposition 4.6 *The price of each firm in Region 1 when the central authority's investment in infrastructure is socially optimal depends positively on w_1, w_2, and d_2, and negatively on d_1 and B.*

Proof: See Appendix.

The price charged by firms in Region 1 will increase as long as the natural difficulties, in itself or in the other region, increase, and with increases in the other region's population, and it will decrease with increases in its own population density or in the available budget. This may suggest an explanation of why prices in a poor country may be higher than in one with a less stringent budget constraint. The suboptimal public provision of transportation infrastructure allows for higher levels of unit transportation cost, hence, for a lower degree of competition, so the firms are able to charge higher prices.

$$k_1^o = \Pi_{i1}^o = \frac{1}{n_1}\sqrt{\frac{d_1 w_1}{2I_1^o}} = \frac{1}{n_1}\sqrt{\frac{\left(\sqrt[3]{(d_1 w_1)}\right)^2\left(\sqrt[3]{(d_1 w_1)} + \sqrt[3]{(d_2 w_2)}\right)}{2B}}. \tag{4.46}$$

Proposition 4.7 *The individual investment and profit of each firm when the central authority's investment in infrastructure is optimal in Region 1 depends positively on w_1, w_2, d_1 and d_2, and negatively on n_1 and B.*

Proof: It is straightforward, and we omit it.

Individual investment and profit for a firm in a given region depend positively on increases in any of both regions population densities and natural difficulties, and negatively on an increase in the budget, or an increase in the number of firms located in that region.

For a given number of firms, profits will be higher in the region with higher population density and natural difficulties. Also, with perfect capital mobility across regions, we would expect higher entry in the region with higher population and worse natural conditions until profits are equalised.

Besides, firms' profits in a rich country will end up being lower than in another country with the same characteristics, except a lower budget, because of the higher competition which produces a better transportation infrastructure.

All the preceding comments in the section can be observed in the following numerical example:

$(\lambda, \mathbf{n}_1, \mathbf{n}_2, \mathbf{w}_1, \mathbf{w}_2, \mathbf{d}_1, \mathbf{d}_2, \mathbf{B})$	$\mathbf{I}_1^o$	$\mathbf{I}_2^o$	$\mathbf{SC}^o$	$\mathbf{p}_1^o$	$\mathbf{p}_2^o$	$\mathbf{k}_1^o$	$\mathbf{k}_2^o$
(0.25,10,10,2,2,100,100,4)	2	2	9.83	0.14	0.14	0.7	0.7
(0.50,10,10,2,2,100,100,4)	2	2	12.6	0.14	0.14	0.7	0.7
(0.25,20,10,2,2,100,100,4)	2	2	9.83	0.14	0.14	0.35	0.7
(0.25,10,10,4,2,100,100,4)	2.23	1.77	11.6	0.18	0.15	0.94	0.75
(0.25,10,10,2,2,200,100,4)	2.23	1.77	11.6	0.09	0.15	0.94	0.75
(0.25,10,10,2,2,100,100,6)	3	3	8.71	0.11	0.11	0.57	0.57
(0.25,10,10,4,2,100,200,6)	3	3	11.7	0.16	0.08	0.81	0.81
(0.50,20,10,4,2,200,100,6)	3.68	2.31	15.74	0.10	0.13	0.52	0.65

Table 4.3: Numerical example of the case of two regions and a binding budget constraint.

4.6 Conclusions

In this chapter, we have modified the monopolistic competition framework in order to account for two facts: first, the relative weights of transportation and entry costs in the social cost function may play an important role in the relationship between the free entry and the optimal number of firms in the market; Second, the consideration of exogenous or endogenous entry costs may be crucial for the effectiveness of public intervention by regulating entry into the market.

Then, we apply the model to the case of exogenous entry costs and we show that, depending on the relative weight of transportation costs and entry costs in the social loss function, the optimal results in terms of number of firms, investment, etc. can be significantly away from those provided by the implicit assumption taken in the literature that both have equal weights. Therefore, when entry costs are exogenous, the socially optimal number of firms may coincide with the free entry equilibrium provided that entry costs are relatively not very important as compared to the transportation costs.

In the case of endogenous entry costs, setting the number of firms by a central planner is not an effective policy. Instead, public investment in a transportation cost-reducing infrastructure will be an effective policy, and its level will depend on the relative weights of entry and transportation costs in the social cost function. Firms' entry costs and firm-specific unit transportation costs are endogenously determined. The result on long run (free entry) equilibrium coincides then with the social optimum but it requires that an infinity of firms enter into the market. This result depends on the fact that (sunk) entry costs are totally endogenous. We are conscious of the fact that with some fixed (exogenous) part which is a necessary minimum to be paid by firms entering into the market, the free-entry equilibrium number of firms would be bounded from above by a number which increases to infinity as the exogenous part of sunk costs decreases to zero. However, we have used the extreme case of totally endogenous entry costs to illustrate a case in which entry control, which is more common in the literature than in real-world policy-making, may be unnecessary. In fact, we have shown that public investment in transportation infrastructure leads to a social optimum which is independent of the number of firms.

In the case of endogenous entry costs and two different regions, the natural difficulties and the population density will play a positive role in the amount of investment in the region by the central authority and also in the number of firms which will enter its market. Besides, in the case of a binding budget constraint the weights of entry and transportation costs will not play a role in the sharing of the budget. Contrary to standard intuition, individual equilibrium prices and profits will tend to be higher in poorer countries.

4.7 Appendix

4.7.1 Restrictions on the Reservation Price

Following the results obtained in the chapter, the assumption that consumers' reservation price must be higher than the generalised price for any of them ($R > p + \tau \cdot \frac{1}{2n}$) in order that we have full market coverage, implies, for the model with exogenous entry costs, $R > \frac{3\tau}{2n}$.

In the social optimum that is: $R > 3\sqrt{\tau f}$. And for the model with endogenous entry costs: $R > \frac{3}{2}\sqrt{\frac{2w}{dI}}$. In the social optimum, that will be:

$$R > 3\sqrt{\left(\frac{\left(\sqrt[3]{2\lambda w}\right)^2}{\left(\sqrt[3]{d^2(\lambda+1)}\right)^2}\right)}.$$

4.7.2 Proof of Proposition 4.3

$$\frac{\partial p^o}{\partial \lambda} = \frac{2}{3}\left(\sqrt[3]{2}\right)^2 \frac{w}{\sqrt{\left(\left(\sqrt[3]{2}\right)^2 \frac{\left(\sqrt[3]{(\lambda dw)}\right)^2}{\left(\sqrt[3]{(\lambda+1)}\right)^2}\right)\sqrt[3]{(\lambda dw)}\left(\sqrt[3]{(\lambda+1)}\right)^5}} > 0.$$

$$\frac{\partial p^o}{\partial d} = -\frac{4\sqrt[3]{2}}{3d\sqrt{\left(\frac{\left(\sqrt[3]{(\lambda dw)}\right)^2}{\left(\sqrt[3]{(\lambda+1)}\right)^2}\right)\sqrt[3]{(\lambda dw)}\left(\sqrt[3]{(\lambda+1)}\right)^2}}\lambda w < 0.$$

$$\frac{\partial \Pi^o}{\partial \lambda} = \frac{1}{3}\left(\sqrt[3]{2}\right)^2 y \frac{w}{n\sqrt{\left(\left(\sqrt[3]{2}\right)^2 \frac{\left(\sqrt[3]{(\lambda dw)}\right)^2}{\left(\sqrt[3]{(\lambda+1)}\right)^2}\right)\sqrt[3]{(\lambda dw)}\left(\sqrt[3]{(\lambda+1)}\right)^5}} > 0. \textbf{ QED}$$

4.7.3 Proof of Proposition 4.5

$$\frac{\partial I_1^o}{\partial d_1} = \frac{1}{3}B\sqrt[3]{w_1}\sqrt[3]{d_2}\frac{\sqrt[3]{w_2}}{\left(\sqrt[3]{d_1}\right)^2\left(\sqrt[3]{d_1}\sqrt[3]{w_1}+\sqrt[3]{d_2}\sqrt[3]{w_2}\right)^2} > 0.$$

$$\frac{\partial I_1^o}{\partial d_2} = -\frac{1}{3}B\sqrt[3]{w_2}\sqrt[3]{d_1}\frac{\sqrt[3]{w_1}}{\left(\sqrt[3]{d_2}\right)^2\left(\sqrt[3]{d_1}\sqrt[3]{w_1}+\sqrt[3]{d_2}\sqrt[3]{w_2}\right)^2} < 0. \textbf{ QED}$$

4.7.4 Proof of Proposition 4.6

$$\frac{\partial p_1^o}{\partial d_1} = -\frac{1}{6}\frac{\sqrt{2}}{\left(\sqrt[3]{d_1}\right)^5}\sqrt[3]{w_1}\frac{3\sqrt[3]{y_1}\sqrt[3]{w_1}+4\sqrt[3]{d_2}\sqrt[3]{w_2}}{\sqrt{\left(\sqrt[3]{d_1}\sqrt[3]{w_1}+\sqrt[3]{d_2}\sqrt[3]{w_2}\right)}\sqrt{B}} < 0. \textbf{ QED}$$

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