The Effect of Liberalisation on Incumbent's Innovation.
The Case of the Postal Sector

PAR

Cátia Alexandra PEREIRA FELISBERTO

Master of Science in Economics, Université de Lausanne, Suisse
et de nationalité portugaise

EPFL

ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Lausanne, EPFL
2008

To Rui,

Maria Antónia, José and Félix

Acknowledgements

Finalmente, quero agradecer aos meus pais e ao meu irmão pelo seu apoio incondicional, por estarem sempre presentes, por me encorajarem nos momentos difíceis, pelo seu amor e pela sua confiança. Vocês estão sempre no meu coração. Um grande obrigado também para a Graciosa, o Vitor e a Rita.

Summary

The network industries have been undergoing a process of reform, where liberalisation is one of the main features. This thesis studies the effect of liberalisation, with and without competition, on the incumbent's incentives to innovate.

A model of incumbent network operator is developed and analysed when the incumbent is a monopolist, as well as when it faces an entrant. The objectives of the incumbent are specified in a general manner to allow for revenue, profit, and/or welfare maximisation. The marginal cost of the incumbent is assumed to depend upon the investment in new technologies and processes. A strictly convex and decreasing cost function is assumed. The incumbent maximises its objective function with respect to prices and to investment in innovation. The entrant is assumed to maximise profits with respect to prices. The incumbent's incentives to innovate under monopoly and duopoly are compared. One of the main results is that the difference between the investment in innovation under monopoly and under duopoly is determined by the incumbent's elasticity of demand under monopoly as well as by the incumbent's market share and elasticity of demand under duopoly. For certain values of these variables it exists an interval where duopoly provides more incentives to innovate than monopoly. The market share of the incumbent has a non-linear relationship with the investment in innovation under duopoly. Until a certain point an increase in the incumbent's market share creates more incentives to innovate under duopoly and from that point on the contrary happens. A decrease (in absolute value) in the incumbent's elasticity of demand has a negative effect on the incentives to innovate under both market structures. Another major result is that the incentives to innovate increase when the incumbent places greater weight on social welfare.

The effect of liberalisation and competition on innovation in the postal sector is empirically assessed. The impact of the quantity supplied and of some control variables is also analysed. An original dataset is put together to perform the analysis. It includes data for seventeen European countries, over ten years. Innovation is measured using an innovation index, the accumulated number of innovations (both based on the results of a survey developed for this purpose), and labour productivity. A liberalisation index is built in order to measure the percentage of liberalised market. The econometric analysis performed, where several models were estimated by GLS and using PW-PCSE, shows that: (1) market liberalisation has a positive effect on innovation, and (2) an increase in the market share of the competitors stimulates the incumbent's investment in innovation, at least until the market share of the competitors reaches a certain threshold. Letter volume and GDP per capita are also significant and have a positive relationship with innovation. In general, the models estimated have a high explanatory power. The econometric analysis only considers end-to-end competition. The effect of upstream and downstream access on innovation is studied by way of three case studies (USPS, La Poste, and Royal Mail). The initial expectations of a positive relationship between both upstream and downstream access and innovation are confirmed.

Key-words: Liberalisation, Competition, Market structure, Innovation, Network industries, Postal sector

Résumé

Les industries de réseaux ont fait, et font encore, l'objet de réformes dont la libéralisation est l'aspect le plus important. Cette thèse étudie l'effet de la libéralisation (avec et sans concurrence) sur les incitations à innover de l'opérateur historique.

Le comportement d'un opérateur historique sous monopole et sous duopole est modélisé et analysé dans le contexte des industries de réseaux. Les objectifs de l'opérateur historique sont spécifiés de façon générale pour permettre la maximisation des revenus, des bénéfices et/ou du bien-être social. Il est admis que le coût marginal de l'opérateur historique dépend de l'investissement dans les nouvelles technologies ou dans les nouveaux processus. Une fonction de coût strictement convexe et décroissante est admise. L'opérateur historique maximise sa fonction objective en choisissant son prix et son investissement dans l'innovation. Il est aussi admis que le nouvel entrant maximise son bénéfice en choisissant le prix. Les incitations à innover de l'opérateur historique sous monopole et sous duopole sont comparées. Le résultat principal est que la différence entre les investissements dans l'innovation est déterminée par l'élasticité de la demande et la part de marché de l'opérateur historique sous duopole et par l'élasticité de la demande de l'opérateur historique sous monopole. Pour certaines valeurs de ces variables il existe un intervalle pour lequel le duopole crée plus d'incitations à innover que le monopole. Il y a une relation non-linéaire entre la part de marche de l'opérateur historique et ses incitations à innover sous duopole. Jusqu'à un certain point une augmentation de la part de marché de l'opérateur historique génère plus d'incitations à innover sous duopole. Au-delà de ce point le contraire se produit. L'élasticité de la demande de l'opérateur historique a un effet négatif sur l'incitation à innover dans le cadre des deux structures de marché. Un autre résultat important est que l'incitation à innover augmente lorsque l'opérateur donne plus de poids au bien-être social.

L'effet de la libéralisation et de la concurrence sur l'innovation est évalué empiriquement dans le secteur postal. L'impact de la quantité fournie et de certaines variables de contrôle est également analysé. Une base de données est constituée pour effectuer les analyses. Elle inclut des données pour dix-sept pays européens sur dix ans. L'innovation est mesurée à travers un indice de l'innovation, du nombre cumulé des innovations – les deux sont basés sur les résultats d'une enquête élaborée à cet effet – et de la productivité du travail. Un indice de libéralisation est construit dans le but de mesurer le pourcentage de marché libéralisé. L'analyse économétrique effectuée, où plusieurs modèles ont été estimés par GLS et PW-PCSE, montre que: (1) la libéralisation du marché a un effet positif sur l'innovation, et (2) une augmentation de la part de marché des concurrents stimule l'investissement de l'opérateur historique dans l'innovation, au moins jusqu'à ce que la part de marché des concurrents atteigne un certain seuil. Le volume de courrier et le PIB par habitant sont également significatifs et sont positivement corrélés avec l'innovation. En général, les modèles estimés ont un pouvoir explicatif élevé. L'analyse économétrique considère la concurrence à travers toute la chaîne de valeur mais pas l'effet de l'accès en aval et en amont sur l'innovation. Ces effets sont étudiés par le biais de trois études de cas (USPS, La Poste, et Royal Mail). Les attentes initiales d'une relation positive entre les deux types d'accès et l'innovation sont confirmées.

Mots-clés: Libéralisation, Concurrence, Structure du marché, Innovation, Industries de réseaux, Secteur postal

Sumário

A liberalização é um dos aspectos mais importantes do processo de reforma das indústrias de rede. Esta tese estuda o efeito da liberalização, acompanhada ou não do desenvolvimento de competição, no incentivo para inovar do operador histórico.

O comportamento de um operador histórico em monopólio e em duopólio é modelado e analisado no contexto das indústrias de rede. Os objectivos do operador histórico são especificados de uma forma geral de modo a permitir a maximização da receita, do lucro e/ou do bem-estar social. Assume-se que o custo marginal do operador histórico depende do investimento em novas tecnologias e processos, e que a sua função de custo é estritamente convexa e decrescente. O operador histórico maximiza a sua função objectivo em ordem ao preço e ao investimento em inovação. Assume-se que os novos operadores maximizam o lucro apenas em ordem ao preço. O objectivo é comparar os incentivos para inovar do operador histórico em monopólio e em duopólio. Um dos resultados mais importantes é que a diferença entre o investimento em inovação em monopólio e em duopólio depende da quota de mercado do operador histórico em duopólio e das elasticidades da procura do operador histórico tanto em monopólio como em duopólio. Para determinados valores destas variáveis, existe um intervalo em que o duopólio favorece mais a inovação efectuada pelo operador histórico do que o monopólio. A relação entre a quota de mercado do operador histórico e o investimento em inovação em duopólio não é linear. Um aumento da quota de mercado do operador histórico origina um aumento da inovação em duopólio até um certo ponto. A partir desse ponto verifica-se o contrário. Verificou-se também que o aumento da elasticidade da procura do operador histórico tem um efeito negativo sobre o investimento em inovação em ambas as estruturas de mercado estudadas. Um outro resultado de relevo é que os incentivos para inovar aumentam quando o operador histórico dá maior peso à maximização do bem-estar social.

O efeito da liberalização e da competição na inovação no sector postal é analisado empiricamente. O impacto da oferta e de algumas variáveis de controlo é também estudado. Para este efeito, compilou-se uma base de dados que inclui informação relativa a dezassete países para um período de dez anos. A inovação é medida usando um índice de inovação e o número acumulado de inovações (medidas baseadas nos resultados de um questionário desenvolvido para este efeito), assim como a produtividade do trabalho. É construído um índice de liberalização para medir a percentagem de mercado liberalizado. Através da análise econométrica, na qual são estimados vários modelos usando GLS e PW-PCSE, concluiu-se que: (1) a liberalização do mercado tem um efeito positivo na inovação, e (2) um aumento da quota de mercado dos concorrentes incentiva o operador histórico a investir em inovação, pelo menos até que a quota de mercado dos concorrentes atinja um determinado valor. O volume de correspondência e o PIB *per capita* também são variáveis significativas e estão positivamente relacionadas com o incentivo do operador histórico para inovar. Os modelos estimados têm, em geral, um poder explicativo elevado. A análise econométrica tem em consideração a competição ao longo de toda a cadeia de valor ("end-to-end competition") mas não considera os efeitos do acesso a montante e a jusante ("upstream access" e "downstream access"). Estes efeitos são estudados através de três estudos de caso (USPS, La Poste, et Royal Mail). Confirma-se a previsão de que ambos os tipos de acesso estão positivamente relacionados com a inovação.

Palavras-chave: Liberalização, Competição, Estrutura do mercado, Inovação, Indústrias de rede, Sector postal

Acronyms

ACP	Avoided Cost Pricing
AGV	Automated Guided Vehicles
AR(1)	First Order Autoregressive Process
ARCEP	L'Autorité de Régulation des Communications Électroniques et des Postes (French regulatory authority for electronic communications and post)
BG	Bulgaria
CER	Community of European Railway and Infrastructure Companies
CH	Switzerland
DAP	Delivery-Area Access Pricing
DE	Germany
ECPR	Efficient Component Pricing Rule
EU	European Union
EE	Estonia
ES	Spain
FI	Finland
FR	France
GDP	Gross Domestic Product
GLS	Generalised Least Squares
HR	Croatia
IE	Ireland
IT	Italy
IPC	International Post Corporation
LV	Latvia
NAP	Negotiated Access Pricing
NI	Network Industries
NL	The Netherlands
NRA	National Regulatory Authority
OCR	Optical Character Recognition
OLS	Ordinary Least Squares
PL	Poland

PRC	Postal Rate Commission
PT	Portugal
PW-PCSE	Prais-Winsten estimation with Panel Corrected Standard Errors
R&D	Research and Development
RFID	Radio Frequency Identification
RO	Romania
SE	Sweden
SGI	Services of General Interest
UK	United Kingdom
UN	United Nations
UPU	Universal Postal Union
USA	United States of America
USO	Universal Service Obligation
USP	Universal Service Provider
USPS	The United States Postal Service
VAT	Value Added Tax

Table of contents

List of tables

List of figures

1. Introduction

1.1 Context

The network industries are extremely important for the national economies because they provide vital services for society and/or services of general economic interest. They are characterised by having a network infrastructure through which the delivery of products and services is made. Examples of network industries include telecommunications, postal services, energy (electricity and gas), railways and public local transport, air transport, water distribution and sanitation.

Over the past decades, network industries have been going through a process of reform. Most network industries have evolved from being dominated by integrated state-owned monopolies to restructured industries with private sector participation and/or to partially or almost completely liberalised industries. The progressive liberalisation is definitely the most important aspect of this reform.

The reform process does not necessarily follow a specific order of events, and differs across network industries and regions. In fact, some sectors were and are being liberalised without having been privatised first (e.g. air transport in several European countries); while others were privatised but not liberalised (e.g. water utilities in England and Wales in 1989).

The United States of America (USA) is traditionally more liberal regarding market liberalisation than Europe. In the USA there is a strong belief in the market and on *ex-post* intervention, whereas in Europe, public ownership is assumed to protect the general interest against private interests, and interventions are mainly done *ex-ante*. Many developing countries present a different path, primarily due to the influence of World Bank policies. The World Bank started by pro(im)posing privatisation; however, lately it has focused on competition as the restructuring solution for these industries.

Traditionally, the default resolution to the conflict between consumer protection and investment needs has been public ownership, which allows access to investment funds and political control over final prices (Newbery, 2004). However, in the early stages of the process of restructuring the network industries, there was a shift from public to private ownership. There were several reasons grounding the decision to privatise. One of the most important reasons was the increase in operational efficiency expected with a change in ownership. Neo-classical authors presented other reasons to privatise, such as reducing the public sector borrowing requirement, and reducing government involvement in enterprise decision making (Vickers and Yarrow, 1988).

With the trend towards the privatisation of public utilities came the need for government regulation. State ownership was substituted by economic regulation, i.e. by government intervention in the market. At this stage, the need for regulation was fundamentally related to ensuring that the monopolist would not abuse its privileged position in the market.

Over time, contradictory findings on the relationship between ownership and efficiency questioned the purpose of privatisation. Some authors argued that the restructuring of the network industries should not result from a change of ownership, i.e. from privatisation, but rather from opening the markets to competition, i.e. from liberalisation (e.g. Armstrong, 2003, Newbery, 2002, Vickers and Yarrow, 1991).

To recall, liberalisation refers to a process by which legal entry barriers are eliminated in order to make competition possible in situations or sectors so far characterised by monopolies. Its economic rationale is grounded on the recognition that, in principle, competition is more prone to achieve efficiency than monopoly[1]. In most of the markets, competition ensures that the interest of the

---

[1] Although this is a relatively consensual principle in economics, some authors (e.g. von Ungern-Sternberg, 2004) argue that the unsatisfactory results of some privatisation and liberalisation projects sustain the hypothesis that state monopolies might outperform competitive markets, even in markets that do not exhibit economies of scale. This issue is discussed in dept further on in this thesis.

consumer is satisfied because it obliges the firms to be cost efficient, to attain a certain level of quality and/or to be innovative. This is the only way firms can survive and be profitable in the competitive market (Armstrong et al., 1994).

The process of liberalisation can also be characterised as a process of "deregulation". The idea behind this is that, where there is competition, normal competition policy should replace regulatory control exercised by the regulatory entities. However, in practice, many "deregulating" measures in the network industries involved a change in the intensity, rather than in the number of, measures (Ogus, 2004). This means that regulatory forms are less interventionist (e.g. less prescriptive standards; general targets as opposed to detailed mandatory requirements) and not necessarily that they are completely removed.

In effect, in the event of market failures there are two ways to overcome the problem of market power: to regulate the market or to introduce more competition in the market (Armstrong et al., 1994). The introduction of competition may not be desirable if the industry presents important natural monopoly characteristics, or if there is the threat of "cream-skimming". In these cases, regulation tends to persist. In many network industries competition is limited, at least in a first stage. Therefore, government regulation is nonetheless deemed necessary as a means to ensure that the pursuit of profits does not conflict with social welfare (e.g. Vickers and Yarrow, 1991, Train, 1997).

Newbery (2002) goes a step further, suggesting that regulation should not be confined to the natural monopoly elements. The author advocates that the potentially competitive elements also need regulatory oversight so as to ensure that markets are not manipulated nor market power abused. According to this author, deregulated industries will still need to be regulated (a process also called re-regulation).

1.2 Problem Statement

As already mentioned, one of the major motivations for the reform of the network industries, and in particular for the liberalisation process, is the belief that competition stimulates process innovation (development or adoption of new

technologies and processes) and product innovation (development or adoption of new products and services), encourages efficiency, and drives prices down. Innovation is an important vehicle for economic and productivity growth, and ultimately for the improvement of living standards (Tang, 2006).

There is a considerable amount of literature on the relationship between competition and innovation. However, there is no clear consensus on whether competition has a positive effect on innovation or not. The lack of consensus is more apparent when theoretical and empirical results are compared. Also, the models developed until today only consider profit maximisation as the objective of the firm. Therefore, they do not capture the richness inherent in the alternative ownership and governance structures, as well as the potential regulation of the network industries.

On the empirical side, there is also a need for further research. The network industries have been under considerable change. Some sectors are completely liberalised and others are close to achieving full market opening. Competition has been developing in those sectors, sometimes faster than in others. However, the effect of liberalisation and competition on innovation has not yet been assessed. Reforms are being pursued without understanding the actual results, in terms of innovation, of the measures already taken.

1.3 Objectives

The two main objectives of this thesis are to: (1) theoretically assess the incumbents' incentives to innovate under various market structures in a setting where the incumbent can maximise sales revenue, profit and/or welfare and (2) empirically observe the effect of liberalisation and competition on the incumbents' investment in innovation.

Other objectives besides profit maximisation can credibly be advanced as representing those of network industries' incumbents and, in particular, of postal sector incumbents. For example, a traditional public bureaucracy whose management is concerned primarily with maximising the size of the organisation will engage in maximising sales revenue. On the contrary, a public enterprise that

is explicitly regulated to achieve efficiency (in pricing) will be concerned about welfare maximisation. A theoretical model that allows the incumbent to have different maximising objectives is developed in order to analyse the effect of these alternative objectives on the incumbent's incentives to innovate.

The aim of the empirical assessment is to analyse the impact of liberalisation and competition on innovation and, simultaneously, to test the predictions of the theoretical model. The empirical analysis is performed for the postal sector.

This thesis focuses on process innovations, i.e. the development or adoption of new or substantially improved technologies, techniques, and processes. Both incremental and radical innovations are considered. An incremental innovation is a minor change in the existing products or processes while a radical innovation corresponds to a completely new product or process. Therefore, "innovation" refers to the adoption of a new or improved technology or process. An innovation should result either in a reduction of operational costs, an increase in product/service quality, or an increase in the level of output.

Both in the theoretical and empirical parts of this thesis, we consider that only the incumbent (or historical operator) innovates. For the sake of simplicity in the theoretical model, the entrants do not have the possibility to innovate, and in the empirical analysis, the innovations of the entrants are not considered due to the difficulty associated with the collection of that type of data. The relevance of the study's conclusions is not affected by this simplification, since incumbents still currently represent (and will probably continue for the foreseeable future) a large share of the markets. Also, the fact that this experiment focuses on process innovations reduces the importance of entrant's possible innovations since process innovations are less likely to be disruptive than product innovations.

1.4 Structure of the thesis

The methodology followed to attain the objectives described above is as follows.

Firstly, a literature review regarding the impact of liberalisation on innovation, and the relationship between competition and innovation is made (Chapter 2).

This literature review confirms the lack of consensus concerning the impact of competition on innovation.

Chapter 3 begins with an analysis of the relationship between liberalisation and the development of competition. In particular, we describe the liberalisation process, examine the factors that often block the development of competition, and identify the state of competition in the network industries. This analysis is important because the results concerning the impact of competition on the incumbent's investment in innovation are only pertinent if indeed there is the possibility that competition develops in the market. This analysis serves as a background for the study of the relationship between liberalisation and innovation made later in Chapter 3. It is also a complement to the theoretical model developed in Chapter 4. The predictions concerning the effect of liberalisation *per se* on innovation will be tested in the empirical analysis (Chapter 5).

In order to fill the gaps identified in the literature, we developed a theoretical model to examine the incumbents' incentives to innovate under various market structures in a setting where the incumbent can maximise sales revenue, profit, and/or welfare (Chapter 4).

In Chapter 5 we make an empirical assessment of the effect of liberalisation and competition on the incumbents' investment in innovation in the postal sector. In a first part, we make an econometric analysis where the explanatory variables of interest are the percentage of market liberalised and the market share of the entrants competing along the whole value chain (end-to-end competition). In order to perform this analysis, we questioned eighteen postal incumbents through a survey about the date of introduction of seventeen critical process innovations. In a second part, we performed three case studies in order to analyse the effects of two other models of competition (upstream and downstream access) on innovation. The case studies are: United States Postal Service (USPS - USA), La Poste (France), and Royal Mail (United Kingdom). We proceeded in this way because of the lack of quantitative data concerning upstream and downstream access.

Finally, in Chapter 6 the main conclusions of this thesis are summarised.

2. Literature review

The analysis of the effect of liberalisation and competition on innovation implies the study of the literature regarding: (1) the relationship between competition and innovation, and (2) the effect of the threat of competition on efficiency.

Firstly, the literature on the relationship between competition and innovation is reviewed (section 2.1). This old theme of the industrial organisation literature, on which a lot has been written, is the background of the theoretical model developed in Chapter 4 and also motivates some arguments in section 3.3 (Chapter 3). The literature review made here is not exhaustive[2]. We make reference to some of the major contributions in the field and to those that are most relevant to the work developed in this thesis.

Secondly, we analyse the effect of the threat of competition on efficiency (section 2.2). Our focus is on the Theory of Contestable Markets. This theory does not analyse the effect of liberalisation on innovation directly. However, it deals with concepts that are related to liberalisation, innovation and, consequently, to the relationship between liberalisation and innovation. The concept of "threat of competition" implies that a market is liberalised but no actual competition develops. Also, efficiency is improved through the introduction of new technologies and processes, i.e. through innovation. This body of literature is important for the analysis made in section 3.3 (Chapter 3).

2.1 Effect of competition on innovation

There is a large body of literature on the effect of competition on innovation. Table 1 (at the end of this chapter) summarises the key ideas of the major contributions. In order to facilitate the review, we start by presenting the theoretical contributions and then we examine the empirical ones.

---

[2] For an exhaustive literature review on market structure and innovation see Baldwin and Scott (Baldwin and Scott, 1987) and Cohen and Levin (Cohen and Levin, 1989).

2.1.1 Theoretical contributions

The debate about the influence of the intensity of competition on technical progress started with Schumpeter (1942) and continued with Arrow (1962). Schumpeter argues that monopoly favours the development of research and development (R&D) activities because it provides the necessary cash flow to invest in such activities and reduces uncertainty in the market. Twenty years later, Arrow investigated the effects of market structure on the firm's incentives to invest in R&D in order to reduce costs. Arrow concluded that under competition the single firm gets more benefits from innovation than under monopoly. The logic behind his conclusion is that under monopoly, part of the benefits coming from innovation serves only to replace the monopolist's rents earned before innovating, i.e. the monopolist has greater opportunity costs of innovating. Therefore, a firm operating under competition has larger net returns from innovation than a monopolist. This is the so-called "replacement effect".

The Schumpeterian analysis of new processes was extended by Swan (1970) to new products, in order to examine the timing of product innovations under monopoly and competition. The author proves that the monopolist's time preference for the introduction of new substitute products coincides with those of a firm in competition, under particular conditions. The monopolist will introduce the new substitute products "along with the previous products in smaller amounts and at higher prices and profits than would a competitive industry." (Swan, 1970: page 627). The author argues that the monopolist does not have interest in delaying product innovation because he wants customers to spend the maximum possible on his product(s). The introduction of new products, closer to customer's preferences, will certainly help with that objective. In order to avoid that economies of scale on existing products are lost when the firm introduces a new product, the author assumes that all firms have constant returns to scale.

Kamien and Schwartz (1970) build on the work by Arrow (1962) and Demsetz (1969). Kamien and Schwartz present additional considerations and develop conditions under which monopoly gives more incentive to innovate than competition and vice-versa. The incentive to innovate is measured by the increase

in profit due to a cost reduction, or through the total royalty. The authors demonstrate that the incentive to innovate increases with the industry's elasticity of demand, independently of its internal structure. The basis of this result is the larger output expansion associated with higher elasticity. The exception to this rule occurs in a competitive industry when the innovation is "nondrastic", in which case the industry output does not change and neither do the incentives. If the elasticity of demand and the "preinvention size" before innovation are the same for the monopolist and competitive industry, then the monopolist's incentive to innovate is larger. Nevertheless, the authors find that if the elasticity of demand of the competitive firm is sufficiently higher than the elasticity of demand of the monopolist, then the competitive industry can provide a greater incentive for drastic innovation.

The value of the innovation or the benefits associated with it are the major features in Kamien and Schwartz (1975). The authors make a survey of the literature on market structure and innovation. In what concerns the relationship between competition and innovation, the authors show that

> "[…] within the context of a specific model, there is a degree of rivalry that results in the most rapid development of an innovation. For inventions of small value, the absence of rivalry, monopoly, leads to most rapid development, while a positive level of rivalry will achieve this for more valuable innovations."   (Kamien and Schwartz, 1975: page 33)

One year later the authors analyse the relationship between the rate of innovative activity and the intensity of rivalry (Kamien and Schwartz, 1976). The authors assume that individual firms face a stochastic relationship between investment in R&D and the introduction of a new technology and find two possible relationships. If the innovation is likely to cause large benefits, then a rise in rivalry's intensity, up to a certain point, shortens the development period chosen by the firm. An increase in rivalry's intensity beyond that point lengthens the development period. In the case where the innovation does not involve large benefits, the intensity of rivalry is positively correlated with the development rate of innovation.

The models of product differentiation and monopolistic competition of Salop (1977) and Dixit and Stiglitz (1977) lead to the conclusion that increased product market competition discourages innovation by reducing post-entry rents.

We must also make reference to the literature on X-efficiency (Leibenstein, 1966) and in particular to the work of Primeaux (1977) on X-efficiency and competition. Primeaux analyses the effect of competition on a firm's costs by comparing the costs of municipally owned firms under competition and under monopoly. The author concludes that competition generates X-efficiency.

Other authors have elaborated on the relationship between competition and innovation, introducing additional factors like the level of fixed and variable costs.

An equilibrium model of investment in R&D under competition, where firms maximise their expected discounted profits with respect to their investment decisions while facing technological and market uncertainty, is developed by Loury (1979). Technological uncertainty arises from the assumed stochastic relationship between investment in R&D and the time at which an innovation occurs. The assumption that firms do not know when one of their rivals will succeed in its R&D efforts is the origin of the market uncertainty. Another key aspect of Loury's model is that he assumes R&D costs to be lump sum initial investment. The author finds that the incentives of individual firms in equilibrium to invest in R&D decrease as competition increases. Nevertheless, under certain conditions, additional competition increases the probability that the innovation will be introduced at any future date.

The work developed by Lee and Wilde (1980) reaches rather different conclusions from Loury (1979). Lee and Wilde make a critical analysis of two major conclusions by Loury: 1) the equilibrium level of firm investment in R&D decreases as the number of firms increases and 2) "excess capacity" in the R&D technology will always exist in a zero expected profit industry equilibrium with a finite number of firms when there are initial increasing returns to scale in the R&D technology. The authors argue that these two conclusions as sensible to the R&D cost specification and they investigate the consequences of different specifications. They focus on the importance of variable costs (R&D cost as a

flow investment) instead of fixed costs (R&D cost as a lump sum initial investment) as in Loury's model. The authors model a one-shot non-cooperative game with n firms that invest in R&D. The objective is to be the first to innovate in order to receive a prize (that is given exogenously) and not to incur a loss corresponding to R&D cost. Patent protection is perfect and infinitely lived, and the probability that a firm succeeds depends on its expenditure on R&D. The conclusion is that an increase in rivalry increases the equilibrium individual R&D effort. In an attempt to reconcile this conclusion with Loury's work, the authors hypothesize that if fixed costs in the R&D technology are larger than the variable costs, then an increase in competition leads to a decrease in the equilibrium level of firm investment in R&D. The opposite occurs if fixed costs in the R&D technology are smaller than the variable costs.

The generality of the conclusions drawn by Lee and Wilde (1980) is questioned by Delbono and Denicolo (1991). They argue that Lee and Wilde's results depend on the particular specification of incentives and payoffs adopted. Firstly, the prize is independent of the number of firms and is exogenously determined. Secondly, the firms that don't succeed in being the first to innovate get nothing. Finally, possible positive profits previous to the innovation are neglected. Delbono and Denicolo model a patent race between Cournot oligopolists using the fundamentals of Lee and Wilde's framework. Nevertheless, some of the conclusions obtained are not the same when Delbono and Denicolo specialise the model: an increase in the degree of rivalry can reduce the equilibrium R&D effort of each firm and the equilibrium total effort.

Gilbert and Newbery (1982) argue that, in an auction model of R&D, potential entrants have less stimulus to search for innovations than the incumbent monopolist. This happens because, with additional entrants, the total industry profits decrease and only the incumbent internalises this externality, which is the so-called "efficiency effect". Therefore, under certain conditions, a monopolist has incentive to patent new technologies before potential competitors in order to maintain his monopoly power. Some of those patents will not be used by the monopolist nor licensed to other firms.

Schumpeter's view that monopoly is a precondition for innovation is supported by Romer (1990) and Grossman and Helpman (1991a). The authors argue that firms innovate because they seek profitable opportunities that arise from monopoly.

Grossman and Helpman (1991b) show that when competition facilitates imitation, R&D and growth are negatively affected.

The association between the degree of substitutability and cost-reducing innovation is studied by Bester and Petrakis (1993). The authors conclude that the degree of substitutability has an important impact on the incentives to innovate.

> "When goods are imperfect substitutes, both Cournot and Bertrand competition result in underinvestment in the sense that a social planner would be wiling to pay more for a given cost reduction than a profit-maximizing firm. Overinvestment may occur when the goods are sufficiently close substitutes." (Bester and Petrakis, 1993: page 519).

The authors also conclude that if the degree of substitutability is low, then Bertrand competition provides less incentive to innovate than Cournot competition. If the degree of substitutability is high enough, then Bertrand competition provides stronger incentives than Cournot competition. This happens because "price competition is more effective and results in a more drastic increase in the innovator's market share than quantity competition" (Bester and Petrakis, 1993: page 521). The degree of product substitutability is exogenously determined.

The issue of market structure and innovation is analysed in a broader perspective by Boone and Dijk (1998). They use the concepts of persistence of leadership and intensity of competition instead of persistence of monopoly and market structure, respectively. Another particularity of this paper is that the authors interpret competition as an increased exposure of firms to each others' actions. This makes efficiency differences between firms more pronounced and cost advantages more valuable. The authors investigate whether persistence of leadership or leapfrogging is more likely to occur, and how this is affected by intensity of competition. The authors also study the effect of intensity of competition on total R&D expenditures. The model developed for these purposes is a model of

technological competition, with two periods and that assumes two firms with cost asymmetries. In the first period, both firms choose their R&D investments. In the second period, these investments result in a probability of finding a unique process innovation that lowers the production cost. Under the assumption that R&D is effective enough (i.e. innovation is not too costly), the authors conclude that a rise in competition leads to higher R&D expenditures and increases the probability of persistence of firm leadership, and the leader tends to invest more in R&D than the follower.

The relationship between market structure and product innovation is examined by Greenstein and Ramey (1998). The authors consider product innovations that are vertically differentiated from older products and motivate their findings on the effects of replacement and product inertia. The replacement effect reflects the fact that under monopoly, part of the added returns from innovation replaces rents earned by the monopolist before innovating. The latter effect of product inertia, which is introduced by the authors, corresponds to the reduction of the profits of the new-product supplier due to competition from firms producing the old product, when the old product is competitively supplied. The authors show that when the monopolist is protected from new product entry and innovation is non-drastic[3], both competition and monopoly in the old product market provide identical incentives to innovation. On the contrary, a threatened monopoly creates strictly greater incentives than does competition.

The work of Yi (1999) shows that if Cournot competition is assumed instead of Bertrand competition (Arrow, 1962), then, under weak conditions, an increase in the number of firms leads to a decrease in the benefit of a small process innovation. These conditions are that the demand functions have to be weakly concave and there must be a weakly decreasing elasticity of the slope of the inverse demand. The negative effect of the number of firms in the market on the incentives for small process innovations is not surprising. The author explains that the benefit of reducing the costs through innovation is proportional to total output.

---

[3] The authors define an innovation as being non-drastic innovation when the monopolist supplies positive quantities of both old and new products.

Since in Cournot equilibrium (and under the weak conditions mentioned before) the output produced by the firm decreases with the number of firms, there is a negative direct effect of an increase in the number of firms on the incentives for small process innovation. If output is held constant, then the incentives for small process innovations will increase with the number of firms. The negative effect dominates the potential positive indirect effects. The author also concludes that the effect of product-market competition on the incentives to innovate is strongly influenced by the elasticity of the slope of the inverse demand function.

Philippe Aghion is probably the author who has written more on the relationship between competition and innovation. He and his co-authors have made important contributions in the field. Aghion et al. (1997) examine the relationship between product market competition and growth through a simple example. They build a model with step-by-step innovations, i.e. a model where laggard firms must catch up with the leaders before aiming for technological leadership. Leapfrogging the existing leader is not possible. Contrary to findings of the Schumpeterian models, the authors show that product market competition and/or imitations are likely to stimulate growth.

Aghion et al. (1999) introduce agency considerations in the analysis of the impact of competition on the incentives of non-profit maximising managers to innovate. The motivation for this comes from the idea that competition, together with the threat of liquidation, reduces the "slackness of the manager" and fosters technological adoption and growth. They use a model of monopolistic competition with no entry, where it is possible to observe the Schumpeterian effect when no additional assumptions are made. The authors demonstrate that if the firm maximises profits, then product market competition has a negative impact on growth whereas subsidising innovation has a positive impact on growth. On the other hand, if the firm is "conservative", then the effects are inverted.

Aghion et al. (2001) uses the same basic framework as Aghion et al. (1997). The main differences are that in the later paper, the technological gap between firms is not restricted to one step and a continuous parameterisation is used to measure the degree of product market competition. Another novelty in this paper is the

assumption that each industry is duopolistic, whereas others assume a monopolistic competition. Moreover, it analyses the effect of imitation on growth for the first time. The main findings are that, holding imitation constant, a little competition always stimulates growth. Allowing both product market competition and imitation to vary, the authors find that the maximal degree of competition always corresponds to the maximal growth rate. The intuition behind this result is that the "Schumpeterian effect of more intense competition is almost always outweighed by the increased incentive for firms to innovate in order to escape competition." (Aghion et al., 2001: page 470). Concerning imitation, it is shown that a little imitation is, in the large majority of the cases, growth enhancing but a lot of imitation has the opposite effect.

Other authors have made a clear distinction between individual and industry innovation or investment in R&D and find a positive effect of competition on aggregate innovation and a negative effect of competition on individual innovation (Cellini and Lambertini, 2005, Blundell et al., 1999). We describe the work of Blundell et al. (1999) when analysing the empirical contributions. Cellini and Lambertini (2005) study the relationship between R&D efforts for process innovations and market structure through a dynamic analysis. The authors consider an oligopoly where n firms compete in prices and invest in cost-reducing activities. The authors conclude that the individual R&D investment decreases with the number of firms, whereas the industry R&D investment monotonically increases with the number of firms. This conclusion diverges from the ambiguous conclusions of static models, where the smoothing of investment efforts on the long run is not possible. The authors call the reader's attention to the value added of the dynamic analysis over the static approach upon a multistage game. An additional conclusion of the paper is that an increase in product substitutability reduces R&D efforts if competition is sufficiently strong.

Between Schumpeter's followers and Arrow's defenders, a third group of authors emerged who have attempted to combine the previous arguments in order to rationalise the "inverted-U" relationship between market concentration and R&D as well as technological advance found by some authors in the empirical studies.

Scherer (1967) studies industrial firm's research and rivalry's development in a dynamic profit maximisation framework with the aim to predict which market structural conditions are more favourable to a rapid technological development. By performing a cross-sectional analysis and allowing for additional non-linearities, the author observes that the speed of technological research accelerates with rivalry, provided that the number of firms competing is not excessive. Scherer is the first hinting an inverted-U relationship between competition and innovation.

The effect of competitive pressure on the firm's incentives to invest in both product and process innovation is also examined by Boone (2000). The author shows that the firm's efficiency level relative to that of its competitors is a major determinant of the impact competition intensity has on the firm's incentive to innovate. According to the author, the relative level of efficiency gives origin to a "complacent", "eager", "struggling" or "faint" firm. The parameter that measures competitive pressure has to satisfy this order of cases and the profits of the least efficient firm in the industry has to decrease with an increase in the competition parameter. The main conclusion is that an increase in the competitive pressure can not induce an increase in both product and process innovations at the industry level at the same time. The explanation is that the least efficient firm in the market faces an additional pressure through the cost reduction of the other firms and ends up exiting the market, reducing the products available. The author derives conditions to ensure that a rise in competitive pressure raises industry wide efficiency.

Later, Boone introduces firms with different cost levels to study the relationship between intensity of competition and the value of an innovation (Boone, 2001). Boone also makes an important contribution in what concerns a formal definition of intensity of competition. Four axioms that a measure of intensity of competition should satisfy are proposed. The author finds a non-monotone association between intensity of competition and R&D incentives: "for weak intensity of competition a follower leapfrogs, while for high intensity of competition the leader increases its dominance." (Boone, 2001: page 722).

The impact of competition on product innovation is examined by Dubey and Wu (2001) through a model of Cournot competition where firms can innovate in order to improve the quality of their product. They argue that when the number of firms is large, competition forces prices to be low, implying that the price of the improved product (resulting from innovation) has to be low enough in comparison to the low-quality product. Otherwise, customers may not buy the high-quality product. Nevertheless, the low price of the high-quality product may not be sufficient to cover the costs of innovation. On the other hand, if the number of firms in the market is small and there are few firms enjoying high profits, firms will be motivated to invest in innovation only if the profit from the new high-quality product is at least equal to the cost of innovating. Since actual profits are high, innovation in this scenario is unlikely. The authors conclude that innovation "occurs only when the industry is of intermediate size" (Dubey and Wu, 2001: page 309).

Aghion et al. (2005) say that the explanation for the inverted–U pattern hinted by Scherer could be pieced together by combining agency models (Hart, 1983, Schmidt, 1997, Aghion et al., 1999) with Schumpeterian models. However, they find this unsatisfactory and re-examine the relationship between product market competition and innovation. The model developed, where firms innovate "step by step" and both the leaders and their followers can innovate, is an extension of Aghion et al. (1997). A key assumption made concerns the innovation incentives. Contrary to other authors who assume that innovation incentives depend upon post-innovation rents, Aghion et al.(2005) assume that innovation incentives depend upon the difference between post-innovation and pre-innovation rents. The authors find a nonlinear relationship between competition and innovation in the form of an inverted U relationship. This result is related to the disincentive to innovate that laggard firms experience in competition and the incentive to innovate that "neck-and-neck" firms[4] experience in competition. These different behaviours are due to the fact that among "neck-and-neck" firms pre-innovation

---

[4] The expression "neck-and-neck firms" is used by the authors to designate firms that operate at similar technological levels.

rents are reduced more than post-innovation rents by competition, and among laggard firms the initial profits are already low and competition mainly affects post-innovation rents. In the first case, firms invest to escape competition and in the second case the Schumpeter effect of competition dominates. In the empirical part of the paper, which uses panel data, the authors measure innovation through the average number of patents (each patent is weighted by the number of times it has been cited) and use the Lerner index to measure competition.

The following section summarises the major empirical contributions to the understanding of the relationship between market structure and innovation.

2.1.2 Empirical contributions

On the empirical front, the number of contributions is considerably smaller. In this section we make reference to the major ones.

Mansfield (1963) was one of the first authors (if not the first) to empirically investigate the impact of competition on innovation. He focused on the iron and steel, petroleum refining, and bituminous coal industries during 1919-1938 and 1939-1958. After in-depth research of innovation in these industries, he suggested that innovative activity would increase if the five largest firms in the petroleum and coal industries would break up. Two years later Williamson (1965) analysed the dataset used by Mansfield and concluded that the market share of the four largest firms has to be between 5 and 30 percent in order to maximise the incentives to innovate.

The set of hypotheses by Schumpeter that focus on the effect of market concentration on R&D investment and technological development was re-examined by Levin et al. (1985). To do this, the authors used new data on appropriability and technological opportunity collected in 130 industries. The results obtained call attention to the fact that it is necessary to "look to underlying differences in technological opportunities and appropriability conditions" (Levin et al., 1985: page 24) when analysing the association between innovative effort or innovative output and industrial concentration.

Nickell (1996) supports the existence of a positive relationship between competition and innovation. The author states that there are some theoretical and empirical reasons, although not too strong, to believe that competition might improve corporate performance. Therefore, he analysed 670 British manufacturing firms and their productivity performance in order to reach a conclusion on the association between competition and both the level and the growth of total factor productivity. The author shows that there is a positive relationship between the rate of total factor productivity and competition, measured either by the number of competitors or by the level of rents. Also, an increase in market power, measured by market share, is associated with reduced levels of productivity.

The empirical relationship between innovation, market structure and stock market value, and its statistical robustness is studied by Blundell et al. (1999). The authors use firm-level panel data and two measures of innovation: count of the major technological innovations and patents. The latter is used to test the robustness of the results obtained. The authors control for unobserved firm specific heterogeneity. They find, in a dynamic feedback model that controls for firm specific effects, that the industries with higher concentration levels and lower import penetration have fewer aggregate innovations. Within industries, a positive effect of market share on observable innovation and patent counts was found, although technological innovations tend to positively react to a rise in product market competition in the industry.

New measures of competition are introduced by Tang (2006) in order to empirically investigate the relationship between innovation behaviour and different types of competition. The author argues that "both competition and innovation have many dimensions and that different innovation activities are associated with different types of competitive pressure" (Tang, 2006: page 69) and "firm's perceptions about their competitive environment are important for innovation and are better measures of firm-specific competition" (Tang, 2006: page 68). The four types of competition considered are: easy substitution of products, constant arrival of competing products, quick obsolescence of products, and rapid change of production technologies. The technological innovation

activities analysed are: innovation input (R&D and acquisition of technologies) and innovation output (product innovation and process innovation). The author analyses both the relationship between the different innovation activities, as well as the different types of competition and the relationship between different combinations of innovation activities and the different types of competition. The way firms bundle their innovation activities is also investigated. The estimations are based in a simple logit model and a multinomial logit model. The major conclusions are that easy substitution of products is negatively related to R&D and product innovation, whereas constant arrival of competing products is positively related to those innovation activities. Quick obsolescence of products is positively associated with R&D and product innovation but negatively associated with acquisition of technology and process innovation. Finally, rapid change of production technologies is positive for acquisition of technology and process innovation. The results are derived from the *Statistics Canada 1999 Survey of Innovation* for Canadian manufacturing firms.

Markard and Truffer (2006) analyse how liberalisation has changed innovation processes in the electricity sector. The methodology used consisted of studying three radical innovations under monopoly and analysing a survey of the innovation behaviour in liberalised markets. The authors concluded that market liberalisation has contributed to change "the scope of variation and the focus of innovation management" (Markard and Truffer, 2006: page 623). The comparison of innovation processes under monopoly with innovation processes in a liberalised market showed changes in organisational routines, investment principles and strategic goals. Concerning the focus of innovation management, liberalisation altered the orientation of the innovations undertaken from incremental to more radical, and from technology to customer service. The authors also conclude that liberalisation "can serve as a driver for the overall level of innovation activity as competition represents a significant challenge for incumbent electric utilities as well as newcomers" (Markard and Truffer, 2006: page 623).

To our knowledge, there are very few empirical studies about the network industries and none in the postal sector. The need for further research is clear.

In the following section, we present the Theory of Contestable Markets that relates the threat of competition to efficiency.

2.2 Threat of competition and efficiency

According to the Theory of Contestable Markets, the threat of competition (or potential competition) induces by itself a monopoly to be efficient (Baumol et al., 1982, Baumol, 1982, Baumol and Willig, 1986). Therefore, there is no need to intervene in the market (i.e. to regulate). Basically, the threat of entry regulates a monopolist effectively, i.e. it induces optimality with no need of regulatory procedures under certain conditions. As long as the monopolist behaves optimally (makes zero profit) entry will not actually occur.

The conditions required for a market to be contestable are that there is free entry and costless exit. There is free entry when the new entrant does not have a cost disadvantage with respect to the incumbent. In order for this to occur, the entrant needs to have access to the same technology and inputs as the incumbent, and customers need to perceive the incumbent and entrant's goods/services as being the same (Train, 1997). The possibility for costless exit exists when there are no sunk costs. With free entry and free exit, a competitor can profitably enter the industry, undercut the incumbent, and take away its business (hit-and-run competition). The best way for the incumbent to respond to that threat is to eliminate such profit opportunities by being productively efficient and pricing at average cost (given uniform pricing). Given the constraint that profits cannot go negative, this outcome is welfare optimal, i.e. allocative efficiency is maximised subject to the break-even constraint without any duplication of fixed costs (Armstrong et al., 1994).

One of the major criticisms made of this theory is that entry can happen faster than the incumbent's price response[5]. Another important critique, especially in the

---

[5] Train (1997) advances two ways of overcoming this critique: (1) the entrant can sign long-term contracts with customers before it establishes its operations and (2) the regulator can intervene

context of the network industries, is that by slightly relaxing the hypothesis of no sunk costs, the predictions of the theory change substantially. One interesting result is that, rather than being an argument for the elimination of regulation, the Contestability Theory can be used as a guide for regulation (Baumol and Willig, 1986). In effect, regulation should simulate contestability by setting the regulated prices between incremental and stand alone costs in markets that are not contestable.

One way to make a natural monopoly contestable is to assign a franchise through a competitive tender. Demsetz (1968) proposes a return to concession contracts, which were common in the nineteenth century, as an alternative form of competition (as opposed to both competition in the market and potential competition). The idea is to auction the right to operate the natural monopoly to the firm offering the lowest price of supply. The author criticises the performance of United States regulatory agencies and argues that competition for the right to serve the market can substitute for competition within a market. Franchise bidding is regarded as being beneficial for efficiency. The fact that the concession is competitively awarded ensures that prices and services standards are fair to both consumers and investors. Even though franchise bidding still has strong advocates, it presents some drawbacks especially under asset specificity and cost uncertainty.

2.3 Concluding remarks

The discussion about the impact of competition on the investments in R&D and incentives to innovate was opened by Schumpeter (1942) and Arrow (1962). Schumpeter argues that monopoly is a precondition for innovation whereas Arrow defends that the single firm gets more benefits from innovation under competition than under monopoly.

---

in order to require that the incumbent does not lower the price in response to entry obliging the incumbent to *a priori* choose a low price that prevents entry.

Many other authors have developed models to investigate this issue and have made important contributions to the field. Some corroborated Schumpeter's conclusion, some found the same result as Arrow, and most authors arrived at the conclusion that the results depend upon specific conditions related, for example, to the elasticity of demand, the value of innovation, or the degree of substitutability. Another group of authors, notably Aghion et al. (2005), distinguished themselves with the theory that the relationship between the intensity of competition and innovation is non-linear and has the form of an inverted-U.

The lack of consensus concerning the effect of competition on innovation is evident. Moreover, the literature does not take into account the specific context of the network industries where governance structures and regulation play an important role and may further complicate the relationship between competition and innovation.

The Theory of Contestable Markets alerts to the differences between liberalisation and competition and analyses the possibility of having efficient markets without actual competition.

Our aim is to contribute to the existing literature by developing an extension of the traditional profit-maximising model to investigate whether investment in new technologies and processes is higher under competition or under monopoly. This extension is intended to encompass contexts, not unusual for many network industries, in which the incumbent has the form of a public enterprise or is a part of a government ministry.

Through theoretical and empirical analysis, we also aim to clarifying the impact that competition has on innovation.

Table 1: Synthesis of major contributions on the effect of competition on innovation

Author	Year	Key ideas
Schumpeter	1942	- monopoly favours R&D (provides necessary cash flow and reduces uncertainty)
Arrow	1962	- the single firm gets more benefits from innovation under competition (replacement effect)
Mansfield	1963	- focus on iron and steal, petroleum refining, and bituminous coal industries - concentration has negative impact on innovation
Williamson	1965	- market share of 4 largest firms has to be between 5 and 30% in order to maximise incentives to innovate
Scherer	1967	- first author hinting an inverted-U relationship between competition and innovation
Swan	1970	- extends Schumpeterian analysis of new processes to new products - monopolist's time preference for product innovation is the same as under competition
Kamien and Schwartz	1970	- incentive to innovate measured through increase in profit - industry elasticity of demand and type of innovation (drastic vs. non-drastic) determine which market structure creates more incentives to innovate
Kamien and Schwartz	1975	- innovation of small value: monopoly leads to most rapid development of innovation - valuable innovation: competition leads to most rapid development of innovation
Kamien and Schwartz	1976	- assumes stochastic relationship between investment in R&D and introduction of new technology - innovation involves small benefits: rise in rivalry's intensity up to a certain point shortens development period chosen by the firm - innovation involves large benefits: intensity of rivalry positively correlated with development rate of innovation
Salop	1977	- models of product differentiation and monopolistic competition
Dixit and Stiglitz	1997	- increased product market competition discourages innovation by reducing post-entry rents
Loury	1979	- firms maximise expected discounted profits with respect to their investment decisions and face technological and market uncertainty - assumes R&D cost to be lump sum initial investment - R&D investment decrease with competition (but depends on certain conditions)
Lee and Wilde	1980	- Loury's conclusions are sensible to R&D cost specification - assumes: R&D as a flow investment, perfect patent protection, 1st to innovate receives a prize - if fixed costs in R&D are larger than variable costs then firms invest less in R&D as competition increases (the contrary happens if fixed costs in R&D are smaller than variable costs)
Gilbert and Newbery	1982	- auction model of R&D - potential entrants have less stimulus to search for innovations than the incumbent monopolist
Levin et al.	1985	- technological opportunities and appropriability conditions are very important when analysing relationship between innovation and industry concentration
Romer	1990	- monopoly is precondition for innovation (firms seek profitable opportunities that arise from monopoly)
Grossman and Helpman	1991a	
Grossman and Helpman	1991b	- when competition facilitates imitation R&D is negatively affected
Delbono and Denicolo	1991	- Lee and Wilde's results depend on specification of incentives and payoffs - model a patent race between Cournot oligopolists - rivalry decreases individual and total R&D efforts
Bester and Petrakis	1993	- degree of substitutability has important impact on incentives to innovate

Nickell	1996	- estimates linear specification - competition improves corporate performance (positive linear effect of competition on innovation)
Aghion et al.	1997	- model with step-by-step innovations (concepts of laggard firms and leaders) - product market competition and/or imitations are likely to stimulate growth
Boone and Dijk	1998	- introduce concept of persistence of leadership and intensity of competition - model of technological competition - rise in competition leads to higher R&D expenditures and increases probability of persistence of leadership
Greenstein and Ramey	1998	- focus on product innovation - introduces product inertia effect - a threatened monopoly creates more incentives than competition
Yi	1999	- assumes Cournot competition and some weak assumptions on demand function - increase in number of firms leads to decrease in benefit of small process innovation (but not if output is held constant)
Blundel et al.	1999	- dynamic feedback model - estimates linear specification - measure of innovation: major technological innovations and patent counts - concentration negatively affects innovation at an industry (aggregate) level
Aghion et al.	1999	- introduces agency considerations - model of monopolistic competition - if firm maximises profits then product market competition has negative impact on growth whereas subsidising innovation has positive impact on growth (if firm is "conservative" then the effects are inverted)
Boone	2000	- considers both product and process innovation - an increase in the competitive pressure cannot induce an increase in both product and process innovations at the industry level at the same time
Boone	2001	- introduces firms with different cost levels - finds non-monotone association between intensity of competition and R&D incentives
Dubey and Wu	2001	- product innovation occurs only when the industry is of intermediate size
Aghion et al.	2001	- technological gap between firms is not restricted to one step - continuous parameterisation to measure the degree of product market competition - competition stimulates growth (increased incentive to innovate in order to escape competition outweighs Schumpeterian effect)
Cellini and Lambertini	2005	- dynamic analysis - positive effect of competition on aggregate innovation and negative effect of competition on individual innovation
Aghion et al.	2005	- extension of Aghion et al. 1997 - assumes that innovation incentives depend on the difference between post-innovation and pre-innovation rents and firms innovate step-by-step - find nonlinear relationship between competition and innovation
Tang	2006	- introduces new measures of competition: easy substitution of products, constant arrival of competing products, quick obsolescence of products, and rapid change of production technologies - effect on R&D/product innovation and on acquisition of technology/process innovation depends on the type of competition
Markard and Truffer	2006	- how liberalisation has changed innovation process in electricity sector - focus on three radical innovations - market liberalisation has contributed to change the scope of variation and the focus of innovation management

3. Liberalisation: the development of competition and innovation

In this thesis, a clear distinction is made between liberalisation and competition. Liberalisation is defined as the relaxation or abolishment of previous legal entry barriers, which can give raise to (more) competition or not. We are not only interested in the relationship between competition and innovation, but also in the impact that liberalisation *per se*, i.e. not necessarily accompanied by competition, has on incentives to innovate.

In this chapter, we analyse: (1) how the liberalisation process of the network industries has influenced the development of competition in these industries, and (2) the effect that liberalisation has on innovation.

We start by analysing the relationship between liberalisation and the development of competition in the network industries (section 3.1). In particular, we describe the liberalisation process, examine the factors that often block the development of competition and discuss the state of competition in the different network industries. We analyse the postal sector in more detail, since it is the case studied in the empirical chapter (Chapter 5). The focus is on the member countries of the European Union (EU).

The analysis of the relationship between liberalisation and the development of competition is important because liberalisation is not always synonymous with increased competition. Therefore, the results concerning the impact of competition on the incumbent's investment on innovation are only pertinent if indeed there is the possibility of introducing competition in the market. This analysis is a complement to the theoretical model developed in Chapter 4.

In the second part of this chapter, we turn to the relationship between liberalisation and innovation (section 3.2). The conclusions obtained have as background the literature review performed in Chapter 2 and the analysis from section 3.1. The predictions concerning the effect of liberalisation *per se* on innovation are tested in the empirical chapter (Chapter 5).

3.1   Liberalisation and development of competition

3.1.1   Liberalisation of the network industries

The regulatory reform of the telecommunications, airlines, gas, and railway sectors began in the United States of America (USA) in the 1970s (Armstrong et al., 1994). Today it is in progress worldwide, including in Western Europe where the single market program of the EU has promoted the liberalisation of the majority of the network industries. This process often implied the liberalisation and harmonisation of network access among the member countries.

In Europe, the liberalisation of the network industries began in the 1980s. Today, European consumers have some choice over utilities' suppliers (in some sectors), while a few years ago they had no choice. Nevertheless, this process is more accentuated in some industries like the telecommunications, airlines and electricity, and less accentuated in other industries, such as water or rail transport. In the telecommunications sector, technological changes and demand growth played an important role in the liberalisation of the sector. They reduced the extension of natural monopoly and created the necessary conditions for new competitors to enter the market. Another implication of the reform of the network industries is that incumbents expand their activities beyond their traditional ones.

Next, we present the different models of liberalisation.

3.1.1.1   *The different models of liberalisation*

There are three different routes to establishing market conditions and competition, i.e. to liberalise: competition in the market, competition for the market, and comparative competition. In practice, competition may not always develop despite the introduction of these rules.

Competition in the market exists when operators compete for end users. It encompasses full market opening, third-party access or a combination of the two.

Technical unbundling, i.e. the separation of the network into its reserved and competitive elements, is a pre-condition to third party access. The existence of a bottleneck or of an essential facility that can not be replicated (for physical or

economic reasons) and that is controlled by the historical operator are the reasons why the incumbent is asked to allow access to its network. There is third party access in energy (electricity and gas) and railways sectors. In the telecommunications sector there is also third party access but only to a specific part of the value chain, the last mile. Some countries, e.g. the United Kingdom (UK), also have third party access in the postal sector. In the UK, third party access is also being tested in the water sector, where it is already in law but only for large customers. The telecommunications sector in the EU is an example of a market that is fully opened to competition. The postal sector already has a date fixed for the full market opening.

We now focus on the access regulation pertaining to competition in the market, namely the use of the infrastructure through third-party access.

The "classic" third party access problem in the network industries involves requiring the owner of a monopoly infrastructure to allow a third party to provide a service using their infrastructure[6]. One of the main issues related to third-party access pertains to access pricing. The price should offer the access provider an adequate return on capital in order to encourage investment in the infrastructure and also encourage its efficient use by third parties. Often there is a concern with the fact that the incumbent may use its privileged position and regulated monopoly to increase the access price or to induce larger costs to the entrant in the access process.

The principles governing access pricing are an application of natural monopoly pricing theories. In the event of scale or other economies, marginal cost pricing does not allow the firm to cover its total costs. If other sources of revenue are unavailable (e.g. tax revenues), then prices must be raised above marginal costs. In some cases, it is efficient to charge two-part tariffs. An important variant of two-part pricing is capacity based pricing, where the fixed component determines

---

[6] Other types of access problems refer to cases where competing firms purchase essential inputs (e.g. the use of the infrastructure) from a monopolist and, in addition, the monopoly firm must purchase inputs from the competing firms. In this review, only the classic problem of one way access is considered.

the capacity, and the variable component depends upon the purchased quantity (being very high for quantity purchases above that capacity limit) (OECD, 2004).

One of the main challenges for the regulator is the substantial requirements of information (e.g. on the cost structure of the regulated firms), as well as problems of asymmetry of information. Price-caps (i.e. the regulated firm sets prices subject to an overall constraint defined by the regulator) allow regulators to overcome these issues.

Finally, it is important to mention the widely discussed efficient component pricing rule (ECPR), which was popularised by Baumol and Sidak (1994). ECPR states that the appropriate access price equals the monopolist's opportunity cost of providing the access, ensuring that production or service provision is not diverted to an inefficient firm[7].

Competition for the market (operators compete for the right to operate in the sector) is an alternative to the cases where competition in the market is difficult or impossible to implement. Usually, it involves a competitive bidding where one of the operators bidding obtains a delegation contract. Competition for the market is the most common form of competition in the water sector.

The definition and allocation of exclusive rights is very important when there is competition for the market. In terms of franchising, it is important to define the way firms are selected and the conditions under which they are to operate. There are different reasons for allocating the right of supply to a firm, such as the existence of a natural monopoly, potential for cream-skimming, or technological or resource scarcity. The franchisee normally becomes a monopolist in a specific market for the duration of the franchise.

The franchise may be directly awarded by the public authority or it may be allocated through competitive bidding (based on public interest or pricing criteria). The degree of competition of the allocation process is an important variable to take into account. The fairness and transparency of the competitive

---

[7] For a critical view on ECPR see, for example, Economides and White (1995).

process is essential in determining its consequences on allocative and productive efficiency.

Comparative competition (also called yardstick or benchmark competition) consists of comparing the performance of different firms operating in similar services but in different locations. The variables often used for comparison are operating costs, prices, and service quality. Comparative competition exists in the water sector and in the energy sector, at a local level, for transport prices.

3.1.1.2 The state of liberalisation in the EU

In this section, we briefly describe the process and current state of liberalisation in each of the network industries in the EU.

In order to create a single market for air transport, the EU initiated in the 1980s the liberalisation of its air transport sector. The first package of liberalisation measures was adopted in December 1987 and the second in 1990. In January 1993 it applied the third package of measures regarding internal air transport, which was determinant for the liberalisation and competition in the sector and to establish common rules and standards, namely in safety and security. In 1997 the domestic markets of Member States were opened to competition (freedom to provide "cabotage"[8]). In July 2006, the European Commission made a proposal for modernising and simplifying the legal framework for the internal air transport market and, in 2007, an agreement was reached. The main objective of the new legislation is to impose price transparency and to better control the airlines in order to ensure more safety and quality for the passengers. The air transport can be considered to be almost fully liberalised. There are, however, some conditions that prevail in the industry (namely bottlenecks like airports) which, in some cases, prevent competition from being effective.

The first step towards opening of the electricity market was the Directive 96/92/EC, which established common rules for the internal market in electricity

---

[8] "Cabotage" is the right for an airline of one Member State to operate a route within another Member State.

and set the pace for the progressive market opening of the sector. In 2003, the European Commission introduced a new Electricity Directive (Directive 2003/54/EC) and Gas Directive (Directive 2003/55/EC). These directives were a decisive step towards accomplishing the internal market of the energy sector. The deadlines established for the full market opening for business customers was July 1st, 2004 and for households July 1st, 2007. The evolving environment and the need to enhance the energy security and competitiveness led the EU to propose a new package of measures in the beginning of 2007.

The history of rail freight liberalisation in Europe starts in 1991 with Directive 91/440/EC and the subsequent First Railway Package which concerned: management autonomy and independency, vertical separation of the infrastructure, debt and state aid, and access to the infrastructure. In 1995, the Commission felt the need to complement this directive with two other directives (Directive 95/18/EC and 95/19/EC) on licensing, capacity allocation and charging, which were transposed only in 1997. In 2001 the EU implemented the rail interoperability and infrastructure package composed of three directives: 2001/12/EC on the development of European railways (amends Directive 91/440/EC), 2001/13/EC on licensing (amends Directive 95/18/EC), and 2001/14/EC on capacity allocation, infrastructure charging, and safety certification. A second railway package was adopted in 2004. This package extended access rights to all types of rail freight service starting January 1st, 2007. It also extended the scope of interoperability directives and provides a common approach to European rail safety.

In order to promote the liberalisation and harmonisation of the EU telecommunications market, the European Commission introduced various directives, which together make up the "1998 regulatory package". This package was primarily designed to manage the transition from monopoly to competition and was, therefore, focused on the creation of a competitive market and the rights of new entrants. In 1998, all the telecommunications services and networks, in Europe were liberalised. The growing convergence between telecoms, broadcasting and information technology led to the adaptation of the rules which were reviewed in 2002 (2003 policy framework). A new revision was launched in

2007 in order to adapt the framework to the fast development of the telecommunications sector.

The water sector has not been subject to the same rules regarding the European policy of liberalisation of services until now. It is not expected that the liberalisation process in this sector in the EU will converge towards a single model, for two main reasons. Firstly, the EU is clear about its neutrality regarding asset ownership. Secondly, according to the subsidiarity principle, nation states are left with significant areas of competence, including on water services, given the fact that these are by definition local services (Luís-Manso, 2004). The liberalisation of the water sector is made at a national or local level. Since the measures adopted vary from country to country, it is not possible to describe them here.

The case of the postal sector is treated in section 3.1.3.

3.1.2 Development of competition in the network industries

Liberalisation does not necessarily lead to an increase in competition because of the existence of barriers to entry. Some of these are intrinsically related to the special characteristics of the network industries.

3.1.2.1 Barriers to the development of competition

Barriers to entry refer to disadvantages (such as higher costs, difficulties accessing key inputs, etc) that affect potential entrants but not incumbents, and that might restrict entry or prevent it from occurring in cases where incumbent firms are earning excess profits. The supra-normal profits earned by the incumbent due to barriers to entry should not be confused with cost disadvantages that arise because incumbent firms are more efficient than potential entrants (Nera, 2004, Bain, 1956).

Barriers to entry can be classified into two types: legal and natural barriers to entry. Included in the legal barriers are the barriers created by regulation such as the reserved area in the postal sector and the licensing processes that make entrance difficult or impossible. Regulatory uncertainty and asymmetries can also

work as entry barriers. An example of regulatory asymmetries is the difference in the Value Added Tax (VAT) treatment between new entrants and the historical operator in the postal sector. In general, legal entry barriers are specific to a sector since they result from sector legislation. In the scope of this thesis, we are more interested in understanding the barriers to entry that characterise the majority of the network industries, i.e. the natural barriers to entry.

The natural barriers to entry can be divided into two groups: those related to the demand side and those related to the supply side. The first group includes reputation of the incumbent, switching costs, portfolio effects, and customer inertia. In the second group, there are economies of scale, economies of density, economies of scope, sunk costs, network effects, and capital requirements or financing.

A description of demand side barriers to entry is as follows. The fact that the incumbent operates for a large number of years and the quality of his service is well known may play a role in customers' choice. Entrants, however, do not have any reputation and may have a hard time establishing themselves. Often, customers are risk averse and prefer the solution that presents less uncertainty.

The existence of switching costs, i.e. costs associated with a change of suppliers, can also play in favour of the incumbent. If customers face high switching costs they will most certainly prefer not to change to another competitor.

The portfolio effects are related to the fact that it may be convenient for the customer to consume two or more products/services from the same firm instead of contacting a second supplier. Since incumbents have large portfolios they are more likely to benefit from this behaviour than new competitors.

Another phenomenon observed frequently among customers is customer inertia. Customer inertia can be related to switching costs and uncertainty related to the quality of the entrant's products/services, but it can also be exclusively an irrational behavioural matter.

Next, the supply side barriers to entry are examined. Economies of scale exist when the unitary cost of production decreases as output and the network size increases in the same proportion (Nera, 2004). More formally, an industry is said

to be a natural monopoly if at any level of output (Y) the cost function is sub-additive, i.e. the cost of producing a certain level of output is smaller if it is a single firm producing it:

$$C(Y) \leq \sum_{i=1}^{n} C(y_i) \quad \text{with} \quad \sum_{i=1}^{n} y_i = Y$$

In other words, a market has natural monopoly characteristics if there are increasing returns to scale. When there is severe natural monopoly, competition is inefficient and in the limit might not be feasible because two or more firms can not profitably coexist. Gas and electricity transmission and distribution, and water supply are examples of utilities with severe natural monopoly cost conditions (Armstrong et al., 1994).

Economies of density are defined as a decrease in unit cost resulting from a traffic increase on a fixed network (Nera, 2004).

Economies of scope refer to the cost advantages enjoyed by a firm by providing two or more products/services using the same network infrastructure.

Sunk costs are costs related to entry that can not be recovered if the firm exits the market. If access to the incumbent's physical network is not possible, the existence of sunk costs might discourage new companies from entering the market. Entrants will enter the market only if their expected profit is high enough to cover these costs. Examples of industries or activities that have a high degree of sunk costs are the electricity industry, the railway industry, and long distance telecommunications.

Network effects exist when additional consumers of a product or service increase the attractiveness of that same product or service for other consumers. This is the case in the telecommunications sector, for instance. Incumbents have a clear advantage over entrants regarding this issue, since they enjoy more network effects.

Capital requirements or financing can also work as an entry barrier. Since entrants are less well known than incumbents and incumbents have a lot of power in the market, financial institutions may find it too risky to finance entrants. Therefore,

entrants may face considerable difficulties finding financing for their investments, which can prevent entry.

3.1.2.2 *The state of competition in the EU*

There are significant differences among countries in Europe regarding the development of competition in the network industries. In some countries (like the UK) competition in these industries is more developed while others (like France) lag behind. The aim of this section is to give a general overview of what the results of the liberalisation process described in section 3.1.1.2 are.

The liberalisation process of air transport has definitely promoted the development of competition in this sector in Europe. Several new airlines have entered the industry with a consequent decrease in prices. There are, however, some bottlenecks that persist, which are related to airport infrastructures and to air traffic control systems.

Regarding the energy sector, there is still some work to be done in order to give real choice for EU energy users (citizens and businesses), and to boost the investment in energy. A clearer separation of energy production from energy distribution and interconnection seems to be critical for these ends. In the upstream activities, the energy sector enjoys some level of competition. In the gas industry, the clear distinction between the commodity and its transport strongly favoured the development of competition among industrial customers. A single competitive European energy market has not yet been achieved, although some progress has been made.

Competition in the rail freight market is progressively reaching all European countries. According to the Community of European Railway and Infrastructure Companies, there are now almost 700 licensed companies in the EU that offer rail transport services. Competition in rail freight is especially marked on certain corridors that are relevant from the economic point of view (e.g. the Rotterdam-Genoa corridor, which links the biggest European seaport with the industry regions in Western Germany and Northern Italy). Intramodal competition has been emerging on those corridors (CER, 2007).

Competition in the telecommunications sector has strongly developed since its liberalisation. The number of fixed-line telecom operators doubled between 1998 and 2003. New entrants invested in new services and infrastructure, and the prices of telecommunications services decreased. Incumbents have also made important investments in the electronic communications services over the past decades. Today, approximately half of the turnover generated in the electronic communications markets in Europe comes from new entrants. A true pan-European telecom industry is emerging (Reding, 2006).

The specificities of the water sector hampered the liberalisation of the sector, at least liberalisation in the image of other network industries. In fact, there are no EU directives calling for the opening of the markets. It is very difficult to implement competition in the market due to strong network and economies of scale, the obligation to provide services of general interest (SGI), and quality issues. However, and despite the evidence that many parts of the sector are considered as natural monopolies, new dynamics are pushing towards the opening of markets to competition, i.e. to a *de facto* liberalisation (Luís-Manso, 2004). Competition for the market, or ex-ante competition, is the most common form of competition in the water sector (e.g. France, Spain and Italy). It consists of competing for the right to operate in the sector, i.e. for a delegation contract. Comparative competition (also called yardstick or benchmark competition) is also sometimes used in the water sector (e.g. in England and Wales).

The case of the postal sector is developed in the next section.

3.1.3 The case of the postal sector

In this section we analyse the postal sector in detail since this will be the case studied in the empirical analysis (Chapter 5). We restrict ourselves to the study of the letter segment. Throughout this thesis when we mention "postal sector" we refer only to the letter segment, if not specified otherwise.

For the purposes of this thesis, the traditional value chain of the postal sector is considered. The postal value chain can be divided into the following activities: clearance, outward sorting, transport, inward sorting, and delivery. Clearance

consists of the process of collecting postal items from postal offices, street letter boxes, or directly from the customer, and introducing them in the sorting plant. Then the postal items are sorted by destination area (outward sorting) and transported to the destination area or to a central sorting plant. The transport of postal items within the same area is considered to be part of clearance or delivery. The inward sorting corresponds to the sorting of postal items to be delivered in a certain area. Finally, the postal items are delivered, i.e. transported from the sorting plant to the recipients.

We start by describing the different models of liberalisation in the postal sector. Then, we analyse the barriers to the development of competition that are specific to this sector. Finally, we examine the state of competition in the European postal sector.

3.1.3.1 The different models of liberalisation

In the postal sector, there are two models of competition: end-to-end competition and competition with access to the incumbent's network. These two models are not mutually exclusive and can coexist in the same country. Access to the incumbent's network can be of two types (according to the stage at which access occurs): worksharing or upstream access, and downstream access.

End-to-end competition is the European regulatory approach to liberalisation. It consists of opening the market by allowing competition with the historical operator along the entire value chain, without granting access to the incumbent's network. The market is opened progressively accordingly with some price or weight limitations. Simultaneously, the incumbent keeps the Universal Service Obligation (USO). One of the main drawbacks of end-to-end competition is that the incumbent struggles as he must provide the universal service while losing monopoly, i.e. market share.

Worksharing consists of unbundling the postal value chain while maintaining the delivery monopoly of the historical operator. The new entrants can select the activities (collection, franking, pre-sorting, consolidation and other types of mail preparation) they want to perform, provided that the incumbent performs the

delivery function. The competitors negotiate with the historical operator the discounts they get from performing the selected activities. In some cases, if no agreement is reached, the regulatory authority intervenes. In general, the incumbent is obliged to offer the same conditions or rates to all the competitors. Again, the historical operator has the burden of providing the universal service, but this time the access fees of the competitors help the incumbent to finance its USO. Worksharing creates opportunities for mailers and third-party consolidators to enter the market. Worksharing is the model used in the USA to introduce competition in the postal sector. In France, there is also a long history of worksharing.

The so-called "worksharing with bypass" corresponds to a situation where both end-to-end competition and worksharing are possible.

Another variation within worksharing refers to the entity that gets the worksharing discounts. In some countries, the discounts are conceded exclusively to the incumbent's customer, who may have already paid a third party to perform upstream activities (e.g. Switzerland, The Netherlands, and Portugal). A direct consequence of this procedure is that no consolidation is allowed. In other countries, the incumbent may have contracts with both customers and third parties (i.e. they also accept mail directly from the third parties - e.g. France).

Worksharing or upstream access is usually advantageous to both the entrant and the incumbent, at least when it is subject to the process of business negotiations. The entrant chooses to undertake upstream access when it can perform an upstream activity at a lower cost than the incumbent. The incumbent provides access discounts equal to the average avoided cost of upstream activities bypassed.

Downstream access concerns the access to the local delivery network. Only in a few European countries, does postal legislation require the Universal Service Provider (USP) to give its competitors access to its delivery network. When it is not possible to reach an agreement, the regulator intervenes and often settles the access price. Downstream access to the incumbent's network started to be imposed in order to facilitate the liberalization of upstream services. This is the

case in the United Kingdom (analysed in detail in chapter 5) and in Germany, where mandatory downstream access has been recently introduced. Deutsche Post, the German historical operator, is obliged by law to provide downstream access under conditions mostly settled by the regulator (BundesNetzAgentur). The EU Postal Directive does not provide for a specific regulation of downstream access but it requires transparency and non-discriminatory treatment concerning special tariffs (Wik, 2006).

Downstream access is considered, by some, to be important in the early stages of competition in order to facilitate entry. However, when imposed by law and if the entrant has the option to bypass the incumbent's network it may lead to distortions and to cream-skimming.

The common practice concerning access pricing is to charge a uniform rate according to the amount of upstream work performed (Avoided Cost Pricing, ACP). Another way to proceed in terms of access pricing is to base the access price on the work that is still to be performed in delivering the mail, and not in the work that was done (Delivery-Area Access Pricing, DAP). With this approach the mail destination is taken into account in the access price. A third possibility is the Negotiated Access Pricing (NAP), where the free negotiation between the incumbent and the firm asking for access determines the access price (PricewaterhouseCoopers, 2006). The Netherlands and Sweden are examples of countries where NAP is in force.

3.1.3.2 *The state of liberalisation*

The postal sector in Europe is subject to both EU and national legislation. In the majority of the countries, it is the European legislation that has been driving the liberalisation process.

The aim of the postal policy of the EU is to complete the single market for postal services and to ensure their supply at affordable prices with a minimum level of efficiency, reliability and quality to all European citizens. In order to accomplish these objectives, a regulatory framework for European postal services was established.

The liberalisation of the postal sector started in 1992 with the Green Paper on the development of the single market for postal services. It followed in 1997 the first Directive (97/67/EC) on the liberalization of the sector, which introduced common rules for the gradual market opening and development of a single market within the European Union. In 2002 the European Parliament and the Council adopted the second Directive (2002/39/EC) that amends the Directive of 1997 and speeds up the liberalization process by defining further steps concerning market opening.

Besides the definition of the maximum reserved area (whose evolution is described in detail in Chapter 5, section 5.2.2.2) the directives also set: a minimum universal service, the conditions determining the provision of non-reserved services and access to the network, tariff principles and the transparency of accounts, minimums for quality of service, and the harmonisation of technical standards. Moreover, directive 97/67/EC required the creation of independent national regulatory authorities.

The full market opening of the postal sector is programmed for 2011 with a few exceptions. However, some EU countries decided not to wait for this date to accomplish the full market opening. Sweden, Finland, and Estonia have already fully liberalised their postal markets for some years, and the British postal market has been completely opened to competition since the 1st of January, 2006. Spain has the intra-city mail historically opened to competition. In the remaining countries, the percentage of postal market that is liberalised (in terms of volumes) does not yet reach fifty percent.

3.1.3.3 Barriers to the development of competition

There are several legal barriers to entry in the postal sector. Among the barriers created by regulation are the reserved area, licensing processes, and regulatory uncertainty and asymmetries. Included in the set of legal asymmetries in the postal sector are the difference in the VAT treatment between new entrants and the historical operator, the access to the P.O. Boxes and to letterboxes, and the obligation to provide universal service.

The reserved area is, at present, the main legal barrier that prevents the entry of new operators in the postal market. Today the reserved area is limited to items of correspondence weighting less than 50 grams and costing less than two and a half times the basic tariff. Although the reserved area has been progressively reduced, potential entrants have difficulties to enter the market or to increase their market share because they can not offer their clients a comprehensive business solution.

Licensing processes constitute in many countries an important barrier to entry. In some cases the licence requirements are such that potential entrants are prevented from adopting the most interesting business models. The most restrictive requirements are related to the minimum number of times per week that delivery should take place, to the required national coverage of the network, and to the type of services provided. For example, in Estonia and Finland, operators must provide all services under the USO in order to obtain a licence. The Netherlands is one of the few countries where no licence or authorisation is required (Ecorys, 2005).

The full market opening was recently set for 2011 (although with some exceptions), which has considerably reduced regulatory uncertainty. However, there is still uncertainty concerning the USO and licensing requirements that may affect or delay investors' decisions.

The difference in the VAT treatment between new entrants and the historical operator creates a clear disadvantage to the competitors of the USP. In fact, the incumbent does not have to levy VAT and, consequently, cannot reclaim paid VAT. Because of its VAT exemption, the incumbents' services will be cheaper than those of the competitors. The price difference between the national postal operators and the entrants originated by the different VAT treatments is minimised if the customer buying the postal services can reclaim the VAT. The advantage of the incumbent over the competitors is nevertheless clear regarding customers that cannot reclaim the VAT (Ecorys, 2005).

Another important barrier to entry in delivery is the access to the P.O. Boxes and to letterboxes. If the entrants are not granted access to either the P.O. Boxes or the letterboxes, entry in some segments is unlikely. In some European countries

(namely Austria, France and Poland), only the postmen from the USP has access to the letterboxes located inside certain apartment buildings, which have the front door locked (Ecorys, 2005).

The USO also originates a discriminatory treatment between the national postal operator and competitors because it imposes strong restrictions on the business model of the USP. These restrictions are related with the size of the network, the frequency of delivery, and the uniform price. In the majority of the countries, the burden of the USO falls exclusively over the USP. The exceptions among the member states are: Estonia, Finland, and Sweden. The USP is granted a reserved area in order to compensate for the USO. After the full liberalisation, the reserved area will disappear but some obligations related with the universal service provision may persist (Ecorys, 2005).

Regarding the natural barriers to entry, all barriers to entry related to the demand side described in section 3.1.2.1 are present in the postal sector. The barriers to entry related to the supply side are also present in the postal sector in a larger or smaller scale with the exception of the network effects, which are small or inexistent in the postal sector.

The potential economies of scale in the sector depend on the number of collection points, sorting centres, transport routes and delivery points. When an increase in the size of the network or in the mail volume allows a reduction in the long run average cost of each unit then there are economies of scale. According to Nera (2004), there are no economies of scale for end-to-end mail processing in the former Member States, but there seem to be economies of scale in the new Member States. If that is the case, then a competitor postal operator with a relatively smaller network and smaller volumes can enjoy the same cost advantages based on economies of scale as the incumbent. However, these findings are controversial.

There are important economies of density in the postal sector. The economies of density in the postal sector are related to the total mail volume handled through the network and to the geographic characteristics of a country. For instance, economies of density are significant in countries where mail *per capita* is small,

population density is also small, and/or the geography of the country makes it difficult to reach certain regions.

Examples of economies of scope in the postal sector are the delivery of both transaction mail and direct mail, or addressed mail and un-addressed mail (Nera, 2004). Entrants do not enjoy as much economies of scope as the incumbent since their portfolio of products is smaller.

The postal sector is probably, among the network industries, the sector where sunk costs are least important. In fact, this is one of the features that distinguish it from other network industries. The main features of the postal network, namely delivery and road transport, do not have significant sunk costs (Nera, 2004). The incumbent's delivery network can be replicated more readily than the delivery network of an incumbent in the energy sector, for instance. Nevertheless, the collection network and the sorting equipment give rise to sunk costs.

3.1.3.4 *The state of competition*

Competition in the postal sector (letter segment) has been developing very slowly. In all the countries from the EU, except Spain, the incumbents preserve a market share of at least ninety percent in addressed mail. In fact, in the large majority of these countries, the entrants' market share does not exceed two percent, indicating that competition is still very limited. However, it should be noted that in 2006 all countries, except Finland, Estonia, United Kingdom and Sweden, still had reserved areas of 50 or 100 grams. According to Wik (2004), lowering the weight threshold to 50 grams opens only 25 percent of the letter post market to competition. This fact partially explains the reduced competition observed in those countries.

Incumbents in the postal sector enjoy some other special and exclusive rights that may contribute to discouraging new competitors to enter the market. The special tax treatment accorded to the USPs is often mentioned. Also, the USPs enjoy a preferential treatment regarding customs as compared to other operators (Wik, 2006). Moreover, competition in the delivery segment is difficult, given the economies of scale that delivery entails.

We are now going to focus on the countries that are more advanced in terms of liberalisation.

Spain has the highest level of actual competition in the European letter post market because intra-city letter mail, which represents a large share of the total volume of mail, is historically open to competition. The market share of the incumbent in Spain is approximately eighty-nine percent. "In Spain private operators deliver a higher percentage of letter post items than in Member States which have repealed the reserved area entirely." (Wik, 2006: page 55).

Sweden follows Spain. Among the four member states that have already accomplished full market opening (Estonia, Finland, United Kingdom, and Sweden), Sweden is the one where competition is the most developed. The Swedish postal market has been completely open to competition since 1993. In Sweden, the license requirements to deliver addressed mail are not restrictive. Moreover, there are no licence requirements to deliver catalogues, magazines and un-addressed mail. Nevertheless, the development of competition has been slow and today the incumbent still preserves a very dominant position. This slow development of competition can be related to different factors. Ecorys (2005) advances as possible explanations the fact that, initially, the legislation was not adapted to support or create the preconditions for competition. Also, CityMail (the largest competitor of the incumbent, Posten AB) faced numerous internal problems that limited its business development and expansion. Since 1991, the year when CityMail entered the market, it faced bankruptcy several times (Box 1). It was, however, able to stay in the market and to expand its geographical area of activity. Finally, Sweden has a large territory with a low population density, which may demotivate entry.

Box 1: CityMail Business Model

"CityMail delivers only pre-sorted mailings with at least 500 items. Customers need to sort their mail to all five numbers of the postal code and book the day of delivery in advance. This allows CityMail to abstain from capital-intensive investments in automatic sorting facilities. CityMail's strategy is based on three main factors. First, customers can rely on the exact day of delivery of all items three days after the mail has been handed in, a preciseness that Sweden Post offers only at a surcharge. Second, CityMail offers updating and tracing address data as an important component of mail delivery, in order to guarantee their customers effective mailings. The third factor is the price aspect, since CityMail's prices are significantly lower than those of Posten AB. Customers have to be aware that they can benefit from CityMail's lower prices only by sharing a greater amount of pre-sorting than at Posten AB. Although Posten AB has worksharing discounts for large mailings as well, there are differences concerning the permitted content of mailings and the minimum volumes: Posten AB accepts only direct marketing mail whereas CityMail accepts all mass mailings regardless of content and has a lower minimum volume requirement than Posten AB." (Wik, 2004: page 95)

After Spain and Sweden, the countries where competition is most developed are Germany, The Netherlands, and Estonia. However, one would expect Finland and Estonia to be at the level of Sweden or, at least, to follow it closely, in terms of development of competition in the postal market. The fact that two countries (Germany and The Netherlands) that are less liberalised than Finland and Sweden have the same or a higher level of competition than those that are more liberalised is surprising. The justification is the following: although Finland and Estonia liberalised their mail markets some years ago, competition has not emerged in these countries, mainly due to the restrictive licence conditions and taxation policy (Ecorys, 2005).

In Finland, the postal law requires all the postal operators to collect and deliver mail on a daily basis. Moreover, the operators have to achieve next working day delivery of 95 percent of domestic items. These requirements are a serious barrier

to entrants that, in the beginning of the activity, do not have the necessary volumes and financial means to satisfy these requirements. In Finland, potential entrants are also required to provide postal services in the whole territory of the country[9]. If they opt for license restricted to a certain area they will have to support an additional turnover tax of 5-20%, depending on the territorial coverage of mail delivery. The spirit of these measures is to avoid cream-skimming and to ensure national coverage, but today they work as serious obstacles to competition.

In Estonia, all the postal operators providing services inside the universal service area are also required to provide services at a uniform price, to deliver at least five times per week, and to cover the whole territory of Estonia. The postal service providers are also subject to requirements concerning the collection and delivery network, namely regarding the distance from postal users. Nevertheless, the Estonian postal law is not as restrictive as the Finnish one. In fact, in 2004, Estonia had already more than twenty courier and three direct mail service providers who were not subject to the licence requirements (besides one licence holder providing universal service) (Wik, 2004).

In 2004, competition in the UK postal market was below the British postal regulator's (Postcomm) expectations. Postcomm presented as main justification for this the difficulties in obtaining access to Royal Mail's network, Royal Mail's exemption from value added tax (not shared by other operators), the interim nature of licences, and some customer inertia to change (Wik, 2004). Additional measures were adopted in an attempt to stimulate competition. In 2004 mandatory downstream access was introduced and in 2006 the reserved area was completely eliminated. The results of these measures are still to be observed.

---

[9] With the exception of the Aland Islands in Finland.

3.2 Liberalisation and innovation

The impact of liberalisation on innovation depends on whether liberalisation results in:

- actual competition

- no actual or potential competition

- potential competition only.

The impact of liberalisation on innovation when liberalisation turns into competition, i.e. when there is actual competition, is studied in Chapter 4.

Liberalisation results in no actual or potential competition when there are strong barriers to entry on the supply side with no mechanisms put in place to overcome those barriers. In this case, the threat of competition is not real and, therefore, liberalisation has no effect on innovation. For example, if there are strong sunk costs and access to the incumbent's network is not possible, then liberalisation has no effect on innovation.

Potential competition exists when: (1) there are no strong barriers to entry on the supply side; however, actual competition does not develop; or (2) there are barriers to entry yet there is regulation capable of overcoming those barriers and making the threat of competition real. Based on the literature on the relationship between competition and innovation as well as on the theory of contestable markets, we argue that if there is liberalisation with only potential competition than there is a positive impact on innovation.

The vast literature on the effect of competition on innovation (discussed in Chapter 2) identifies a positive and a negative effect of competition on innovation. The positive effect is a result of the firm's quest to optimize profits by increasing its efficiency and reducing its cost of production. Profitability pushes the development and adoption of more efficient technologies and processes. The negative effect is related to the fact that competition decreases the rents of the monopolist and might reduce its market share. Therefore, revenue will also decrease. As a result, firms will have fewer resources to invest, for instance, in research and development. Similarly, they may encounter more difficulties when

trying to recover potential investments in new technologies and new processes because of erosion of scale or scope economies resulting from lost market share under competition. These two effects co-exist when liberalisation leads to the development of competition. However, if liberalisation is not followed by the development of competition, firms do not lose market share nor scale economies and their capacity to invest in new technologies and processes should be larger, as compared to a situation where there are other firms operating in the market. In this case, the negative effect does not exist but the positive effect subsists. Hence, liberalisation *per se* is expected to have a positive effect, larger than that of competition, on innovation.

The theory of contestable markets (discussed in Chapter 2) argues that under free entry and exit, the threat of competition *per se* is sufficient for firms to become more efficient and to originate a decrease in prices. In order to increase efficiency, firms have to invest in new technology and new processes, i.e. they have to innovate. In this sense, it can be said that the theory of contestable markets suggests a positive effect of potential liberalisation on innovation.

For example, when there are no sunk costs or they are not too strong yet competition does not develop, liberalisation is expected to have a positive impact on innovation (independently of the access to the incumbent's infrastructure). Also, if there are strong sunk costs but access regulation requires the incumbent to provide access to its network, then liberalisation is expected to have a positive effect on innovation.

We conclude that the impact of liberalisation on innovation when liberalisation is not followed by competition, depends on the presence of natural barriers to entry on the supply side (e.g. sunk costs) and on the mechanisms put in place (or not) to overcome the obstructive effect of these barriers (e.g. access regulation). The size or intensity of those barriers to entry is also relevant.

In the case of the postal sector the barriers to entry are not very accentuated. In particular, sunk costs are negligible. Hence, we expect a positive impact of liberalisation on innovation. This hypothesis is tested empirically in Chapter 5.

3.3 Concluding remarks

The liberalisation of the network industries is *en route* in Europe. Some industries, like the telecommunications, air transport, and rail freight are already fully liberalised. Others already have a deadline to accomplish full market opening, like the postal sector. The energy sector is also quite advanced regarding its liberalisation. The water sector is not an object of European regulation; decisions concerning the introduction of competition in the sector are made at a national or even local level.

The development of competition has been faster in some sectors than in others. The telecommunications sector enjoys a considerable level of competition. Competition is also visible in air transport. In the postal sector (letter segment), competition is still very limited even in countries that have completely liberalised the postal markets. In the remaining sectors, only recently have signs of competition become apparent. Interconnection of the incumbent's infrastructure with those of the entrants has been revealed as essential to allow competition and to overcome some natural barriers to entry.

Regarding the effect of liberalisation on innovation, we argue that it depends upon the presence and intensity of natural barriers to entry on the supply side and on the mechanisms implemented to overcome those barriers. If there are no strong barriers to entry, then there is potential competition and, consequently a positive effect on innovation is expected. If there are barriers to entry, but there is regulation capable of overcoming those barriers and making the threat of competition real, then liberalisation will have a positive impact on innovation. Inversely, if there are barriers to entry and no mechanisms to make the threat of competition real, then liberalisation will not have any effect on innovation.

In short, in order to understand the impact of liberalisation on innovation one has to analyse the existence and intensity of natural barriers to entry as well as of mechanisms capable of overcoming the obstructive effect of those barriers and of making the threat of competition real.

4. Theoretical model - Investments in innovation made by an incumbent under various market structures

In Chapter 3 we started by analysing the relationship between liberalisation and the development of competition in the network industries. After, we examined the relationship between liberalisation and innovation. We are now going to study the effect of competition on innovation. For that purpose we will develop and analyse, in this chapter, a model of incumbent network operator investment in innovation when the incumbent is a monopolist and when it faces an entrant.

The incumbent and the entrant compete in prices. The objectives of the incumbent are specified in a general manner to allow for revenue, profit, and/or welfare maximisation, subject to the profit being non-negative. The general objective function of the incumbent has the following form: $\alpha_1 R_I + \alpha_2 \prod_I + \alpha_3 W$, where α_1, α_2 and α_3 are weights given to revenue (R_I), profit ($\prod_I$) and welfare (W), respectively. Welfare is measured in the usual fashion as the unweighted sum of producer profits and consumer surplus. The incumbent's marginal cost is a function of the amount invested in innovation. We assume this marginal cost function to be strictly convex and decreasing in innovation investment. The incumbent maximises its objective function with respect to prices and to investment in innovation. The entrant maximises its profit with respect to its price. The Nash equilibrium of the ensuring price-innovation game is characterised.

The incumbent's incentives to innovate under monopoly and duopoly are compared. The theoretical developments are examined through some computational experiments based on a calibrated model of innovation in the postal sector. The model development is nevertheless generic and applies to other industries.

In the next section (4.1) we will present the theoretical model. Then we will describe the model's calibration with data from the postal sector (4.2). Following this, the main results are presented (4.3) and the main findings are summarised in the concluding remarks (4.4).

4.1 Theoretical model

For the purpose of investigating whether the incumbent's investment in new technologies and processes is higher under competition or under monopoly in the context of network industries, two stages of competition are assumed. In the first stage, the historical operator or incumbent has a monopoly in the market, and in the second stage a new operator (entrant) enters the market and competes on price with the incumbent (duopoly). We will first characterise the demand side.

4.1.1 Demand side

Consumer preferences are assumed to be quasi-linear with respect to the incumbent's and entrant's products/services and money, so that:

$$U(q_I, q_E, m) = V(q_I, q_E) + m$$

where m represents money spent on other goods and the willingness-to-pay function V for the incumbent's and entrant's products/services is assumed to be quadratic over the quantity of products/services consumed from the incumbent (q_I) and from the entrant (q_E):

$$V(q_I, q_E) = a_I q_I - \frac{b_I}{2} q_I^2 + a_E q_E - \frac{b_E}{2} q_E^2 - e\phi q_I q_E,$$

where $a > 0$, $\phi > 0$ and $b > 0$ are the parameters that determine the size of the market and the slope of the demand curve. The parameter e, which varies between zero and one, determines the degree of differentiability of the services offered by the incumbent and the entrant. If e is close to zero, then the services are highly differentiated. As e approaches one, then the services become more homogeneous, being perfect substitutes when $e = 1$.

Only a representative consumer model is considered here; introducing consumer heterogeneity would only add notation with no additional insights. The (representative) consumer maximises utility with respect to q_I and q_E subject to the following budget constraint, which clearly holds with equality at the optimum:

$$p_I q_I + p_E q_E + m \leq M \ ,$$

where p_I and p_E are the prices of the product/service supplied by the incumbent and the entrant, respectively. M is the initial wealth endowment of the consumer. By solving the consumer's problem, the following demand functions are obtained:

$$q_I(p_I, p_E) = \frac{1}{b_I b_E - e^2 \phi^2} \left(b_E a_I - e\phi a_E - b_E p_I + e\phi p_E \right) \qquad (1)$$

$$q_E(p_I, p_E) = \frac{1}{b_I b_E - e^2 \phi^2} \left(b_I a_E - e\phi a_I - b_I p_E + e\phi p_I \right) \qquad (2)$$

A viable outcome in terms of non-negative quantities exists under the following conditions:

$$b_E \left(a_I - p_I \right) > e\phi \left(a_E - p_E \right) , \ b_I \left(a_E - p_E \right) > e\phi \left(a_I - p_I \right) \ \text{and} \ b_I b_E - e^2 \phi^2 > 0 \qquad (3)$$

Adapting the utility function and the budget constraint of the consumer to a monopoly situation, i.e. setting q_E equal to zero, the demand function in monopoly becomes:

$$q_I(p_I) = \frac{1}{b}\left(a_I - p_I \right)$$

The condition to obtain a viable outcome under monopoly is $a_I > p_I$.

4.1.2 Supply side

On the supply side, in both stages of competition the marginal cost of the incumbent (c_I) is assumed to depend on the investment in new technologies (k). The following marginal cost function, which is strictly convex and decreasing, is assumed:

$$c_I(k) = c_{I0}e^{-\gamma k}$$

where c_{I0} is the initial marginal cost of the incumbent and γ establishes the relationship between the investment in innovation or new technologies and the reduction in the marginal cost. The higher the value of γ is, the lower the investment needed to attain a certain percentage of cost reduction is. This equation accommodates the assumption that if initial cost is high (e.g. due to internal inefficiency), then a smaller level of investment is needed to obtain a certain reduction in the marginal cost as compared to a situation where the initial cost is low.

Our objective is to analyse how the incumbent's incentives to innovate change under monopoly as compared to a competitive environment. Therefore, only the case where the incumbent has the choice to invest in innovation in order to reduce its marginal cost is considered.

Many postal incumbents are public enterprises or have other forms of ownership and governance than profit-maximizing private firms. To capture some of the richness inherent in these alternative ownership and governance structures, as well as the potential of regulation on these firms, various objectives are posited for the incumbent in the analysis that follows. In particular, the incumbent modelled here can maximise sales revenue, profit, and/or welfare, subject to a breakeven

constraint on profit. For example the sales revenue maximisation objective might be relevant for a traditional public bureaucracy whose management is concerned primarily with maximising the size of the organisation (e.g., Niskanen, 1971), while a welfare maximisation objective might be relevant for a public enterprise that is explicitly regulated to achieve efficiency (in pricing). The point of this rather general analysis is to consider the impact of alternative objectives that might credibly be advanced as representing the objectives of postal incumbents[10] on investment strategies.

The objective function of the historical operator is assumed to have the following form: $\alpha_1 R_I + \alpha_2 \prod_I + \alpha_3 W$, where α_1, α_2 and α_3 are non-negative weights, which without loss of generality are assumed to add up to one, attributed to the size of the firm as measured by revenue (R_I), profit ($\prod_I$) and welfare (W), respectively. α_1 is assumed to be different from one[11], i.e. $\alpha_1 \in [0,1)$, while $\alpha_2, \alpha_3 \in [0,1]$. This weighted objective function allows the study of alternative preferences of the incumbent.

4.1.2.1 Monopoly

Under monopoly, the revenue and profit of the incumbent and the welfare are respectively given by:

$$R_I(p_I) = p_I q_I(p_I)$$

$$\prod_I(p_I, k) = \big(p_I - c_I(k)\big) q_I(p_I) - k - F_I$$

---

[10] See Crew and Kleindorfer (2008) for a related discussion of such a weighted objective function in the context of price-cap regulation.

[11] This is a purely technical assumption. α_1 can be extremely close to one but it can not be exactly one, otherwise there is no solution to the problem we are investigating.

$$W(p_I,k)=V\left(q_I(p_I)\right)-p_I q_I(p_I)+\Pi_I=V\left(q_I(p_I)\right)-c_I(k)q_I(p_I)-k-F_I$$

Hence, the Lagrangian for the breakeven-constrained incumbent can be written as:

$$L(p_I,k,\lambda)=\left[(\alpha_1+\alpha_2+\lambda)p_I-(\alpha_2+\alpha_3+\lambda)c_I(k)\right]q_I(p_I)+\alpha_3 V\left(q_I(p_I)\right)-(\alpha_2+\alpha_3+\lambda)k-(\alpha_2+\alpha_3+\lambda)F_I$$

where $\lambda \geq 0$ is the Lagrange multiplier associated with the breakeven constraint, which measures the sensitivity of the optimal solution of the objective function to changes in required minimum profit level of the incumbent.

Result 1: $L(p_I,k,\lambda)$ is strictly concave in k for any fixed prices and is also strictly concave in p_I for any fixed k. Nevertheless, $L(p_I,k,\lambda)$ is not jointly strictly concave.

∎

To see that $L(p_I,k,\lambda)$ is strictly concave in k for any fixed prices it is necessary to compute the first and second order derivatives with respect to k:

$$\frac{\partial L}{\partial k}=(\alpha_2+\alpha_3+\lambda)\left[\gamma c_I(k)q_I(p_I)-1\right]$$

$$\frac{\partial^2 L}{\partial k^2}=-(\alpha_2+\alpha_3+\lambda)\gamma^2 c_I(k)q_I(p_I)<0$$

It is easy to see that $L(p_I,k,\lambda)$ is also strictly concave in p_I for any fixed k:

$$\frac{\partial L}{\partial p_I} = \frac{1}{b}\left[\left(\alpha_1 + \alpha_2 + \lambda\right)\left(a_I - 2p_I\right) + \left(\alpha_2 + \alpha_3 + \lambda\right)c_I(k) - \alpha_3 p_I\right]$$

$$\frac{\partial^2 L}{\partial p_I^2} = \frac{-2\left(\alpha_1 + \alpha_2 + \lambda\right) - \alpha_3}{b} < 0$$

Nevertheless, $L\left(p_I, k, \lambda\right)$ is not jointly strictly concave, i.e. the Hessian matrix (H) is not negative definite in the domain of $L\left(p_I, k, \lambda\right)$. For H to be negative definite, its first order leading principal minor has to be negative and the second order leading principal minor has to be positive. Concerning the first order leading principal minor there are no problems since it is always negative:

$$H = \begin{pmatrix} \dfrac{\partial^2 L}{\partial k^2} & \dfrac{\partial^2 L}{\partial k \partial p_I} \\[2ex] \dfrac{\partial^2 L}{\partial p_I \partial k} & \dfrac{\partial^2 L}{\partial p_I^2} \end{pmatrix} = \begin{pmatrix} -\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma^2 c_I(k)q_I(p_I) & -\dfrac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma c_I(k)}{b} \\[3ex] -\dfrac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma c_I(k)}{b} & -\dfrac{2\left(\alpha_1 + \alpha_2 + \lambda\right) + \alpha_3}{b} \end{pmatrix}$$

The second order leading principal minor is the one creating problems because it is not always positive:

$$\begin{vmatrix} -\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma^2 c_I(k)q_I(p_I) & -\dfrac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma c_I(k)}{b} \\[3ex] -\dfrac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma c_I(k)}{b} & -\dfrac{2\left(\alpha_1 + \alpha_2 + \lambda\right) + \alpha_3}{b} \end{vmatrix} = \frac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma^2 c_I(k)q_I(p_I)\left[2\left(\alpha_1 + \alpha_2 + \lambda\right) + \alpha_3\right]}{b}$$
$$-\left[\frac{\left(\alpha_2 + \alpha_3 + \lambda\right)\gamma c_I(k)}{b}\right]^2$$

However, given that $L\left(p_I, k, \lambda\right)$ is strictly concave in p_I for any fixed $k \geq 0$, it is possible to derive the optimal p_I from the necessary and sufficient first-order conditions.

Result 2: Assuming an interior solution for price, the optimal solution is characterized by $\dfrac{\partial L}{\partial p_I} = 0$, which yields:

$$p_I^*(k) = \frac{(\alpha_1 + \alpha_2 + \lambda)a_I + (\alpha_2 + \alpha_3 + \lambda)c_I(k)}{(1 + \alpha_1 + \alpha_2 + 2\lambda)} \tag{4}$$

∎

Since $p_I^*(k)$ is unique and feasible for every $k \geq 0$, the problem of $\max\{L(p_I, k, \lambda)|p_I \geq 0, k \geq 0, \lambda \geq 0\}$ can be restated as $\max\{L(p_I^*(k), k, \lambda)|k \geq 0, \lambda \geq 0\}$. The solution is recovered as $(p_I^*(k^*), k^*, \lambda^*)$ where k^* solves $\max\{L(p_I^*(k), k, \lambda)|k \geq 0, \lambda \geq 0\}$. From equation (4) is possible to obtain:

$$L(p_I^*(k), k, \lambda) = \frac{1}{b}\Big[(\alpha_1 + \alpha_2 + \lambda)p_I^*(k) - (\alpha_2 + \alpha_3 + \lambda)c_I(k) + \alpha_3 a_I\Big](a_I - p_I^*(k))$$
$$- \frac{\alpha_3}{2b}(a_I - p_I^*(k))^2 - (\alpha_2 + \alpha_3 + \lambda)k - (\alpha_2 + \alpha_3 + \lambda)F_I \tag{5}$$

The first order conditions for $\max\{L(p_I^*(k), k, \lambda)|k \geq 0, \lambda \geq 0\}$ are:

$$\frac{\partial L(p_I^*(k), k, \lambda)}{\partial k} \leq 0; \quad \frac{\partial L(p_I^*(k), k, \lambda)}{\partial \lambda} \geq 0; \quad k\frac{\partial L(p_I^*(k), k, \lambda)}{\partial k} = 0 \tag{6}$$

An interior solution $k > 0$ is obtained from (6) only if $\partial L\left(p_I^*(k), k, \lambda\right)/\partial k = 0$. From (5) one can obtain:

$$\frac{\partial L\left(p_I^*(k), k, \lambda\right)}{\partial k} = \frac{1}{b}\left\{\begin{array}{l}\left[\left(\alpha_1 + \alpha_2 + \lambda\right)\dfrac{\partial p_I^*(k)}{\partial k} + \gamma\left(\alpha_2 + \alpha_3 + \lambda\right)c_I(k)\right]\left(a_I - p_I^*(k)\right) + \\ + \left[\left(\alpha_1 + \alpha_2 + \lambda\right)p_I^*(k) - \left(\alpha_2 + \alpha_3 + \lambda\right)c_I(k) + \alpha_3 a_I\right]\left(-\dfrac{\partial p_I^*(k)}{\partial k}\right)\end{array}\right\}$$

$$+ \frac{\alpha_3}{b}\left(a_I - p_I^*(k)\right)\frac{\partial p_I^*(k)}{\partial k} - \left(\alpha_2 + \alpha_3 + \lambda\right)$$

$$\frac{\partial L\left(p_I^*(k), k, \lambda\right)}{\partial k} = c_I(k)\left(h_8 - h_9 c_I(k)\right) - \left(\alpha_2 + \alpha_3 + \lambda\right) \tag{7}$$

where

$$h_8 = \frac{\gamma\left(\alpha_2 + \alpha_3 + \lambda\right)\left(1 + \lambda\right)}{b\left(1 + \alpha_1 + \alpha_2 + 2\lambda\right)}a_I > 0 \text{ and } h_9 = \frac{\gamma\left(\alpha_2 + \alpha_3 + \lambda\right)^2\left(2 + 2\lambda - \alpha_3\right)}{b\left(1 + \alpha_1 + \alpha_2 + 2\lambda\right)^2} > 0$$

The zeros of the quadratic on the right-hand side of equation (7) are:

$$c_I^*(k) = \frac{h_8 \pm \sqrt{h_8^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_9}}{2h_9} \tag{8}$$

The following proposition concerning the existence and uniqueness of a solution holds.

Proposition 1: A solution exists to the problem $\max\left\{L\left(p_I^*(k),k,\lambda\right)\big|k\geq 0,\lambda\geq 0\right\}$

(and therefore to the original problem). The optimal solution $k^*\geq 0$ is the following:

i) If $h_8^2\leq 4\left(\alpha_2+\alpha_3+\lambda\right)h_9$, then $k^*=0$

ii) If $h_8^2>4\left(\alpha_2+\alpha_3+\lambda\right)h_9$, define $\hat{k}$ and $\hat{\lambda}$ as the k and λ, respectively, corresponding to the negative root in (8), namely, corresponding to $c_I(\hat{k})=\dfrac{h_8-\sqrt{h_8^2-4\left(\alpha_2+\alpha_3+\lambda\right)h_9}}{2h_9}$; then k^* is the

solution to: $L\left(p_I^*(k^*),k^*,\lambda^*\right)=\max\left\{L\left(p_I^*(\hat{k}),\hat{k},\hat{\lambda}\right),L\left(p_I^*(0),0,\lambda^*\right)\right\}$.

In particular, if an interior solution is obtained, then $k^*=\hat{k}$.

∎

The proof of this proposition is as follows.

Proof 1:

When the profit constraint is imposed (e.g. as in the profit-constrained welfare maximising case or Ramsey case) the existence of a solution is proved using the Weierstrass Theorem and noting the continuity of $\Pi_I\left(p_I^*(k),k\right)$ as well as that from $\Pi_I\left(p_I^*(k),k\right)$ attention can be restricted to the compact set $k\in\left[0,\overline{k}\right]$, where

$$\overline{k}=\frac{1}{b\left(1+\alpha_1+\alpha_2\right)}\left[\left(\alpha_1+\alpha_2\right)a_I^2+\left(\alpha_2+\alpha_3\right)c_{I0}a_I\right]$$

There clearly is a k such that there is at least some price for which profits are greater than or equal to zero (assuming $\left[(\alpha_1+\alpha_2)a_I-(2\alpha_1+\alpha_2)c_{I0}\right]\left[a_I-(\alpha_2+\alpha_3)c_{I0}\right]>b(1+\alpha_1+\alpha_2)^2 F_I$). One such k is $k=0$, since that definitely leads to $\Pi_I\left(p_I^*(k),k\right)\geq 0$ and, therefore, to non-negative profits in the original objective function. If k is larger than $\bar{k}$, there is no feasible price that will allow $\Pi_I\left(p_I^*(k),k\right)\geq 0$, and consequently, the incumbent cannot breakeven in the original maximisation problem.

When the profit constraint is not imposed, i.e. $\lambda=0$ (e.g. as in the welfare-maximising case), the existence of a solution is proved using, again, the Weierstrass Theorem and noting the continuity of the maximand corresponding to (5) as well as that from that maximand attention can be restricted to the compact set $k\in\left[0,\bar{\bar{k}}\right]$, where

$$\bar{\bar{k}}=\frac{1}{b(\alpha_2+\alpha_3)}\left[\frac{(\alpha_1+\alpha_2)^2 a_I^2+(\alpha_1+\alpha_2)(\alpha_2+\alpha_3)c_{I0}a_I}{(1+\alpha_1+\alpha_2)}+\alpha_3 a_I^2\right]$$

The feasible solution $k=0$ establishes a lower bound on the maximand corresponding to (5), since it leads to non-negative maximand, and therefore, the original objective function is also non-negative. For k larger than $\bar{\bar{k}}$, the solution for the maximand corresponding to (5) is lower than zero and, therefore, lower than the value of the maximand at $k=0$. Hence, the original objective function is also negative for k larger than $\bar{\bar{k}}$.

Given the existence of a solution and the differentiability of the objective function, if the hypothesis in i) holds, then the quadratic in equation (7) is negative (it certainly is negative for $c_I(k)=0$ and if it ever became positive, it would have to cross the horizontal axis, giving rise to at least one zero on the right

hand side of equation (7)). Thus, under i), it is clear that the optimal solution must be $k^* = 0$.

If there is an interior solution, i.e. $k^* > 0$, then the right hand side of equation (7) must equal zero giving rise to the two roots in equation (8). It is easily verified that the second order condition $\partial^2 L\left(p_I^*(k), k, \lambda\right)/\partial k^2 \leq 0$ can only be fulfilled at the negative root in (8). This can be showed by computing:

$$\frac{\partial^2 L\left(p_I^*(k), k, \lambda\right)}{\partial k^2} = -\gamma c_I(k)\left(h_8 - h_9 c_I(k)\right) + \gamma h_9 c_I^2(k) = \gamma\left[h_9 c_I^2(k) - \left(\alpha_2 + \alpha_3 + \lambda\right)\right]$$

where we use the fact that $c_I(k)\left(h_8 - h_9 c_I(k)\right) = \left(\alpha_2 + \alpha_3 + \lambda\right)$ for an interior solution. Therefore, $\partial^2 L\left(p_I^*(k), k, \lambda\right)/\partial k^2 \leq 0$ if and only if $h_9 c_I^2(k) \leq \left(\alpha_2 + \alpha_3 + \lambda\right)$. Using again the fact that $c_I(k)\left(h_8 - h_9 c_I(k)\right) = \left(\alpha_2 + \alpha_3 + \lambda\right)$, i.e. $h_9 c_I^2(k) = c_I(k)h_8 - \left(\alpha_2 + \alpha_3 + \lambda\right)$, the second order condition holds if and only if $h_8 c_I(k) \leq 2\left(\alpha_2 + \alpha_3 + \lambda\right)$. With further computing we obtain:

$$h_8 c_I(k) = h_8\left(\frac{h_8 \pm \sqrt{h_8^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_9}}{2h_9}\right) \leq 2\left(\alpha_2 + \alpha_3 + \lambda\right)$$

if and only if

$$h_8^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_9 \pm h_8\sqrt{h_8^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_9} \leq 0 \tag{9}$$

Equation (9) can only hold for the negative root. Thus, if an interior solution is obtained, it must be at the negative root of (8).

Finally, note that it is not possible in general to rule out the boundary solution, so that the optimal solution in case ii) occurs at the point k^* at which $L\left(p_I^*(k), k, \lambda\right)$ is maximized on the boundary (i.e. at $k = 0$) or in the interior (i.e. at $k = \hat{k}$).

Q.E.D.

Nevertheless, it seems reasonable to assume that the optimal solution is interior for this problem.

Note that the optimal k corresponds to $k^* = \ln\left(c_{I0}/c_I^*(k)\right)/\gamma$. The optimal price, under monopoly, can be obtained by substituting $c_I(\hat{k})$ into (4).

4.1.2.2 Duopoly

In duopoly, the equilibrium is given by the intersection of the reaction functions of the incumbent and entrant. The entrant maximizes his profit

$$\Pi_E\left(p_I, p_E\right) = \left(p_E - c_E\right) q_E(p_I, p_E) - F_E$$

with respect to p_E, where c_E is the marginal cost of the entrant and F_E represents its fixed costs. The reaction function of the entrant has the following form:

$$p_E(p_I) = \frac{b_I a_E - e\phi a_I + e\phi p_I + b_I c_E}{2b_I} \tag{10}$$

The revenue and profit of the incumbent and the welfare under duopoly are as follows:

$$R_I(p_I, p_E) = p_I q_I(p_I, p_E)$$

$$\Pi_I(p_I, p_E, k) = (p_I - c_I(k)) q_I(p_I, p_E) - k - F_I$$

$$\begin{aligned} W(p_I, p_E, k) &= V(q_I(p_I, p_E), q_E(p_I, p_E)) - p_I q_I(p_I, p_E) - p_E q_E(p_I, p_E) + \Pi_I + \Pi_E \\ &= V(q_I(p_I, p_E), q_E(p_I, p_E)) - c_I(k) q_I(p_I, p_E) - c_E q_E(p_I, p_E) - k - F_I - F_E \end{aligned}$$

Therefore, under duopoly, the Lagrangian for the breakeven-constrained incumbent can be written as:

$$\begin{aligned} L(p_I, k, \lambda) &= \left[(\alpha_1 + \alpha_2 + \lambda) p_I - (\alpha_2 + \alpha_3 + \lambda) c_I(k) \right] q_I(p_I, p_E) - (\alpha_2 + \alpha_3 + \lambda) k \\ &\quad - (\alpha_2 + \alpha_3 + \lambda) F_I + \alpha_3 \left[V(q_I(p_I, p_E), q_E(p_I, p_E)) - c_E q_E(p_I, p_E) - F_E \right] \end{aligned} \tag{11}$$

where $\lambda \geq 0$ has the same meaning as before.

Result 3: $L(p_I, k, \lambda)$, under duopoly, is also strictly concave in k for any fixed prices and strictly concave in p_I for any fixed k. $L(p_I, k, \lambda)$ under duopoly, as under monopoly, is not jointly strictly concave.

∎

This result is proved by analysing the first and second order derivatives with respect to k (for any fixed prices) and p_I (for any fixed k):

$$\frac{\partial L}{\partial k} = (\alpha_2 + \alpha_3 + \lambda)\left[\gamma c_I(k)q_I(p_I, p_E) - 1\right]$$

$$\frac{\partial^2 L}{\partial k^2} = -(\alpha_2 + \alpha_3 + \lambda)\gamma^2 c_I(k)q_I(p_I, p_E) < 0$$

$$\frac{\partial L}{\partial p_I} = \frac{1}{b_I b_E - e^2\phi^2}\left[\begin{array}{l}(\alpha_1 + \alpha_2 + \lambda)(b_E a_I - e\phi a_E - 2b_E p_I + e\phi p_E)\\ +(\alpha_2 + \alpha_3 + \lambda)b_E c_I(k) + \alpha_3\left(-b_E p_I + (p_E - c_E)e\phi\right)\end{array}\right]$$

$$\frac{\partial^2 L}{\partial p_I^2} = \frac{-2(\alpha_1 + \alpha_2 + \lambda)b_E - \alpha_3 b_E}{b_I b_E - e^2\phi^2} < 0$$

As explained before, L is jointly strictly concave if the Hessian matrix (H) is negative definite in the domain of L. Again, it is necessary to find the sign of the first and second order leading principal minors:

$$H = \begin{pmatrix} \frac{\partial^2 L}{\partial k^2} & \frac{\partial^2 L}{\partial k \partial p_I} \\ \frac{\partial^2 L}{\partial p_I \partial k} & \frac{\partial^2 L}{\partial p_I^2} \end{pmatrix} = \begin{pmatrix} -(\alpha_2 + \alpha_3 + \lambda)\gamma^2 c_I(k)q_I(p_I, p_E) & -\frac{(\alpha_2 + \alpha_3 + \lambda)b_E \gamma c_I(k)}{b_I b_E - e^2\phi^2} \\ -\frac{(\alpha_2 + \alpha_3 + \lambda)b_E \gamma c_I(k)}{b_I b_E - e^2\phi^2} & -\frac{2(\alpha_1 + \alpha_2 + \lambda)b_E + \alpha_3 b_E}{b_I b_E - e^2\phi^2} \end{pmatrix}$$

$$\begin{vmatrix} -(\alpha_2 + \alpha_3 + \lambda)\gamma^2 c_I(k)q_I(p_I, p_E) & -\frac{(\alpha_2 + \alpha_3 + \lambda)b_E \gamma c_I(k)}{b_I b_E - e^2\phi^2} \\ -\frac{(\alpha_2 + \alpha_3 + \lambda)b_E \gamma c_I(k)}{b_I b_E - e^2\phi^2} & -\frac{2(\alpha_1 + \alpha_2 + \lambda)b_E + \alpha_3 b_E}{b_I b_E - e^2\phi^2} \end{vmatrix} =$$

$$= \frac{(\alpha_2 + \alpha_3 + \lambda)\gamma^2 c_I(k)q_I(p_I, p_E)\left[2(\alpha_1 + \alpha_2 + \lambda)b_E + \alpha_3 b_E\right]}{b_I b_E - e^2\phi^2} - \left[\frac{(\alpha_2 + \alpha_3 + \lambda)b_E \gamma c_I(k)}{b_I b_E - e^2\phi^2}\right]^2$$

The first order leading principal minor is negative but the second order leading principal is not always positive. Hence, L is not jointly strictly concave.

The procedure applied to find the optimal solution under monopoly is followed here in order to find the optimal solution under duopoly. Firstly, the optimal p_I is derived from the necessary and sufficient first-order conditions and then the problem of $\max\left\{L(p_I, k, \lambda) \middle| p_I \geq 0, k \geq 0, \lambda \geq 0\right\}$ is restated as $\max\left\{L(p_I^*(k), k, \lambda) \middle| k \geq 0, \lambda \geq 0\right\}$.

Again an interior solution for price is assumed. Under duopoly, the optimal solution is characterised by $\dfrac{\partial L}{\partial p_I} = 0$, which yields:

$$p_I(k, p_E) = \frac{(\alpha_1 + \alpha_2 + \lambda)(b_E a_I - e\phi a_E) + (1 + \lambda)e\phi p_E + (\alpha_2 + \alpha_3 + \lambda)b_E c_I(k) - \alpha_3 e\phi c_E}{(1 + \alpha_1 + \alpha_2 + 2\lambda)b_E} \quad (12)$$

Result 4: Putting the reaction function of the incumbent and of the entrant together (equations (10) and (12)) gives:

$$p_I^*(k) = \xi \begin{bmatrix} 2(\alpha_1 + \alpha_2 + \lambda)(b_E a_I - e\phi a_E)b_I + 2(\alpha_2 + \alpha_3 + \lambda)b_I b_E c_I(k) \\ -2\alpha_3 b_I e\phi c_E + (1 + \lambda)e\phi(b_I a_E - e\phi a_I + b_I c_E) \end{bmatrix} \quad (13)$$

$$p_E^*(k) = \xi \begin{bmatrix} e\phi(\alpha_1 + \alpha_2 + \lambda)(b_E a_I - e\phi a_E) + e\phi(\alpha_2 + \alpha_3 + \lambda)b_E c_I(k) \\ -\alpha_3 e^2 \phi^2 c_E + (1 + \alpha_1 + \alpha_2 + 2\lambda)b_E(b_I a_E - e\phi a_I + b_I c_E) \end{bmatrix} \quad (14)$$

where $\xi = 1/\left[2(1 + \alpha_1 + \alpha_2 + 2\lambda)b_I b_E - (1 + \lambda)e^2 \phi^2\right] > 0$.

■

The solution for $\max\left\{L\left(p_I^*(k),k,\lambda\right)\middle|k\geq 0,\lambda\geq 0\right\}$ is recovered as $\left(p_I^*(k^*),k^*,\lambda^*\right)$

where k^* solves $\max\left\{L\left(p_I^*(k),k,\lambda\right)\middle|k\geq 0,\lambda\geq 0\right\}$. Equation (13) yields:

$$
\begin{aligned}
L\left(p_I^*(k),k,\lambda\right) &= \\
&= \frac{1}{b_I b_E - e^2\phi^2}\left[\left(\alpha_1+\alpha_2+\lambda\right)p_I^*(k)-\left(\alpha_2+\alpha_3+\lambda\right)c_I(k)+\alpha_3 a_I\right]*\left(b_E a_I - e\phi a_E - b_E p_I^*(k)+e\phi p_E^*(k)\right) \\
&+ \frac{\alpha_3}{b_I b_E - e^2\phi^2}\left[a_E - c_E - \frac{e\phi}{b_I b_E - e^2\phi^2}\left(b_E a_I - e\phi a_E - b_E p_I^*(k)+e\phi p_E^*(k)\right)\right]*\left(b_I a_E - e\phi a_I - b_I p_E^*(k)+e\phi p_I^*(k)\right) \\
&- \frac{\alpha_3}{2(b_I b_E - e^2\phi^2)^2}\left[\begin{array}{l}b_I\left(b_E a_I - e\phi a_E - b_E p_I^*(k)+e\phi p_E^*(k)\right)^2 \\ +b_E\left(b_I a_E - e\phi a_I - b_I p_E^*(k)+e\phi p_I^*(k)\right)^2\end{array}\right]-\left(\alpha_2+\alpha_3+\lambda\right)k-\left(\alpha_2+\alpha_3+\lambda\right)F_I-\alpha_3 F_E
\end{aligned}
\tag{15}
$$

Recall that the first order conditions for $\max\left\{L\left(p_I^*(k),k,\lambda\right)\middle|k\geq 0,\lambda\geq 0\right\}$ are:

$$
\frac{\partial L\left(p_I^*(k),k,\lambda\right)}{\partial k}\leq 0;\quad \frac{\partial L\left(p_I^*(k),k,\lambda\right)}{\partial\lambda}\geq 0;\quad k\frac{\partial L\left(p_I^*(k),k,\lambda\right)}{\partial k}=0
\tag{16}
$$

If $\partial L\left(p_I^*(k),k,\lambda\right)\big/\partial k=0$ then an interior solution $k>0$ is obtained. The derivative of (15) with respect to k is:

$$\frac{\partial L\left(p_I^*(k),k,\lambda\right)}{\partial k}=$$

$$=\frac{1}{b_I b_E -e^2\phi^2}\left\{\begin{array}{l}\left[\left(\alpha_1+\alpha_2+\lambda\right)\frac{\partial p_I^*(k)}{\partial k}+\gamma\left(\alpha_2+\alpha_3+\lambda\right)c_I(k)\right]\left(b_E a_I -e\phi a_E -b_E p_I^*(k)+e\phi p_E^*(k)\right)\\[2mm]+\left[\left(\alpha_1+\alpha_2+\lambda\right)p_I^*(k)-\left(\alpha_2+\alpha_3+\lambda\right)c_I(k)+\alpha_3 a_I\right]\left(-b_E\frac{\partial p_I^*(k)}{\partial k}+e\phi\frac{\partial p_E^*(k)}{\partial k}\right)\end{array}\right\}+$$

$$+\frac{\alpha_3}{b_I b_E -e^2\phi^2}\left\{\begin{array}{l}-\frac{e\phi}{b_I b_E -e^2\phi^2}\left(-b_E\frac{\partial p_I^*(k)}{\partial k}+e\phi\frac{\partial p_E^*(k)}{\partial k}\right)\left(b_I a_E -e\phi a_I -b_I p_E^*(k)+e\phi p_I^*(k)\right)\\[2mm]+\left[a_E -c_E -\frac{e\phi}{b_I b_E -e^2\phi^2}\left(b_E a_I -e\phi a_E -b_E p_I^*(k)+e\phi p_E^*(k)\right)\right]\left(-b_I\frac{\partial p_E^*(k)}{\partial k}+e\phi\frac{\partial p_I^*(k)}{\partial k}\right)\end{array}\right\}-$$

$$-\frac{\alpha_3}{(b_I b_E -e^2\phi^2)^2}\left\{\begin{array}{l}b_I\left(b_E a_I -e\phi a_E -b_E p_I^*(k)+e\phi p_E^*(k)\right)\left(-b_E\frac{\partial p_I^*(k)}{\partial k}+e\phi\frac{\partial p_E^*(k)}{\partial k}\right)\\[2mm]+b_E\left(b_I a_E -e\phi a_I -b_I p_E^*(k)+e\phi p_I^*(k)\right)\left(-b_I\frac{\partial p_E^*(k)}{\partial k}+e\phi\frac{\partial p_I^*(k)}{\partial k}\right)\end{array}\right\}-\left(\alpha_2+\alpha_3+\lambda\right)$$

In order to make computations easier, the optimal prices are re-written as follows:

$$p_I^*(k)=h_4 +2b_I h_3 c_I(k)$$

$$p_E^*(k)=h_5 +e\phi h_3 c_I(k)$$

where

$$h_3 =\xi\left(\alpha_2+\alpha_3+\lambda\right)b_E$$

$$h_4 =\xi\left[2\left(\alpha_1+\alpha_2+\lambda\right)\left(b_E a_I -e\phi a_E\right)b_I -2\alpha_3 b_I e\phi c_E +\left(1+\lambda\right)e\phi\left(b_I a_E -e\phi a_I +b_I c_E\right)\right]$$

$$h_5 =\xi\left[e\phi\left(\alpha_1+\alpha_2+\lambda\right)\left(b_E a_I -e\phi a_E\right)-\alpha_3 e^2\phi^2 c_E +\left(1+\alpha_1+\alpha_2+2\lambda\right)b_E\left(b_I a_E -e\phi a_I +b_I c_E\right)\right]$$

Defining $h_1 = \alpha_1 + \alpha_2 + \lambda$ and $h_2 = \alpha_2 + \alpha_3 + \lambda$, and knowing that $\partial p_I^*(k)/\partial k = -2b_I\gamma h_3 c_I(k)$ and $\partial p_E^*(k)/\partial k = -e\phi\gamma h_3 c_I(k)$ gives:

$$\frac{\partial L\left(p_I^*(k),k,\lambda\right)}{\partial k} = c_I(k)\left(h_6 - h_7 c_I(k)\right) - \left(\alpha_2 + \alpha_3 + \lambda\right) \tag{17}$$

where

$$h_6 = \frac{\gamma}{b_I b_E - e^2\phi^2}\left[\left(h_2 - 2b_I h_1 h_3\right)\left(b_E a_I - e\phi a_E\right) + e\phi b_I \alpha_3 h_3 c_E + \left(h_2 - 2b_I h_1 h_3 - \alpha_3 b_I h_3\right)e\phi h_5\right] \tag{18}$$

$$h_7 = -\frac{2\gamma}{b_I b_E - e^2\phi^2} h_3 \left(2b_I h_1 h_3 - h_2\right)\left(2b_I b_E - e^2\phi^2\right)$$
$$- \frac{\alpha_3\gamma h_3^2}{(b_I b_E - e^2\phi^2)^2}\left[e^2\phi^2 b_I^2 b_E + b_I\left(2b_I b_E - e^2\phi^2\right)^2 - 2e^2\phi^2 b_I\left(2b_I b_E - e^2\phi^2\right)\right]$$

In order to apply the reasoning used for the monopoly case, to prove uniqueness of the equilibrium, there is the need to make sure that h_6 and h_7 are positive. It can be proved that h_6 is always positive. The first two terms of equation (18) are always positive, i.e. $\left(h_2 - 2b_I h_1 h_3\right)\left(b_E a_I - e\phi a_E\right) + e\phi\alpha_3 h_3 c_E > 0$. $\left(h_2 - 2b_I h_1 h_3 - \alpha_3 b_I h_3\right)$ and h_5 are always positive as well. It is also easy to prove that h_7 is always positive.

The zeros of the quadratic on the right hand side of equation (17) are:

$$c_I(k) = \frac{h_6 \pm \sqrt{h_6^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_7}}{2h_7} \tag{19}$$

The following proposition refers to the existence and uniqueness of equilibrium under duopoly. It is basically Proposition 1 applied to the duopoly case.

Proposition 2: A solution exists to the problem $\max\left\{L\left(p_I^*(k), k, \lambda\right)\middle| k \geq 0, \lambda \geq 0\right\}$ (and therefore to the original problem). The optimal solution $k^* \geq 0$ is the following:

i) If $h_6^2 \leq 4(\alpha_2 + \alpha_3 + \lambda)h_7$, then $k^* = 0$

ii) If $h_6^2 > 4(\alpha_2 + \alpha_3 + \lambda)h_7$, define $\hat{k}$ and $\hat{\lambda}$ as the k and λ, respectively, corresponding to the negative root in (19), namely, corresponding to $c_I(\hat{k}) = \dfrac{h_6 - \sqrt{h_6^2 - 4(\alpha_2 + \alpha_3 + \lambda)h_7}}{2h_7}$; then k^* is the

solution to: $L\left(p_I^*(k^*), k^*, \lambda^*\right) = \max\left\{L\left(p_I^*(\hat{k}), \hat{k}, \hat{\lambda}\right), L\left(p_I^*(0), 0, \lambda^*\right)\right\}$.

In particular, if an interior solution obtains, then $k^* = \hat{k}$.

∎

Proof 2: The proof of existence of a solution under duopoly goes exactly as under monopoly (Proof 1), except that now:

$$\overline{k} = \frac{1}{\left(b_I b_E - e^2\phi^2\right)\left[2(1+\alpha_1+\alpha_2)b_I b_E - e^2\phi^2\right]^2}\left\{\begin{matrix}\left[2(\alpha_1+\alpha_2)b_I b_E a_I + 2(\alpha_2+\alpha_3)b_I b_E c_{I0} + e\phi b_I\left(a_E + c_E\right)\right]* \\ * \begin{bmatrix}2(1+\alpha_1+\alpha_2)b_I b_E^2 a_I + e^2\phi^2\left(\alpha_1+\alpha_2\right)b_E a_I \\ + e^2\phi^2\left(\alpha_2+\alpha_3\right)b_E c_{I0} + b_I b_E\left(1+\alpha_1+\alpha_2\right)\left(a_E + c_E\right)\end{bmatrix}\end{matrix}\right\},$$

and

$$\bar{\bar{k}} = \frac{1}{\left(b_I b_E - e^2 \phi^2\right)\left(\alpha_2 + \alpha_3\right)}\left\{\frac{\left(\alpha_1 + \alpha_2\right)}{2\left(1 + \alpha_1 + \alpha_2\right)b_I b_E - e^2 \phi^2}\left[2\left(\alpha_1 + \alpha_2\right)b_I b_E a_I + 2\left(\alpha_2 + \alpha_3\right)b_I b_E c_{I0} + e\phi b_I\left(a_E + c_E\right)\right] + \alpha_3 a_I\right\} *$$

$$* \left\{\frac{e\phi}{2\left(1 + \alpha_1 + \alpha_2\right)b_I b_E - e^2 \phi^2}\left[e\phi\left(\alpha_1 + \alpha_2\right)b_E a_I + e\phi\left(\alpha_2 + \alpha_3\right)b_E c_{I0} + \left(1 + \alpha_1 + \alpha_2\right)b_I b_E\left(a_E + c_E\right)\right] + b_E a_I\right\} +$$

$$+ \frac{\alpha_3 a_E}{\left(b_I b_E - e^2 \phi^2\right)\left(\alpha_2 + \alpha_3\right)}\left\{\frac{e\phi}{2\left(1 + \alpha_1 + \alpha_2\right)b_I b_E - e^2 \phi^2}\left[2\left(\alpha_1 + \alpha_2\right)b_I b_E a_I + 2\left(\alpha_2 + \alpha_3\right)b_I b_E c_{I0} + e\phi b_I\left(a_E + c_E\right)\right] + b_I a_E\right\}$$

Also, under duopoly there clearly is a k such that there is at least one price for which profits are greater than or equal to zero, assuming:

$$\frac{\left[2\left(1 - \alpha_3\right)b_I b_E - e^2 \phi^2\right]\left(a_I - c_{I0}\right) - 2\alpha_1 b_I b_E c_{I0} + \left(2\alpha_3 - 1\right)e\phi b_I\left(a_E - c_E\right)}{2\left(1 + \alpha_1 + \alpha_2\right)b_I b_E - e^2 \phi^2} *$$

$$* \frac{\left(2b_I b_E - e^2 \phi^2\right)b_E\left[a_I - \left(\alpha_2 + \alpha_3\right)c_{I0}\right] - \left[\left(b_I b_E - e^2 \phi^2\right)\alpha_3 + b_I b_E\right]e\phi\left(a_E - c_E\right)}{2\left(1 + \alpha_1 + \alpha_2\right)b_I b_E - e^2 \phi^2} > \left(b_I b_E - e^2 \phi^2\right)F_I$$

(20)

The proof of uniqueness of the solution under duopoly also follows the proof of Proposition 1. Under duopoly,

$$\frac{\partial^2 L\left(p_I^*(k), k, \lambda\right)}{\partial k^2} = -\gamma c_I(k)\left(h_6 - h_7 c_I(k)\right) + \gamma h_7 c_I^2(k) = \gamma\left[h_7 c_I^2(k) - \left(\alpha_2 + \alpha_3 + \lambda\right)\right]$$

and the second order condition holds if and only if $h_6 c_I(k) \leq 2\left(\alpha_2 + \alpha_3 + \lambda\right)$. By computing further we obtain:

$$h_6 c_I(k) = h_6\left(\frac{h_6 \pm \sqrt{h_6^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_7}}{2h_7}\right) \leq 2\left(\alpha_2 + \alpha_3 + \lambda\right)$$

if and only if

$$h_6^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_7 \pm h_6\sqrt{h_6^2 - 4\left(\alpha_2 + \alpha_3 + \lambda\right)h_7} \leq 0 \qquad (21)$$

Equation (21) can only hold true for the negative root. Thus, if an interior solution is obtained, it must be at the negative root of (19).

Q.E.D.

The optimal solution is also assumed to be interior under duopoly.

The optimal prices under duopoly can be obtained by substituting $c_I(\hat{k})$ into equations (13) and (14).

In the next section the model is calibrated with data from the postal sector and in the section thereafter some computational results are presented.

4.2   Model calibration – Postal sector data

In this section, the model presented earlier is calibrated with data from the postal sector. We have decided to calibrate the model with data from four countries in order to account for the different characteristics of the firms in terms of volumes, costs, and prices. We defined four groups of historical operators in terms of their volumes (Figure 1). From each group we selected a representative country. The four countries selected are Latvia, Portugal, Sweden, and France.
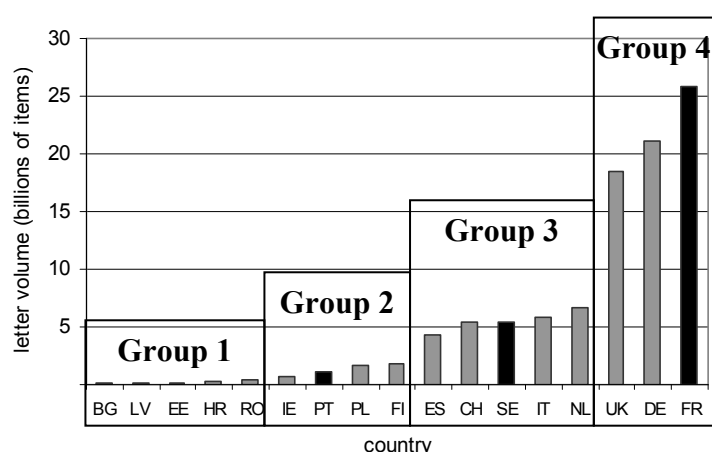
Figure 1: Letter volume in 1997 of 17 European historical operators

In order to estimate the demand functions, parameters *a* and *b* are calibrated with data from the Latvian, Portuguese, Swedish and French postal markets from 1997, when there was no competition yet. To calibrate b_I, b_E, and ϕ it is necessary to know the quantity, average price and own price elasticity of the incumbent's and the entrant's demand, and the cross elasticity of demand. In order to compute the quantity of the entrant we assume that it has a market share (*mktshareI*) of 80%. The price of the entrant is assumed to be 20% lower than the price of the incumbent. Once the values of b_I, b_E, ϕ, and *e* are known it is possible to compute a_I and a_E from equations (1) and (2).

The total volume of mail, including non-addressed mail, of the French (Latvian, Portuguese, Swedish) postal operator in 1997 was 25'770 (107, 1'116, 5'483) million objects.

The average price in France (Latvia, Portugal, Sweden) in 1997 was approximately 0.46 (0.29, 0.38, 0.42) euros (CTcon, 1998, Deutsche Post, 2007).

The own price elasticity of the incumbent's demand under monopoly (*elastIM*) is assumed to be -0.4 and under duopoly (*elastID*) is assumed to be -0.5. The own price elasticity of demand of the entrant (*elastE*) is assumed to be -0.6. The cross elasticity of the incumbent's demand relatively to the entrant (change in the

quantity of the incumbent due to a change in the price of the entrant) (*crosselast*) is assumed to be 0.1. The rationale for these assumptions is as follows.

There is considerable divergence in the literature concerning price elasticity of demand in the postal sector. According to Robinson's extensive review of the literature on price elasticity models for postal products (Robinson, 2007), the price elasticity measures for postal products in various studies and countries were between -0.2 and -0.8. We consider that under monopoly, the price elasticity of demand in absolute value (-0.4) is lower than under duopoly (-0.5 and -0.6). We also assume that under duopoly the incumbent has a price elasticity of demand smaller (in absolute value) than that of the entrant due to reputation effects and customer inertia. The value -0.5 was chosen for the incumbent and the value of -0.6 for the entrant. Even though some authors defend that the elasticity of demand in the postal sector is lower, we believe that these values are adequate since the innovations considered here are likely to focus on business products that have higher elasticities (in absolute value).

We assume that the services provided by the incumbent and the entrant are similar but not perfect substitutes. Therefore, we assume that the degree of differentiability of the services (parameter e) is $e = 0.8$. A sensitivity analysis for this parameter will be performed afterwards (section 4.3.6).

Regarding the supply side, the total operational costs of the French (Latvian, Portuguese) group were 9'848 (19, 442) million euros. Based on German data[12] from 1998, the costs associated with the letter segment are assumed to be 75% of the total costs of the group. The operational costs linked to the letter segment of the Swedish postal operator in 1997 were 1'502 million euros.

---

[12] There was no data available for France, Latvia, and Portugal on the operational costs of the letter segment. In fact, this information is available for very few countries and few years. We have decided to use the information we found for Germany in 1998 as a reference.

It is assumed that approximately 40% of the operational costs of the incumbent are fixed[13]. Therefore, the initial marginal cost of the French (Latvian, Portuguese, Swedish) incumbent is 0.17 (0.1, 0.18, 0.16) euros. The structure of competitors is more flexible than the structure of the historical operator. Hence, the percentage of fixed costs of the entrant is smaller than that of the incumbent. Competitors have a smaller infrastructure than the incumbent because the former has almost no private customers, has few postal outlets, sorting centres and delivery offices. Table 2 summarises the assumed cost structure of the incumbent and of the entrant.

Table 2: Cost structure of the incumbent and entrant

		Collection	Processing	Delivery	Overhead	Total
Percentage of total costs		10	30	55	5	100%
Fraction of variable costs	I	50	80	50	10	57%
	E	75	85	60	50	69%

Source: Adapted from Dietl et al. (2005)

The major differences in terms of costs between the entrant and the incumbent are that the entrant: 1) has a smaller infrastructure which allows smaller overhead costs; 2) focuses on business customers which allows the extensive use of computerised sorting in the printing stage; 3) pays lower wages than the incumbent and these represent the major share of the total costs (80%); and 4) is likely to have more recent technology. The wage premium is estimated to be approximately 15% (Dietl et al., 2005).

In order to account for these differences in terms of costs, the entrant is assumed to have a cost saving of 30% in collection and processing. The cost saving in delivery is smaller, approximately 5%, because most business mailings are business-to-customer originating a huge number of delivery points. Also,

---

[13] This is a typical figure (in the medium run applicable to pricing decisions) for postal incumbents. See the discussion in Cohen et al. (2006) and d'Alcantara and Amerlynck (2006).

innovation to reduce delivery costs is very limited since delivery depends basically on manpower (Dietl et al., 2005). Finally, it is assumed that the entrant has a cost saving of 33% in overhead costs (Dietl and Waller, 2002).

The elasticity of innovation cost (parameter γ) changes accordingly to the size of the operator. A large operator[14] has to invest much more than a small operator in order to obtain the same percentage of cost reduction in the marginal cost. For instance the letter volume of La Poste (France) is 23 times larger than the letter volume of CTT-Correios de Portugal (Portugal). Hence, a reduction of 10 percent in the marginal cost in La Poste will demand larger investments than a reduction of 10 percent in CTT-Correios de Portugal. Therefore a large operator will have a smaller elasticity of innovation cost and a small operator will have a larger elasticity of innovation cost.

The estimate of parameter γ is based on the cost of achieving a reduction of the marginal cost of 10%. The resulting investment in innovation (k) for the values of γ considered are the following (Table 3):

Table 3: Values of parameter γ considered for each historical operator

Country	cI(k) / cI0	gamma	k (million Euros)
LV	0.9	2.5E-07	421
PT	0.9	1.0E-08	10.536
SE	0.9	2.5E-09	42.144
FR	0.9	5.0E-10	210.721

Figure 2, Figure 3, Figure 4, and Figure 5 depict the relationship between the investment in new processes and technologies and the cost reduction obtained for $\gamma = 2.5E - 07$, $\gamma = 1.0E - 08$, $\gamma = 2.5E - 09$, and $\gamma = 5.0E - 10$, respectively, which are the values of γ chosen to calibrate the model. A sensitivity analysis for this parameter will be performed in section 4.3.6.

---

[14] We assume that the size of the operator is proxied by the letter volume handled by the operator.
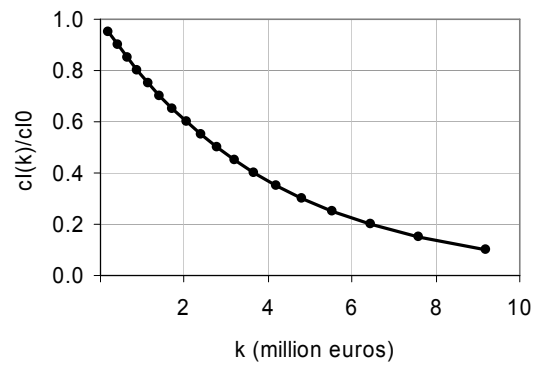
Figure 2: Relationship between the investment in new processes and technologies and the cost reduction obtained for Latvia ($\gamma = 2.5E - 07$)
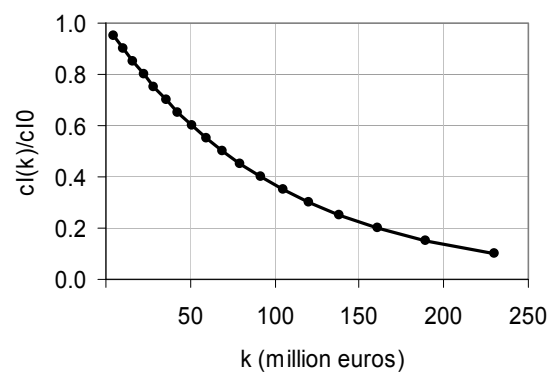
Figure 3: Relationship between the investment in new processes and technologies and the cost reduction obtained for Portugal ($\gamma = 1.0E - 08$)
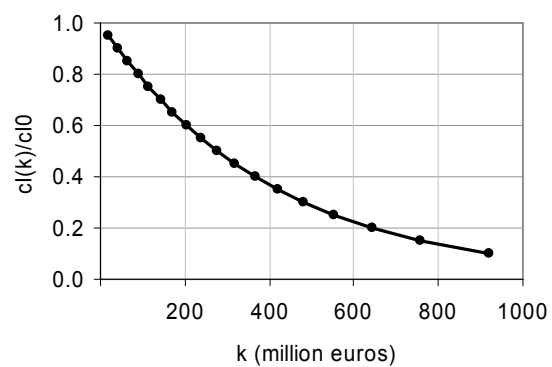
Figure 4: Relationship between the investment in new processes and technologies and the cost reduction obtained for Sweden ($\gamma = 2.5E - 09$)
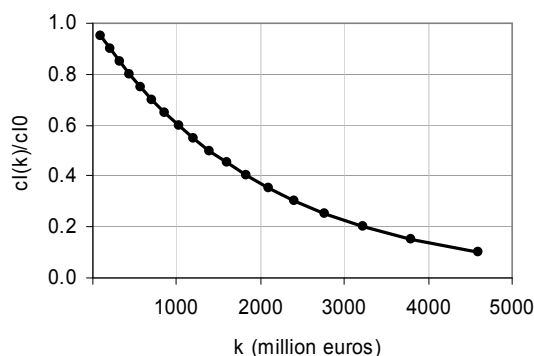
Figure 5: Relationship between the investment in new processes and technologies and the cost reduction obtained for France ($\gamma = 5.0E - 10$)

The results of the model, using the calibration just described, are presented and discussed in the next section.

4.3 Results

This section presents the results of a number of computational experiments for the model.

Only the results for France are presented here. However, reference is always made to the similarities and differences between the results of France and those of Latvia, Portugal, and Sweden. The tables and figures corresponding to these three countries can be found in Annexes 2 , 3 , and 4, respectively.

Although the model was calibrated with data from the postal sector, the results can in general be extrapolated to other industries, namely to other network industries.

Firstly, we present the general results of the model for the calibration values (section 4.3.1). After, the influence of competition on the incentives to innovate is analysed (section 4.3.2). We then focus on the individual effect that the incumbent's price elasticity of demand (under monopoly and duopoly), the entrant's price elasticity, and the cross elasticity of demand have on the incentives to innovate (section 4.3.3). The combined effect of the incumbent's market share

and elasticity of demand on innovation is studied in section 4.3.4. Then the role of the different objectives of the incumbent on the incentives to innovate is investigated (section 4.3.5). Finally, the robustness of the results is tested for changes in the degree of product/service differentiation (e) and the elasticity of innovation cost (γ) (section 4.3.6).

4.3.1 General results for the calibration values

Table 4 shows the main results of the model for the calibration values presented in the previous section, namely:

- *elastIM* equal to -0.4

- *elastID* equal to -0.5

- *elastE* equal to -0.6

- *crosselast* equal to 0.1

- degree of substitution (e) equal to 0.8

- elasticity of innovation cost (γ) equal to 5E-10

- incumbent's market share equal to 80%

The first column of Table 4 ($\alpha_1 = 1, \alpha_2 = 0, \alpha_3 = 0, \lambda \geq 0$) corresponds to maximising revenue subject to the breakeven constraint. The second column ($\alpha_1 = 0, \alpha_2 = 1, \alpha_3 = 0, \lambda = 0$) refers to the profit maximisation case. Finally, the third column ($\alpha_1 = 0, \alpha_2 = 0, \alpha_3 = 1, \lambda \geq 0$) regards the profit-constrained welfare maximising case or Ramsey case.

Table 4: Results for France (I)

		1	0	0
alpha1		1	0	0
alpha2		0	1	0
alpha3		0	0	1
lambda		≥ 0	$= 0$	≥ 0
Monopoly				
average price		0.80	0.86	0.23
quantity		18'040	16'684	30'940
welfare		15'633	14'667	21'165
consumer surplus		7'195	6'154	21'165
profit		8'438	8'513	0
k		775	619	1'854
Duopoly				
average price	I	0.63	0.70	0.59
	E	0.64	0.67	0.62
quantity	I	17'483	15'731	18'518
	E	4'066	4'295	3'930
welfare		15'331	14'486	15'589
consumer surplus		10'548	9'268	11'359
profit	I	5'198	5'402	4'777
	E	-416	-184	-547
k		612	400	0
k duopoly - k monopoly		-164	-219	-1'854

Units: prices are in euros, quantities are in millions of items and the remaining variables are in millions of euros.

Firstly, it is interesting to note that for the calibration values the investment in process innovations is always larger under monopoly than under duopoly, independently of the weight given to revenue, profit, and welfare.

However, when the objective is either revenue or profit maximisation, prices are higher, while the quantity supplied is smaller under monopoly than under duopoly. When the objective is welfare maximisation, the quantity supplied is higher, with prices being smaller under monopoly than under duopoly. Welfare is always higher under monopoly than under duopoly.

4.3.2 The effect of competition on innovation

The market share of the incumbent has a non-linear influence on innovation under duopoly (Figure 6). Until a certain point, the effect of the incumbent's market share on the incentive to innovate is positive, and from that point on it is negative.

When the market share of the incumbent is sufficiently small, the net effect of competition on cost efficiency, and therefore on the incentives to process innovation, is also small. This is because competition does not reduce operating costs sufficiently to offset the higher fixed costs of operation. Competition may force firms to minimise cost for a given output, but each firm produces less output, fails to achieve minimum efficient scale, and suffers excess unit cost (Kwoka, 2006).

The incentives to innovate strongly depend on the quantity supplied by the firm. The result that with a larger mail volume the gains from reducing the unit delivery cost by a given amount are larger, was also found by Gautier and Bloch (2008).

When the incumbent preserves a certain market share, competition has a stronger positive effect on cost efficiency.

After a certain value of the incumbent's market share, once the pressure of competition is very low, the investment in innovation decreases as the market share of the incumbent increases.

These results also apply to Latvia, Portugal, and Sweden.
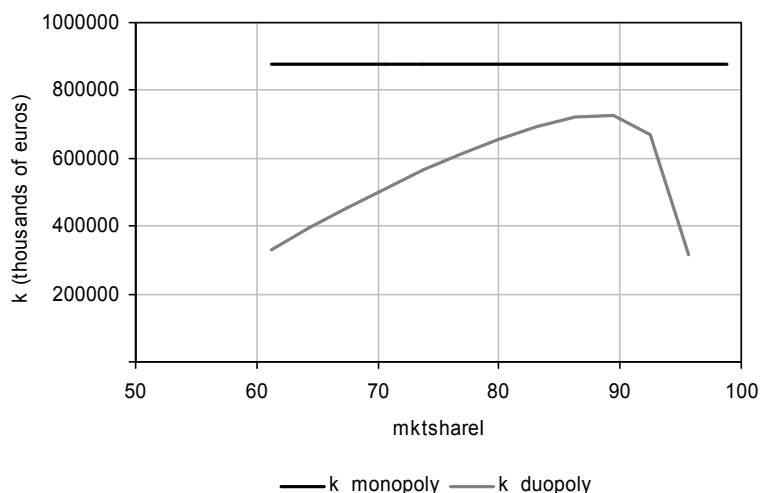
Figure 6: Effect of the incumbent's market share on k (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =5E-10, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)

From Figure 6 one can anticipate that if a change in the parameters' values makes the curve of investment in innovation under duopoly shift upwards, then there will be an interval where the incentives to innovate under duopoly are larger than under monopoly. In this case, the incumbent's market share under duopoly will be relevant to determine which market structure creates more incentives to innovate.

4.3.3 The effect of the various elasticities of demand on innovation

In this part we analyse the individual effect that the elasticity of demand of the incumbent under monopoly and duopoly, the elasticity of demand of the entrant, and the cross elasticity of demand have on the incentive to innovate. We perform several simple sensitivity analyses where only one parameter changes at a time. In the next section we present a more complex analysis where each elasticity of demand assumes two or more values that are combined in all possible ways (more than one elasticity of demand changing simultaneously).

Figure 7 shows that the investment in innovation under monopoly has a negative relationship with *elastIM* (the larger the value of *elastIM*, the smaller the *k* under monopoly). We can also see that the value of *elastIM* also determines which of the

market structures creates more incentive to innovate. The turning point corresponds to *elastIM* close to -0.2. The same results are obtained for Latvia, Portugal, and Sweden including the value of the turning point, which is approximately the same.
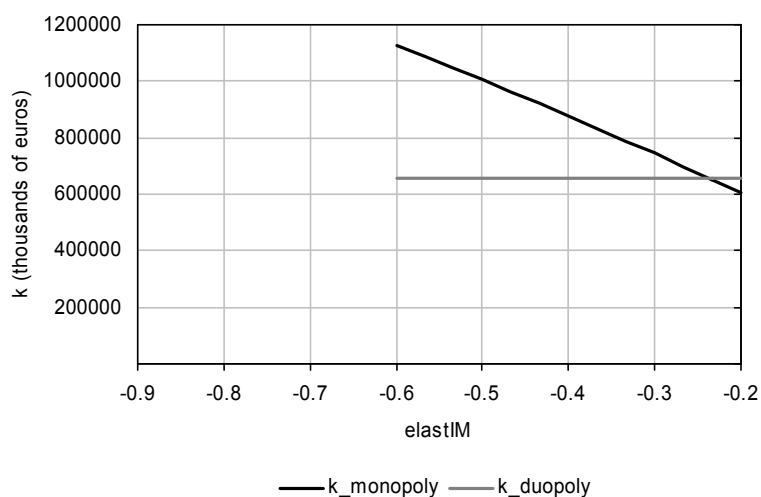
Figure 7: Sensitivity analysis for elastIM (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =5E-10, mktshareI=80%, elastID=-0.5, elastE=-0.6, crosselast=0.1)

In a similar way, an increase in the elasticity of demand of the incumbent under duopoly leads to a decrease in the incentives to innovate under duopoly (Figure 8). Again, if the other parameters are held constant, there is a region where duopoly creates more incentives to innovate than monopoly, and another region where the contrary happens.
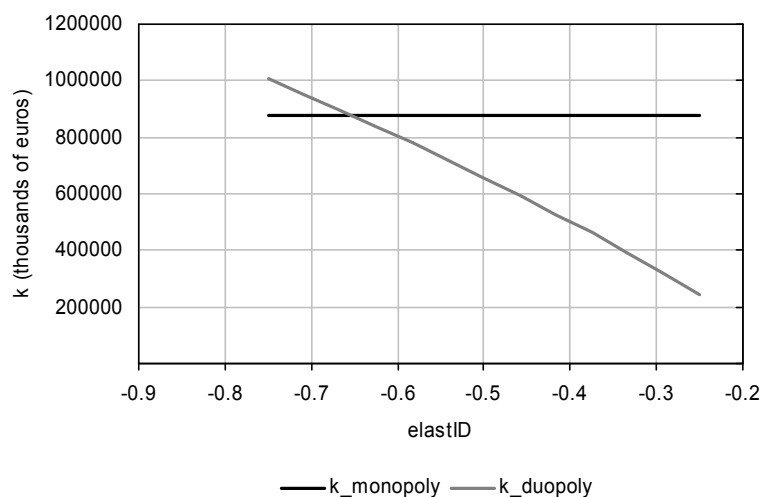
Figure 8: Sensitivity analysis for elastID (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=5E-10, mktshareI=80%, elastIM=-0.4, elastE=-0.6, crosselast=0.1)

As we can observe in Figure 9, changes in *elastE* almost do not affect the incumbent's investment in innovation.
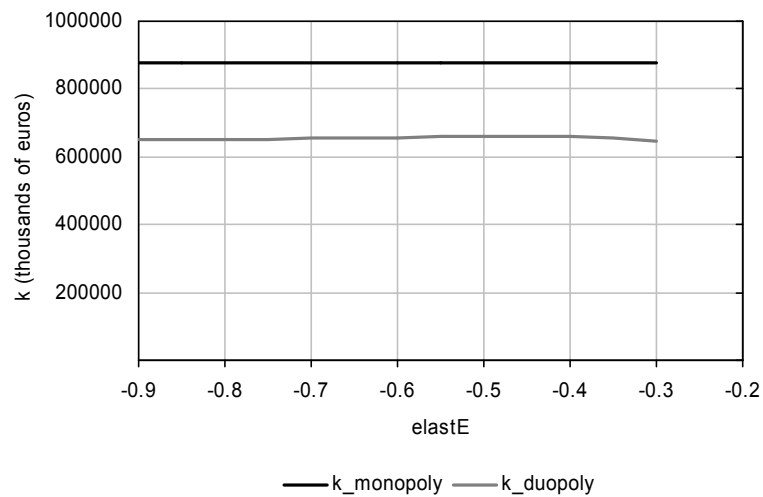
Figure 9: Sensitivity analysis for elastE (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=5E-10, mktshareI=80%, elastIM=-0.4, elastID=-0.5, crosselast=0.1)

The cross elasticity of demand has a non-linear impact on *k* under duopoly (Figure 10). This parameter does not seem to have an important role in determining which market structure creates more incentives to innovate.
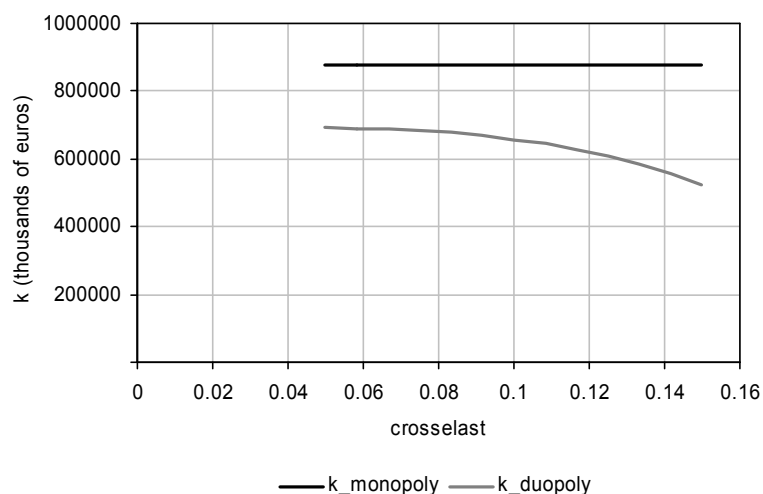
Figure 10: Sensitivity analysis for crosselast (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=5E-10, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6)

The results obtained in this section also apply to Latvia, Portugal, and Sweden and will be further investigated in the analysis that follows.

4.3.4 The combined effect of the various elasticities of demand and of competition on innovation

We now allow the elasticity of demand of the incumbent under monopoly and duopoly, the elasticity of demand of the entrant, and the cross elasticity of demand to vary simultaneously. Since we are only interested in studying the impact of elasticity of demand on innovation, we held the degree of differentiability, the elasticity of innovation cost, the weight given to revenue, to profit, and to welfare constant at 0.9, 6E-10, 0.2, 0.6, and 0.2, respectively. The market share of the incumbent is also held constant, first at 60% (Figure 11) and then at 90% (Figure 12). As we have seen before, the incumbent's market share under duopoly has a significant impact on the incentives to innovate under duopoly. Therefore, it is

important to perform the analysis that follows for a market share that creates few incentives for the incumbent to innovate under duopoly (e.g. 60%) and for a market share close to the one that creates the highest incentives for the incumbent to innovate under duopoly (e.g. 90%). In part 4.3.6, we discuss the results for other values of the degree of differentiability and of the elasticity of innovation cost.

Figure 11 shows that when the incumbent has a market share of 60%, the investment in innovation under duopoly is larger than that under monopoly only if *elastID* is significantly larger than *elastIM*. We can also note that, the point where the investment in innovation is the same under monopoly and under duopoly slightly moves to the right as *crosselast* decreases. As *elastE* decreases, there is almost no change in the intercept of the difference between investment in innovation under monopoly and duopoly with the horizontal axis.

When the incumbent's market share is 90% (Figure 12[15]) and *crosselast* is low, *elastID* does not need to be much larger than *elastIM* in order to obtain more incentives to innovate under duopoly than under monopoly. For larger values of *crosselast*, the difference between *elastID* and *elastIM* needs to be larger in order to obtain that same result. When the incumbent's market share is 90%, there is an accentuated movement of the curves to the right as *crosselast* decreases. This means that investment in innovation under duopoly starts to be larger than that under monopoly at a lower value of *elastID* (in absolute value). As *elastE* decreases, the point where investment under monopoly and duopoly are equal slightly moves to the right.

---

[15] The top-left graph in Figure 12 does not present any points because there were no feasible solutions for the combination of parameters that correspond to this graph.
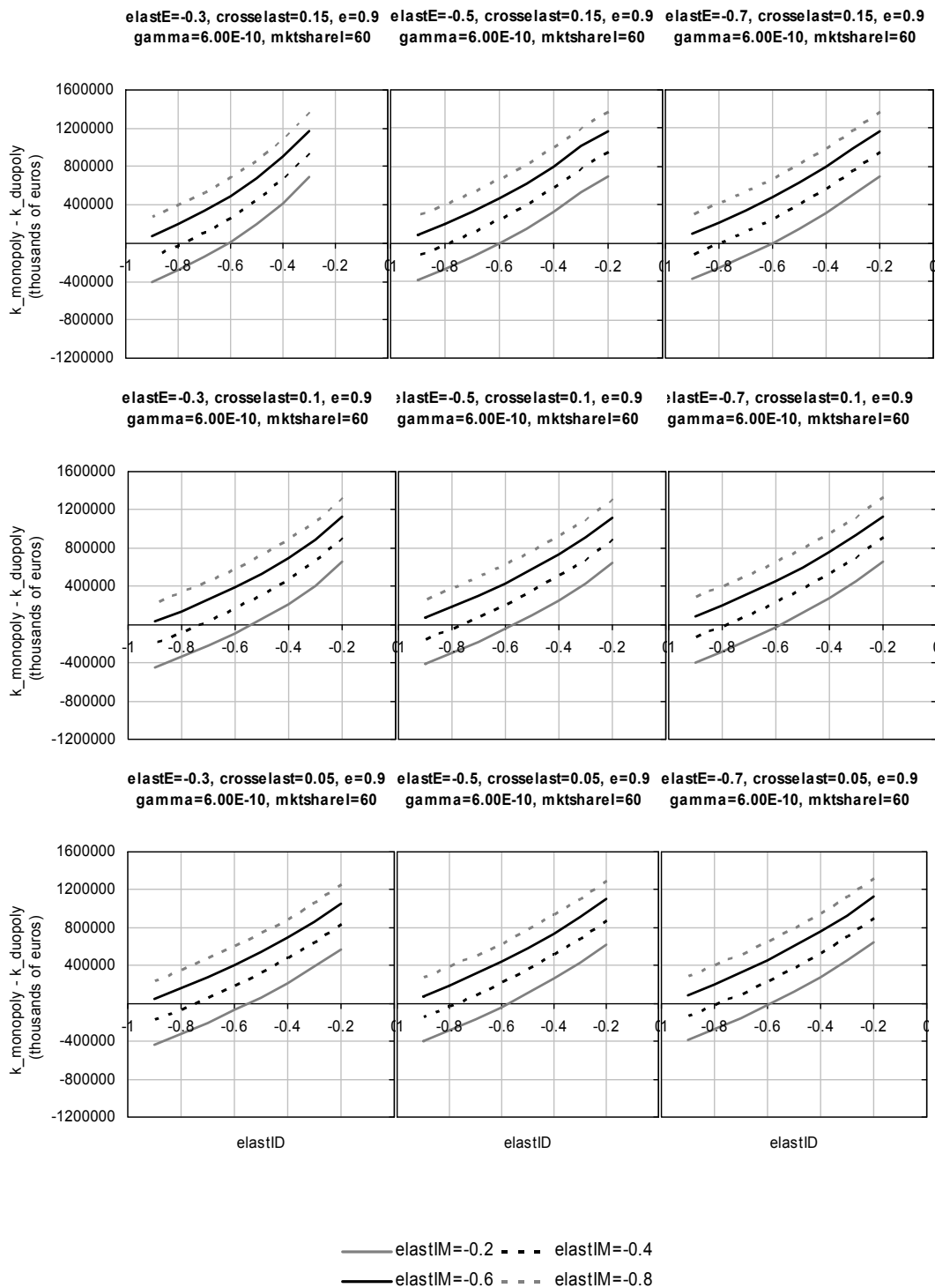
Figure 11: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation ($\alpha_1 = 0.2$, $\alpha_2 = 0.6$, $\alpha_3 = 0.2$, e=0.9, $\gamma = 6E-10$, and mktshareI=60%)
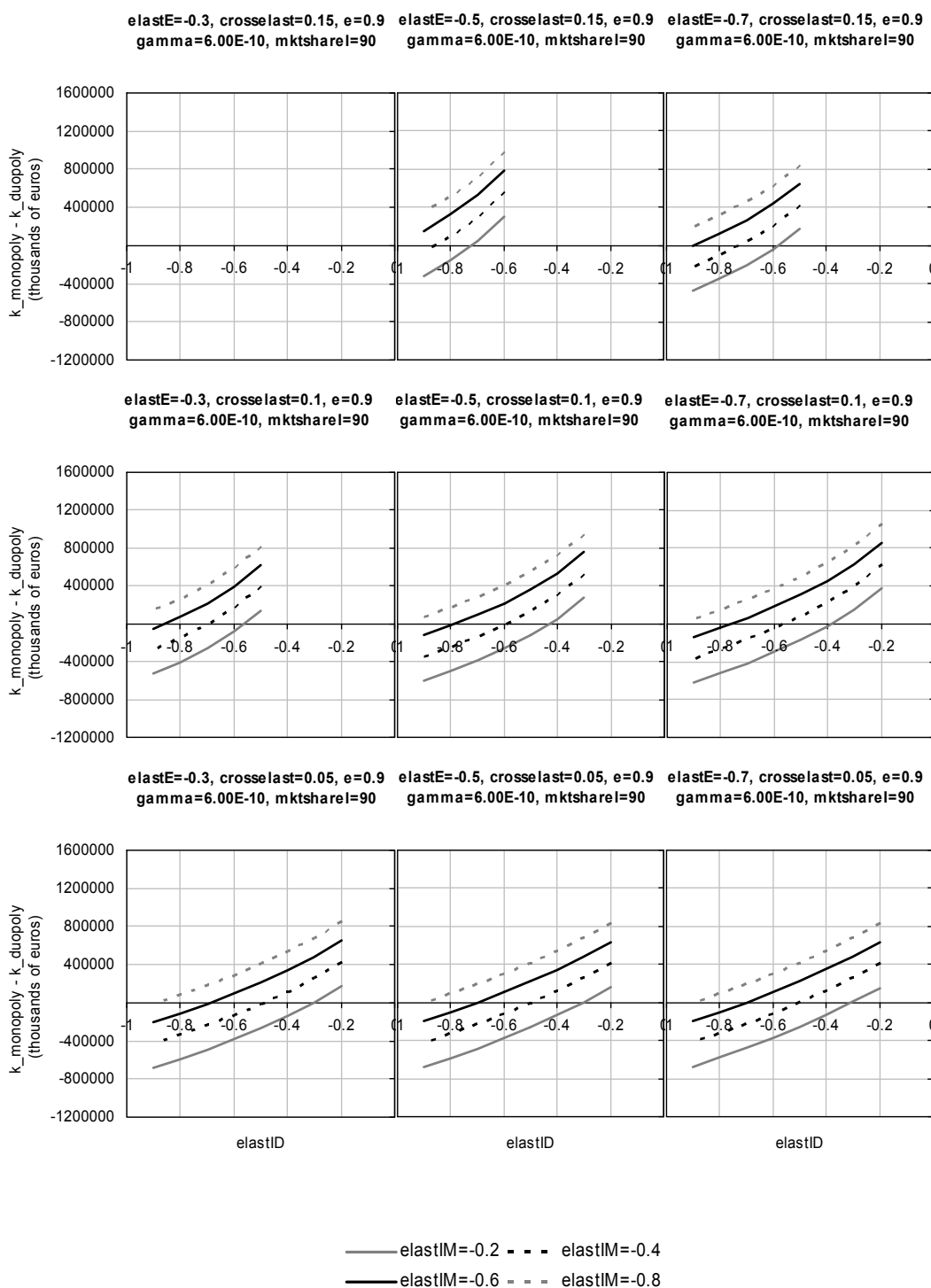
Figure 12: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation ($\alpha_1=0.2$, $\alpha_2=0.6$, $\alpha_3=0.2$, e=0.9, $\gamma=6E$-10, and mktshareI=90%)

In short, the incumbent's market share and the differential between *elastIM* and *elastID* govern the relationship between *k* under monopoly and duopoly. Let us focus on the interval where *k* is larger under duopoly than under monopoly. The smaller *elastIM* is (in absolute value), or the larger (in absolute value) *elastID* is, the wider this interval is (holding the incumbent's market share constant). In other words, the incumbent's market share needed for *k* under duopoly to be larger than *k* under monopoly reduces as *elastIM* gets smaller (in absolute value) and as *elastID* gets larger (in absolute value).

When the market share of the incumbent is 90%, *crosselast* is important to determine which market structure originates larger investment in innovation whereas when the market share of the incumbent is 60%, *crosselast* plays almost no role. The role of *elastE* is always very reduced.

Figure 13 shows the combined effect of the incumbent's market share, *elastIM*, and *elastID* on innovation under monopoly and duopoly (holding α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=5E-10, *elastE*=-0.6, and crosselast=0.1).
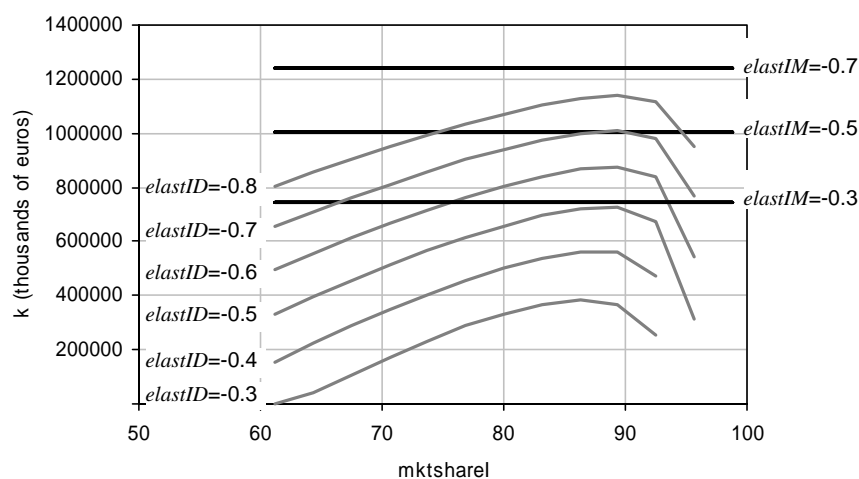
Figure 13: Combined effect of the incumbent's market share, elastIM, and elastID on k under monopoly and duopoly (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=5E-10, elastE=-0.6, and crosselast=0.1)

For certain values of the incumbent's market share and of the incumbent's elasticity of demand under monopoly and duopoly it exists an interval where investment in innovation under duopoly is larger than that under monopoly. The size of this interval depends on the incumbent's market share and elasticities of demand under monopoly and duopoly.

Given this result, it is important to analyse the general results of the model (i.e. redo Table 4) for an incumbent's market share and elasticity of demand under duopoly and monopoly where the incentives to innovate are smaller under monopoly than under duopoly (e.g. incumbent's market share equal to 90%, *elastIM* equal to -0.3, and *elastID* equal to -0.6). The remaining parameters are held constant at the values presented in section 4.2 (i.e. *elastE* equal to -0.6, *crosselast* equal to 0.1, degree of substitution (e) equal to 0.8, elasticity of innovation cost (γ) equal to 5E-10).

Table 5: Results for France (II)

alpha1		1	0	0
alpha2		0	1	0
alpha3		0	0	1
lambda		≥ 0	$= 0$	≥ 0
Monopoly				
average price		0.99	1.05	0.23
quantity		16'751	15'668	29'516
welfare		19'012	18'041	25'681
consumer surplus		8'272	7'237	25'681
profit		10'740	10'804	0
k		627	493	1'760
Duopoly				
average price	I	0.62	0.69	0.60
	E	0.71	0.76	0.69
quantity	I	20'032	18'267	20'647
	E	2'257	2'464	2'185
welfare		19'939	19'084	19'891
consumer surplus		14'811	13'439	15'306
profit	I	6'279	6'553	5'815
	E	-1'151	-908	-1'230
k		807	623	0
k duopoly - k monopoly		180	129	-1'760

Units: prices are in euros, quantities are in millions of items and the remaining variables are in millions of euros.

Here, the difference between the investment in process innovation under monopoly and under duopoly depends on the weight of welfare. When the objective of the firm is revenue or profit maximisation, investment in innovation under duopoly is larger than under monopoly.

The price and the profit of the incumbent are larger under monopoly than under duopoly, except when the objective is welfare maximisation (i.e $\alpha_3 = 1$). The contrary happens with the quantity supplied and welfare.

All the results presented in this section also apply to Latvia, Portugal, and Sweden[16].

4.3.5 The role of revenue, profit and welfare maximisation

In this part, we investigate how changes in the weight given to revenue (α_1), profit (α_2), and welfare (α_3) affect the investment in innovation. This analysis is made for several combinations of the remaining parameters of the model. We fix *elastE* at -0.6 and *crosselast* at 0.1 because, as we have seen in section 4.3.3, these two parameters *per se* do not play an important role in determining which market structure creates more incentives to innovate. The other parameters can assume two extreme values:

- *elastIM* is equal to -0.3 or to -0.7

- *elastID* is equal to -0.4 or to -0.8

- *e* is equal to 0.6 or to 0.9

- γ is equal to 4E-10 or to 6E-10.

All the possible combinations of these values originate sixteen graphs for each market share of the incumbent, which also assumes two different values: 60% (Figure 14) and 90% (Figure 15).

Each graph in Figure 14 and Figure 15 depicts the evolution of investment in innovation according to changes in the alphas (holding other parameters constants). α_1 is fixed along each line in the graph but it changes across lines. α_3 is equal to α_1 and α_2 subtracted from one ($\alpha_3 = 1 - \alpha_1 - \alpha_2$).

---

[16] The only difference is that in the case of Portugal, as crosselast and elastE decrease there are a series of points that are not feasible and, therefore, are not represented (Annex 3, Figure 70). A point is not feasible either because it does not satisfy condition (3) or condition (20).
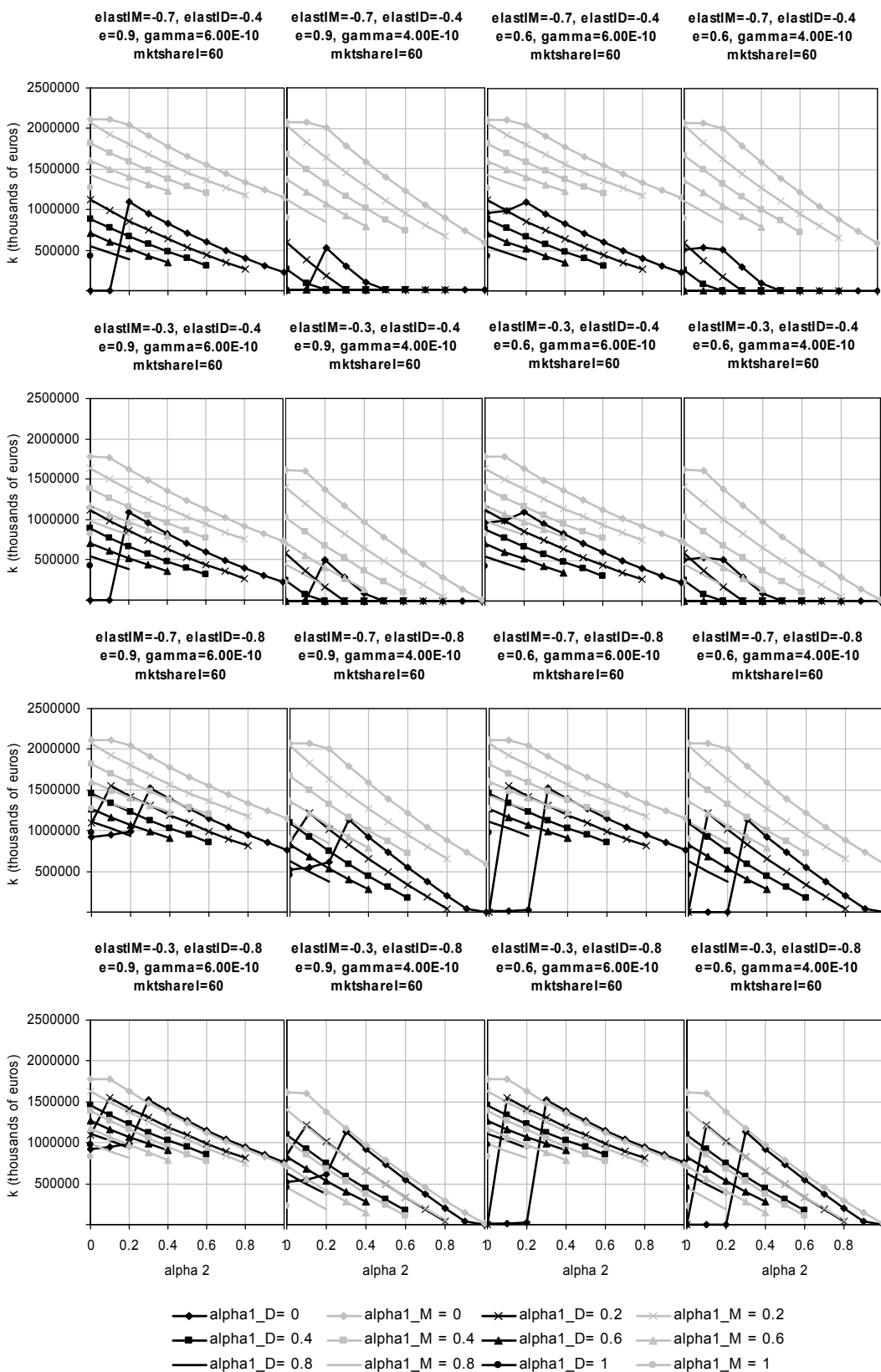
Figure 14: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=60%)
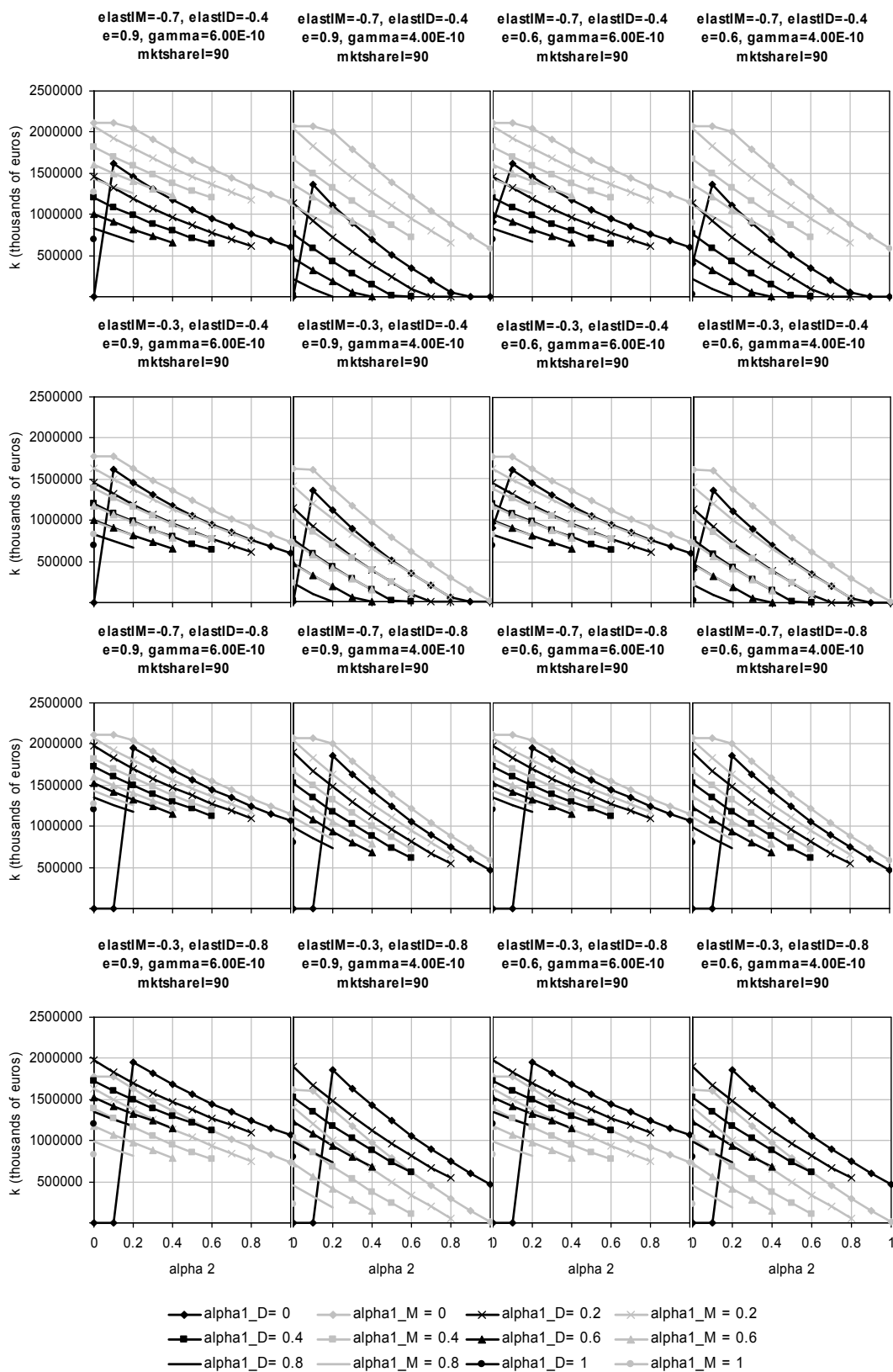
Figure 15: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=90%)

Figure 14 and Figure 15 show that as α_2 increases, holding α_1 constant, the incentives to innovate decrease. An increase in α_1, for α_2 constant, also originates a decrease in k. Moreover, the larger the sum of α_1 and α_2 relatively to α_3 is, the smaller the investment in innovation under both monopoly and duopoly is. An increase in the weight associated with welfare (α_3), holding α_1 constant, stimulates innovation up to the point where the incumbent's profit reaches zero. This conclusion is independent of the market share of the incumbent.

This means that regulation which motivates the incumbent to place greater weight on welfare maximisation favours innovation.

When the market share of the incumbent is 60% (Figure 14), there is more stimulus to innovate under monopoly than under duopoly in almost all the scenarios. The only case where the investment in innovation under duopoly is very close to, or slightly larger than, the investment made under monopoly is when *elastIM* is -0.3 and *elastID* is -0.8, i.e. when *elastIM* is very small compared to *elastID*.

When the incumbent's market share is equal to 90% (Figure 15) the relationship between investment in innovation under monopoly and duopoly clearly depends on the differential between *elastIM* and *elastID*. When *elastIM*=-0.7 and *elastID*=-0.4, *elastIM*=-0.3 and *elastID*=-0.4, and *elastIM*=-0.7 and *elastID*=-0.8 the incentive to innovate under monopoly is larger than under duopoly. When *elastIM*=-0.3 and *elastID*=-0.8, the incentive to innovate under monopoly is smaller than under duopoly[17]. The fact that the difference between the incentives to innovate under monopoly and duopoly is larger for the combination *elastIM*=-0.3 and *elastID*=-0.4 than for the combination *elastIM*=-0.7 and *elastID*=-0.8

---

[17] In some cases, for this result to be verified, we also have to impose that the weight given to revenue (α_1) and to profit (α_2) are not both very small, i.e. zero or 0.2.

indicates that it is not only the differential between *elastIM* and *elastID* that matters but also the level of *elastID*.

The lowest level of investment is registered when the incumbent is exclusively concerned with profit maximisation. Contrarily to what could be expected, a larger level of investment is registered under the revenue maximisation case (α_1=1) than under the profit maximisation case (α_2=1). This happens because when the incumbent maximises revenue it does not take into account the cost of innovation, which is what prevents the incumbent from investing more when the objective is profit maximisation. Also, more innovation results in smaller marginal costs and, consequently, in a price decrease in order to increase the quantity supplied. The price decreases up to the point where the product of the quantity supplied and the price is maximised.

The same results are obtained for Latvia, Portugal and Sweden.

4.3.6 Sensitivity analysis for the degree of differentiability (e) and elasticity of innovation cost (γ)

From the analyses performed earlier, the degree of differentiability and the elasticity of innovation cost do not seem to be relevant to determine which market structure is more favourable to innovation. In order to verify this preliminary result, we will investigate in detail the role these two parameters play in the investment in innovation. We start by examining the impact of a change in e and γ holding other parameters constant at the values defined in section 4.2.

According to Figure 16 the degree of differentiability does not have any impact on the investment to innovate for the values chosen to calibrate the model, which confirms previous results. The same applies to Latvia, Portugal, and Sweden.
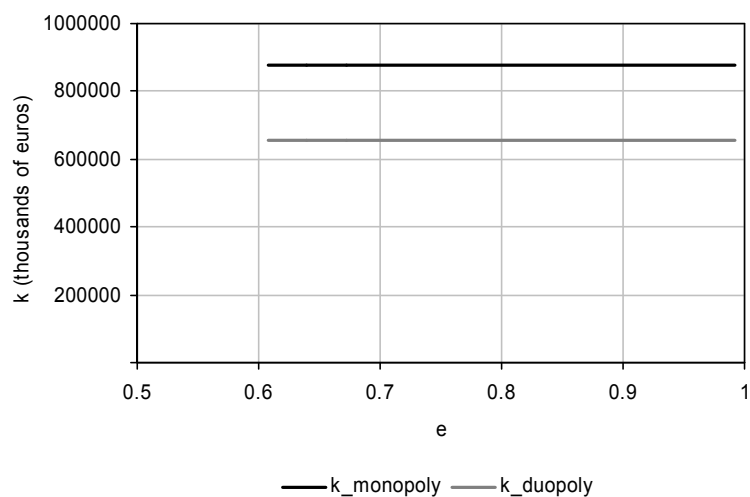
Figure 16: Sensitivity analysis for e (α_1=0.2, α_2=0.6, α_3=0.2, γ=5E-10, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)

The elasticity of innovation cost (Figure 17) has a positive effect on the incentives to innovate, i.e. the incentives to innovate increase as γ increases. This effect is nonlinear. For all the values of γ analysed, *k* under monopoly is always larger than under duopoly. However, the difference between these two variables reduces as γ increases. The same result is obtained for Latvia, Portugal, and Sweden.
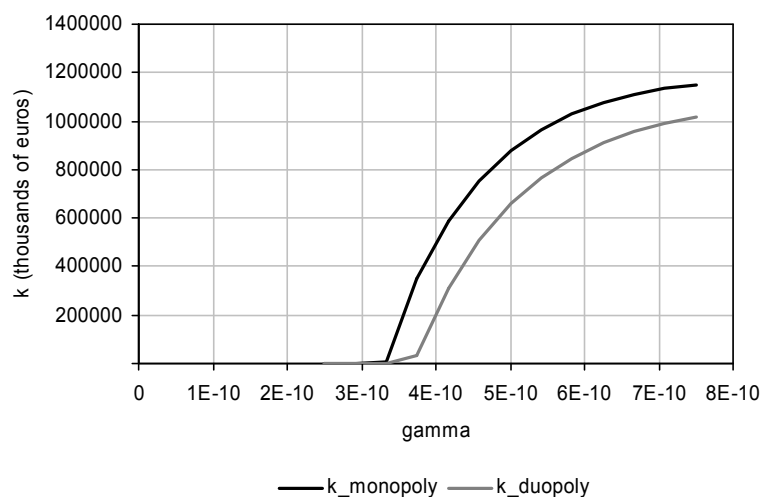
Figure 17: Sensitivity analysis for γ (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)

Next, we present a series of experiments where we test whether the results just described still hold true for other combinations of values of the remaining parameters.

We have previously presented results for γ=6E-10, e=0.9, *mktshareI*=60% (Figure 11, page 87) and *mktshareI*=90% (Figure 12, page 88) (for different values of *elastIM*, *elastID*, *elastE*, and *crosselast* holding α_1=0.2, α_2=0.6, and α_3=0.2). Now, we present the results for γ=4E-10 (Figure 18 and Figure 19).

By comparing Figure 11 and Figure 12 with Figure 18 and Figure 19, respectively, we can analyse the effect of a change in γ on the investment in innovation for different values of *elastIM*, *elastID*, *elastE*, and *crosselast* holding α_1=0.2, α_2=0.6, α_3=0.2, and e=0.9.
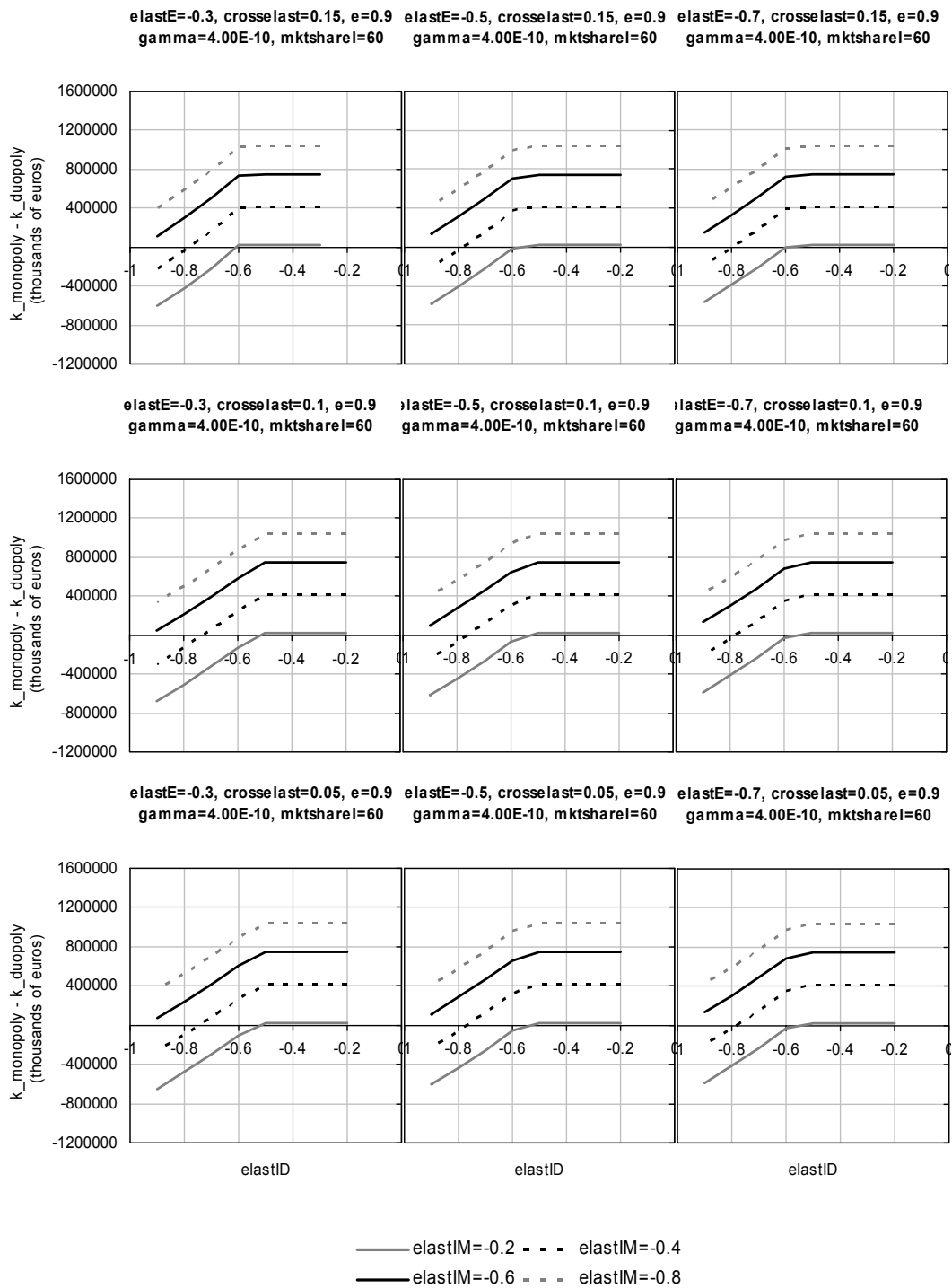
Figure 18: Results for e=0.9, γ =4E-10 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
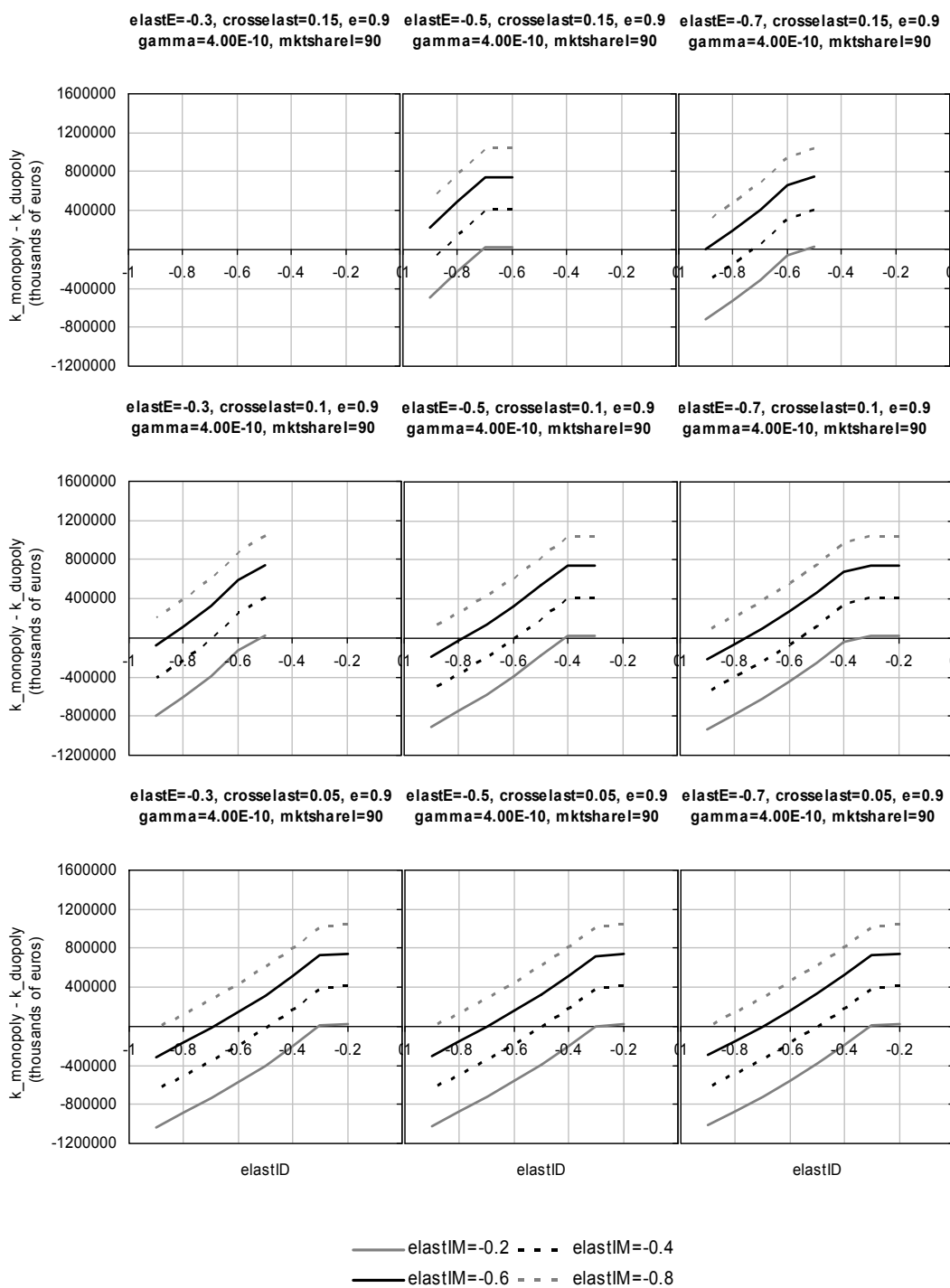
Figure 19: Results for e=0.9, γ =4E-10 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

The results in Figure 11 and Figure 18 are similar with the exception that with γ=4E-10 the difference between k under monopoly and under duopoly remains constant when *elastID* is larger than -0.5 (approximately). Also, from Figure 12 to Figure 19 there are no considerable changes. The results for Latvia, Portugal, and Sweden are very similar to those of France.

The same sets of graphs were constructed for *e*=0.6 and no change in the results was observed relatively to the graphs were *e*=0.9 (see Annex 1).

In conclusion, the main results of the model are robust to changes in the elasticity of innovation cost and to changes in the degree of service differentiation.

4.4 Concluding remarks

The model presented in this chapter investigates the incumbent's optimal investment in innovation under monopoly and under duopoly.

The results show that the difference between investment in innovation under monopoly and under duopoly is determined by the incumbent's market share, as well as by the incumbent's elasticity of demand under monopoly and under duopoly.

The incumbent's market share has a non-linear impact on innovation under duopoly. Until a certain point an increase in the incumbent's market share creates more incentives to innovate under duopoly and from that point on the contrary happens. Once the pressure of competition is very low (incumbent's market share is very large) the investment in innovation decreases as the market share of the incumbent increases.

The elasticity of demand of the incumbent has a negative impact on the level of investment in innovation both under monopoly and duopoly. As for the elasticity of demand of the entrant, it has almost no impact on the incentives to innovate under duopoly, while the cross elasticity of demand has a reduced impact.

For certain values of the incumbent's market share and elasticities of demand under monopoly and duopoly, there exists an interval where investment in innovation under duopoly is larger than that under monopoly (except when

welfare maximisation is the sole objective or has a sufficiently high weight in the incumbent's objective function). The size of this interval depends upon the incumbent's market share and elasticities of demand under monopoly and duopoly.

The market share where investment in innovation under monopoly is equal to investment under duopoly depends on the elasticity of demand of the incumbent in both situations. The smaller (in absolute value) *elastIM* is, or the larger (in absolute value) *elastID* is, the widest is the interval where *k* under duopoly is larger than *k* under monopoly. The incumbent's market share needed for *k* under duopoly to be larger than *k* under monopoly decreases as *elastIM* gets smaller (in absolute value) and as *elastID* gets larger (in absolute value).

Even in the cases where levels of investment in innovation are higher under monopoly, there is a price to pay in the form of the usual deadweight losses of monopoly. The extent of these losses will depend upon the incumbent's "commercial orientation", i.e. on its objective function.

It was also proven that the incentives to innovate decrease as the weight given to revenue and/or to profit increases. In other words, the more regulation can push the incumbent to act as a welfare maximiser, the larger the investment in innovation is. This conclusion is independent of the market share of the incumbent. The more sensible way to induce the incumbent to behave like a welfare-maximising firm, at least with respect to cost-reducing innovations, is through price cap regulation.

Although the results were derived from the model calibration for a specific sector, the postal sector, the model development is generic, and the conclusions above apply to the network industries with similar characteristics.

5. Empirical analysis – The case of the postal sector

This chapter presents an empirical analysis of the impact of liberalisation and competition on incumbents' innovation. The predictions from Chapter 3 and the results from the theoretical model developed in Chapter 4 are tested here for a particular network industry: the postal sector.

As discussed in Chapter 3, section 3.3, there are two models of competition in the postal sector: end-to-end competition and competition with access to the incumbent's network. Access to the incumbent's network can be of two types (according to the stage at which access occurs): worksharing or upstream access, and downstream access.

The effects of liberalisation and end-to-end competition on the incumbent's innovation are analysed through an econometric analysis (section 5.1), which does not take access into account.

In order to perform the econometric analysis, we collected data on liberalisation and competition in the postal sector, and on innovation performed by the postal incumbents. Additionally, we collected data on the following control variables: quantity supplied, average number of employees, percentage of public ownership of the incumbents, population density, and Gross Domestic Product (GDP) *per capita* in the countries being studied. The dataset used for the econometric analysis includes seventeen member countries of the European Union (EU), over ten years.

An index of liberalisation was built in order to measure the degree of liberalisation. The index is an approximation of the percentage of letter mail volume liberalised (includes correspondence and inbound cross border mail, direct mail and outbound cross border mail). This approximation is based on the reserved area weight limit.

The degree of end-to-end competition in the market is measured through the market share of the entrants.

Regarding innovation, seventeen critical innovations were identified and the postal operators were surveyed, about their date of introduction. Based on this information, an innovation index and the accumulated number of innovations were computed. Additionally, a measure of productivity was also computed. Several models were estimated using the three innovation proxies and the results were compared.

The effects of worksharing and downstream access on incumbents' innovation are analysed separately through three case studies (section 5.2) due to the lack of quantitative data available on the volumes of worksharing and downstream access. The countries analysed in the case studies are France (FR), the United Kingdom (UK) and the United States of America (USA).

5.1 Evidence on the impact of liberalisation and end-to-end competition on incumbents' innovation

The impact of liberalisation and end-to-end competition on innovation in the postal sector is empirically analysed in this section. In particular, we test the results obtained in Chapters 3 and 4.

The structure of this section is as follows. Firstly, the hypotheses being tested are presented. Then, the data used is described and analysed in detail. It follows the presentation of the model and of the estimation procedures. Finally, the results are discussed.

5.1.1 Hypotheses

The hypotheses being tested in this section, which follow from Chapters 3 and 4, are the following:

Hypothesis 1: Liberalisation in the postal sector has stimulated operators to be more efficient and therefore, more innovative (Chapter 3).

Hypothesis 2: When the incumbents preserve a relatively high market share, competition favours innovation (Chapter 4). Therefore, a positive effect of end-to-

end competition on innovation and efficiency is expected because the incumbents analysed here kept market shares of at least 90%.

Hypothesis 3: A decrease in public ownership is expected to have a negative impact on innovation under the assumption that public ownership is the most likely ownership structure to promote welfare maximisation. In fact, the theoretical model (Chapter 4) predicts a positive effect of welfare maximisation on innovation, i.e. the larger the weight given to welfare (and the smaller the weight given to both profit and revenue) in the incumbent's objective function, the larger is the investment in innovation.

Hypothesis 4: The larger the amount of goods and services supplied (letter volume) the more efficient and innovative the operator is (Chapter 4).

5.1.2 Data analysis

The dataset presented here results from the compilation of different sources and from a survey conducted by the author. It constitutes a unique source of information for analysing the liberalisation process, the development of competition, and the development of incumbents' innovation in the postal sector in the last decade.

We collected data to measure the degree of liberalisation and competition in the postal market, and the innovativeness of the incumbents (including the letter mail volume and the average number of employees). Some additional control variables, namely the percentage of capital owned by the state, population density, and GDP *per capita*, were also collected.

All these variables were collected for the period between 1995 and 2005 (some were also collected for 2006), in seventeen European countries and operators:

Table 6: Countries and operators included in sample

Country	Operator
Bulgaria (BG)	Bulgarian Posts plc
Croatia (HR)	Hrvatska pošta d.d.
Estonia (EE)	Eesti Post Ltd
Finland (FI)	Itella Oyj
France (FR)	La Poste
Germany (DE)	Deutsche Post AG
Ireland (IE)	An Post
Italy (IT)	Poste Italiane S.p.A.
Latvia (LV)	Latvijas Pasts
Poland (PL)	Poczta Polska
Portugal (PT)	CTT - Correios de Portugal, S.A.
Romania (RO)	C.N. Posta Romana S.A.
Spain (ES)	Correos y Telégrafos S.A.
Sweden (SE)	Posten AB
Switzerland (CH)	Die Post/La Poste/La Posta
The Netherlands (NL)	TNT Post
United Kingdom (UK)	Royal Mail Group PLC

The data used to build the liberalisation index was collected from the several studies mandated by the European Commission, as well as the regulators' reports, the annual reports of the operators, and the International Post Corporation (IPC) regulatory database (see Annex 5 with list of references). The same sources were used to collect the data on the degree of competition, i.e. market shares.

The data necessary to build the innovation index and the accumulated number of innovations, two of the three measures of innovation used, was collected through a survey (see Annex 6). In that survey, incumbents were asked about the data of introduction of 17 critical innovations identified by the author.

We first analyse the different measures of innovation and the liberalisation index. After, we examine the degree of competition and the remaining variables.

5.1.2.1 Measures of innovation

Three proxies for innovation are used: an innovation index (***inindex***), the accumulated number of innovations (***accuminno***), and labour productivity (***itemperempl***).

The innovation index developed in this thesis aims to measure innovativeness in the postal sector. It corresponds to the average delay or advance, in years, in introducing the critical innovations.

If a certain innovation was already introduced by a country (called the pioneer country) and the country being analysed did not introduce that innovation yet, then the latter will be penalised with the number of years that elapsed from the year the innovation was first introduced until the year in question. On the contrary, if the country being analysed has already introduced a certain innovation, then it is beneficed with the number of years that elapsed from the year that country introduced the innovation until the year in question.

In this way, we computed for each country and each year the number of years the country is, on average, late or advanced in introducing the critical innovations (the same weight was given to all innovations).

The pioneer country is identified among the seventeen countries plus the United States of America[18].

In our sample, the innovation index ranges from -18 until 18, which are the maximum average delay and the maximum average advance a country can have, respectively.

This measure is richer than the simple count of the number of innovations because it takes into account whether the innovation is more or less recent, i.e. it takes into account the year the innovation was first introduced. As explained before, for each year that elapses without the introduction of an innovation, the country is

---

[18] The USA is not included in the econometric analysis because it does not have end-to-end competition. However, the USA was considered when deciding the date of introduction by the pioneering country because, traditionally, the USA has indeed been the pioneer country introducing new technologies and processes.

penalised. Hence, in order to ensure a symmetric treatment of the innovations that were already introduced relative to the ones that were not, a country must benefit for each year that elapses from the introduction of an innovation.

The innovation index and the accumulated number of innovations are based on the date of introduction of the following seventeen critical innovations, supplied by the incumbents through a questionnaire:

- Optimisation of collection routes (using software)

- Hybrid mail

- Digital stamp

- Radio Frequency Identification (RFID) used to identify trucks

- RFID used to identify trolleys

- RFID used to identify trays or bags

- RFID used to monitor the performance of the letter post

- Automated sorting machines using Optical Character Recognition (OCR) that can read whole front side of the letter

- OCR that can read hand-written whole addresses

- OCR that can read hand-written postal codes

- OCR that can read machine written postal codes and whole addresses

- Video coded address reading equipment: online coding

- Video coded address reading equipment: scanning and remote coding (off-line video coding equipment)

- Automated sequence sorting to delivery route

- Automatic tray handling systems

- Automated guided vehicles (AGV)

- Route planning and optimisation software for delivery

These seventeen critical innovations were identified through the literature (Arthur D. Little Limited, 2004, Wik, 2004, Nera, 2004, PricewaterhouseCoopers, 1997),

the annual reports of the operators, and interviews with experts in the postal sector[19]. Firstly, the ensemble of the more significant innovations was listed. Secondly, the more recent innovations and the ones that have more impact on costs and costumers' satisfaction were selected.

Figure 20 shows the evolution of the innovation index for all the countries at study.

---

[19] Mr. Josef Bösch, CEO Postmail, Swiss Post; Mr. Michel Kunz, CEO Logistics, Swiss Post; Mr. Peter Stoop, Responsible Business Technology Center, Swiss Post; Mr. Kenneth Lützelschwab, Responsible REMA project, Swiss Post; Mr. Pedro Saldanha, Business Strategy and Development, CTT Correios de Portugal, S.A.
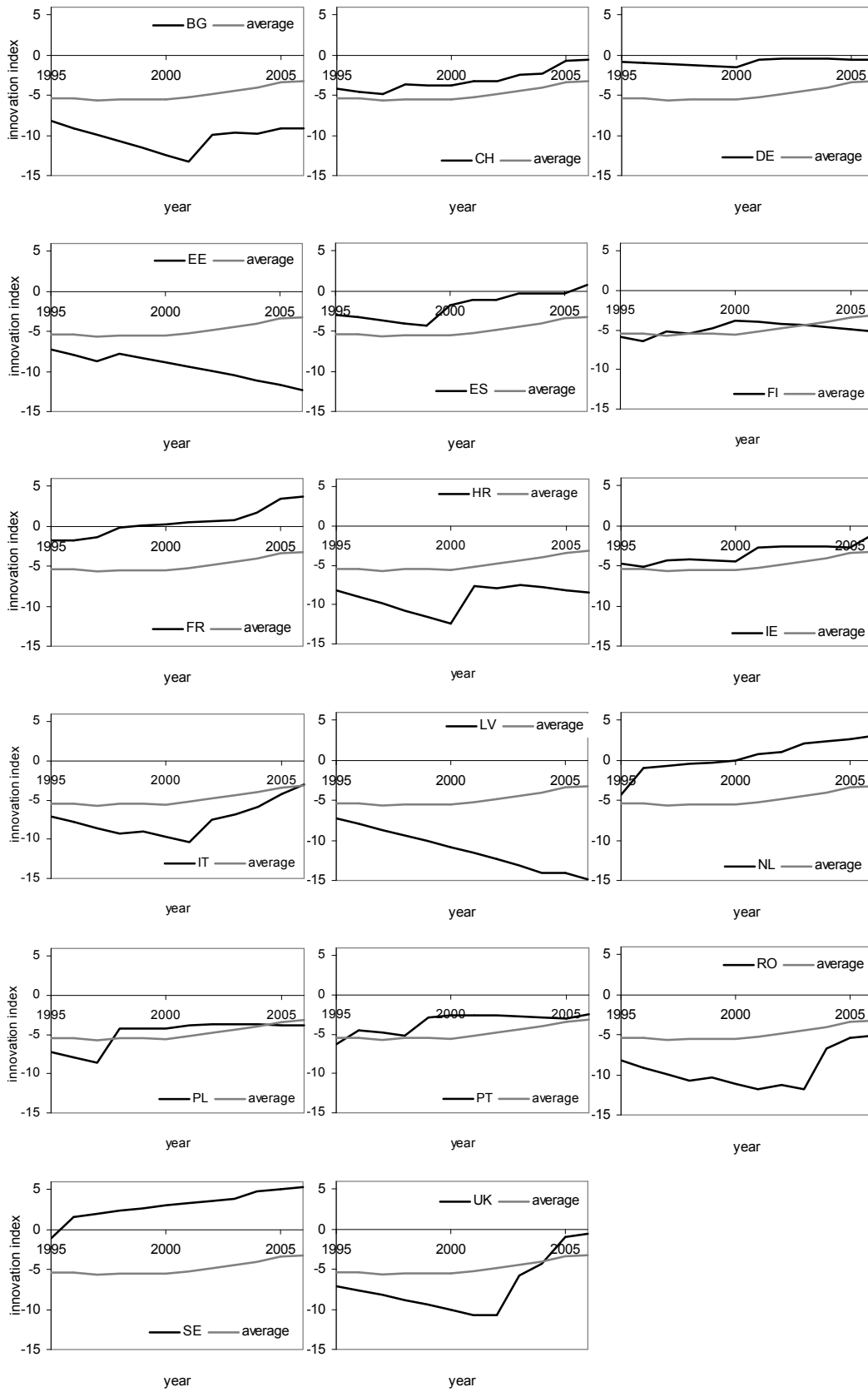
Figure 20: Innovation index

The countries with larger technological delay are Bulgaria, Estonia, Croatia, and Latvia. Italy, Romania, and the United Kingdom used to have an innovation index much lower than the average. However, in 2003 both the United Kingdom and Italy inverted the negative trend and, in 2004, Romania did it too. Today the United Kingdom is above the average, Italy just reached the average and Romania is very close to it.

The innovation delay/advance introducing the critical innovations of the incumbents from Switzerland, Finland, Ireland, Poland, and Portugal have been around the average throughout the period of study.

Spain, Germany, France, The Netherlands, and Sweden have registered an innovation index above the average.

We now analyse the second measure of innovation: the accumulated number of innovations. This variable corresponds to the number of innovations, among the critical innovations, that were implemented until the year in analysis. Figure 21 displays the evolution of the accumulated number of innovations for the seventeen countries. The evolution of this variable is consistent with the evolution of the innovation index.
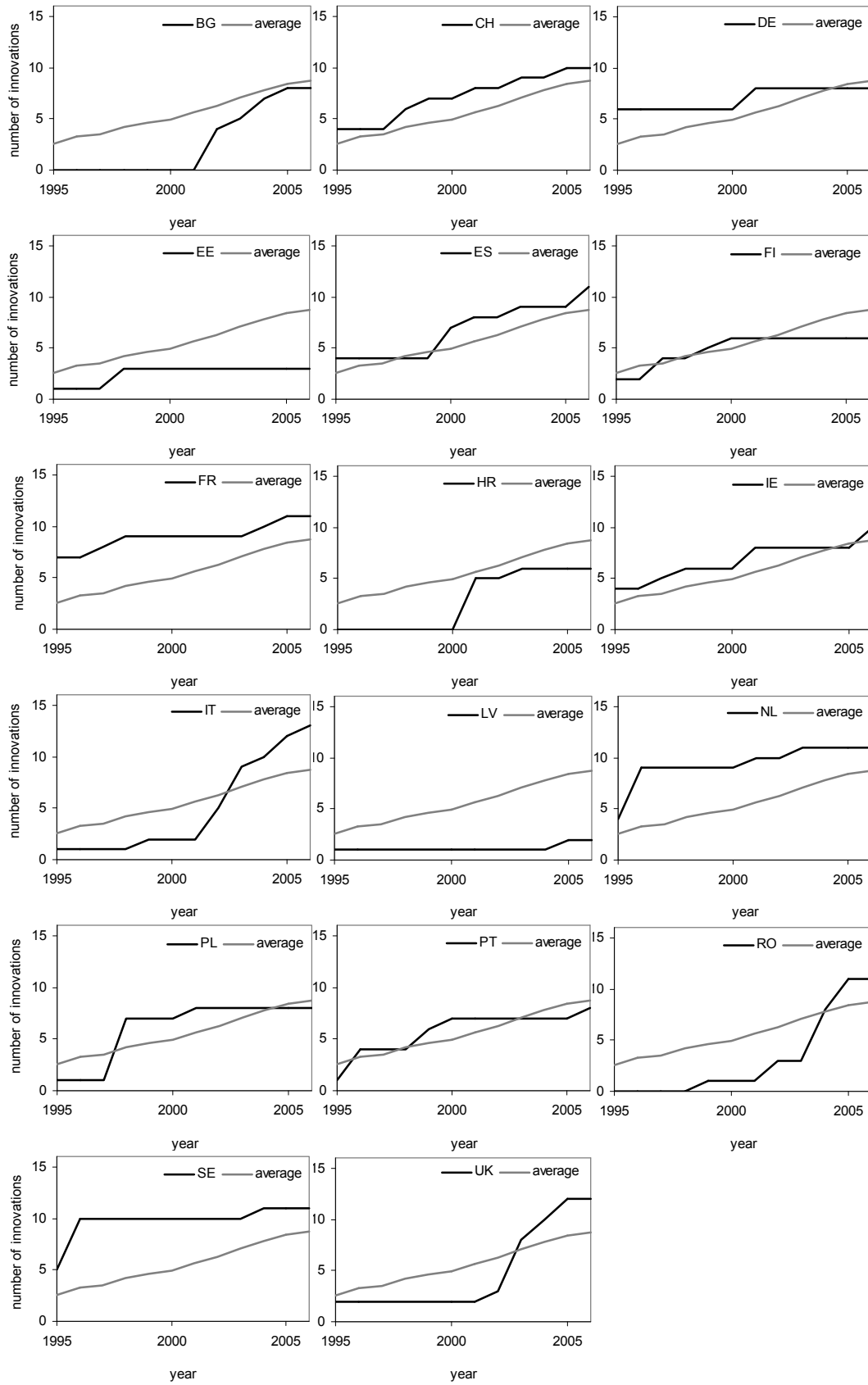
Figure 21: Accumulated number of innovations

Finally, we consider the third measure of innovation: labour productivity. This variable is equal to the letter mail volume (in thousands) divided by the average number of employees.

The data on the volume of letter mail in billions of items (***tvolume***), which includes domestic and international correspondence, registered items, insured letters, newspapers, as well as addressed and unaddressed advertising items, is available through the Universal Postal Union (UPU) database.

Figure 22 shows that there have been some small fluctuations in the volumes yet not significant ones. The impact of electronic substitution on mail volumes has been weaker than predicted by some operators. The expectations are that letter post will become more a means of distribution of direct mail than for exchange of correspondence. The direct mail growth should partially compensate for the loss of correspondence and transaction mail (Wik, 2005).

The French market is the one with the larger letter mail volume, followed by the British and the Deutsch markets. For the remaining countries, the letter mail volumes are below 7 billion items per year, in 2005. France, the United Kingdom and Portugal have experienced growing mail volumes. The total average has also been increasing slightly.
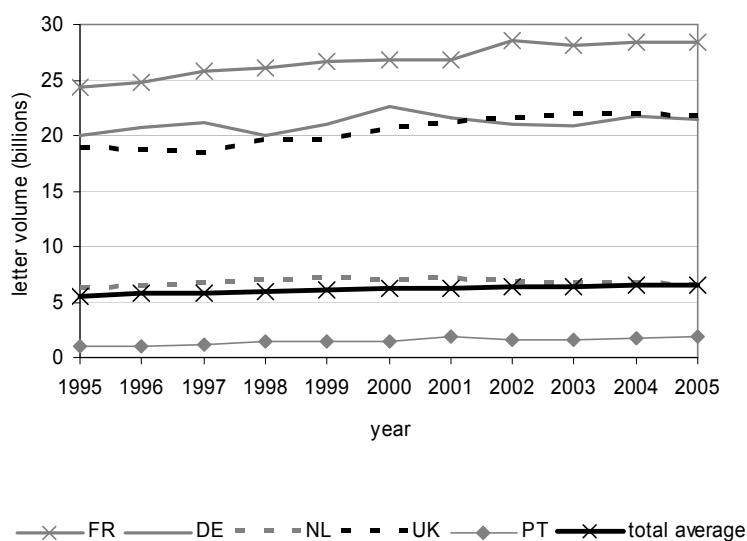
Figure 22: Evolution of letter mail volumes

The average number of employees (includes permanent employees and employees with a term contract) in thousands (***empl***) was also collected from the UPU database except for Latvia Post. The average number of employees of Latvia Post was collected from Amadeus database.

The countries with most employees are Germany, France and the United Kingdom (Figure 23). These three countries are also the ones with larger volumes as observed before. Italy stands out because it has a relatively large number of employees although its letter mail volume is around the average of the countries being studied. The same happens with Poland whose letter mail volumes are approximately half of the average, whereas its number of employees is very close to the average.
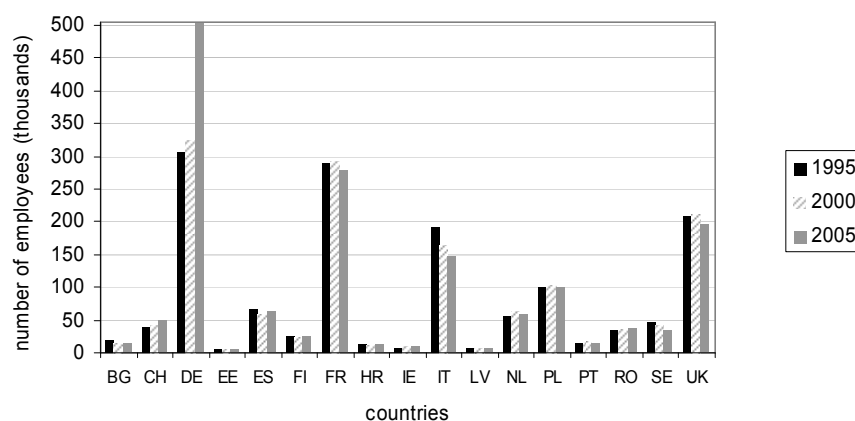
Figure 23: Average number of employees for the years 1995, 2000, and 2005

The average number of employees corresponds to the whole company since there was no data available by segments.

The measure "labour productivity" presents some drawbacks, which are important to keep in mind. Firstly, labour productivity was computed with the total number of employees and not only the employees working in the letter segment. One consequence of this is that a postal operator with a large diversification of products and where financial services, for instance, have a large weight will have a relatively small labour productivity.

Secondly, an increase in mail volume does not trigger a proportional increase in the number of employees because the postal services are characterised by economies of scale and scope. Therefore, comparisons among countries with different mail volumes have to be cautious.

It must also be considered that sometimes firms can not lay-off as soon as there is a decrease in volumes, which may cause a decrease in labour productivity.

The evolution of labour productivity is presented in Figure 24.
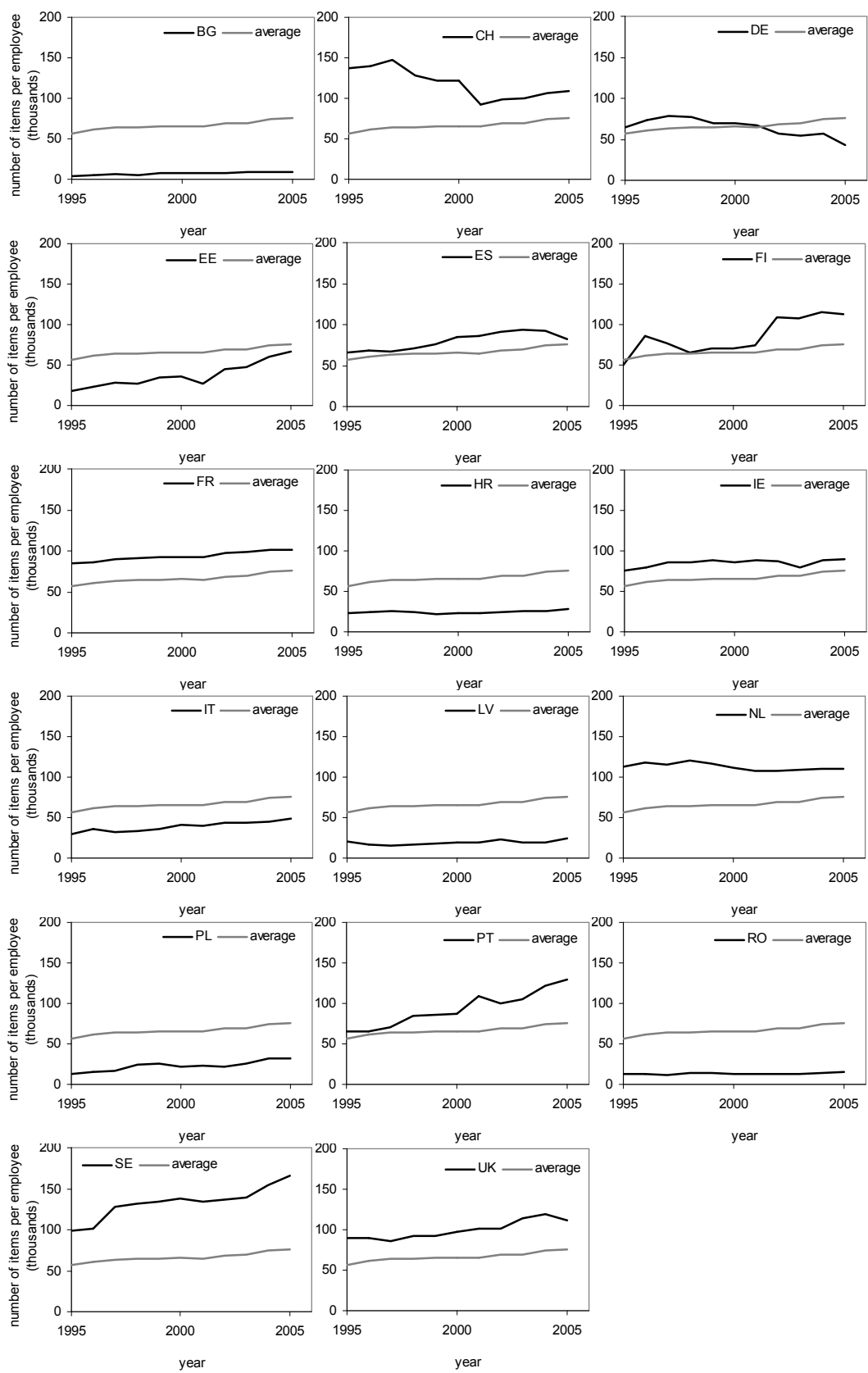
Figure 24: Labour productivity (thousands of items per employee)

Since labour productivity is generated from completely different data than the innovation index, it is interesting to compare both measures.

Bulgaria has a labour productivity below the average, which is consistent with the technological delay introducing the seventeen innovations mentioned before. In the same situation are: Estonia, Croatia, Italy, Latvia, and Romania. In Estonia, however, the innovation index is deviating more and more from the average while labour productivity is approaching the average. In Latvia, the innovation index is also deviating more and more from the average whereas labour productivity remains more or less stable.

The evolution of labour productivity for the French, Dutch, Spanish, Swedish, Finnish, and Irish incumbents is also consistent with the evolution of the innovation index. The French, Dutch, Spanish, and Swedish incumbents have an innovation index above the average and their labour productivity is larger than the average labour productivity. In Finland and Ireland, both measures of innovation have always been very close to the average.

In Germany, the innovation index has always been above the average whereas labour productivity has been decreasing and is now below the average.

Switzerland and Portugal have registered, through the years studied, an innovation index close to the average while their labour productivity has always been above the average. In Portugal labour productivity has been steadily increasing.

In Poland, there is a divergence between the two indexes: the innovation delay is close to the average while labour productivity has always been below the average.

Finally, in the United Kingdom, the innovation index was very low until 2003, when it started to increase, while labour productivity has always been above the average.

5.1.2.2 *Measuring the degree of liberalisation*

In 1998, the European Postal Directive 97/67/EC was implemented, which sets the maximum weight limit of the reserved area at 350 grams for items of

correspondence and the price limit at five times the basic tariff for a first class letter in the lowest weight band. The directive 2002/39/EC reduces the reserved area to items of correspondence that weigh less than 100 grams and cost less than three times the basic tariff as of January 1st, 2003, and to 50 grams and two and a half times the basic tariff as of January 1st, 2006. Furthermore, the outgoing cross-border mail is required to open to competition on January 1st, 2006 but exceptions are accepted if needed to ensure universal service. Directive 2002/39/EC sets the full market opening of the postal markets for January 1st, 2009, subject to confirmation by the European Parliament and the Council. In 2007, the European Parliament voted to delay the full market opening until January 1st, 2011. The new member states and posts that work in difficult terrain can delay full liberalisation for a further two years.

The letter post items can be divided into four categories: items of correspondence, addressed printed matter, newspapers, and un-addressed printed matter (i.e. un-addressed direct mail). Items of correspondence include letters, postcards, and transaction mail such as bills and bank statements. Included in addressed printed matter are: addressed direct mail, catalogues, and magazines or periodicals.

The reserved area includes the clearance, sorting, transport and delivery of items of domestic and incoming cross-border correspondence. It may also include direct mail (addressed items only) and outgoing cross-border mail falling in the same weight and price limits to the extent necessary to ensure the maintenance of universal service. There are nevertheless exceptions to this reserved area. Among the countries at study, Germany and Ireland exclude the collection and transportation of mail to a post office for final delivery from the reserved area. France, Germany, Italy, The Netherlands, Portugal, and Spain exempt "special services" (i.e. services that are "distinct from the universal service") from the reserved area. Also, Portugal does not include "day certain" delivery in the reserved area (Wik, 2006).

The liberalisation index (*mktliberalised*) developed in this thesis to measure the degree of liberalisation in the postal sector corresponds to the percentage of letter mail volume opened to competition. The index refers only to items of

correspondence and addressed direct mail. It takes into account whether the following categories are part of the reserved area:

- domestic and inbound cross-border correspondence (weight criteria transformed in percentage of mail liberalised according to Table 7)

- local intra-city mail

- direct mail

- outbound cross-border correspondence.

Each category was given a weight according to the composition of the mail market in physical terms (Table 8).

Table 7: Correspondence between reserved area and percentage of letter mail volume liberalised (domestic and inbound cross border correspondence)

Weight limit of the reserved area	Percentage of mail volume
>0g	100
>50g	25*
>100g	18*
>150g	14
>200g	10
>350g	7*
>500g	2
>1000g	1
>2000g	0

* Wik (2004), page 98

Table 8: Composition of the mail market in physical terms

	Domestic and inbound CB	Direct mail	Outbound CB
FR	74%	23%	2%
DE	62%	37%	2%
ES	75%	21%	4%
SE	73%	23%	4%
CH	66%	31%	3%
NL	76%	20%	4%
UK	69%	28%	3%
US	73%	26%	0%
PT	81%	15%	4%
BG	88%	10%	1%
CZ	76%	21%	3%
HR	62%	37%	1%
EE	85%	11%	4%
FI	77%	22%	1%
IE	82%	7%	11%
IT	67%	32%	1%
LV	93%	4%	4%
PL	92%	5%	3%
RO	75%	24%	2%

Source: Ecorys (2005), Country reports

Before the Postal Directive 97/67/EC, the incumbents retained monopolies for letters, generally up to 1 or 2 kilograms. It was assumed that the maximum reserved area for domestic and incoming cross-border mail was two kilograms.

Figure 25 displays the evolution of the liberalisation index for the seventeen countries.
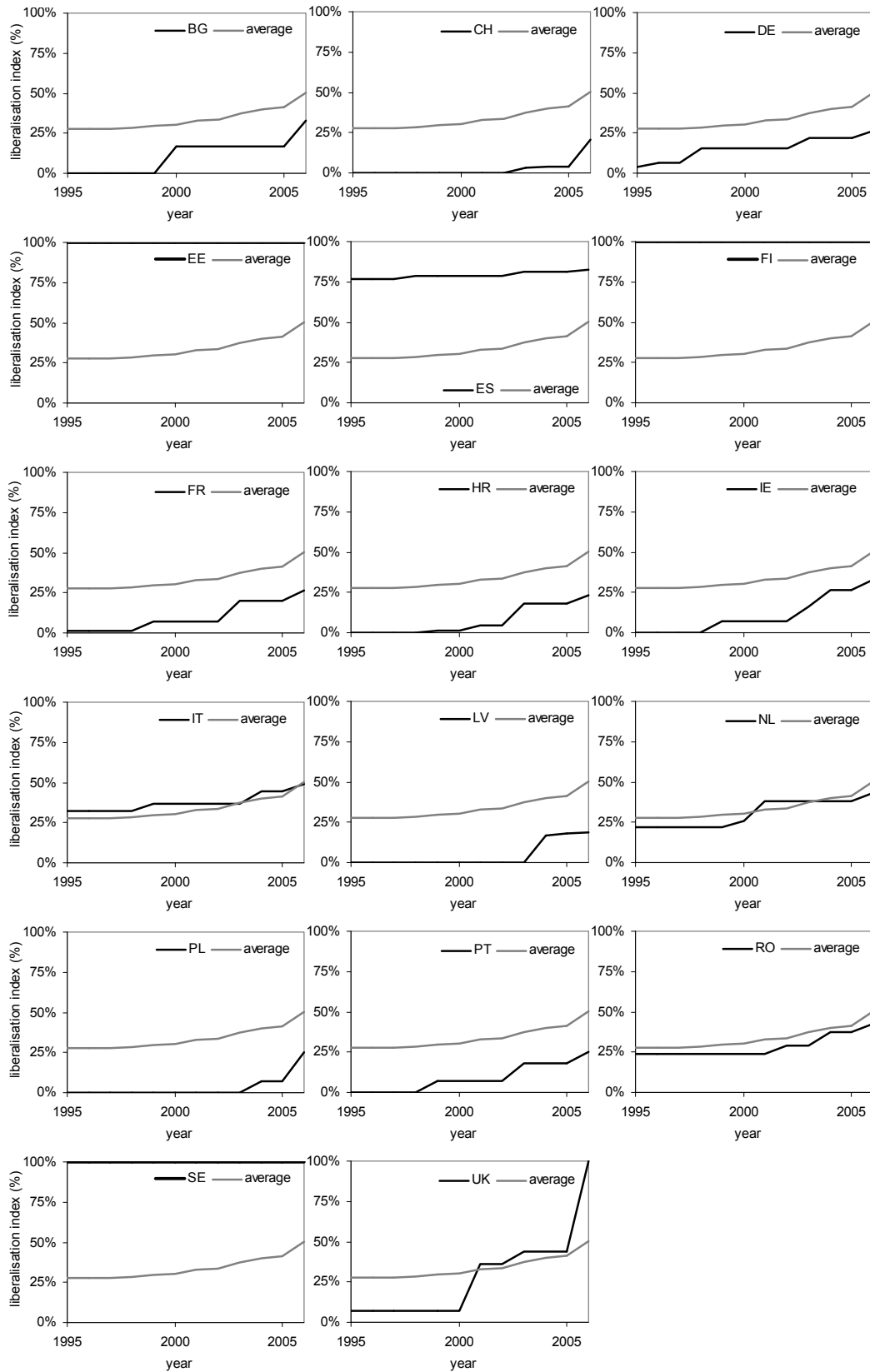
Figure 25: Liberalisation index

Spain was, among the countries at study, the first one to liberalise a considerable part of its letter market. In the 1960s the intra-city mail in Spain was fully opened to competition. For decades, the reserved area in Spain has been restricted to letters and postcards that are inter-urban or international. Therefore, the Spanish market is one of the most competitive European postal markets.

The liberalisation process in Sweden started in 1985 when the Swedish government established quality and profitability as the objectives of Posten. Posten was given more freedom in the capital markets in 1987 and measures of consumer satisfaction were put in place. Five years later, Posten was given the freedom to set prices within certain limits, and in 1993 the letter monopoly was abolished (PricewaterhouseCoopers, 1997). Since then, the market share of the incumbent (Posten) has been declining. Today, the most important private operator (CityMail) has a market share of approximately 8.5%.

Estonia and Finland have also fully liberalised their postal market. Finland took the decision to fully liberalise the mail market in 1991, which took effect in 1994. Estonia has liberalised its mail market in 2002. However, competition has not developed in these countries due mainly to restrictive licence conditions and taxation.

In the United Kingdom, the Postal Services Act 2000 abolished the reserved area and from January 1st, 2006, the Postal Services Commission ("Postcomm") grants licenses to all operators subject only to compliance with certain essential requirements, instead of only bulk mail providers and certain other special categories of postal services operators as before 2006 (Eccles and Kuipers, 2006).

In 2004 the Dutch Minister of Economic Affairs, Laurens-Jan Brinkhorst published a paper on the future of postal policy in the Netherlands[20]. In this paper, he defends the full market opening of the Dutch market in 2007, but conditioned on the full liberalisation of the British and German markets. He justifies this position by the need to create a level playing field (Wik, 2004).

---

[20] « Postal Memorandum » available at http://www.ez.nl/content.jsp?objectid=20863 [8/10/2007].

In Germany, letter items weighting more than 200 grams became open to competition in 1998. Regarding direct mail, the weight limit was firstly reduced in 1995 to 250 grams, then in 1996 to 100 grams, and finally in 1998 to 50 grams.

The liberalisation of direct mail is particularly interesting because direct mail represents a great share of the total volume of letter mail. Eight of the countries analysed here - Croatia, France, Germany, Ireland, Latvia, Poland, Portugal and Switzerland - have maintained a reserved area over direct mail (IPC, 2007). In Italy and The Netherlands, addressed direct mail is liberalised and substantial competition can be observed in this segment.

The definition of direct mail is not homogeneous in all the countries. In the Netherlands direct mail corresponds only to wholly printed matter whereas, for instance, in Germany items of direct mail can differ in respect to specific elements. In Spain and Italy, direct mail is defined as items whose body is "essentially identical". The Directive considers as direct mail the advertising items where the nature of the message is the same even if there are other elements specific to each item (Wik, 2006).

Among the countries at study, seven also reserve outgoing mail. These countries are Bulgaria, Italy Latvia, Poland, Portugal, Romania and Spain (IPC, 2007).

5.1.2.3 The degree of competition

The degree of competition is measured through the market share of the competitor postal operators (in terms of volume) (*mktshareE*) in addressed mail delivery, including both reserved and non-reserved areas. The sources of the market share of the entrants are the following: Ecorys (2005), Wik (2004), Bundesnetzagentur (2006), and the Swedish regulator.

mktshareE is a discrete variable that assumes the values 1,3,5,7,9, and 11. These values correspond to the mid point of the interval to which belongs the market share of the entrants. For example, if entrants have a market share that lies on the interval [0,2%] then *mktshareE* assumes the value 1. If entrants have a market share that lies on the interval (2%,4%] then *mktshareE* assumes the value 3, and

so on. Figure 26 illustrates the evolution of the market share of the entrants between 1995 and 2005.

As discussed in Chapter 3, section 3.2.3, in the majority of the countries under study, the entrants' market share does not exceed the 2%.

Spain is the country where competition is highest, followed by Sweden. Although Finland and Estonia liberalised their mail markets some years ago, the restrictive licence conditions and taxation policy has restricted the development of competition. In both countries, potential entrants are required to provide postal services in the whole territory of the country[21]. In Finland, potential entrants can opt for a restricted license that implies an additional turnover tax of 5-20%, depending on the territorial coverage of mail delivery.

The license requirements to deliver addressed mail in Sweden are not restrictive. Moreover, there are no licence requirements to deliver catalogues, magazines and un-addressed mail. However, not a lot of competition has developed and the incumbent still has a very dominant position currently. This slow development of competition is related to different factors. Initially, the legislation was not adapted to support or create the preconditions for competition. Also, CityMail (the largest competitor of Posten AB) faced numerous internal problems that limited its business development and expansion. Finally, Sweden has a large territory with a low population density, which creates barriers to entry (Ecorys, 2005).

After Spain and Sweden, the countries where competition is most developed are Germany, The Netherlands, and Estonia.

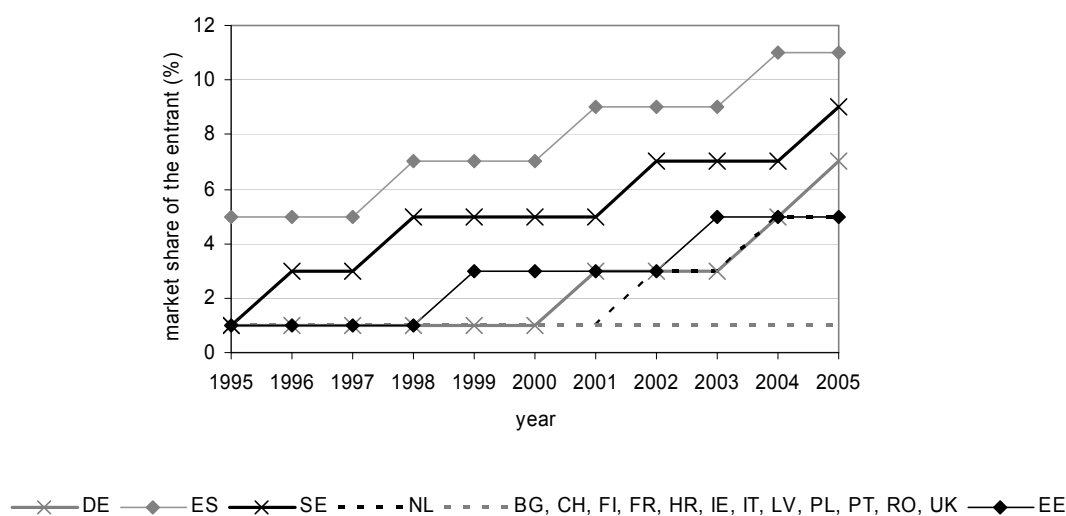[21] With the exception of the Aland islands in Finland.

Figure 26: Evolution of entrants' market share

5.1.2.4 Other variables

In addition to the main variables of interest described above, we also collected data on the following control variables: percentage of public ownership, population density, and GDP *per capita*.

The share of equity owned directly or indirectly by central governments (***publick***) was collected from the operators' annual reports, the IPC Postal regulatory databases, and the operators' websites. Among the countries at study, only Deutsche Post and TNT Post are partially privatised. In 2005, the Deutsche government held 45% of the shares of Deutsche Post and only 10% of the shares of TNT Post were owned (directly or indirectly) by the Dutch government.

Population (in millions) was collected from Eurostat and countries' area is available at the UPU database. These two variables were used to build the variable population density (***popdens***), which is plotted in Figure 27, together with population. Population density is in number of habitants per squared kilometre. France, Germany, United Kingdom, and Italy are the countries with the greatest populations. These countries, except France, are among the four countries with the

highest population density. The Netherlands is the country with the highest population density.
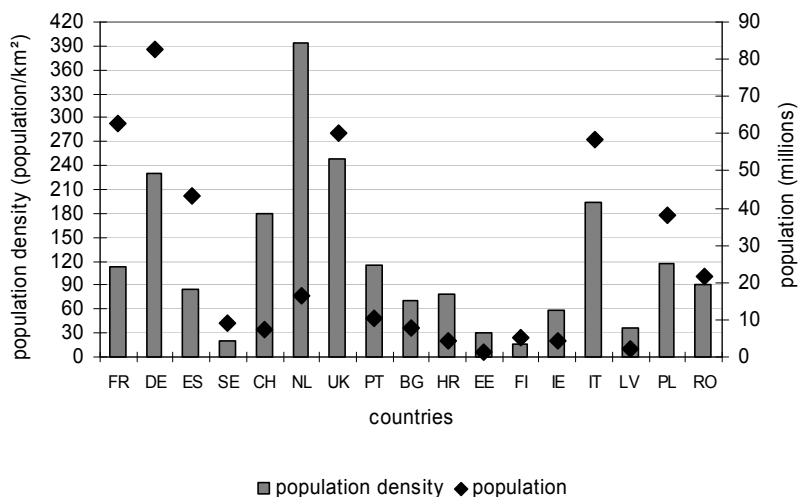
Figure 27: Population and population density in 2005

The GDP at 1995 prices was collected from Eurostat's statistics and used to compute the variable GDP *per capita* (***gdppercap***). GDP *per capita* is in thousands of euros per habitant. Figure 28 displays the GDP *per capita* and GDP in 2005. The countries with the highest GDP are Germany, France, the United Kingdom, and Italy, whereas the countries with the largest GDP *per capita* are Switzerland, Sweden, Finland, Germany, and The Netherlands.
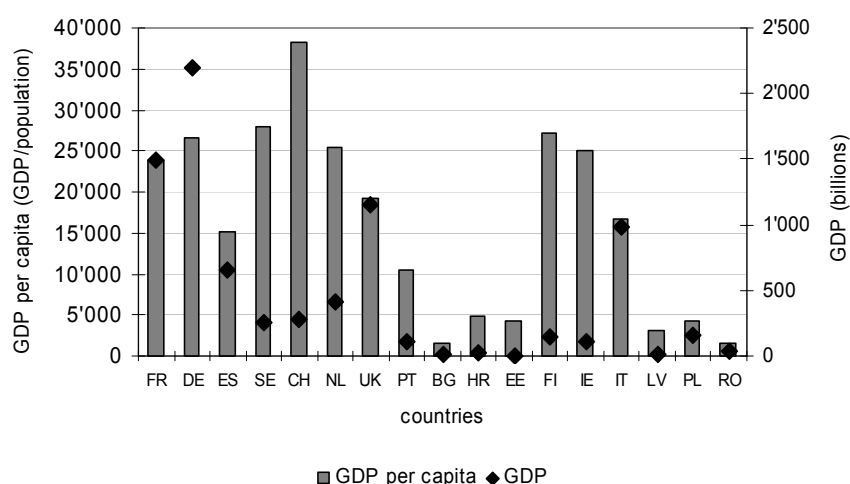
Figure 28: GDP per capita and GDP in 2005

Finally, both exchange rates and inflation rates are from Eurostat.

Table 9 summarises and describes the variables involved in this study.

Table 9: Variables' description

Variable	Description
inindex	Innovation index
accuminno	Accumulated number of innovations
itemperempl	Labour productivity
tvolume	Volume of letter mail (in billions of items)
empl	Average number of employees (includes permanent employees and employees with a term contract) (in thousands)
mktliberalised	Liberalisation index (measures the degree of liberalisation, i.e the percentage of letter mail volume opened to competition)
mktshareE	Market share of the competitor postal operators (in terms of volume)
publick	Share of equity owned directly or indirectly by central governments
popdens	Population density
gdppercap	GDP *per capita*

The detailed descriptive statistics are presented in Annex 7, Table 11.

5.1.3 The model

In this section we present the econometric model estimated in order to test the hypotheses presented in section 5.1.1. Its general form is:

$$Innovation_{it} = \alpha + \beta_1 X_{it} + \beta_2 mktliberalised_{i,t-1} + \beta_3 mktliberalised_{i,t+1} + \beta_4 C_{it} + e_{it}$$

where t represents years, i denotes countries, α is a constant term, X_{it} is a vector of exogenous explanatory variables, and C_{it} is the vector of control variables.

The contemporaneous explanatory variables included in the vector X_{it} are: *mktliberalised* and *mktshareE*. Vector C_{it} includes: *publick, tvolume, popdens*, and *gdppercap*.

This model is estimated for the three different measures of innovation presented before, which are the innovation index (*inindex*), the accumulated number of innovation (*accuminno*), and labour productivity (*itemperempl*).

The aim of lagging and forwarding *mktliberalised* one period is to test if firms react with delay to liberalisation policies or if firms anticipate future changes regarding market liberalisation, respectively.

The correlation matrix between independent variables is displayed in Annex 7, Table 12. The percentage of market liberalised and the percentage of market share of the entrants have a correlation of 54%. Although this correlation is not extremely high, it must be noted that the inclusion of these two variables in the same specification might affect t-statistics. The correlation between *mktliberalised* and *popdens* is -34% and, therefore, caution must be taken when including both variables in the same model. All the other variables have a correlation with *mktliberalised* smaller than 25% and therefore should not cause any problems.

Regarding *mktshareE*, its correlations with *publick, tvolume, popdens*, and *gdppercap* are smaller than 25%. The correlation between *publick* and *gdppercap* slightly exceeds 25% (it is 28% in absolute value) and it should not cause

problems either. However, *publick* and *popdens* have a high correlation of -73%, which deserves particular attention. It is likely that the inclusion of both variables in the same model will distort results, in particular t-statistics. The correlation between *tvolume* and *popdens,* as well as between *tvolume* and *gdppercap,* are close to 50% and, hence, there is a risk of impact on the t-statistics. Finally, *popdens* and *gdppercap* have a correlation of 38%.

We start by estimating a specification only with the contemporaneous variables and control variables. Then, a second model that excludes *popdens*, because of its correlation with *mktliberalised*, is estimated. After, we estimate a model that excludes *gdppercap* from the second model because of its correlation with *tvolume*. We then investigate if the t-statistics are being affected by the correlation between *mktliberalised* and *mktshareE* by estimating two other models: one with *mktliberalised*, *publick*, and *tvolume* as explanatory variables, and another one with *mktshareE*, *publick*, and *tvolume* as explanatory variables.

5.1.4 Estimation procedures

Firstly, the models were tested for the presence of heteroskedasticity and correlation between and within panels. Table 13, in Annex 7, summarises the results of the tests performed.

By plotting the Ordinary Least Square (OLS) residuals it is possible to see (independently of the variable used as proxy for innovation) that the means and the dispersion are different across countries. This finding confirms the existence of a panel structure. Also, the fact that the second moments are different across countries is a first indication of a problem of heteroskedasticity.

A likelihood-ratio test (lrtest hetero) was performed in order to determine the presence of heteroskedasticity. In all the models, the null hypothesis of homoskedasticity is rejected, which indicates the presence of heteroskedasticity. For the purpose of learning more about the type of heteroskedasticity, namely to test for inter-individuals heteroskedasticity, a modified Wald test was performed (xttest3). The rejection of the null hypotheses confirms the existence of inter-individuals hereroskedasticity.

It is not possible to perform a Breusch-Pagan test (xttest2) in order to check for correlation across panels because the number of firms is larger than the number of time periods being analysed (i.e. N>T). Nevertheless, we will assume that there is spatial correlation in the errors since it is very common to find this type of correlation in panel data models. The first order autocorrelation test of Wooldridge (xtserial) indicates the presence of serial autocorrelation in the three models since the null hypothesis of independence of the residuals is rejected.

In the presence of autocorrelation within panels, cross-sectional correlation, and heteroskedasticity, the most appropriated estimation procedures are Generalised Least Squares (GLS) and Prais-Winsten estimation with Panel Corrected Standard Errors (PW-PCSE). Models 1 through 21, in Annex 7, were estimated by GLS and models 22 through 42, in Annex 7, using PW-PCSE estimation.

GLS allows estimation in the presence of a first order autoregressive process (AR(1)) within panels and cross-sectional correlation, and heteroskedasticity across panels. The coefficient of the AR(1) process can be specified as being common to all the panels or as being specific to each panel. We assume that the AR(1) coefficient is specific to each model.

In the PCSE estimation, parameters are estimated by OLS or Prais-Winsten regression. Prais-Winsten estimates are provided when autocorrelation is specified, which is the case. Otherwise, OLS estimates are provided. As with GLS, the coefficient of the AR(1) process can be specified with PCSE estimation as being common to all the panels or as being specific to each panel. Again, the AR(1) coefficient is assumed to be specific to each model.

5.1.5 Results

In this section, the results are presented and discussed. A total of forty two models were estimated and reported in Annex 7 (Tables 14 through 19). Tables 14, 15, and 16 report the results of GLS estimation. Tables 17, 18, and 19 report the PW-PCSE estimation. In the models included in Tables 14 and 17 the dependent variable is the innovation index. Tables 15 and 18 contain the models that have the accumulated number of innovations as dependent variable. Finally, Tables 16

and 19 report the models that use labour productivity as proxy for innovation. Each table contains seven models. Schematically the models are as follows:

Table 10: Scheme of estimated models

Estimation procedure		Dependent variable		
		inindex	*accuminno*	*itemperempl*
GLS	table number	14	15	16
	model number	1-7	8-14	15-21
PW-PCSE	table number	17	18	19
	model number	22-28	29-35	36-42

In all the models estimated, the explanatory variables are found to be jointly significant.

5.1.5.1 Models estimated by GLS

In the models estimated by GLS that include all the contemporaneous explanatory variables (including the control variables), the percentage of market liberalised is shown not to be significant (Models 1, 8, and 15). However, once the population density, which is correlated with $mktliberalised_t$, $publick_t$, and $tvolume_t$ is taken out of these regressions, $mktliberalised_t$ becomes statistically significant in two of the models (in Model 2 and 16, and not in Model 9). Only when $gdppercap_t$ (which is correlated with $tvolume_t$ and $popdens_t$) is taken out of Model 9, $mktliberalised_t$ becomes statistically significant (Model 10).

Concerning the remaining models that have the innovation index as dependent variable, it is observed that in Model 2, $tvolume_t$ is not statistically significant but when $gdppercap_t$ is excluded (Model 3), $tvolume_t$ becomes statistically significant at a 1% level. In Model 3, the $marketshareE_t$ and $publick_t$ are also statistically significant at a 1% level.

With Model 4 and 5 we aim to test whether the correlation between $mktliberalised_t$ and $marketshareE_t$ significantly affects the t-statistics. As one can observe, this is not the case.

The objective of Models 6 and 7 is to analyse the response of innovation (measured through the innovation index) to non-contemporaneous changes in the percentage of market liberalised. Therefore, *mktliberalised$_t$* is replaced by *mktliberalised$_{t-1}$* and *mktliberalised$_{t+1}$*. It is observed that both variables are statistically significant but they have a smaller impact on the innovation index than *mktliberalised$_t$*.

Hence, from the set of models estimated using GLS and where innovation is measured through the innovation index, Model 3 is selected as the one that best fits the data.

We now turn to the models that have the accumulated number of innovations as dependent variable and that have not yet been analysed.

In Model 10, *tvolume$_t$* also becomes statistically significant at a 1% level when *gdppercap$_t$* is excluded from the vector of explanatory variables. *marketshareE$_t$* remains statistically significant at a 1% level. However, *publick$_t$* which was significant becomes not significant.

When we estimate Models 11 and 12, which exclude *mktliberalised$_t$* and *marketshareE$_t$* respectively, from the explanatory variables, it is seen that *publick$_t$* becomes statistically significant at a 1% level again. Also, *mktliberalised$_t$* and *marketshareE$_t$* have a more significant impact on the accumulated number of innovations when they are not included simultaneously in the same regression.

mktliberalised$_{t+1}$ and *mktliberalised$_{t-1}$* are both found to be statistically significant at a 1% level (Models 13 and 14). The coefficient of *mktliberalised$_{t+1}$* is smaller than that of *mktliberalised$_t$* whereas the coefficient of *mktliberalised$_{t-1}$* and its t-statistics are larger than that of *mktliberalised$_t$*. However, *marketshareE$_t$* is no longer statistically significant in Model 14 (probably due to the correlation between *mktliberalised$_{t-1}$* and *marketshareE$_t$*).

Concerning the set of models, which have the accumulated number of innovations as dependent variable and that are estimated using GLS, Model 10 seems to best fit the data. The likelihood-ratio test that compares Model 8 and Model 10 confirms that Model 10 fits the data better than Model 8 (LR chi2(2)=5.50 and Prob>chi2=0.064). When Model 10 is compared to Model 11, the likelihood-ratio

test indicates that Model 10 fits the data better (LR chi2(2)=4.43 and Prob>chi2=0.035).

In the set of models estimated by GLS which use labour productivity as proxy for innovation (Table 16) Model 16 seems to best fit the data.

It is apparent that when *mktliberalised$_t$* and *marketshareE$_t$* are included separately (Models 18 and 19) both variables are statistically significant at a 1% level while in Model 17 *mktliberalised$_t$* is not statistically significant. Model 16, despite including both *mktliberalised$_t$* and *marketshareE$_t$*, and *gdppercap$_t$* seems to display t-statistics that are not significantly influenced by the correlation between *mktliberalised$_t$* and *marketshareE$_t$*, and between *gdppercap$_t$* and *tvolume$_t$*. In Model 16, *marketshareE$_t$*, *publick$_t$*, *tvolume$_t$*, and *gdppercap$_t$* are statistically significant at a 1% level.

mktliberalised$_{t+1}$ is not statistically significant (Model 21) whereas *mktliberalised$_{t-1}$* is found to be statistically significant at a 1% level (Model 21). The coefficient of *mktliberalised$_{t-1}$* and its t-statistics are larger than that of *mktliberalised$_t$*. However, *marketshareE$_t$* is no longer statistically significant in Model 21 (again, probably because of the correlation between *mktliberalised$_{t-1}$* and *marketshareE$_t$*).

When Models 15, 16, 17, and 18 are compared using likelihood-ratio tests the results obtained are: (1) Model 16 fits the data better than Model 15 (LR chi2(2)=-5.51 and Prob>chi2=1); (2) Model 16 is preferable to Model 17 (LR chi2(2)=62.98 and Prob>chi2=0.000); and (3) Model 16 fits the data better than Model 18 (LR chi2(2)=180.76 and Prob>chi2=0.000). This confirms the perception that Model 16 is the one that best fits the data.

5.1.5.2 *Models estimated using PW-PCSE*

We now turn to the estimations using PW-PCSE. We start with the models that have the innovation index as a dependent variable (Models 22 through 28). In all of these models, *mktliberalised$_t$* and *marketshareE$_t$* are statistically significant at at least at a 5% level. *mktliberalised$_{t+1}$* and *mktliberalised$_{t-1}$* are also found to be statistically significant (Models 27 and 28). Its coefficients and t-statistics are very

close to those of *mktliberalised$_t$* in Model 23. Model 23 corresponds to Model 22 without the variable *popdens$_t$*. *publick$_t$* is not statistically significant in Model 22 but once *popdens$_t$* is eliminated from the regression, *publick$_t$* becomes significant.

Taking *gdppercap$_t$* out of the regression (Model 24) does not change things significantly. Since the coefficient of *mktliberalised$_t$* in Model 23 is closer to that in Model 25, Model 23 is preferred over Model 24. Models 25 and 26 show that the t-statistics are not much affected by the correlation between *mktliberalised$_t$* and *marketshareE$_t$*. Model 23 is the model that has the highest R-squared.

Models 29 through 35 correspond to PW-PCSE estimation with the accumulated number of innovations as the dependent variable. In this set of models, *marketshareE$_t$* is always statistically significant while *mktliberalised$_t$* only becomes statistically significant once we exclude both *popdens$_t$* and *gdppercap$_t$* (Model 31). The same happens with *tvolume$_t$*. *publick$_t$* is statistically significant in Models 30 through 35. Again, the correlation between *mktliberalised$_t$* and *marketshareE$_t$* does not noticeably affect the results in Model 31 since the coefficients and t-statistics of these two variables in Model 32 and 33 are very close to those of Model 31. In Model 35, *mktliberalised$_{t-1}$* is found to be statistically insignificant whereas *mktliberalised$_{t+1}$* (Model 34) is statistically significant. Models 31 and 34 have a high R-squared and seem to be the models that best fit the data.

The last group of models (Models 36 through 42) have labour productivity as the dependent variable and are estimated using PW-PCSE. In this set of models neither *mktliberalised$_{t+1}$* nor *mktliberalised$_{t-1}$* are found to be statistically significant. On the contrary, *tvolume$_t$* is always statistically significant in this group of models. The t-statistics of *tvolume$_t$* in Model 37 does not seem to be affected by the correlation between this variable and *gdppercap$_t$*. Surprisingly, when *gdppercap$_t$* is excluded, *marketshareE$_t$* turns out not to be statistically significant (Model 38). The results regarding *marketshareE$_t$* in Model 38 are consistent with those of Model 40. Nevertheless, Model 37 is preferred over Model 38 because of all the previous evidence regarding the significance of *marketshareE$_t$*. Also, Model 37 has a very high explanatory power (R-

squared=0.78). For the first time, *publick$_t$* is not statistically significant in the selected model, i.e. Model 37.

5.1.5.3 Conclusions

From the results presented above, it can be conclude that the response of the incumbent to liberalisation policies occurs either in the same year the policy comes into force or in the years that precede that event, that is, the incumbents may react to liberalisation policies in advance. Nevertheless, there is less evidence concerning the effect of the percentage of market liberalised forward one period (*mktliberalised$_{t+1}$*) than of the contemporaneous percentage of market liberalised (*mktliberalised$_t$*). It may happen that some of the investments in innovation are decided in advance but they are only observable in the following year(s).

If the models that best fit the data are compared (selected models), i.e. Model 3, 10, 16, 23, 31, 34, and 37, the models estimated by GLS provide stronger results. The use of one innovation measure instead of another does not originate significantly different results. This shows that the developed innovation index is a good measure of innovation and gives certain warranties about the quality of the models estimated. If different results had been found depending on the measure of innovation used it would be impossible to know which model (if any) was correct.

All of the selected models indicate a positive effect of liberalisation on innovation. In all of these models, the degree of liberalisation is statistically significant and has a positive impact on innovation, i.e. the estimated coefficients have the expected signs.

The actual competition, measured by the market share of the entrants, is always statistically significant among the selected models and also has a positive effect on innovation. As predicted, the larger the market share of the entrants, the more innovative the incumbent is, at least until the market share of the entrants reaches a certain threshold.

In the selected models, the percentage of public ownership is statistically significant in the majority of the cases but contrary to what was expected, the percentage of public ownership is negatively related to innovation. This does not

necessarily mean that welfare maximisation does not stimulate innovation. It can mean that public ownership is not the ownership structure most likely to promote welfare maximisation. In other words, under the hypothesis that public ownership creates more incentives to innovate than private ownership is the assumption that governments are likely to maximise social welfare, which in reality may not always be true. Moreover, the variable "percentage of public ownership" presents almost no variability and, therefore, all the results related to this variable should be seen as preliminary and taken with considerable caution.

Concerning the letter volume handled by the operators, there is strong statistical evidence that it has a positive impact on the incentives to innovate.

GDP *per capita* is always statistically significant and has a positive sign, which means that the larger the GDP *per capita*, the more innovative the incumbent is. This reflects the fact that in the most developed economies and countries with higher standards of living, the general level of investment in innovation tends to be higher.

5.2 Upstream and downstream access and innovation

The objective of this section is to analyse the relationship between upstream and downstream access, and innovation. As explained above, the lack of data on worksharing volumes and discounts for the majority of the countries renders impossible the accomplishment of this objective through an econometric analysis. For the purpose of drawing conclusions on the effect of upstream and downstream access on innovation three case studies are analysed. The cases studied are: the United States Postal Service (USPS - United States of America), La Poste (France), and Royal Mail (United Kingdom).

As mentioned before (section 3.3), increased competition is expected to have simultaneously a positive and a negative effect on innovation. In the case of worksharing, the negative effect, i.e. the reduction in the incumbent's rents, is significantly attenuated since the Universal Service Provider (USP) keeps some of the upstream activities as well as the monopoly over delivery. Worksharing works as a franchising where the incumbent subcontracts the activities that others can

perform in a more efficient way. Still, worksharing exerts a pressure for the incumbent to become more efficient, at least in those activities that it does not want to alienate to the competitors. Therefore, worksharing is expected to have a positive effect on innovation, i.e. a positive relationship between worksharing and innovation should be observed.

When entrants choose downstream access, the incumbent only performs delivery of the items processed by the entrants. Compared to the situation of end-to-end competition, downstream access allows the incumbent to preserve a larger part of the monopolist rents. Therefore, the negative effect of competition is also much reduced in this case. The pressure to preserve some upstream activities and competition with the new operators is also expected to have a positive impact on innovation.

In the next section (5.2.1) the three case studies are presented, and after, the main results summarised (section 5.2.2).

5.2.1 Case studies

To analyse the relationship between upstream and downstream access, and the incentives to innovate the cases of the USPS, La Poste, and Royal Mail were chosen.

The United States is unavoidable when studying the impact of the liberalisation of upstream activities on the investment in innovation. It is the oldest case of worksharing and the country where worksharing is the most developed. Also, there is a considerable amount of data available on volumes and patents.

The French case is also very interesting. There is an old tradition of worksharing in France and worksharing volumes represent a large share of the total volume of letter mail.

In the United Kingdom, end-to-end competition coexists with both upstream and downstream accesses. Contrary to the American and French cases, worksharing in the United Kingdom is relatively recent. Another particularity of this case is that Royal Mail is obliged to provide downstream access if demanded by a competitor.

The first case being analysed is the American one, followed by the French and the British cases.

5.2.1.1 United States Postal Service (USPS)

The effect of the liberalisation of upstream activities, without the possibility of end-to-end competition, on innovation is analysed in this part. The United States is the country that best illustrates this situation.

When discussing innovation in the context of the postal sector, the size of the market and, consequently, of the operator is critical. A large market is likely to oblige the adoption of certain technologies, capable of processing and treating large volumes of mail that a smaller market probably does not require. The American market is very large compared to the other European markets studied in this thesis (Figure 29). The difference in the average number of employees between USPS and La Poste or Royal Mail (Figure 30) also illustrates well the difference in the operators' size.
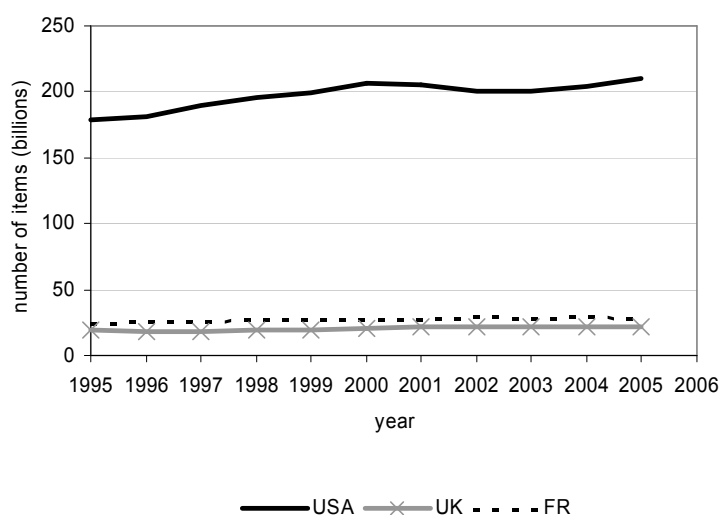
Figure 29: Total letter volume (includes international service, registered items, insured letters, newspapers and addressed and unaddressed advertising items) (in billions)
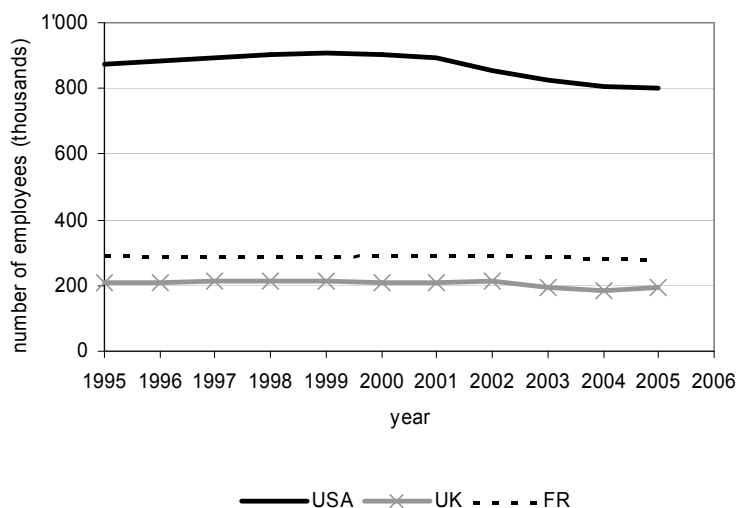
Figure 30: Average number of employees of USPS (includes field career employees and non-career employees), La Poste and Royal Mail (in thousands)

Figure 31 shows the evolution of USPS's operating profit/loss and operating costs in nominal terms. Since 1986, USPS has never experienced negative operating profits again. In 2005, the operating profits amounted to 1.624 million dollars. The operating costs, as well as the operating revenue, have been growing substantially in nominal terms.
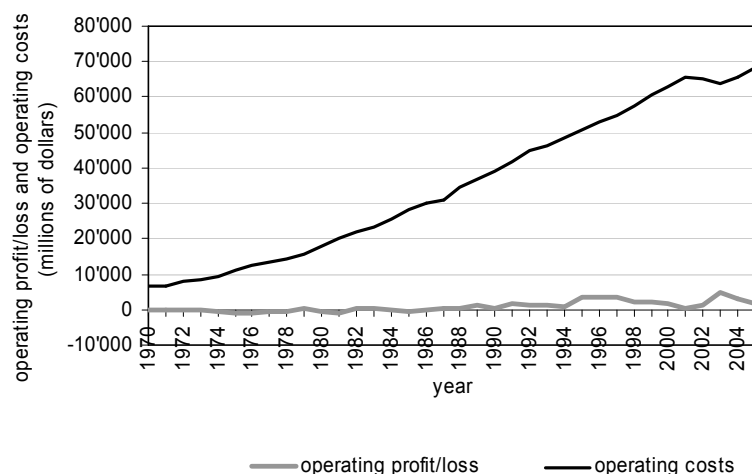
Figure 31: USPS's operating profit/loss and operating costs

Until 1976, all the mail in the United States was collected, transported, processed and delivered exclusively by the USPS and no discount rates were applicable. In 1976, USPS began to offer discounts to First-Class mailers for pre-sorting cards and letters. Discounts for other subclasses of mail and for other kinds of worksharing followed. By 1990, USPS was offering discounts for different levels of pre-sorting, pre-barcoding, and drop shipping on several categories of First-Class, Priority mail, Periodicals (Second Class), and Standard (Third Class) mail (Pearsall, 2005).

The introduction of worksharing in the USA was motivated by the belief that some upstream activities like pre-sorting could be performed more efficiently by printing and mail preparation houses during the preparation of mail. Therefore, USPS would also be able to improve its efficiency because of the improved quality of mail preparation. Both effects were observed, although the productivity effect occurred with some lag (PricewaterhouseCoopers, 2006).

In the American case, USPS has the monopoly in delivery (no by-pass allowed) and the access price is based on avoided cost principles (ACP). The large mailers and consolidators pay the end-to-end price subtracted from the cost that USPS avoids by not performing certain activities. The competitors negotiate with the historical operator the discounts they get from performing the upstream activities.

If no agreement is reached the Postal Rate Commission (PRC) intervenes. The USPS is obliged to offer the same conditions or rates to all the worksharing firms.

The USA is an exception concerning the data available on worksharing volumes and discounts. Therefore, it is possible to make a more formal analysis for the USA than for France and UK.

In the analysis that follows, two measures of worksharing are used, namely the percentage of worksharing volumes and the annual number of accumulated worksharing discounts. Innovation is measured through the patenting activity, labour productivity, and the innovation index described in part 5.1.2.1, which was also calculated for the USA for the period between 1995 and 2006.

Patents are an imperfect measure of innovation because not all new innovations are patented and because patents differ greatly in their economic impact. Many other measures of innovations have been used by researchers, but all of them present some drawbacks. Patents were used in this analysis because the data on patents is available to the general public and because they are one of the most commonly used measures. One drawback of patents that should be kept in mind is that the application date diverges from the data the patent is granted. It might take up to 4 years for a patent to be granted. Nevertheless, the analysis is complemented with two other measures of innovation, which are labour productivity and the innovation index.

The annual volumes of worksharing and letter mail were provided by the Postal Rate Commission. The annual number of worksharing discounts was collected from Cohen et al.(2001). The data on patents was collected from the European Patent Office. The remaining data was collect from different sources: Universal Postal Union (UPU), International Post Corporation (IPC), Postal Rate Commission (PRC), United States Department of Commerce (Bureau of Economic Analysis), United States Census Bureau, and annual reports of the operators.

Next, we present the evolution of worksharing and then we analyse the evolution of the measures of innovation in order to analyse the relationship between both.

Figure 32 shows the evolution of workshared volume compared to the total volume of mail. Only letter mail, including non addressed mail, was considered. It is possible to see that the increase in the total volume of letter mail has been accompanied by a sustained increase in the volume of worksharing. Although worksharing was introduced in 1976, it was only in 1979 that a significant increase in the percentage of worksharing volume was first observed. But by 1982, more than half of the total volume of mail (52%) was workshared. In 2005, approximately, 77% of the mail was workshared mail. The increase in the volume of total letter mail is partially due to the price decrease and new services created by worksharing that stimulate demand (Pearsall, 2005).
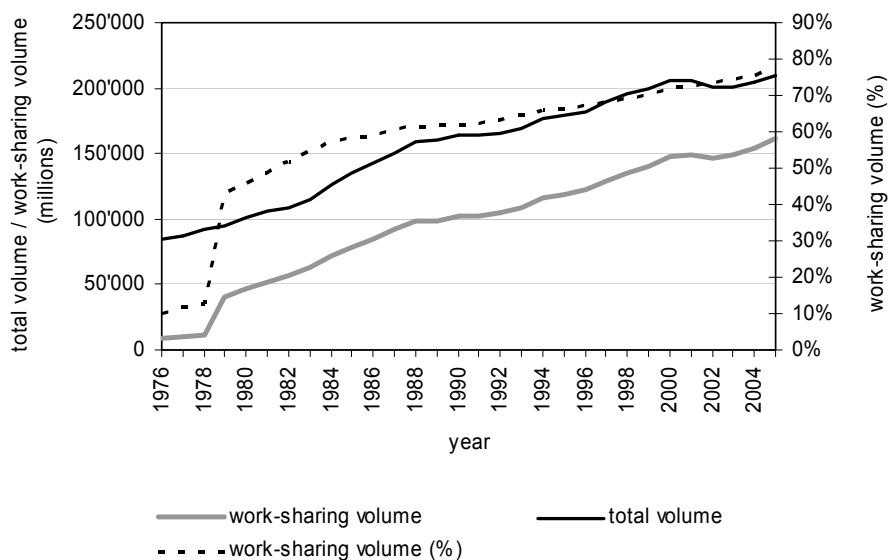
Figure 32: Evolution of workshared volume in the USA

The increase in the number of worksharing discounts since 1976 until 2001 accompanies the evolution of the workshared volume (Figure 33).
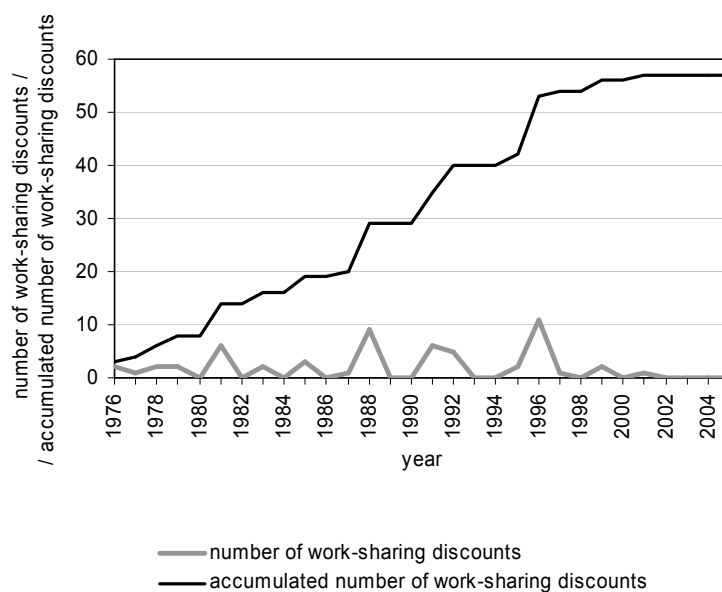
Figure 33: Evolution of the number of worksharing discounts in the USA

According to Cohen et al. (2006), the worksharing discounts in 2004 sum 11 billion euros approximately, and the avoided costs for the USPS also amount to the same value. Nevertheless, the worksharing activities are estimated to have cost much less than this. The authors estimate economy-wide savings of 9 billion euros, approximately.

We now turn to the analysis of evolution of the measures of innovation.

The evolution of the number of patents (Figure 34) shows a great increase 2002, which does not seem to be related to the evolution of worksharing. In fact, the accumulated number of patents displays an exponential behaviour. Therefore, it seems appropriate to transform this series using a logarithm function. Apart from that, the accumulated number of patents also displays a sustained increase over time, like the volume of worksharing.
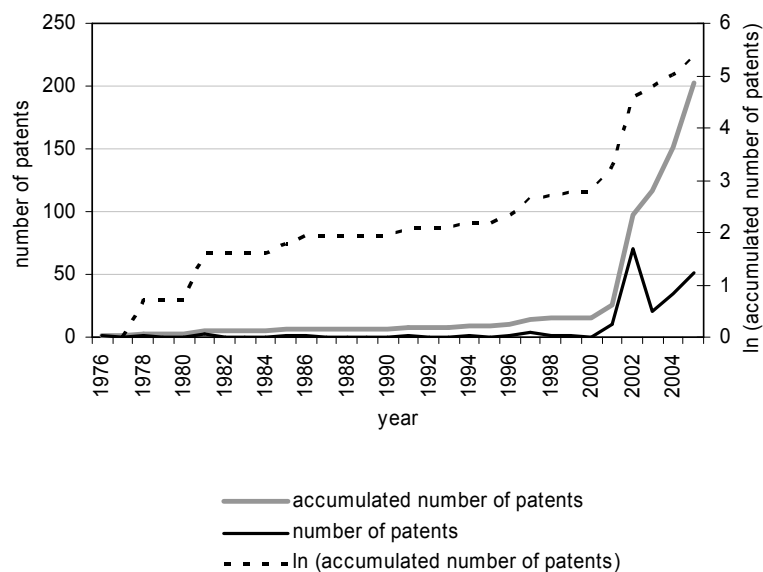
Figure 34: Evolution of the number of patents for USPS

Figure 35 shows the evolution of labour productivity. The number of items per employee more than doubled between 1970 and 2005. This evolution is consistent with the percentage of worksharing volume, except that in 1979 the percentage of worksharing discount increased substantially, something that is not observed in labour productivity.
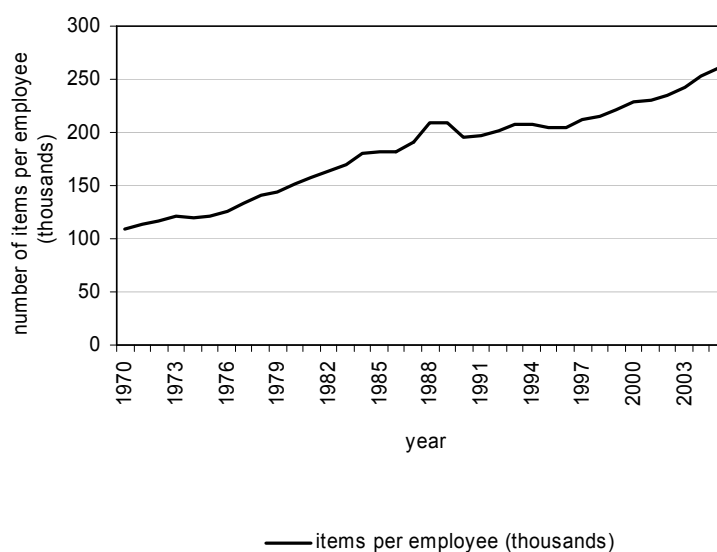

Figure 35: Evolution of labour productivity in USPS

The innovation index[22] between 1995 and 2006 (Figure 36) steadily increases. This evolution is also consistent with the evolution of the percentage of worksharing volume.
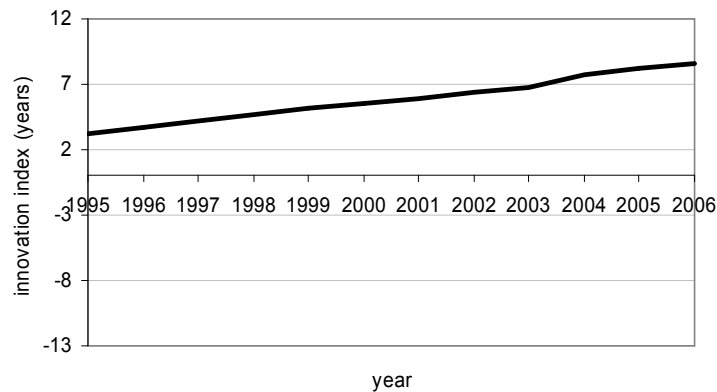
Figure 36: Evolution of the innovation index in USPS

Next, we study the correlation between worksharing and the measures of innovation in order to obtain a more accurate understanding of the relationship between the variables.

The correlation coefficient between two variables is computed using the following formula:

$$Correlation\,(X,Y) = \frac{\sum(x-\bar{x})(y-\bar{y})}{\sqrt{\sum(x-\bar{x})^2\sum(y-\bar{y})^2}}$$

where $\bar{x}$ and $\bar{y}$ are the sample means. The numerator is the sum of the products of the deviations from the sample mean. The denominator is the square root of the product of the sum of the squared deviations.

---

[22] Presented and discussed in part 5.1.2.1.

It is found that the correlation between the percentage of workshared volume and the logarithm of the accumulated number of patents is 0.8. Figure 37 shows that there is a strong non-linear positive association between the variables.
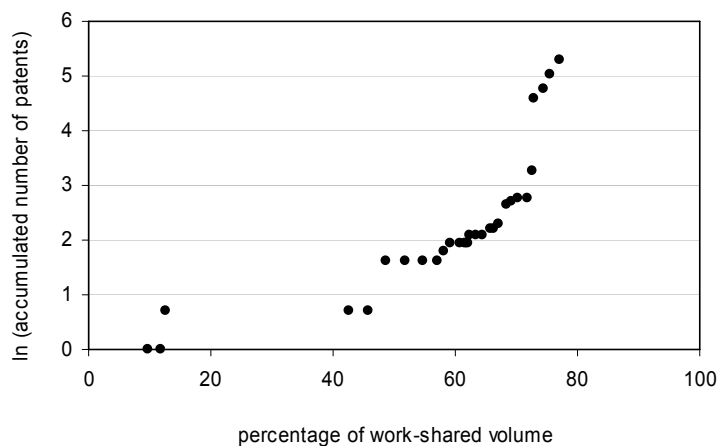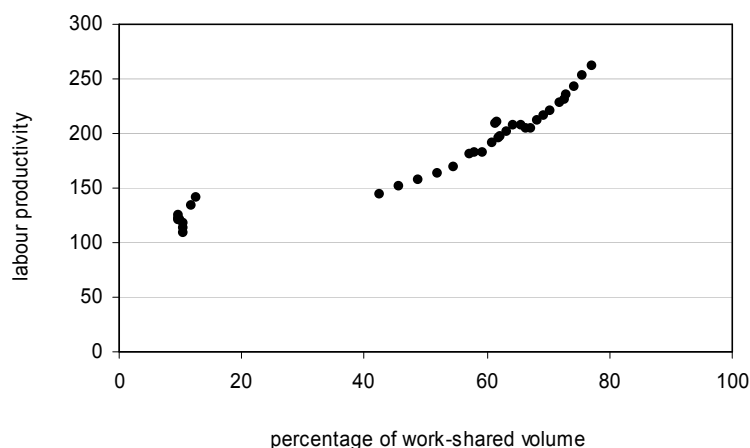

Figure 37: Relationship between the percentage of workshared volume and the logarithm of the accumulated number of patents

The correlation between the accumulated number of worksharing discounts and the logarithm of the accumulated number of patents is 0.85, which corroborates the positive relationship between worksharing and innovation (see Figure 38). It is only possible to speak about a relationship between the two variables since the correlation index does not give any information about causality.
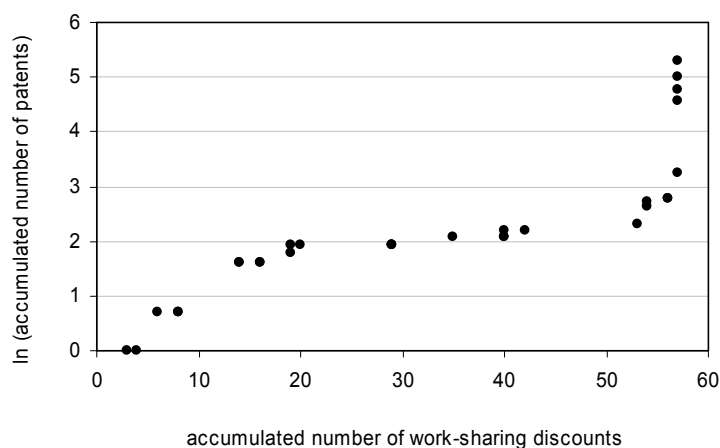
Figure 38: Relationship between accumulated number of worksharing discounts and the logarithm of the accumulated number of patents

There is a correlation of 0.94 between labour productivity and the percentage of workshared volume (Figure 39). Labour productivity increases with the percentage of workshared volume. In principle, if the incumbent and the entrant reach a worksharing agreement it is because that agreement benefits both parts. Hence, it is likely that the activities that are performed by other operators are those where the incumbent is less efficient. As a consequence, the more letter mail is prepared before being handed in to USPS, the more labour productivity increases.

Figure 39: Relationship between the percentage of workshared volume and labour productivity

Finally, we compute the correlation between the percentage of worksharing volume and the innovation index between 1995 and 2006, which is equal to 0.995.

Figure 40 confirms that in the period between 1995 and 2006 there is a strong positive relationship between the two variables in analysis.
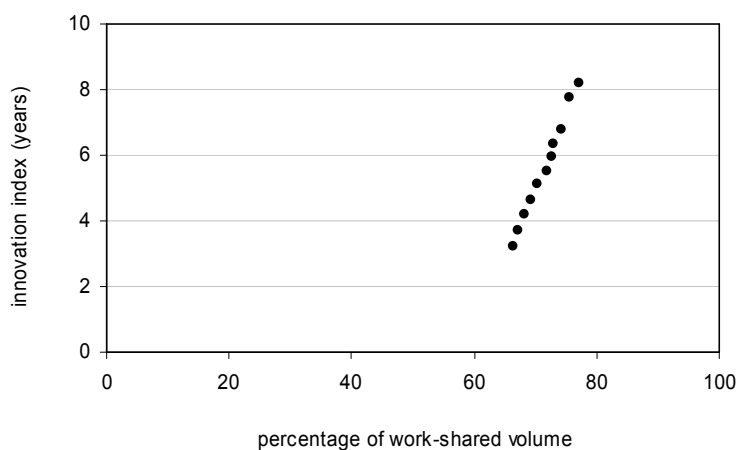
Figure 40: Relationship between the percentage of workshared volume and the innovation index

According to the data analysed in this part, there is evidence of a positive relationship between worksharing and innovation. The correlation between worksharing and the several measures of innovation is always larger or equal to 0.85. The intuition behind this result is that worksharing introduces a type of competition where the incumbent has the pressure to become more and more efficient, at least in the activities that he does not want to transfer to the competitors, without losing market share. Also, even when an activity is transferred from the incumbent to a competitor, it is because it is more advantageous for the incumbent to pay that service to the competitor than to perform it itself.

5.2.1.2 La Poste

The French case illustrates the situation in which worksharing and end-to-end competition coexist. The history of worksharing in France started in the 1960s. By then, La Poste was confronted with large increases in the volume of parcels and of direct mail. The solution found was to resort to contracts with third parties to perform some upstream activities, like collection, sorting and other types of mail preparation. These third parties would then tender the mail to La Poste for delivery.

The first worksharing contract for letter mail was signed in 1969 and concerned direct mail products. Large mailers started pre-sorting and performing other types of mail preparation while La Poste saved by not performing those activities. Since then, worksharing in France has never stopped growing. Today, approximately 56% of the upstream activities are accounted for by third parties[23]; that is, mailers and consolidators handle approximately half of all letter post items delivered in France, which shows the importance of worksharing in the French market.

Contrary to what happens in other countries, namely The Netherlands, Switzerland and Portugal, in France consolidation of volumes is possible. La

---

[23] Source: Mr. Olaf Klargaard, Department of Regulatory Economics, La Poste.

Poste accepts prepared mail from large mailers, printing and mail preparation houses and consolidators. All these entities are offered the same conditions.

The agreements between these entities and La Poste are governed by different types of contracts: the "product", the "technical" and the "commercial" contracts. The first type of contract defines the general access conditions and service quality standards for specific products, namely for direct mail, parcels and transactions mail. It also settles the discounts for several levels of worksharing. The "technical contract" concerns other specific issues, for example, the time windows to tender mail and additional refinements in sortation. The "commercial contracts" stipulate periodic rebates on total mailing costs based on the total volume tendered to La Poste for delivery by clients, printing and mail preparation houses and consolidators (PricewaterhouseCoopers, 2006). La Poste does not give discounts for dropship because the cost with transportation is considered not to be significant.

Similarly to what happens in the USA, in France access pricing is governed by avoided cost rules. Nevertheless, the pricing system is more flexible in France, where the final objective is to increase efficiency by providing the right incentives for each product class and each technical feature (PricewaterhouseCoopers, 2006). The discounts or rebates are negotiated between the entity performing worksharing and La Poste. When there are conflicts between these two entities the French regulatory authority for electronic communications and for post (ARCEP) intervenes. Since the adoption of the new postal law in 2005, ARCEP has the power to require downstream access and to settle access conditions (Wik, 2006).

There are approximately two hundred mailing houses and consolidators operating in the French market. Today, the great majority of them are subsidiaries of international groups and of advertising groups, and routing companies previously owned by the banking sector for their transaction mail[24]. The remarkable evolution registered in the consolidation of transaction and direct mail is due to

---

[24] Transaction mail refers to invoices, bills, financial statements and other bulk mail originated by business or government organisations with receiver-specific content (PricewaterhouseCoopers, 2006).

the development of the transaction mail consolidation market and the quality increase in the direct mail consolidation market. This evolution was associated with large investment in automation, quality control and workforce qualification (PricewaterhouseCoopers, 2006)

La Poste is not active as a Direct Mail consolidator but it has a subsidiary active in Transaction Mail consolidation with ten percent of market share. There is an increased concentration in the sector. The presence of large international, investor-owned groups in the consolidation market motivated by costly investments (information technology, sorting machines, printing machines) should also be noted (PricewaterhouseCoopers, 2006).

Regarding innovation in La Poste, both the innovation index[25] (Figure 20) and labour productivity (Figure 24) have been steadily increasing since 1995. In fact, among the seventeen countries studied in the previous section, France is one of the most innovative. Figure 41 shows the evolution of the accumulated number of innovations during a longer period, i.e. between 1975 and 2006.
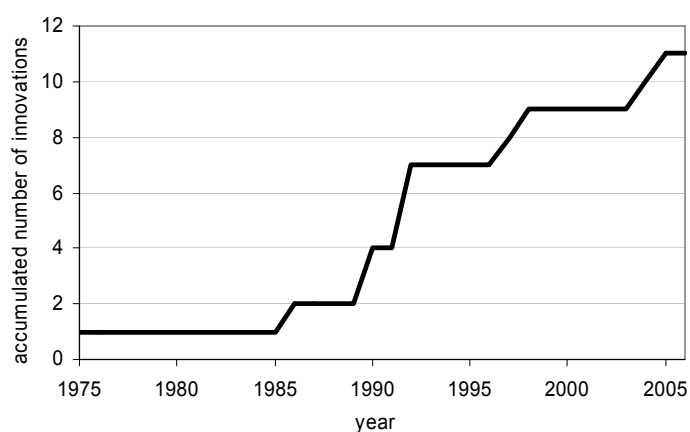
Figure 41: Evolution of the accumulated number of innovations for La Poste (between 1975 and 2006)

---

[25] Presented and discussed in part 5.1.2.1.

The evolution of these three measures of innovation is in harmony with the evolution of the worksharing volumes, which have been increasing since their introduction in the 1960s. Worksharing and innovation also seem to be positively correlated in the case of France.

5.2.1.3 Royal Mail

In the UK, end-to-end competition coexists with both upstream and downstream accesses, which are required by Postcomm, the British postal regulator. End-to-end competition is, nevertheless, very limited. The reserved area was completely abolished in the beginning of 2006. Between 2003 and 2005, the percentage of liberalised market, in terms of volume, was estimated to be 44%. In 2006 Royal Mail retained approximately 97% market share in the regulated addressed letters market.

Access can be demanded by individual customers, consolidators and entrants. The access conditions are negotiated between Royal Mail and the parties in quest of access, but when the parties cannot reach an agreement, Postcomm has the power to impose access conditions. Downstream access emerged in the UK in 2004, when Royal Mail and UK Mail reached an agreement on access prices. Later in the same year, TNT and Deutsche Post settled a similar agreement with Royal Mail.

The first access agreements were set on a "geographically averaged cost recovery basis", i.e. the mail handed over to Royal Mail had to be adapted to its overall letter volume, on the basis of individual postcode areas. Surcharges would be levied by Royal Mail for certain volume increases. Other measures like asking the customer to transfer mail to other zones or even terminate the agreement could also apply. Access contracts based on "geographically de-averaged access prices" or "non-uniform pricing", which are freely negotiated between Royal Mail and other operators and offered on a non discriminatory basis, were introduced by the end of 2004 (PricewaterhouseCoopers, 2006).

According to Postcomm (2006), thus far, competitors have mainly entered the market in upstream activities by targeting high volume mailers like banks, utilities and other large mailers sending regular volumes.

> "Competition has developed most significantly in the part of the market where third party suppliers use access to Royal Mail's delivery network. These operators compete with Royal Mail for collection, sortation and trunking, accessing Royal Mail's network for final delivery. […] In addition, 10 to 15 large customers have direct access agreements with Royal Mail, injecting their mail directly into Royal Mail's pipeline." (Postcomm, 2006: page 35).

As of September 2006, Postcomm had issued 17 licences to postal operators in addition to Royal Mail (Postcomm, 2006).

Downstream access, which includes customer direct access[26] and alternative providers access, accounted for approximately 5.7% of addressed mail volumes. Of the 20.3 billion addressed mail items sent in 2006 in the United Kingdom, 1.2 billion items were handled under access agreements with Royal Mail (contrasted with 87 million items in 2005). The end-to-end volume delivered by other operators in 2006 remained a very small proportion of total mail volumes. It accounted for approximately 39 million items (Postcomm, 2006).

In the case of the British incumbent, the innovation index (Figure 20) and the accumulated number of innovations between 1975 and 2006 (Figure 42) show that there was an extraordinary improvement in terms of innovation in 2003. Interestingly, this increase almost coincides with the introduction of downstream access in the market, which occurred in 2004. From that date forward, both innovation and access have been increasing, which indicates a positive correlation between these two variables.

---

[26] Customer Direct Access (CDA) is where the customer has signed a direct access agreement with Royal Mail, allowing the customer to outsource its upstream activities (collection, sortation and trucking) and access Royal Mail's network for final delivery.
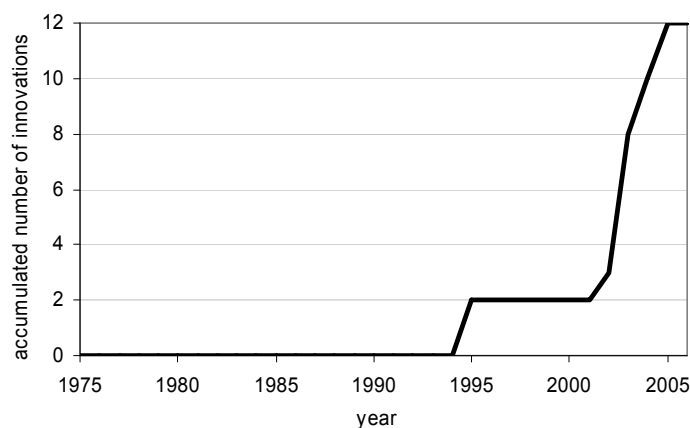
Figure 42: Evolution of the accumulated number of innovations for Royal Mail (between 1975 and 2006)

5.2.2 Results

The three case studies performed in this section show evidence of a positive relationship between innovation and upstream and downstream access. In the American case, high correlations between worksharing and the variables used to measure innovation are found. In the French and British cases, it is observed that the increasing volumes handled by third parties are accompanied by increased innovation index, accumulated number of innovations, and labour productivity.

These results correspond with our initial expectations. With both upstream and downstream access, the incumbent preserves some of its monopolist rents and, therefore, its capacity to invest in new processes and technologies. Simultaneously, it feels the pressure from other operators to become more efficient.

5.3 Concluding remarks

While the process of liberalising the postal sector was initiated a decade ago in Europe, the impact of liberalisation and competition on efficiency and innovation had not yet been assessed.

This chapter aimed at contributing to the literature with empirical evidence on the effect of both liberalisation and competition on innovation in the postal sector. The impact of market size was also analysed and there was an attempt to analyse the effect of private ownership.

To this end, a dataset was put together, which constitutes a unique source of information for analysing the liberalisation process, the development of competition, and the development of innovation in the postal sector in the last decade. The dataset includes data for seventeen European countries, over ten years. Three measures were used as proxies for innovation: (1) an innovation index based on the results of a survey developed for this purpose; (2) the accumulated number of innovations (based on that same survey) and; (3) labour productivity. We also developed a liberalisation index, which allows for the measurement of the percentage of liberalised market (in terms of letter volume).

Several models were estimated by GLS and using PW-PCSE. In general, the models estimated have a high explanatory power. Evidence was found that market liberalisation has a positive effect on innovation. This finding is in line with the predictions made in Chapter 3.

This study also found that an increase in the market share of the competitors stimulates the investment in innovation, at least until the market share of the competitors reaches a certain threshold. Since competition is not very developed in the postal sector, it is not possible to draw conclusions for the cases where the competitors have a larger market share. Nevertheless, evidence was also found in support of the positive impact that mail volume has on the introduction of innovative processes. One can anticipate that if the incumbents lose a considerable part of their market share, it will be more difficult to have the means to invest in innovation and to recover the investments made.

Contrary to what was expected, there was evidence that the percentage of private ownership has a positive effect on innovation. However, the variable "percentage of public ownership" presents almost no variability and, therefore, all the results related to this variable should be seen as preliminary and taken with considerable reserve.

The GDP per capita turned out to be very significant and to have a positive relationship with innovation in all the models.

The case studies supported the initial expectations of a positive relationship between innovation and both upstream and downstream access. In the American case, high correlations were found between worksharing (measured through the percentage of worksharing volumes and the accumulated number of worksharing discounts) and the variables used to measure innovation (i.e. the accumulated number of patents, labour productivity, and the innovation index). In the French and British cases, it was observed that the sustained increase in the volumes handled by third parties is accompanied by persistent increases in the innovation index, accumulated number of innovations, and labour productivity.

6. Conclusions

6.1 Synthesis of contributions and conclusions

The network industries, namely the postal sector, have been undergoing a reform process where liberalisation is one of the main features. The aim of liberalisation is to increase productivity, increase the choice available for the consumers and decrease prices, by promoting rivalry among firms.

In this thesis, we were interested in the effect of liberalisation, with and without competition, on the incumbent's incentives to innovate.

We presented the state of liberalisation and competition in the network industries in the European Union (Chapter 3). We also analysed the factors that can hinder the development of competition in these industries. We concluded that the efforts to liberalise and introduce competition have increased rivalry in the markets, but in some industries there is still a long way to go until significant levels of competition are reached. This is the case of electricity, gas, and railways. The water sector is a particular case where competition in the market is not likely to develop. In the postal sector, competition is also currently very low in the mail segment, but there are signs that with the full market opening in 2011-13 this scenario will change considerably. In the majority of the network industries, interconnection and access to the incumbents' network is an essential factor for the development of competition.

Because liberalisation is not always synonymous with competition, we decided to separately analyse the effect of liberalisation with and without competition on innovation. Based on a literature review, we argued that the effect of liberalisation without competition on innovation depends upon the presence and intensity of natural barriers to entry on the supply side, and on the mechanisms implemented to overcome those barriers. If there are no strong barriers to entry, or there is legislation that minimises the effect of these barriers, then the threat of competition is real. Hence, liberalisation will have a positive impact on innovation. On the contrary, if there are barriers to entry and no mechanisms to

make the threat of competition real, then liberalisation will not have any effect on innovation.

As for the effect of competition on innovation, the literature shows a lack of consensus among the authors. In addition, the majority of the authors use profit maximising models, which do not capture the richness associated with different ownership and governance structures. These aspects are especially important when studying the network industries.

In order to fill this gap in the literature and to bring additional insights to the controversial relationship between competition and innovation, we developed a theoretical model that allows the incumbent to have other objectives than profit maximisation, namely revenue and welfare maximisation (Chapter 4). We analysed the incumbent's optimal investment in innovation under monopoly and duopoly for different objective functions.

The main results of the model are that the critical determinants of whether monopoly or duopoly creates more incentive for the incumbent to innovate are the incumbent's market share under duopoly, as well as the incumbent's elasticity of demand under monopoly and under duopoly. For certain values of these variables, there is an interval where duopoly provides more incentives to innovate than monopoly.

The incumbent's market share has a non-linear impact on innovation under duopoly. Until a certain point an increase in the incumbent's market share creates more incentives to innovate under duopoly and from that point on the contrary happens.

The elasticity of demand of the incumbent has a negative impact on the level of investment in innovation both under monopoly and duopoly, whereas the elasticity of demand of the entrant plays almost no role. As for the cross elasticity of demand, the impact is reduced.

We confirmed that the quantity supplied has a direct effect on innovation incentives, as expected from previous literature. However, other results presented in this thesis differ in several respects from the literature. In particular, if the incumbent places greater weight on social welfare, relative to revenue or profit,

then one can expect an increase in investment in innovation. The more sensible way of inducing the incumbent to behave like a welfare-maximising firm, at least concerning cost-reducing innovations, is through price caps. Price cap regulation is likely to focus attention on cost reduction and associated innovation by the incumbent, leading to behaviour in line with the welfare-oriented incumbent.

We have also empirically tested our predictions regarding the effect of liberalisation and competition on incumbents' investments in innovation (Chapter 5). The impact of the quantity supplied and some control variables was also analysed.

An original dataset was assembled to perform the analysis. The dataset includes data for seventeen European countries, over ten years. Innovation was measured using three proxies: (1) an innovation index based on the results of a survey developed for this purpose; (2) the accumulated number of innovations (based on that same survey) and; (3) labour productivity. Moreover, we built a liberalisation index in order to measure the percentage of the liberalised market (in terms of letter volume).

From the econometric analysis performed, where several models were estimated by Generalised Least Squares (GLS) and Prais-Winsten estimation with Panel Corrected Standard Errors (PW-PCSE), we found evidence that market liberalisation favours incumbents' innovation, which confirms our predictions. Each model is always estimated using the three proxies for innovation and the results are compared. All the models estimated have a high explanatory power and the hypothesis that the explanatory variables coefficients are jointly equal to zero is always rejected.

There is also evidence that an increase in the market share of the competitors stimulates investment in innovation. Note that this result applies when the incumbent preserves a certain market share. When the incumbent's market share is below a certain threshold, an increase in competition is expected to have a negative impact on innovation. Since in the countries included in the econometric analysis the historical operators have at least ninety percent of market share, we could only partially confirm the results from the theoretical model.

The mail volume, or more generally the quantity supplied by the firm, was also found to have a positive impact on the incumbents' investment in innovation.

The Gross Domestic Product (GDP) *per capita* turned out to be very significant and to have a positive relationship with innovation in all the models.

We have also analysed the effect that upstream and downstream accesses, which can be viewed as forms of competition, have on innovation. For that, we resorted to three case studies, which support the initial expectations of a positive relationship between both upstream and downstream access and innovation. In the American case, high correlations were found between worksharing and innovation. In the French and British cases, the continuous increase in the volumes handled by third parties is accompanied by persistent increases in the innovation index, accumulated number of innovations, and labour productivity.

This thesis contributes to clarifying the debate on the impact of different market structures on innovation. Our findings corroborate the existence of a non-linear relationship between rivalry and innovation. Moreover, these findings are of high interest for policy makers since they show that duopoly does not always create more innovation than monopoly. When the industry has large fixed costs, as in the network industries, and economies of scale are important, the loss of considerable volumes makes large investments in new processes and technologies impracticable. Firms will therefore invest less in innovation under a competitive market where their market share is small, than under monopoly.

Another major contribution of this work concerns the importance of price caps to stimulate innovation. In fact, price cap regulation leads to behaviour in line with the welfare oriented incumbent and, therefore, promotes innovation. This conclusion was possible because for the first time an objective function with several dimensions was considered for the study of the incentives to innovate under different market structures.

We also consider that the empirical results are of high importance since there are almost no empirical studies that evaluate the consequences of the liberalisation of the network industries on innovation. We also believe that the list of critical

innovations and the innovation index developed in this thesis, which allow comparisons among different countries, can be very useful for postal operators.

6.2 Policy implications

In this section we summarise the conclusions of major importance for policy makers and regulators.

Liberalisation has *per se* a positive effect on innovation, when the threat of competition is real. From this point of view, it seems indisputable that it is important to create conditions for a competitive environment. Indeed, we have proved that in a first stage, where the incumbent preserves a significant market share, an increase in rivalry has a positive effect on innovation. However, only under certain conditions the incentive to innovate under duopoly overcomes the incentive to innovate under monopoly. Moreover, increased rivalry has a negative effect on incumbent's innovation when the incumbent has a relatively low market share. Hence, incumbent's investment in new technologies and processes is in danger when competition is very intense.

The conditions that ensure a larger investment in innovation and social welfare under duopoly than under monopoly regard the incumbent's market share and its elasticity of demand under both monopoly and duopoly. The investment in innovation and social welfare are larger under duopoly than under monopoly, for instance, when: (1) the incumbent's market share is between 75 and 95 percent (approximately), and (2) the elasticity of demand under duopoly is at least 0.3 units larger (in absolute value) than the elasticity of demand under monopoly. There are other combinations of these parameters' values that lead to the same result but are probably more difficult to attain.

In principle, demand becomes more elastic when we pass from a monopoly to a situation where there is more than one operator in the market. Although regulators can not directly control the price elasticity of demand they can contribute to a more elastic demand under competition by, for example, promoting flexible contractual relationships between firms and consumers. Additionally, regulators

can ensure that consumers are well informed about all goods and services available in the market.

Finally, regulators can make use of the fact that increasing concerns with social welfare, i.e. placing a larger weight on welfare maximisation and reducing the weight given to revenue and profit, has a positive effect on innovation. This can be done through price caps, which are likely to induce the incumbent to behave like a welfare-maximising firm, at least regarding cost-reducing innovations.

6.3 Recommendations for future research

The work developed in this thesis suggests the following topics for future research.

Concerning the theoretical model, there are a series of developments and improvements that can be introduced in the analysis. It would be interesting to expand the theoretical model in order to encompass oligopolistic settings. The introduction of a more general investment game by all competitors (not just the incumbent as analysed here) gains additional importance when competitors are assumed to have a large market share. Other refinements in the theoretical model refer to the cost function assumed. An in-depth study of the elasticity of innovation cost could lead to more accurate results in terms of the optimal level of investment in innovation. Alternatively, the assumption of more general cost function could eventually allow the deduction of analytical results without having to resort to the model calibration. Additionally, it would be interesting to introduce multi-product firms and dynamics in the model.

At an empirical level, further work could introduce worksharing (upstream access) and downstream access, as explanatory variables in the econometric model. Extending the number of countries in the sample could allow withdrawing conclusions on the effect of privatisation (another very important aspect of the reform of the network industries) on innovation. It would also be interesting to replicate this study for other network industries, in particular, the ones where competition is more developed. In this way it would be possible to empirically test

the effect of competition on innovation when the incumbent has less power in the market, i.e. a smaller market share.

References

AGHION, P., BLOOM, N., BLUNDELL, R., GRIFFITH, R. & HOWITT, P. (2005) Competition and innovation: an inverted-U relationship. *The Quarterly Journal of Economics*, 701-728.

AGHION, P., DEWATRIPONT, M. & REY, P. (1999) Competition, financial discipline and growth. *The Review of Economic Studies,* 66, 825-852.

AGHION, P., HARRIS, C., HOWITT, P. & VICKERS, J. (2001) Competition, imitation and growth with step-by-step innovation. *The Review of Economic Studies,* 68, 467-492.

AGHION, P., HARRIS, C. & VICKERS, J. (1997) Competition and growth with step-by-step innovation: an example. *European Economic Review,* 41, 771-782.

ARMSTRONG, M. (2003) Privatisation, regulation and competition. *Competition and Development Conference.* South Africa.

ARMSTRONG, M., COWAN, S. & VICKERS, J. (1994) *Regulatory reform - economic analysis and British experience,* Cambridge, MIT Press.

ARROW, K. (1962) Economic welfare and the allocation of resources for invention. IN NELSON, R. (Ed.) *The rate and direction of inventive activity.* Princeton, Princeton University Press.

ARTHUR D. LITTLE LIMITED (2004) Technology and innovation in the postal sector - a competitive market review.

BAIN, J. (1956) *Bairriers to new competition,* Cambridge.

BALDWIN, W. L. & SCOTT, J. T. (1987) *Market structure and technological change*, Harwood Academic Publishers.

BAUMOL, W. (1982) Contestable markets: an uprising in the theory of industry structure. *American Economic Review,* 72, 1-15.

BAUMOL, W., PANZAR, J. C. & WILLIG, R. D. (1982) *Contestable markets and the theory of industry structure,* New York, Harcourt Brace Jovanovich.

BAUMOL, W. & SIDAK, G. (1994) The pricing of inputs sold to competitors. *Yale Journal on Regulation,* 171.

BAUMOL, W. J. & WILLIG, R. D. (1986) Contestability: developments since the book. *Oxford Economic Papers,* 38, 9-36.

BESTER, H. & PETRAKIS, E. (1993) The incentives for cost reduction in a differentiated industry. *International Journal of Industrial Organization,* 11, 519-534.

BLUNDELL, R., GRIFFITH, R. & REENEN, J. V. (1999) Market share, market value and innovation in a panel of British manufacturing firms. *The Review of Economic Studies,* 66, 529-554.

BOONE, J. (2000) Competitive pressure: the effects on investments in product and process innovation. *The RAND Journal of Economics,* 31**,** 549-569.

BOONE, J. (2001) Intensity of competition and the incentive to innovate. *International Journal of Industrial Organization,* 19**,** 705-726.

BOONE, J. & DIJK, T. V. (1998) Competition and innovation. *De Economist,* 3**,** 445-461.

BUNDESNETZAGENTUR (2006) Ninth market study - Letter market. Mainz.

CELLINI, R. & LAMBERTINI, L. (2005) R&D Incentives under Bertrand Competition: A Differential Game. IN P. HORACEK, M. S. A. P. Z. (Ed.) *Preprints of the 16th IFAC World Congress.* Prague.

CER (2007) Annual report 2006-2007.

COHEN, R. H., FERGUSON, W. W., WALLER, J. D. & XENAKIS, S. S. (2001) Impacts of using worksharing to liberalize a postal market. IN KULENKAMPFF, G. & SMIT, H. (Eds.) *Liberalisation of Postal Markets.* Wissenschaftliches Institut für Kommunikationsdienste GmbH.

COHEN, R. H., FERGUSON, W. W., WALLER, J. D. & XENAKIS, S. S. (2006) Worksharing: how much productive efficiency, at what cost and what price? IN CREW, M. A. & KLEINDORFER, P. R. (Eds.) *Progress toward liberalization of the postal and delivery sector.* New York, Springer.

COHEN, W. M. & LEVIN, R. C. (1989) Empirical studies of innovation and market structure. IN SCHMALENSEE, R. & WILLIG, R. D. (Eds.) *Handbook of industrial organization.* Elsevier Science Publishers B.V.

CREW, M. & KLEINDORFER, P. (2008) Regulation and the USO under entry. IN CREW, M. & KLEINDORFER, P. (Eds.) *Competition and Regulation in the Postal and Delivery Sector.* Cheltenham, UK, Edward Elgar Publ.

CTCON (1998) Study on the weight and price limits of the reserved area in the postal sector. *Studies on the impact of liberalisation in the postal sector.* Brussels.

D'ALCANTARA, G. & AMERLYNCK, B. (2006) Profitability of the Universal Postal Service Provider under Entry with Economies of Scale in Collection and Delivery. IN CREW, M. A. & KLEINDORFER, P. R. (Eds.) *Progress toward Liberalization of the Postal and Delivery Sector.* Boston, Kluwer Academic Publishers.

DELBONO, F. & DENICOLO, V. (1991) Incentives to innovate in a Cournot oligopoly. *The Quarterly Journal of Economics,* 106**,** 951-961.

DEMSETZ, H. (1968) Why regulate utilities? *Journal of Law and Economics,* 11**,** 55-66.

DEMSETZ, H. (1969) Information and efficiency: another viewpoint. *Journal of Law and Economics,* 12**,** 1-22.

DEUTSCHE POST (2007) Letter prices in Europe.

DIETL, H. M., TRINKNER, U. & BLEISCH, R. (2005) Liberalization and regulation of the Swiss letter market. IN CREW, M. A. & KLEINDORFER, P. R. (Eds.) *Regulatory and Economic Challenges in the Postal and Delivery Sector.* Kluwer Academic Punlishers.

DIETL, H. M. & WALLER, P. (2002) Competing with Mr. Postman: business strategies, industry structure, and competitive prices in liberalized letter markets. *Schmalenbach Business Review,* 54**,** 148-170.

DIXIT, A. & STIGLITZ, J. (1977) Monopolistic competition and optimum product diversity. *American Economic Review,* 67**,** 297-308.

DUBEY, P. & WU, C.-W. (2001) When less competition induces more product innovation. *Economics Letters,* 74**,** 309-312.

ECCLES, R. & KUIPERS, P. (2006) A Comparative Study of the UK, the Netherlands, Belgium, France, Germany, Italy and Sweden. IN US, S. (Ed.) *Topics in Regulatory Economics and Policy.*

ECONOMIDES, N. & WHITE, L. (1995) Access and interconnection pricing: how efficient is the "Efficient component pricing rule"? *Antitrust Bulletin,* XL**,** 557-579.

ECORYS (2005) Development of competition in the European postal sector. Rotterdam.

GAUTIER, A. & BLOCH, F. (2008) Access, bypass and productivity gains in competitive postal markets. IN CREW, M. & KLEINDORFER, P. (Eds.) *Competition and Regulation in the Postal and Delivery Sector.* Cheltenham, UK, Edward Elgar Publ.

GILBERT, R. J. & NEWBERY, D. M. G. (1982) Preemptive patenting and the persistence of monopoly. *The American Economic Review,* 72**,** 514-526.

GREENSTEIN, S. & RAMEY, G. (1998) Market structure, innovation and vertical product differentiation. *International Journal of Industrial Organization,* 16**,** 285-311.

GROSSMAN, G. M. & HELPMAN, E. (1991a) *Innovation and growth in the global economy,* Cambridge, MIT Press.

GROSSMAN, G. M. & HELPMAN, E. (1991b) Quality ladders and product cycles. *Quarterly Journal of Economics,* 106**,** 557-586.

HART, O. (1983) The market mechanism as an incentive scheme. *Bell Journal of Economics,* 14**,** 366-382.

IPC (2007) Postal Regulatory Database, Country Directory 2007 - Version 6.

KAMIEN, M. I. & SCHWARTZ, N. L. (1970) Market structure, elasticity of demand and incentive to invent. *Journal of Law and Economics,* 13**,** 241-252.

KAMIEN, M. I. & SCHWARTZ, N. L. (1975) Market structure and innovation: a survey. *Journal of Economic Literature,* 13**,** 1-37.

KAMIEN, M. I. & SCHWARTZ, N. L. (1976) On the degree of rivalry for maximum innovative activity. *The Quarterly Journal of Economics,* 90**,** 245-260.

KWOKA, J. E. (2006) The role of competition in natural monopoly: costs, public ownership, and regulation. *Review of Industrial Organization,* 29**,** 127-147.

LEE, T. & WILDE, L. L. (1980) Market structure and innovation: a reformulation. *The Quarterly Journal of Economics,* 94**,** 429-436.

LEIBENSTEIN, H. (1966) Allocative efficiency vs. "X-efficiency". *The American Economic Review,* 56**,** 392-415.

LEVIN, R. C., COHEN, W. M. & MOWERY, D. C. (1985) R&D appropriability, opportunity, and market structure: new evidence on some Schumpeterian hypotheses. *The American Economic Review,* 75**,** 20-24.

LOURY, G. C. (1979) Market structure and innovation. *The Quarterly Journal of Economics,* 93**,** 395-410.

LUÍS-MANSO, P. (2004) The liberalisation of the water sector in Europe - developments and some national cases. IN INSTITUTO REGIONALE STUDI EUROPEI FRIULI VENEZIA GIULIA (Ed.) *Governare l'acqua.* Pordenone, Edizioni Concordia Sette.

MANSFIELD, E. (1963) Size of firm, market structure, and innovation. *The Journal of Political Economy,* 71**,** 556-576.

MARKARD, J. & TRUFFER, B. (2006) Innovation processes in large technical systems: market liberalization as a driver for radical change? *Research Policy,* 35**,** 609-625.

NERA (2004) Economics of postal services. London.

NEWBERY, D. (2002) Regulating unbundled network utilities. *The Economic and Social Review,* 33**,** 23-41.

NEWBERY, D. (2004) Privatising network industries. *CESifo Working Paper Series No. 1132.*

NICKELL, S. J. (1996) Competition and corporate performance. *The Journal of Political Economy,* 104**,** 724-746.

NISKANEN, W. A. J. (1971) *Bureaucracy and representative government,* Chicago.

OECD (2004) Access pricing in telecommunications. Paris.

OGUS, A. (2004) *Regulation: legal form and economic theory,* Portland, Hart Publishing.

PEARSALL, E. S. (2005) The effects of worksharing and other product innovations on U. S. postal volumes and revenues IN CREW, M. A. & KLEINDORFER, P. R. (Eds.) *Regulatory and Economic Challenges in the Postal and Delivery Sector.* Boston, Kluwer Acadmic Publishers.

POSTCOMM (2006) 2006 Competitive market review.

168

PRICEWATERHOUSECOOPERS (1997) Employment trends in the European postal sector.

PRICEWATERHOUSECOOPERS (2006) The impact on universal service of the full market accomplishment of the postal internal market in 2009.

PRIMEAUX, W. J. (1977) An assessment of X-efficiency gained through competition. *The Review of Economics and Statistics,* 59**,** 105-108.

REDING, V. (2006) The review 2006 of EU Telecom rules: strengthening competition and completing the internal market. Brussels.

ROBINSON, A. (2007) A review of price elasticity models for postal products. *The future of mail.* Pitney Bowes.

ROMER, P. (1990) Endogenous technological change. *Journal of Political Economy,* 98**,** S71-S102.

SALOP, S. (1977) The noisy monopolist: imperfect information, price dispersion, and price discrimination. *Review of Economic Studies,* 44**,** 393-406.

SCHERER, F. M. (1967) Research and development resource allocation under rivalry. *The Quarterly Journal of Economics,* 81**,** 359-394.

SCHMIDT, K. M. (1997) Managerial incentives and product market competition. *The Review of Economic Studies,* 64**,** 191-213.

SCHUMPETER, J. (1942) *Capitalism, socialism and democracy,* New York, Harper.

SWAN, P. L. (1970) Market structure and technological progress: the influence of monopoly on product innovation. *The Quarterly Journal of Economics,* 84**,** 627-638.

TANG, J. (2006) Competition and innovation behaviour. *Research Policy,* 35**,** 68-82.

TRAIN, K. (1997) *Optimal regulation: the economic theory of natural monopoly,* Cambridge, MIT Press.

VICKERS, J. & YARROW, G. (1988) *Privatization: an economic analysis,* Cambridge, MIT Press.

VICKERS, J. & YARROW, G. (1991) Economic perspectives on privatization. *Journal of Economic Perspectives* 5**,** 111-132.

VON UNGERN-STERNBERG, T. (2004) *Efficient monopolies: the limits of competition in the European property market,* Oxford, Oxford University Press.

WIK (2004) Main developments in the European postal sector. Bad Honnef.

WIK (2005) The evolution of the regulatory model for european postal services. Bad Honnef.

WIK (2006) Main developments in the postal sector (2004-2006). Bad Honnef.

WILLIAMSON, O. E. (1965) Innovation and market structure. *The Journal of Political Economy,* 73**,** 67-73.

YI, S.-S. (1999) Market structure and incentives to innovate: the case of Cournot oligopoly. *Economics Letters,* 65**,** 379-388.

Annex 1 – Sensitivity analysis for e (France)
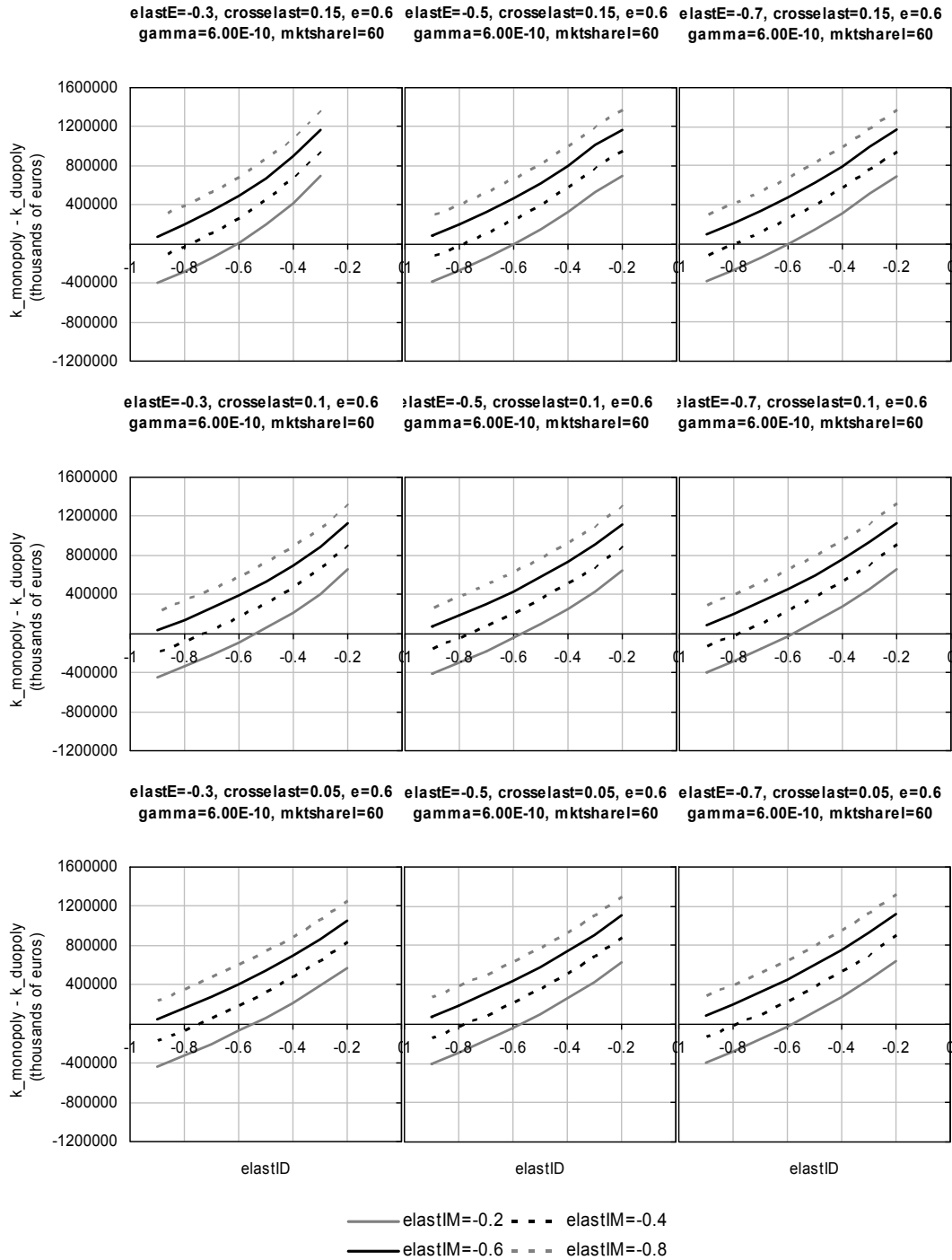
Figure 43: Results for e=0.6, γ =6E-10 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
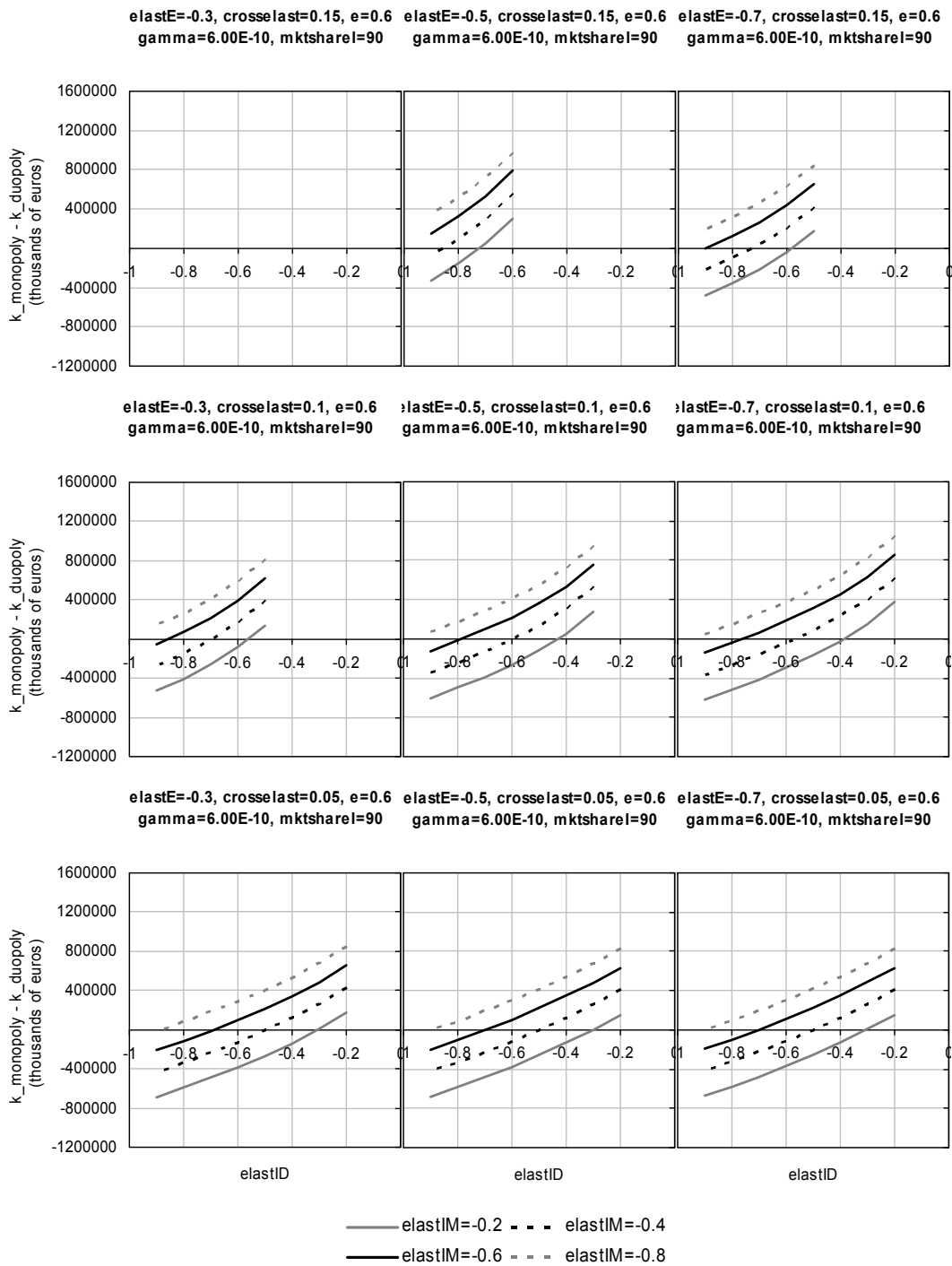
Figure 44: Results for e=0.6, γ =6E-10 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)
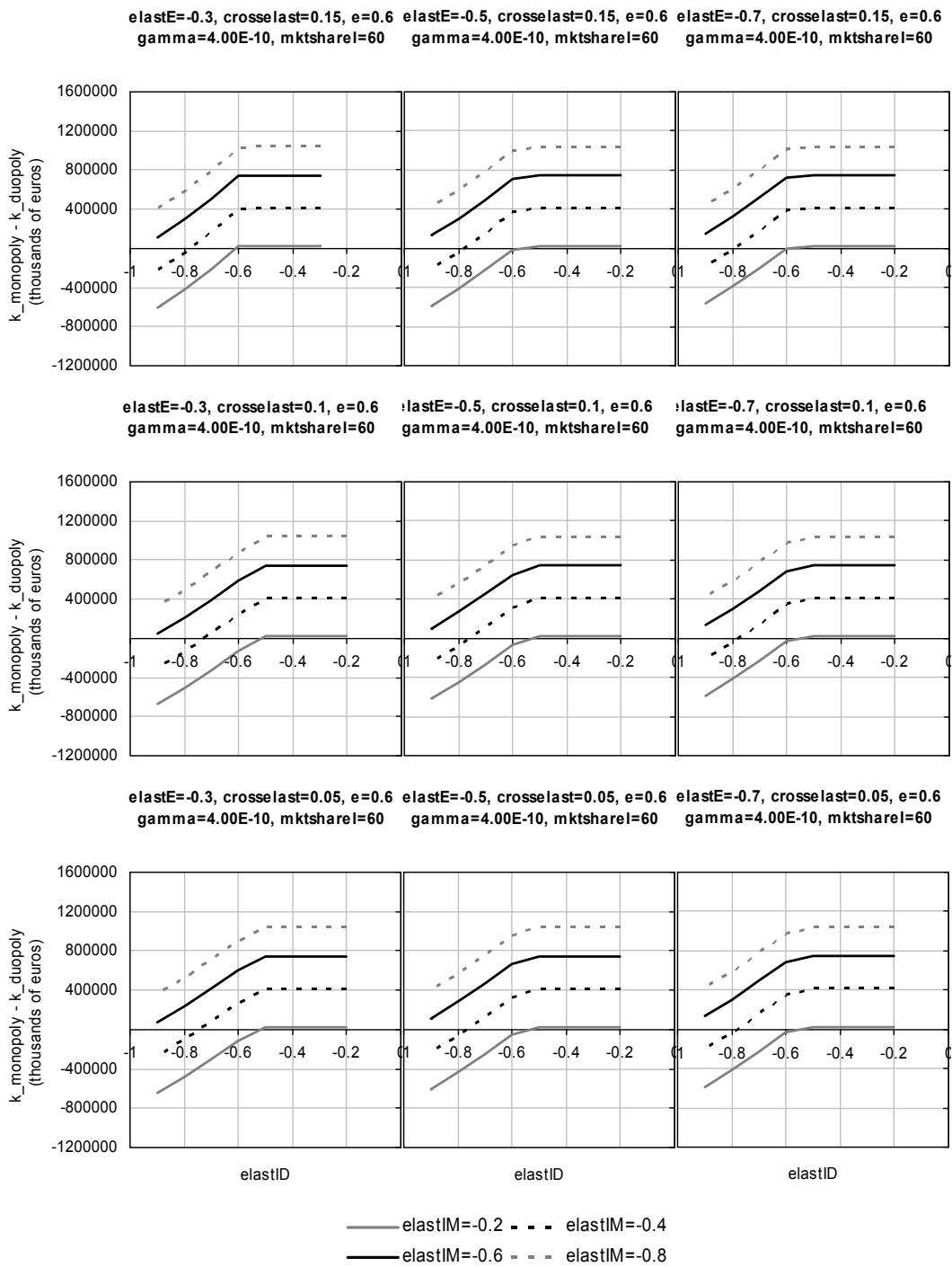
Figure 45: Results for e=0.6, γ =4E-10 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
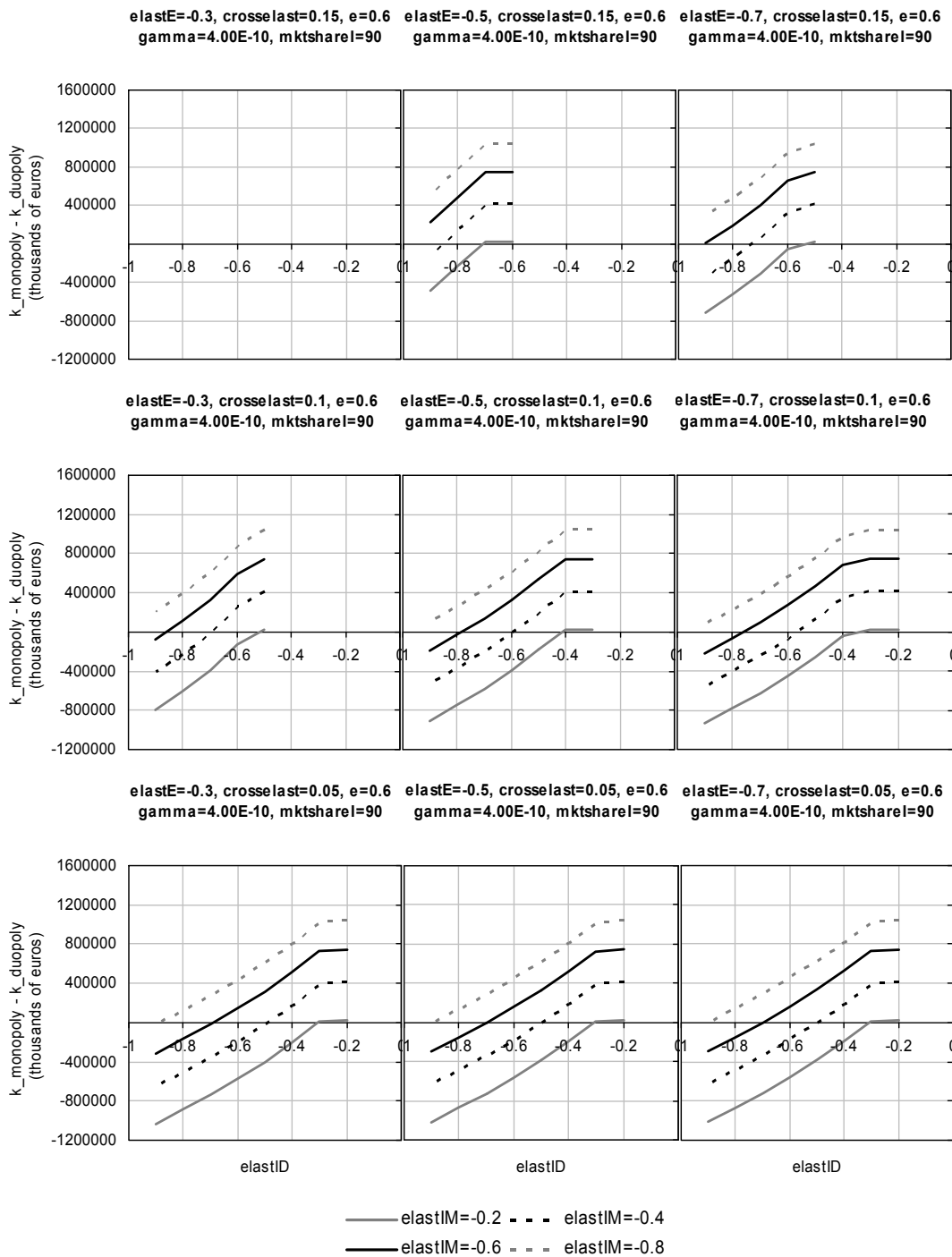
Figure 46: Results for e=0.6, γ =4E-10 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

174

Annex 2 – Results for Latvia
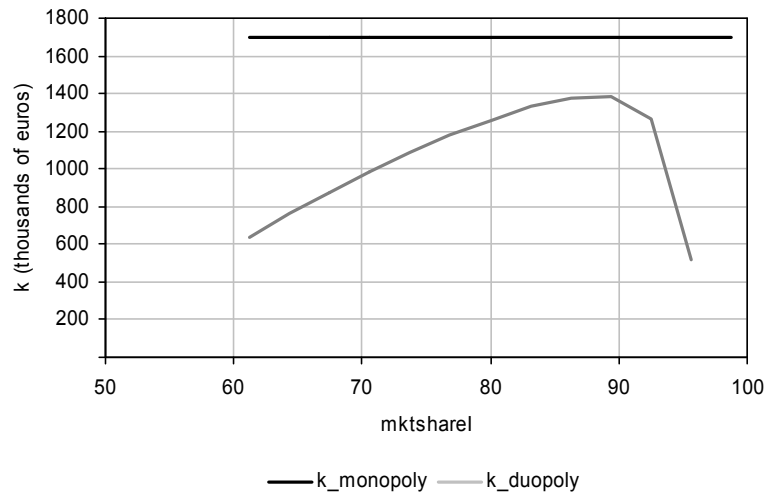
Figure 47: Effect of the incumbent's market share on k ($\alpha_1 = 0.2$, $\alpha_2 = 0.6$, $\alpha_3 = 0.2$, $e = 0.8$, $\gamma = 2.5E-7$, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
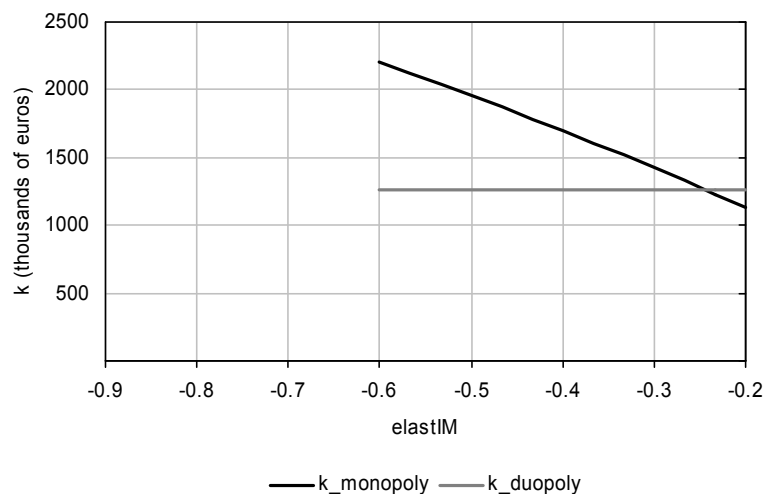
Figure 48: Sensitivity analysis for elastIM ($\alpha_1 = 0.2$, $\alpha_2 = 0.6$, $\alpha_3 = 0.2$, $e = 0.8$, $\gamma = 2.5E-7$, mktshareI=80%, elastID=-0.5, elastE=-0.6, crosselast=0.1)
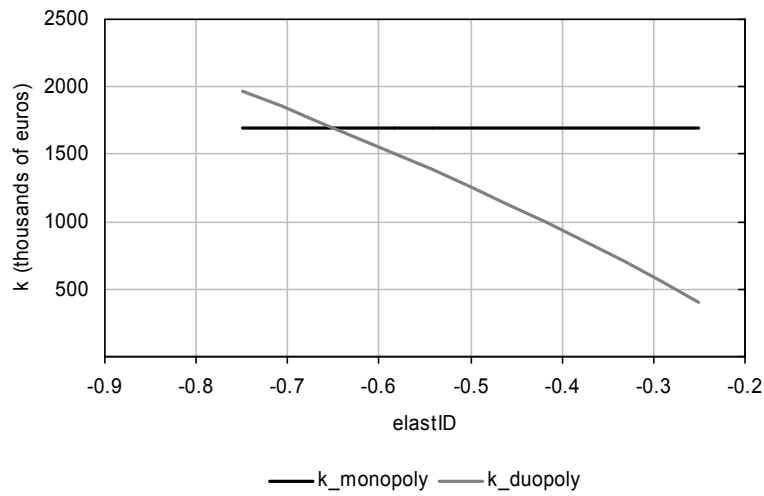
Figure 49: Sensitivity analysis for elastID (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-7, mktshareI=80%, elastIM=-0.4, elastE=-0.6, crosselast=0.1)
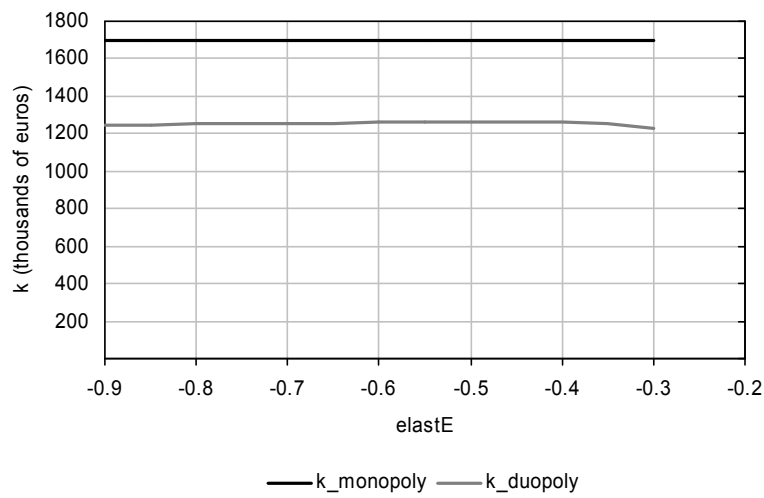
Figure 50: Sensitivity analysis for elastE (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-7, mktshareI=80%, elastIM=-0.4, elastID=-0.5, crosselast=0.1)

176
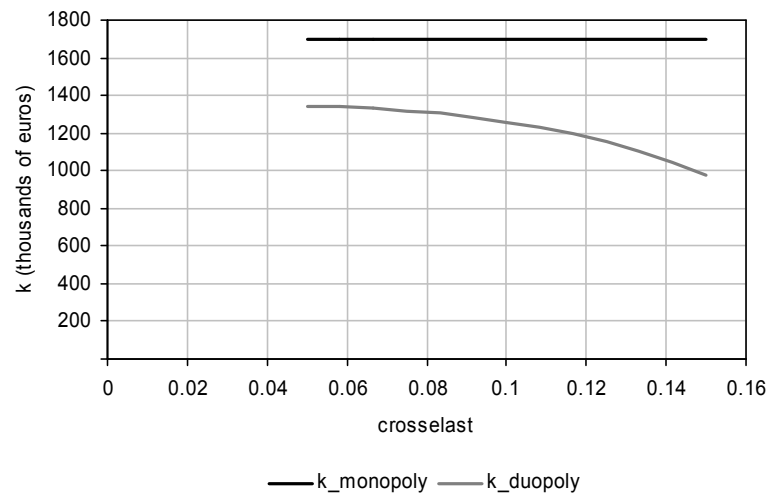
Figure 51: Sensitivity analysis for crosselast (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =2.5E-7, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6)
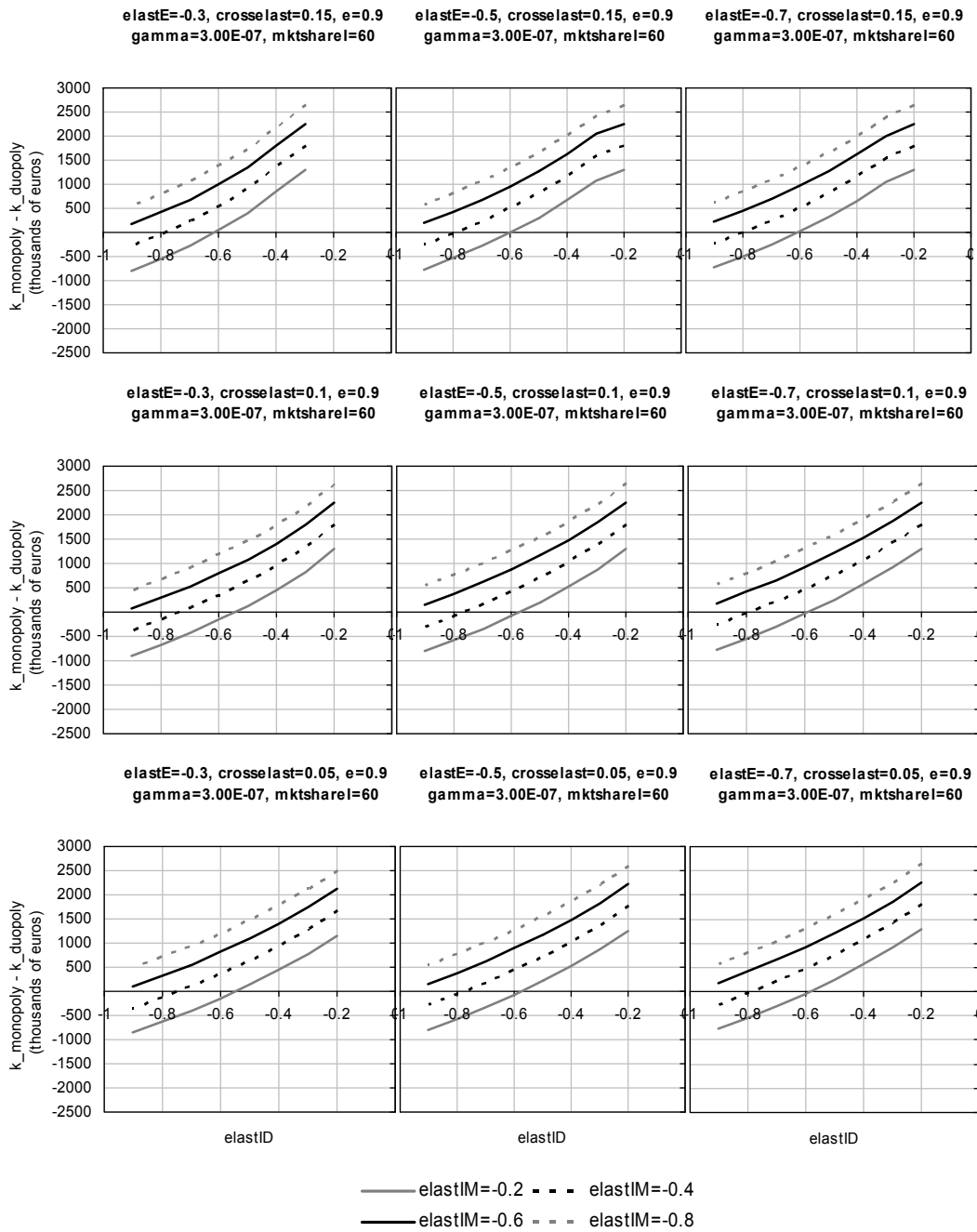
Figure 52: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation (α_1=0.2, α_2=0.6, α_3=0.2, e=0.9, γ=3E-7, and mktshareI=60%)
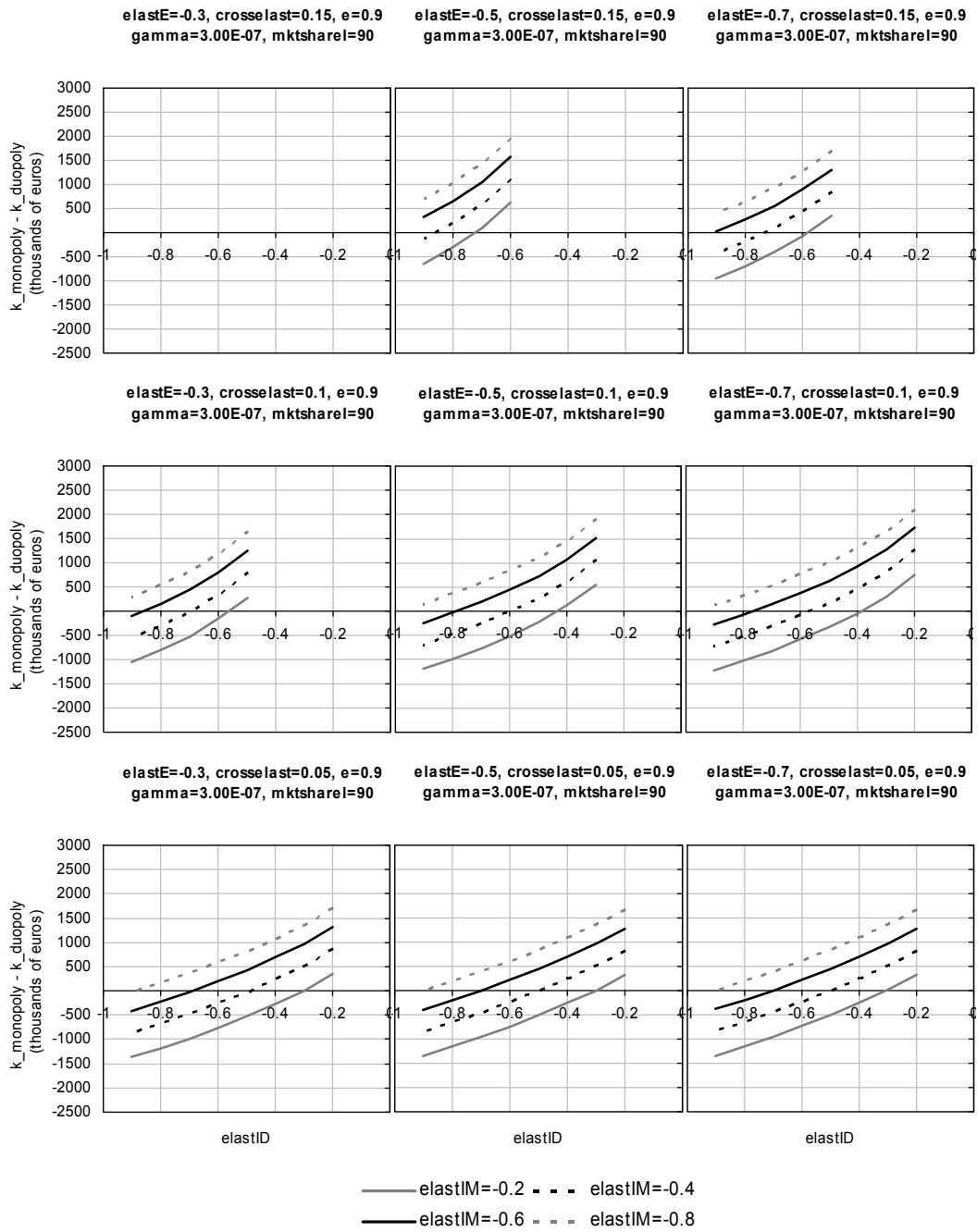
Figure 53: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.9, γ =3E-7, and mktshareI=90%)

179
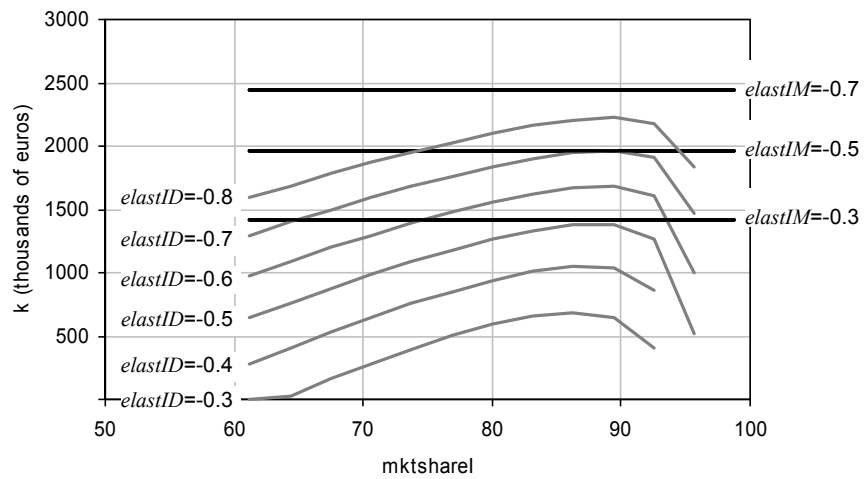
Figure 54: Combined effect of the incumbent's market share, elastIM, and elastID on k under monopoly and duopoly (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =5E-10, elastE=-0.6, and crosselast=0.1)
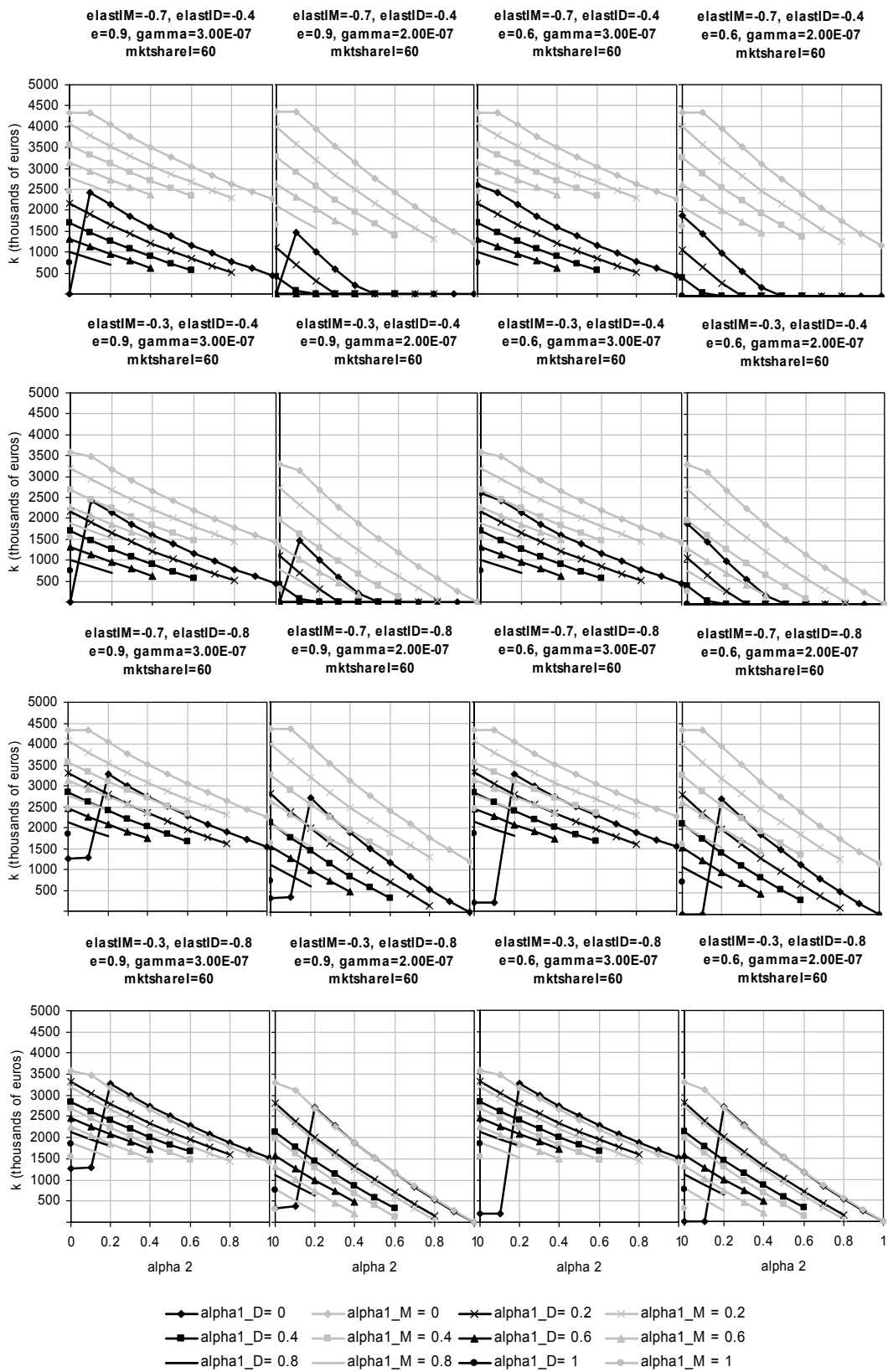
Figure 55: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=60%)
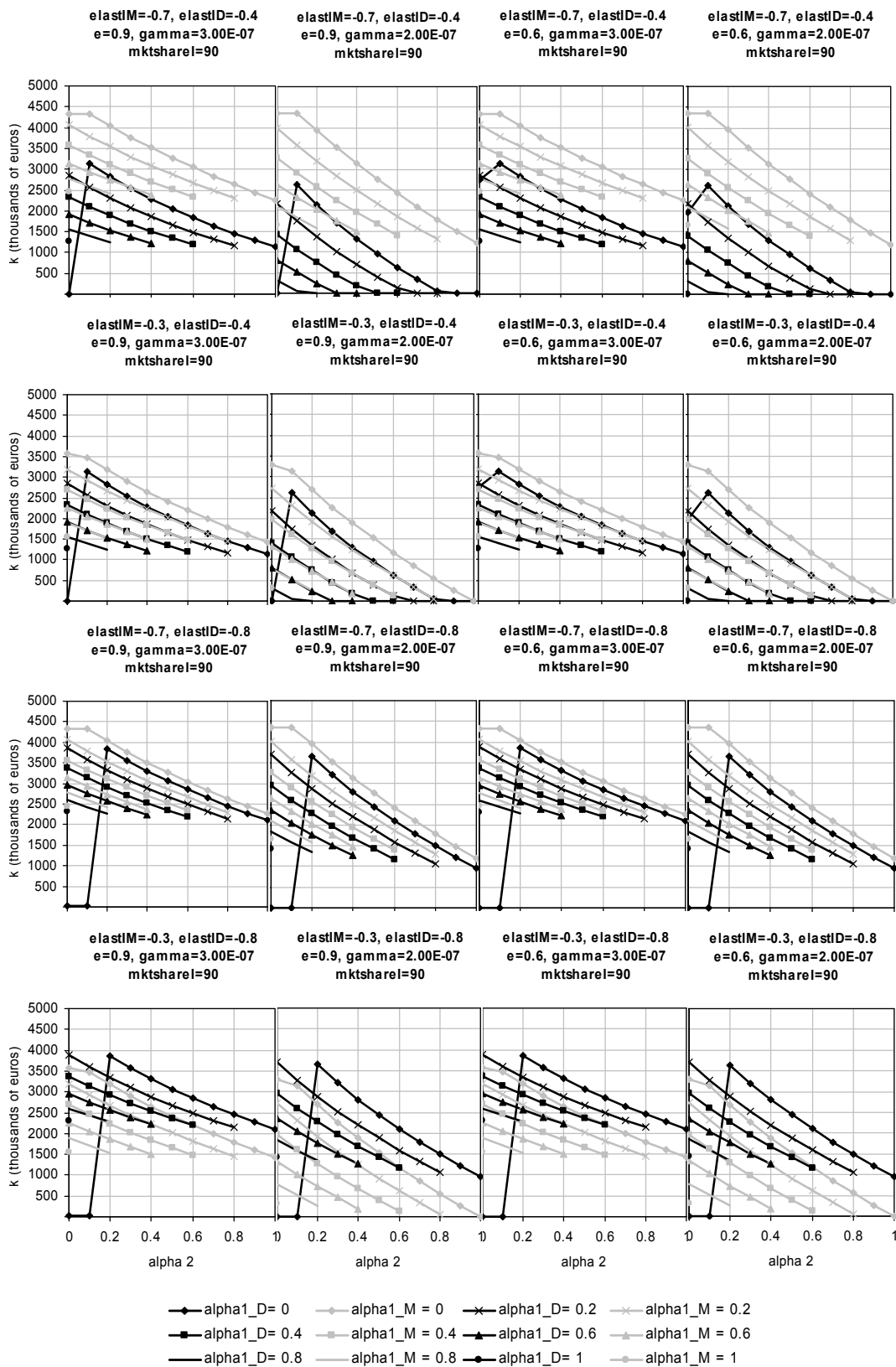
Figure 56: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=90%)
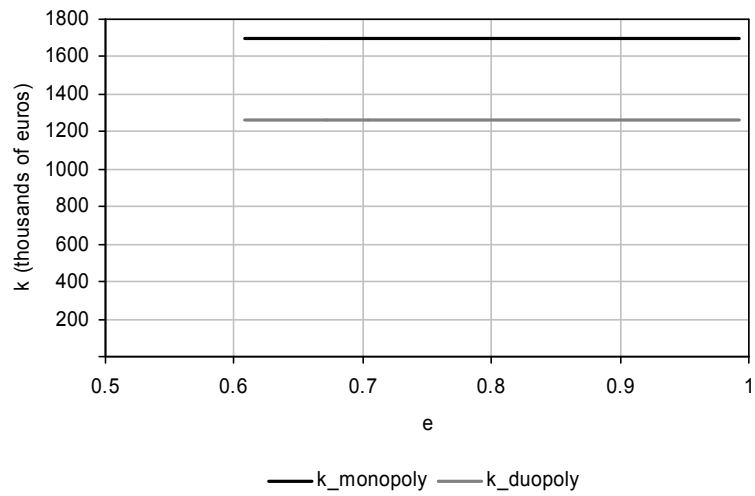
Figure 57: Sensitivity analysis for e (α_1=0.2, α_2=0.6, α_3=0.2, γ=2.5E-7, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
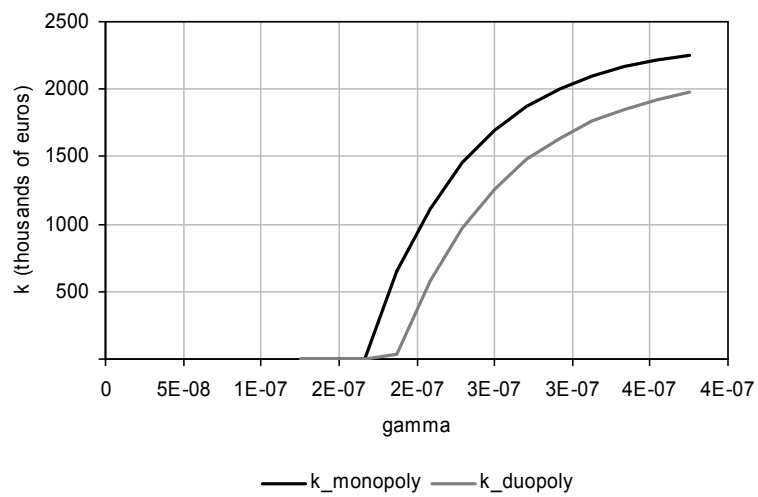
Figure 58: Sensitivity analysis for γ (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
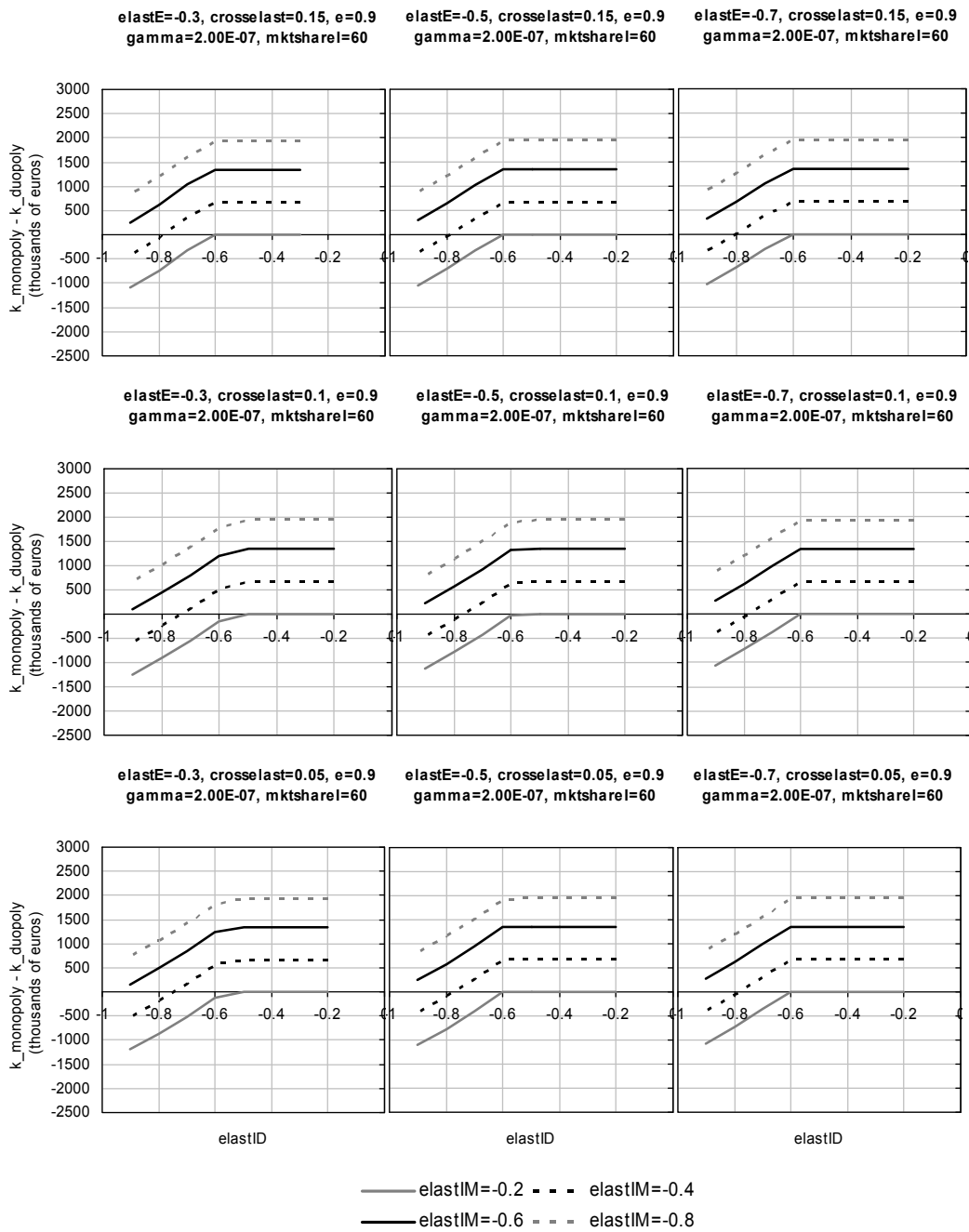
Figure 59: Results for e=0.9, γ =2E-7 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
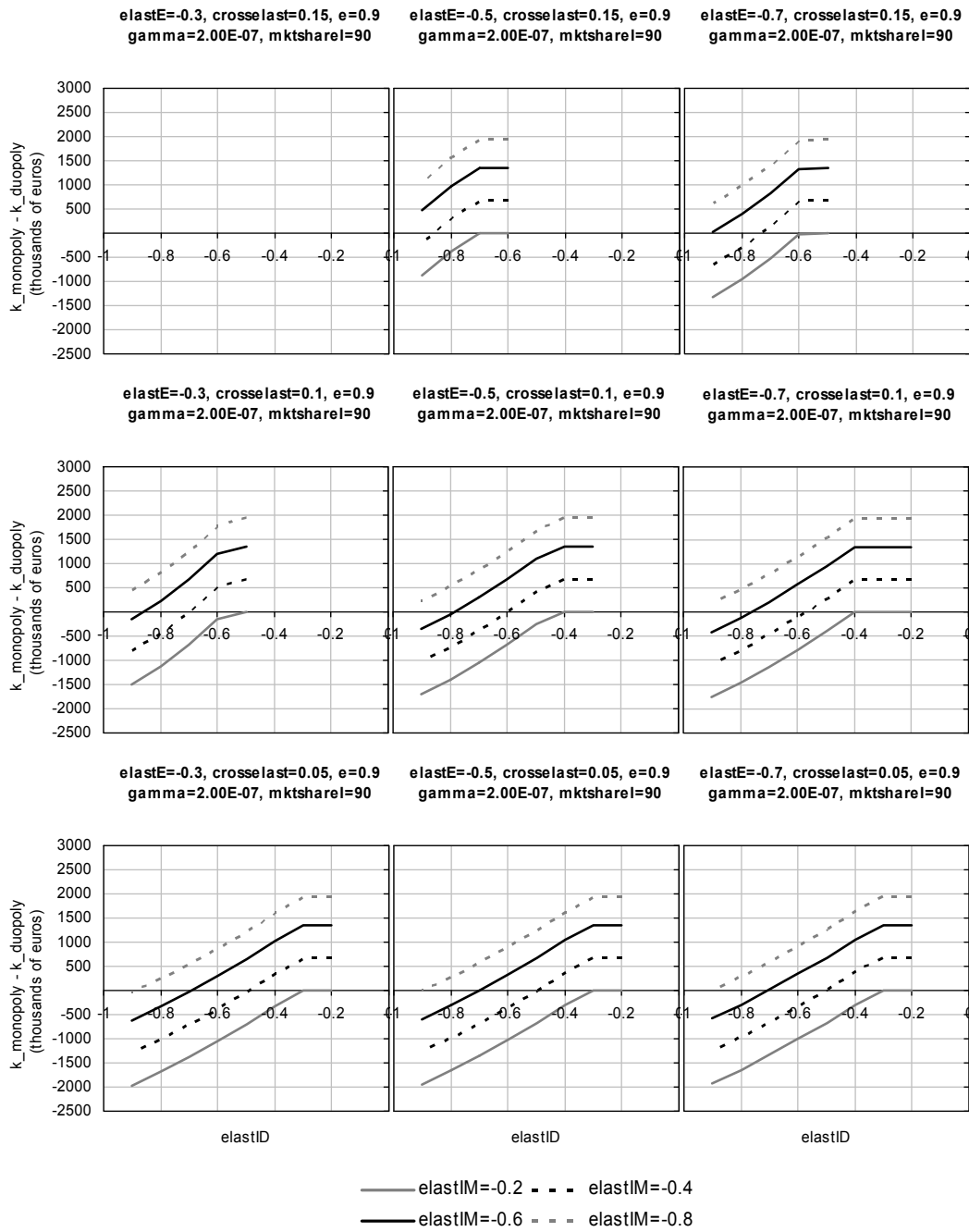
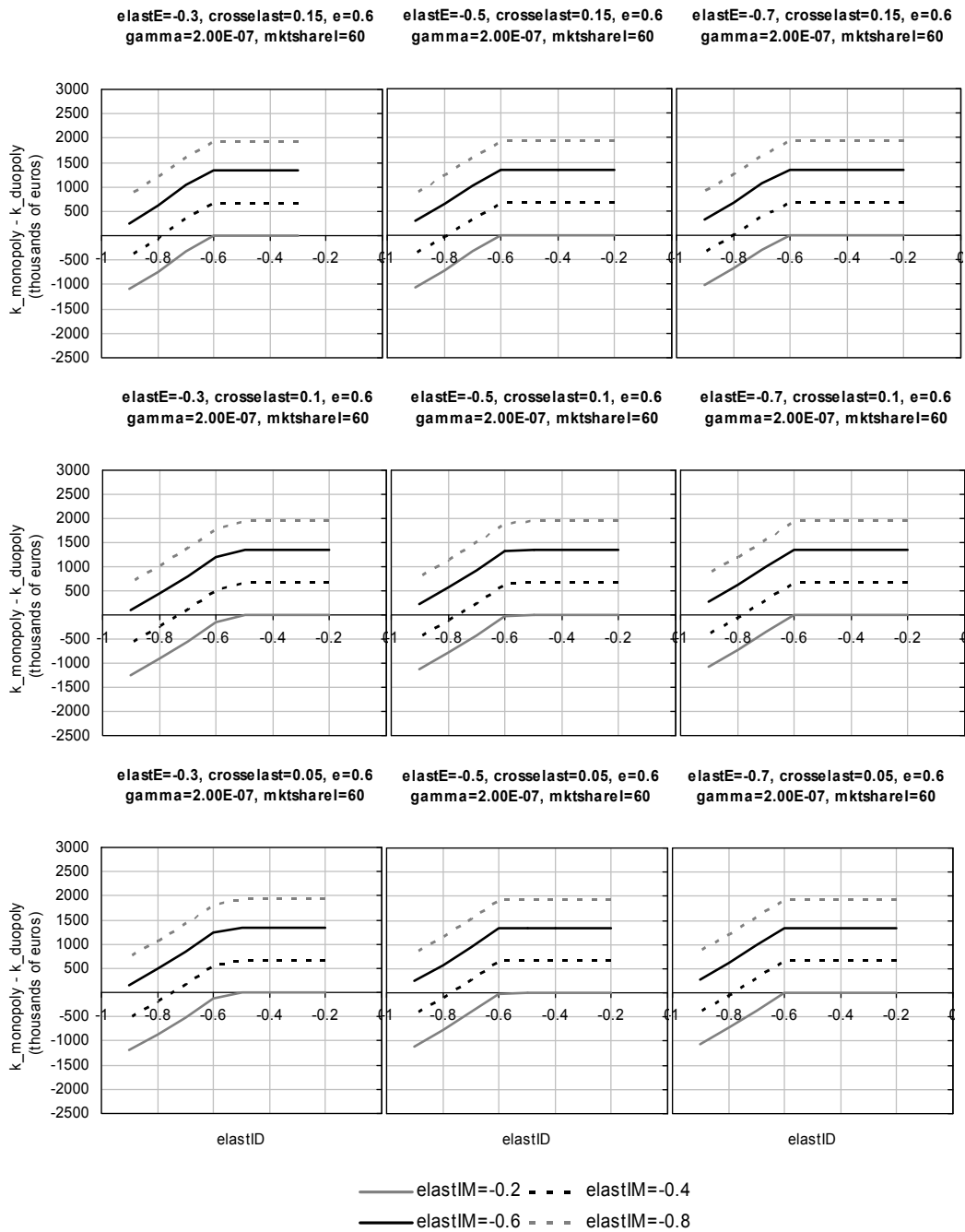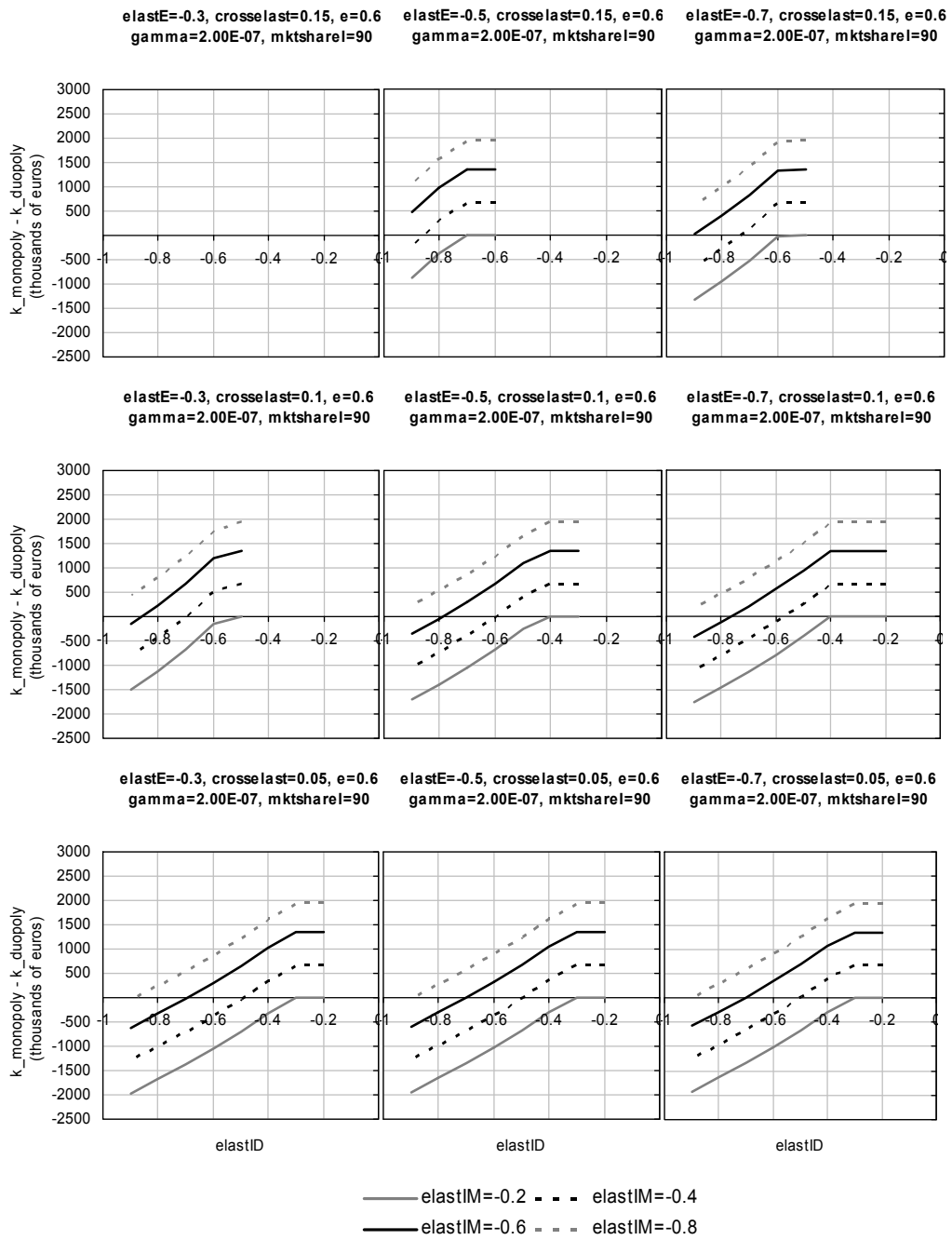*Figure 60: Results for e=0.9, γ =2E-7 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)*
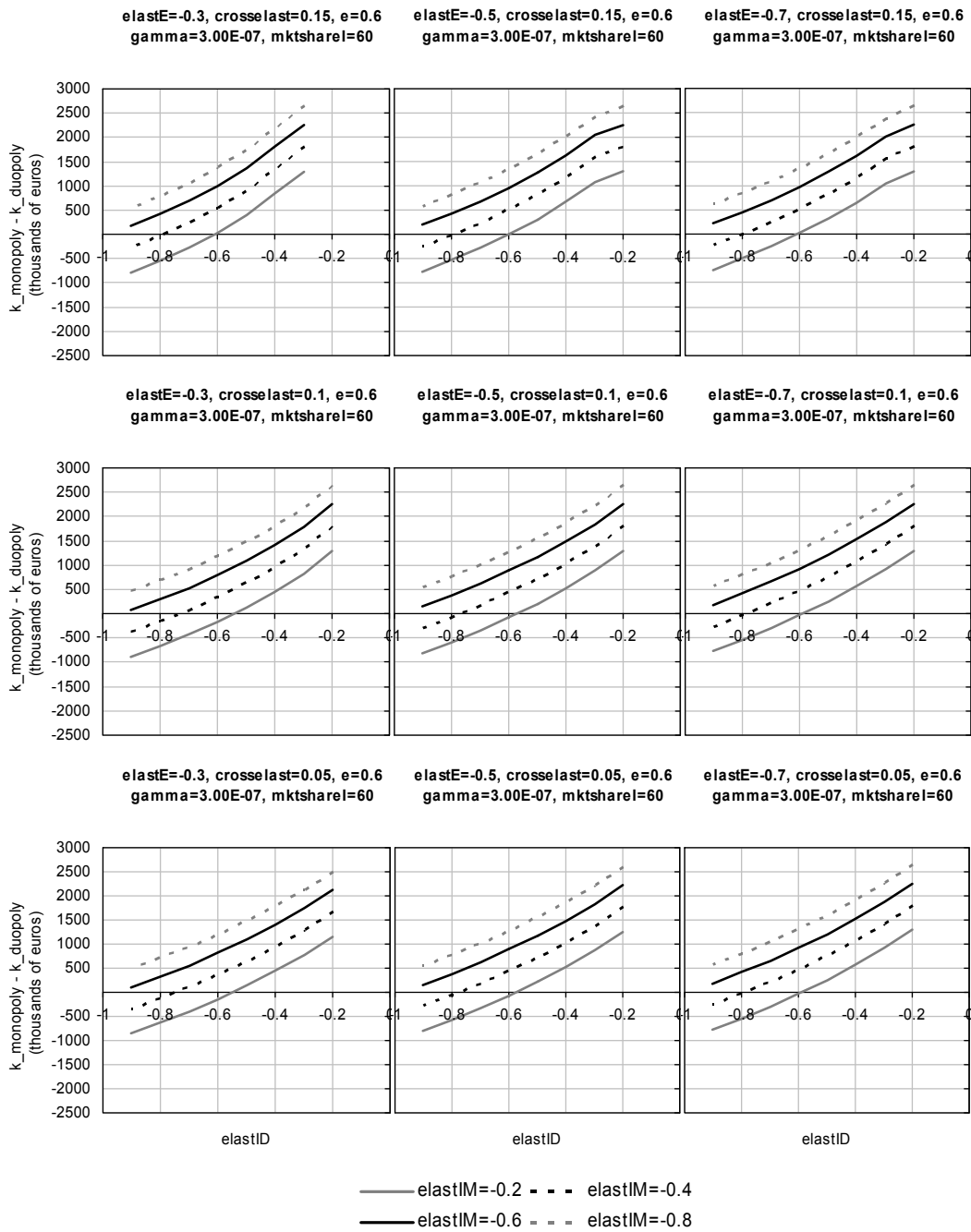
Figure 61: Results for e=0.6, γ =3E-7 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
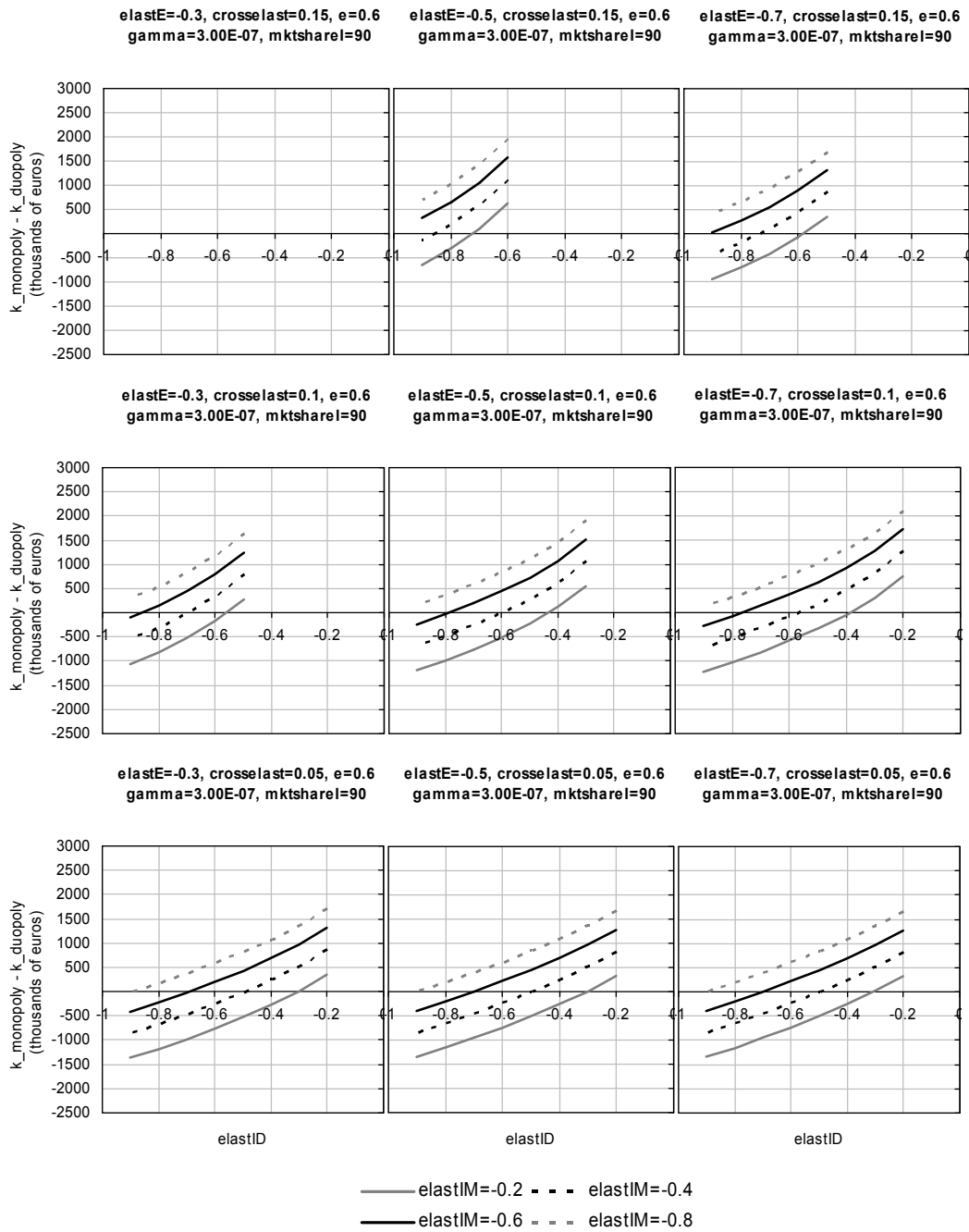
Figure 62: Results for e=0.6, γ =3E-7 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

Figure 63: Results for e=0.6, γ =2E-7 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

Figure 64: Results for e=0.6, γ =2E-7 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

Annex 3 – Results for Portugal
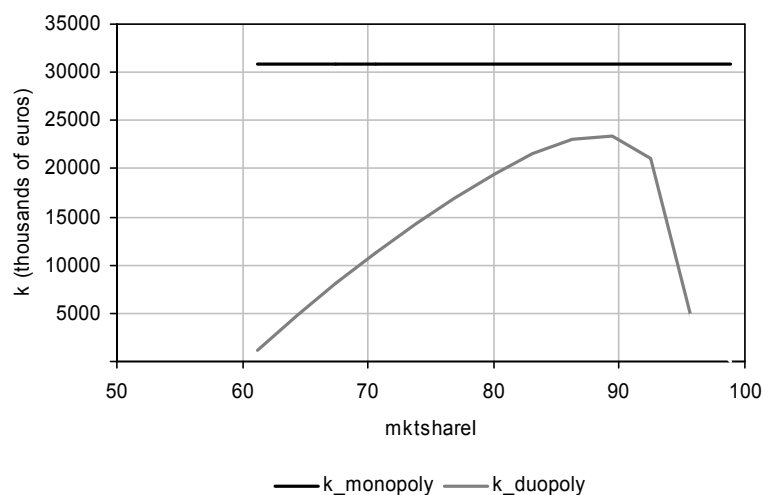
Figure 65: Effect of the incumbent's market share on k (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=1E-8, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
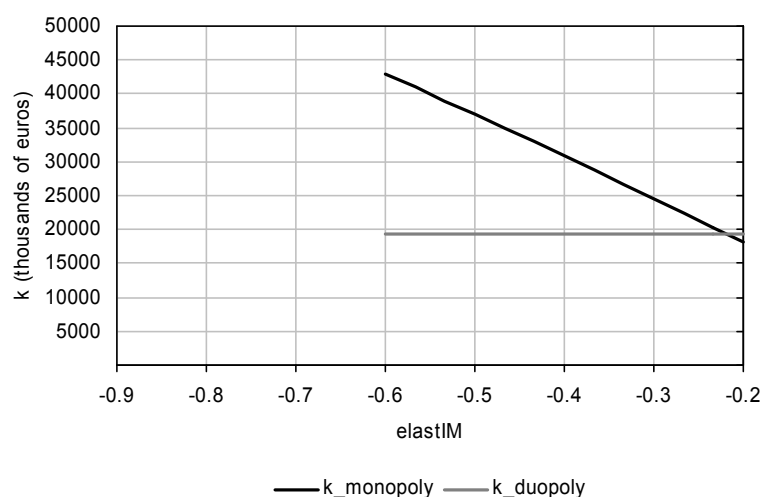

Figure 66: Sensitivity analysis for elastIM (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=1E-8, mktshareI=80%, elastID=-0.5, elastE=-0.6, crosselast=0.1)

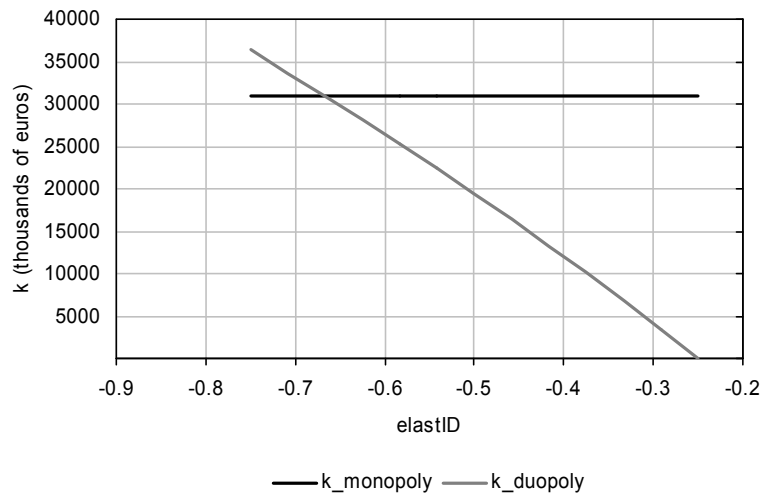*Figure 67: Sensitivity analysis for elastID (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=1E-8, mktshareI=80%, elastIM=-0.4, elastE=-0.6, crosselast=0.1)*
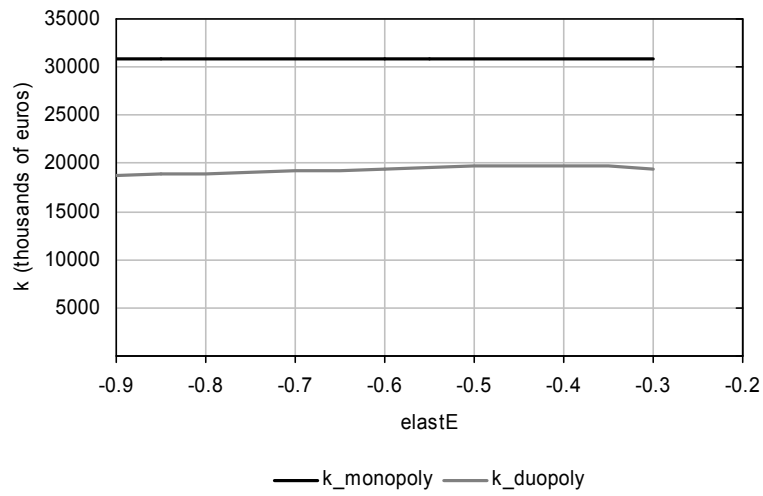

Figure 68: Sensitivity analysis for elastE (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=1E-8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, crosselast=0.1)
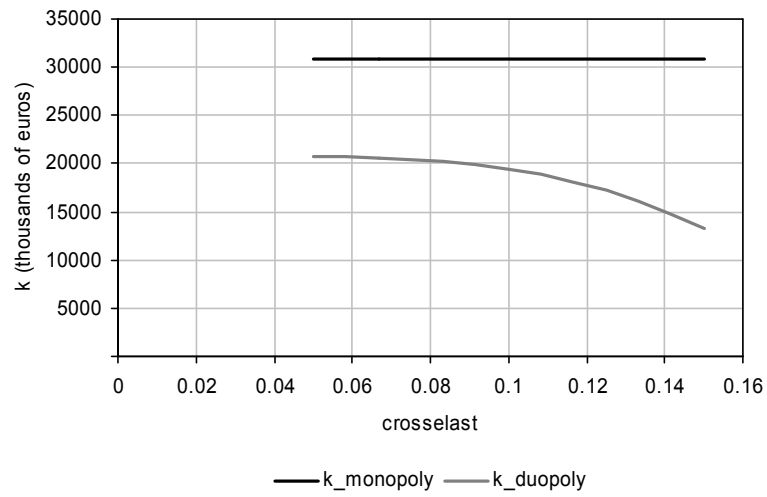
Figure 69: Sensitivity analysis for crosselast (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =1E-8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6)

Figure 70: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation ($\alpha_1 = 0.2$, $\alpha_2 = 0.6$, $\alpha_3 = 0.2$, $e = 0.9$, $\gamma = 1.2E\text{-}8$, and mktshareI=60%)
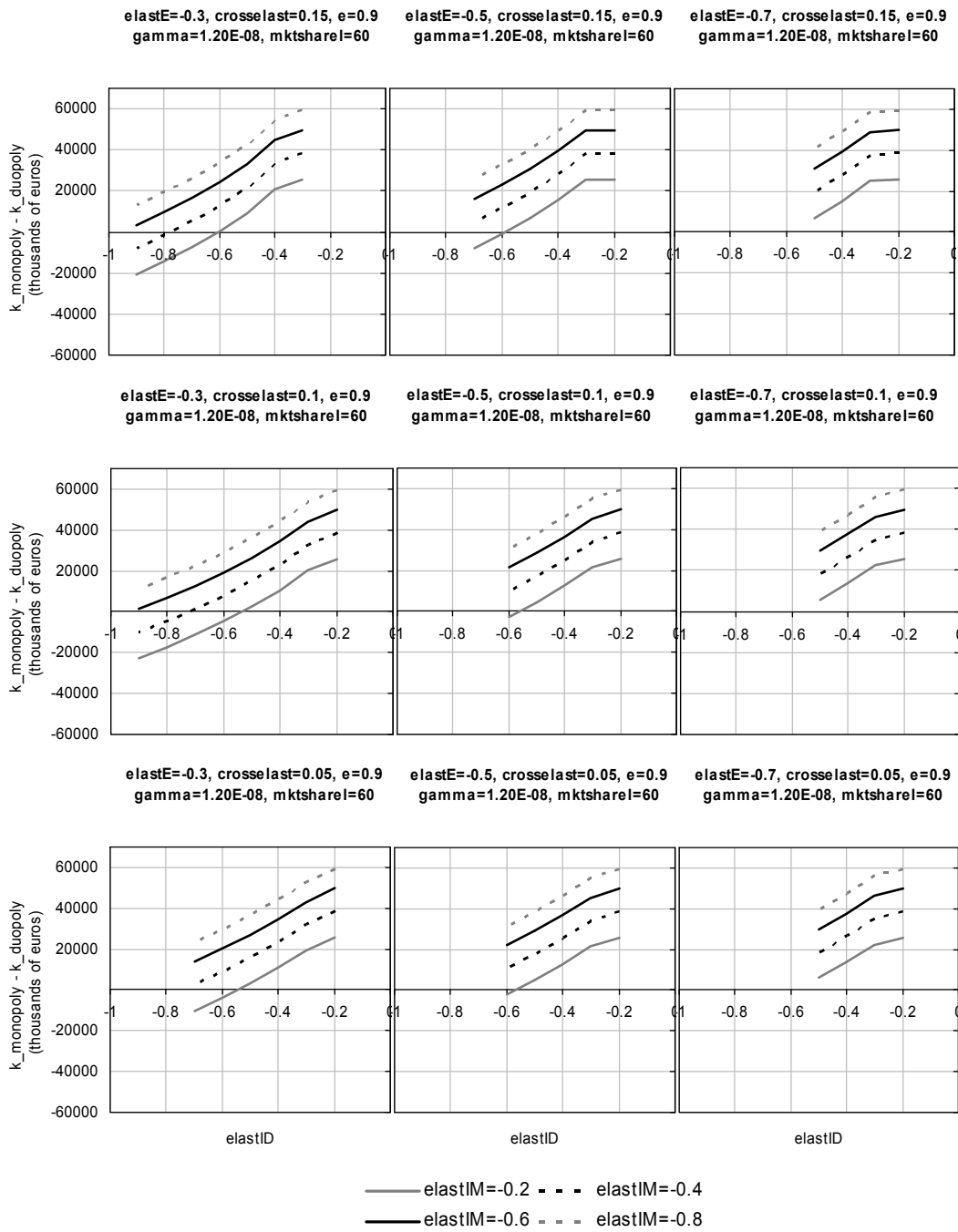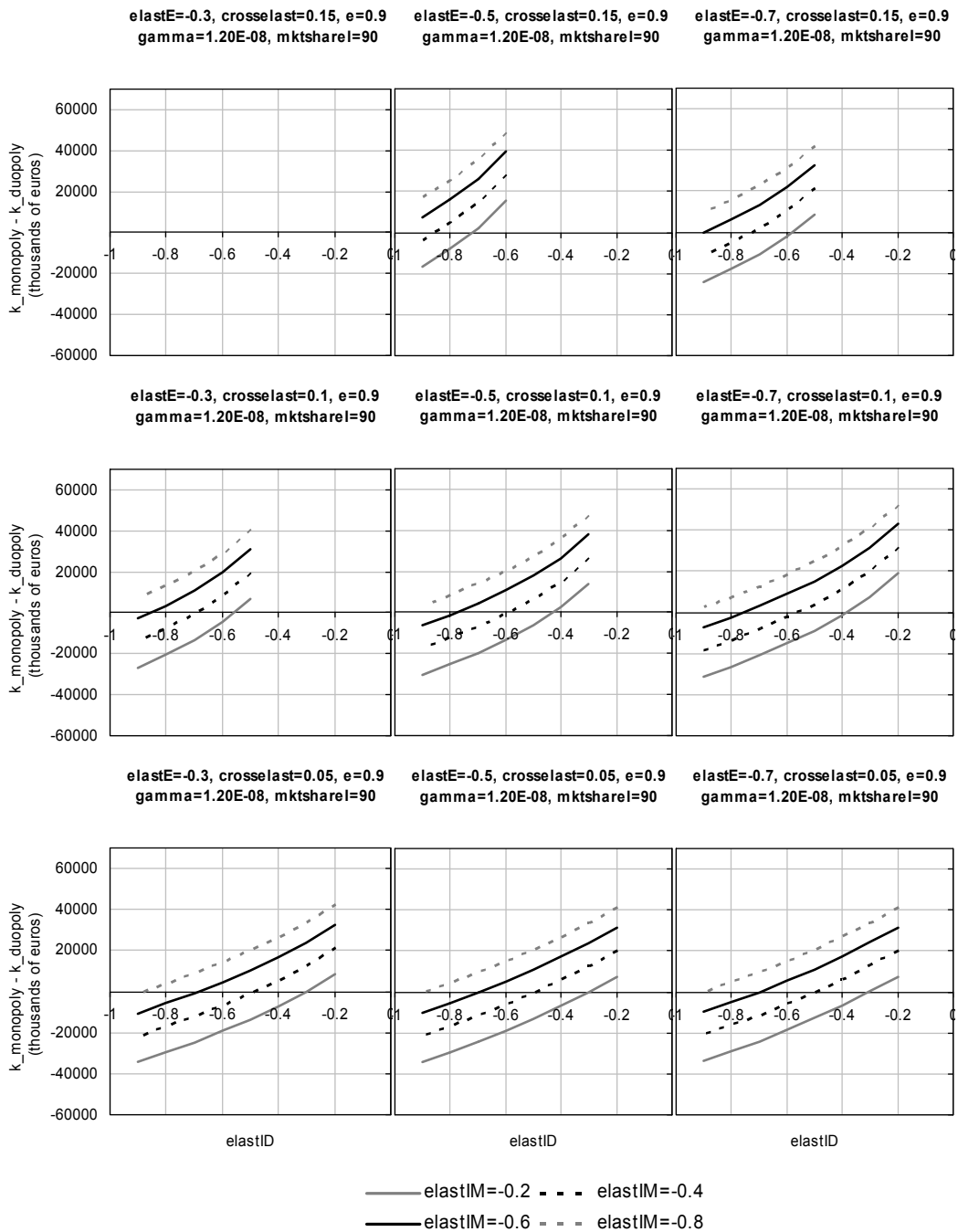
Figure 71: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation ($\alpha_1 =0.2$, $\alpha_2 =0.6$, $\alpha_3 =0.2$, $e=0.9$, $\gamma =1.2E\text{-}8$, and mktshareI=90%)
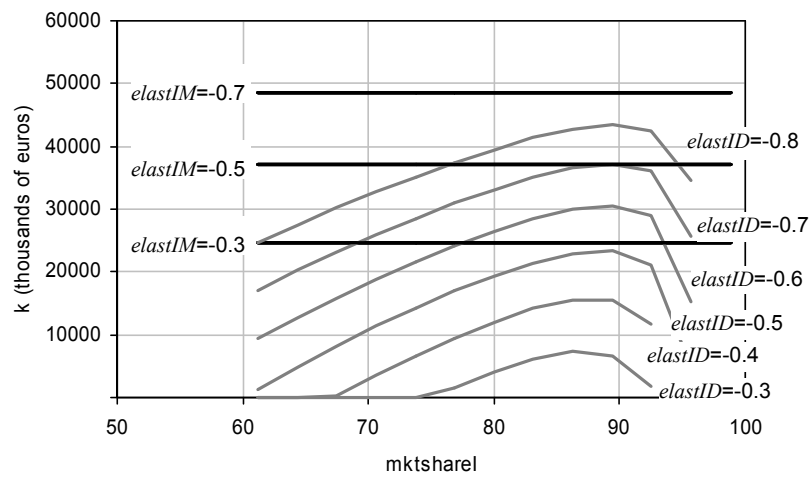
Figure 72: Combined effect of the incumbent's market share, elastIM, and elastID on k under monopoly and duopoly ($\alpha_1 = 0.2$, $\alpha_2 = 0.6$, $\alpha_3 = 0.2$, $e = 0.8$, $\gamma = 5E\text{-}10$, elastE=-0.6, and crosselast=0.1)
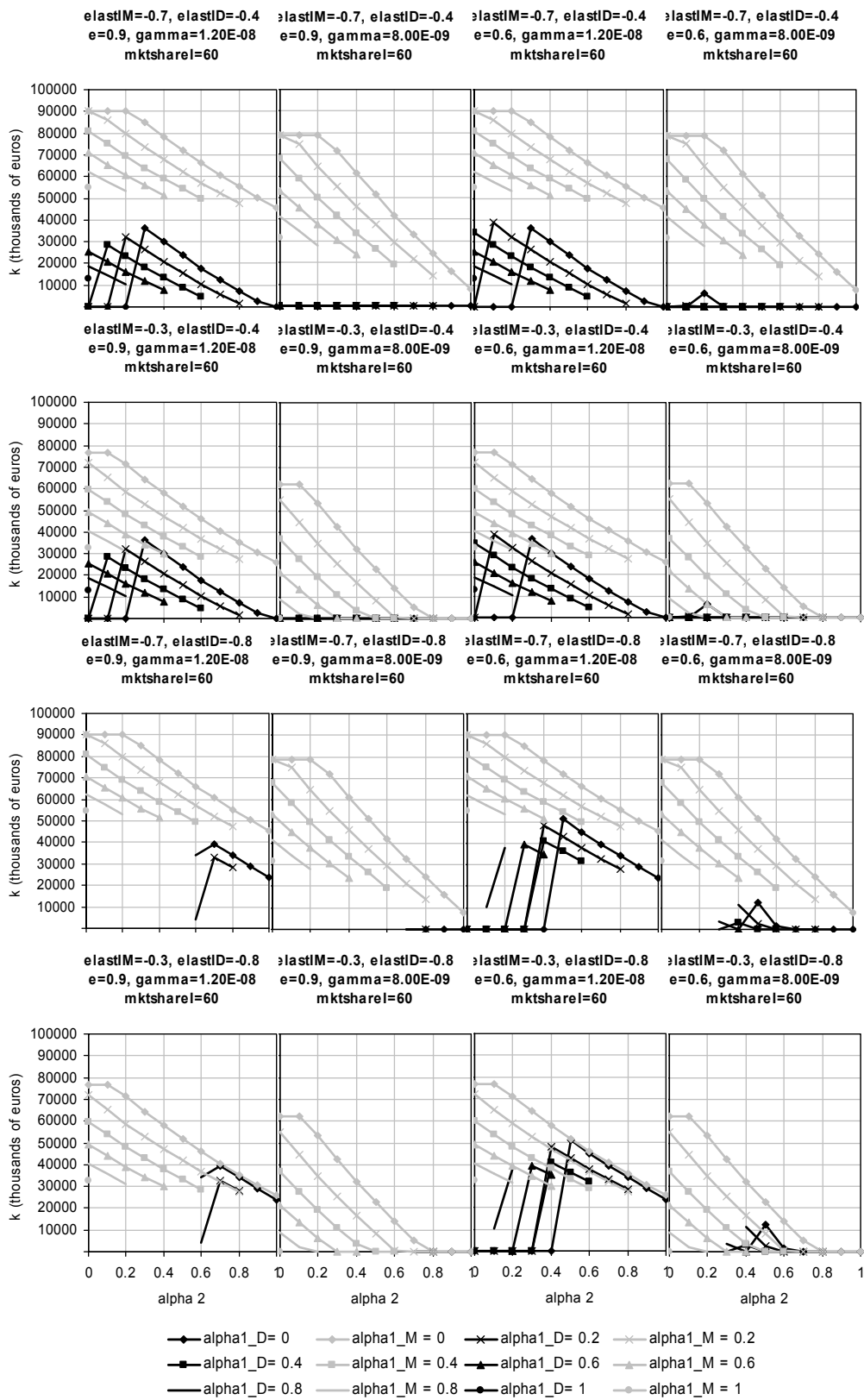
Figure 73: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=60%)
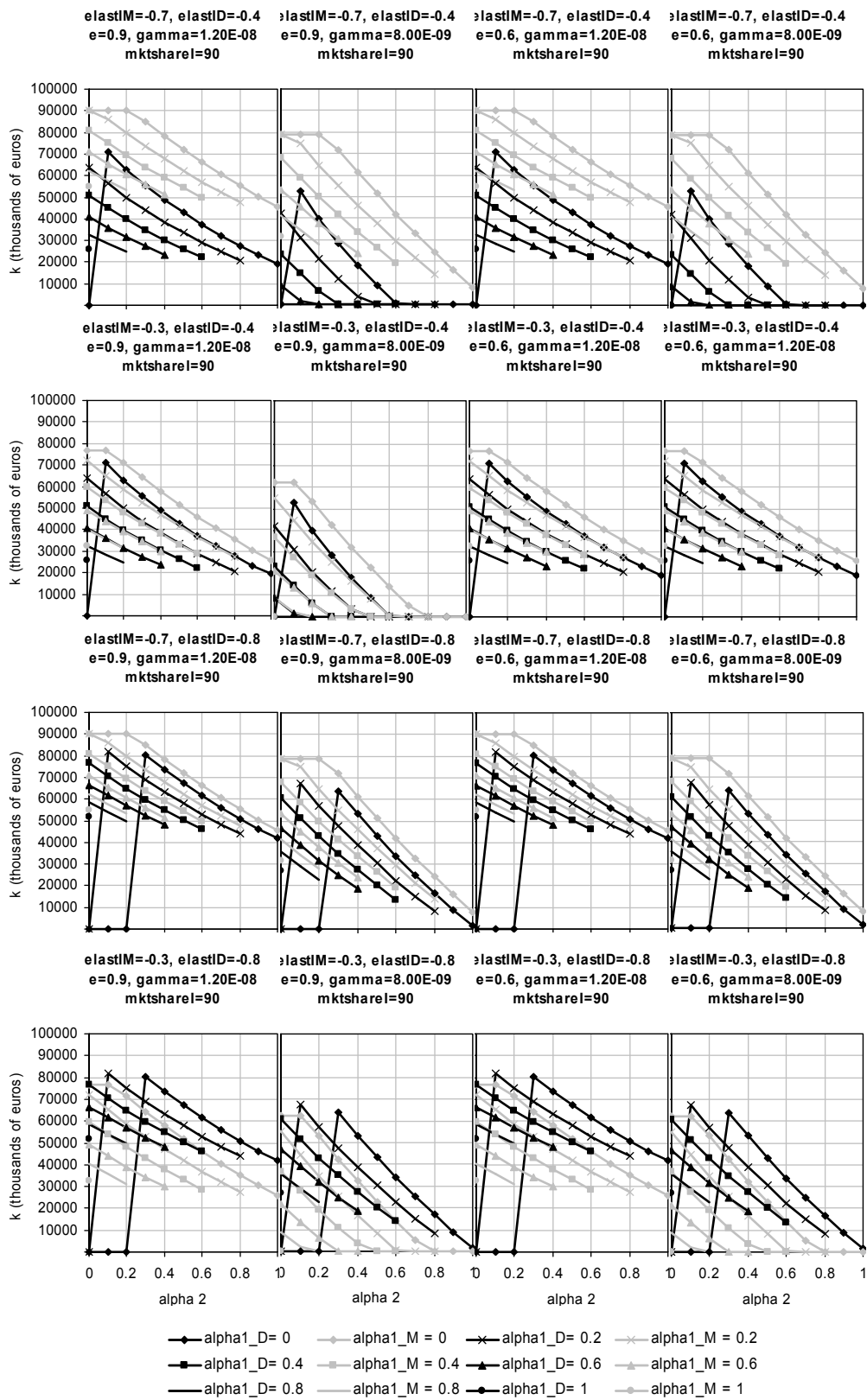
Figure 74: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=90%)
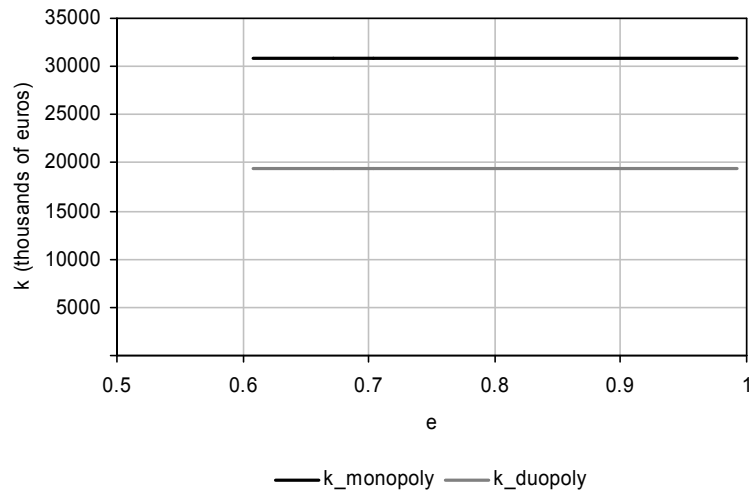
Figure 75: Sensitivity analysis for e (α_1=0.2, α_2=0.6, α_3=0.2, γ=1E-8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
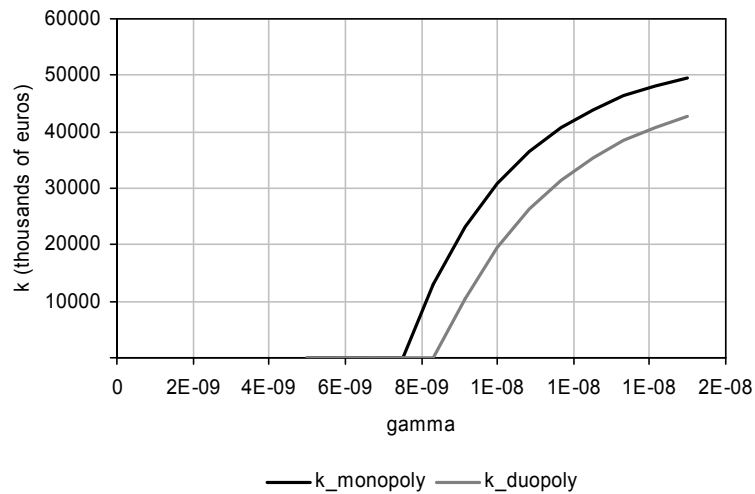
Figure 76: Sensitivity analysis for γ (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)

199
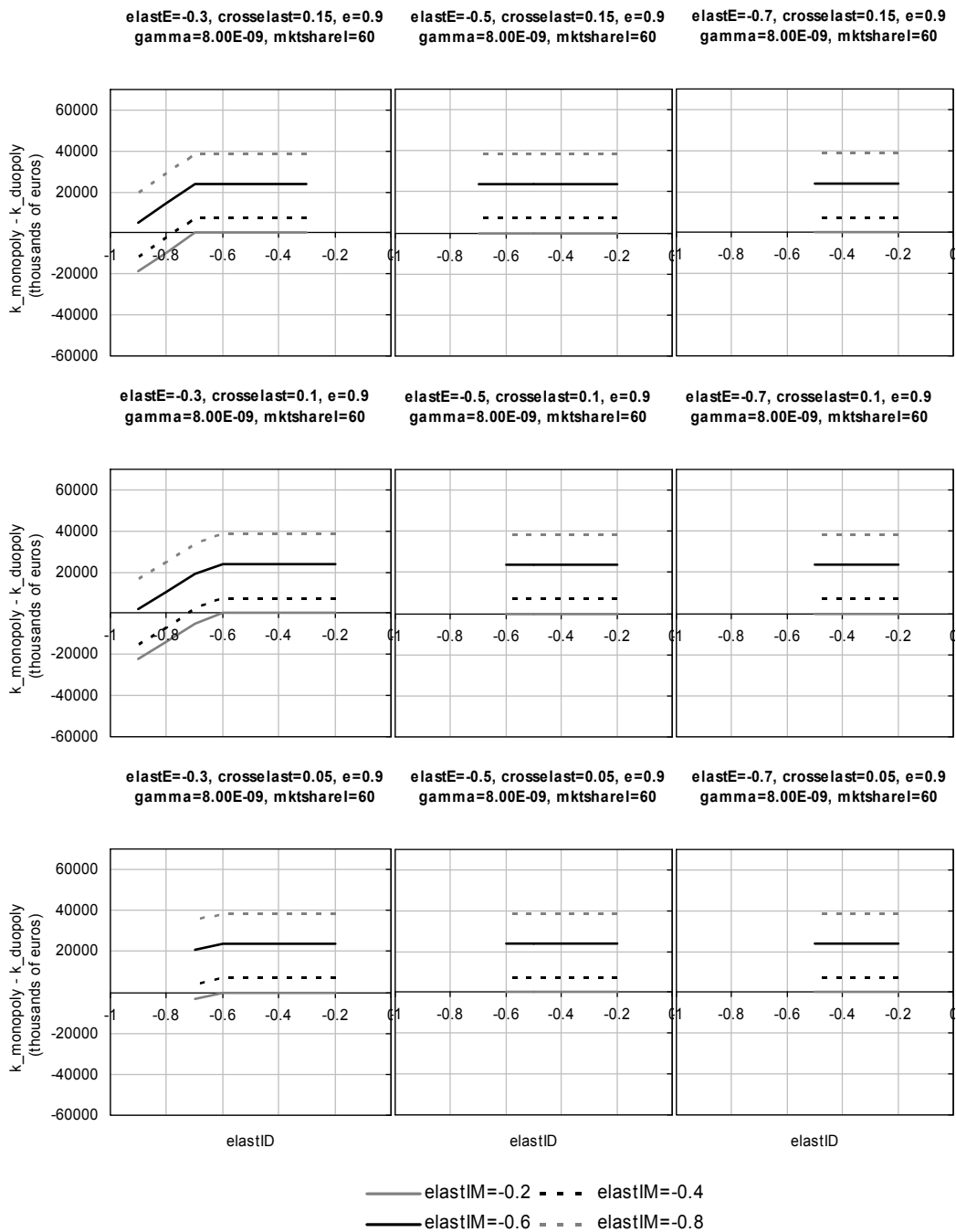
Figure 77: Results for e=0.9, γ =8E-9 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
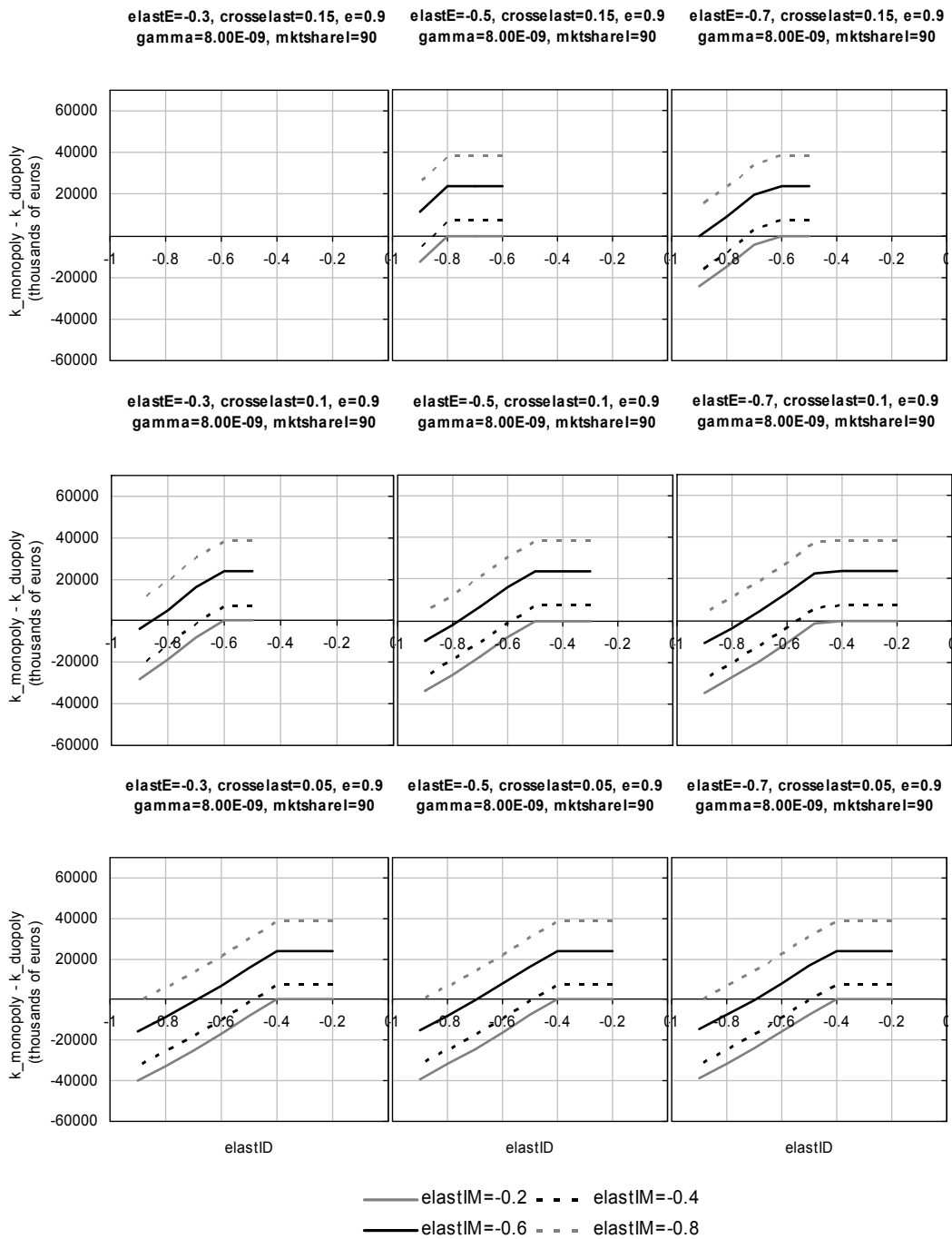
Figure 78: Results for e=0.9, γ =8E-9 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)
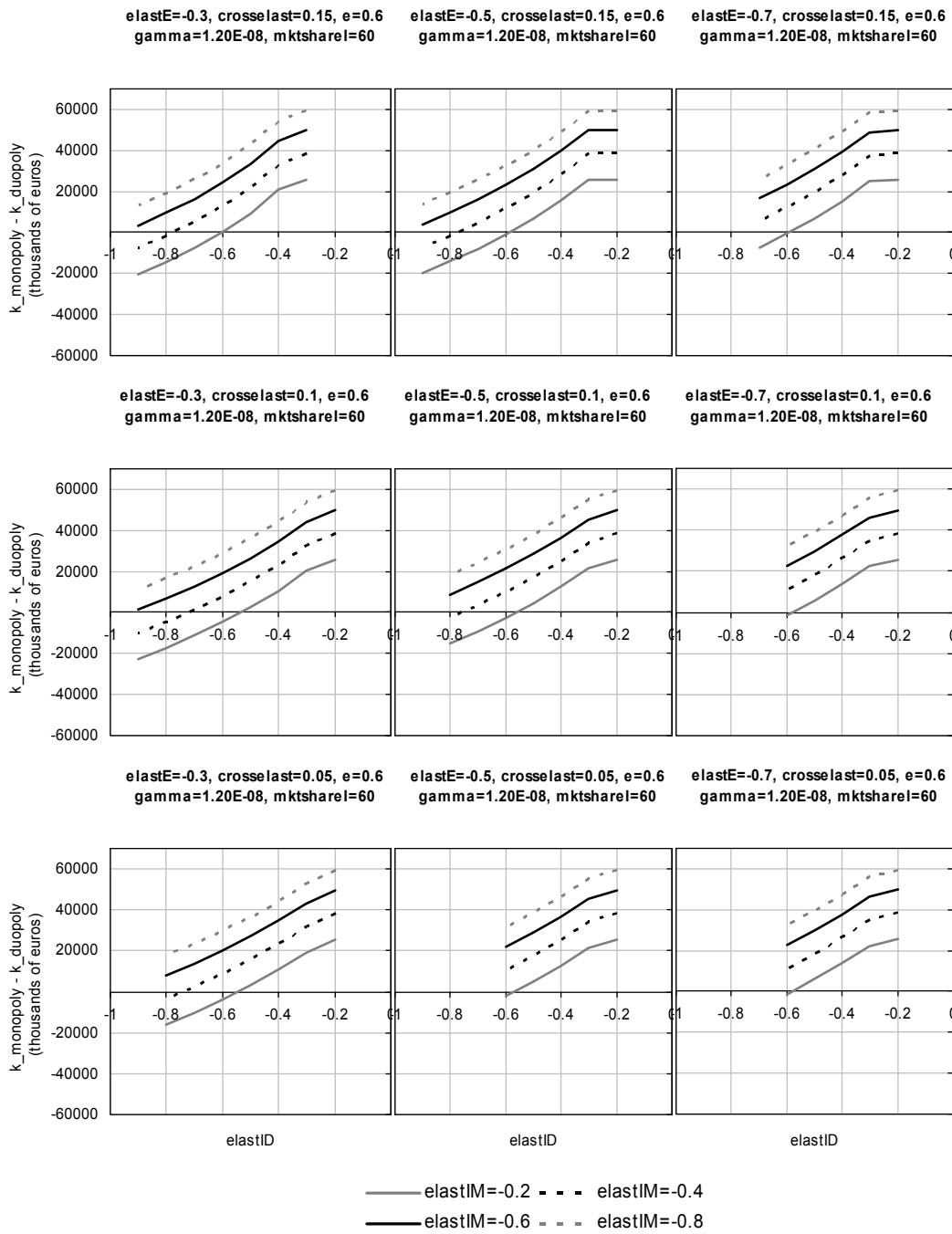
Figure 79: Results for e=0.6, γ =1.2E--8 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
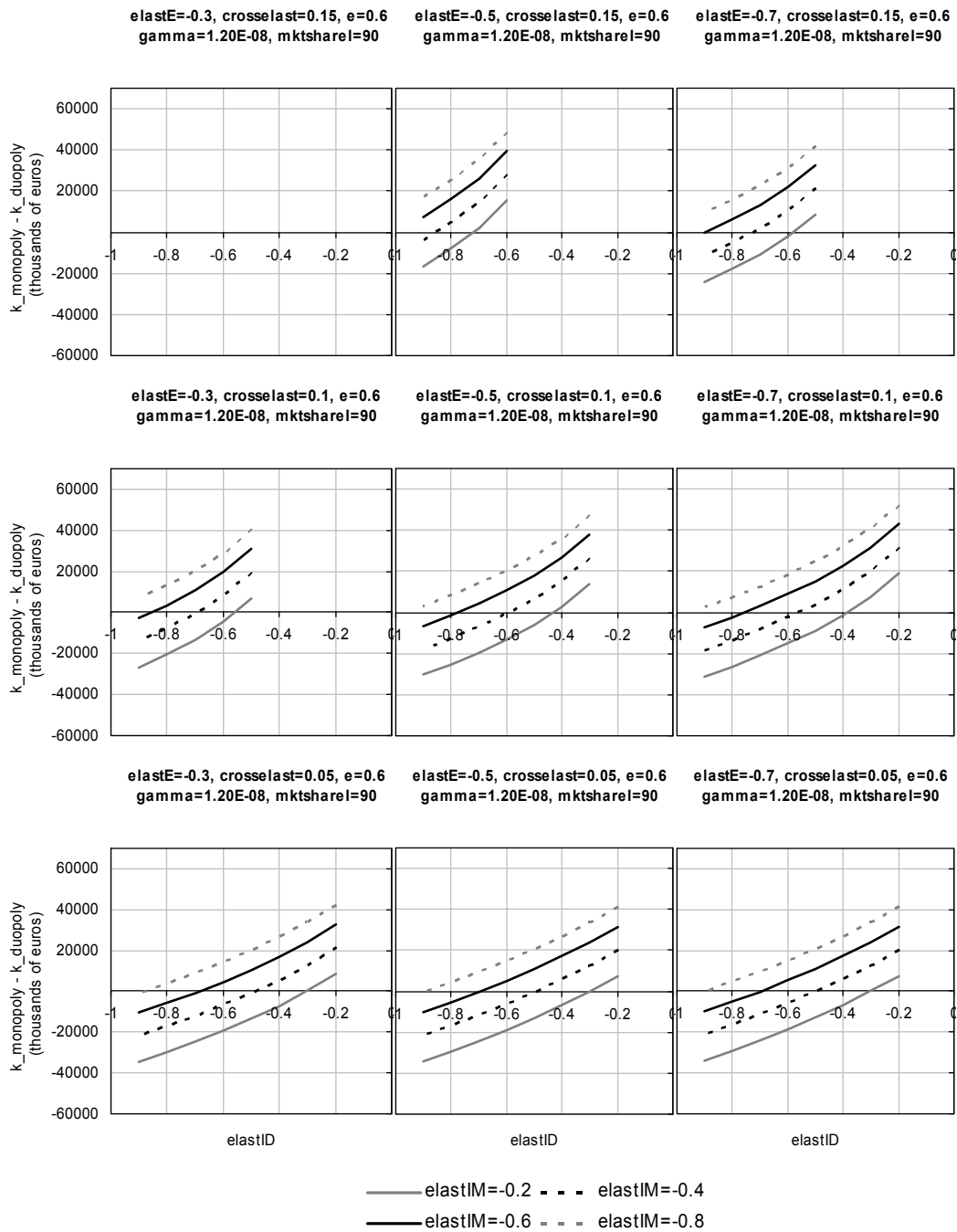
Figure 80: Results for e=0.6, γ =1.2E--8 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
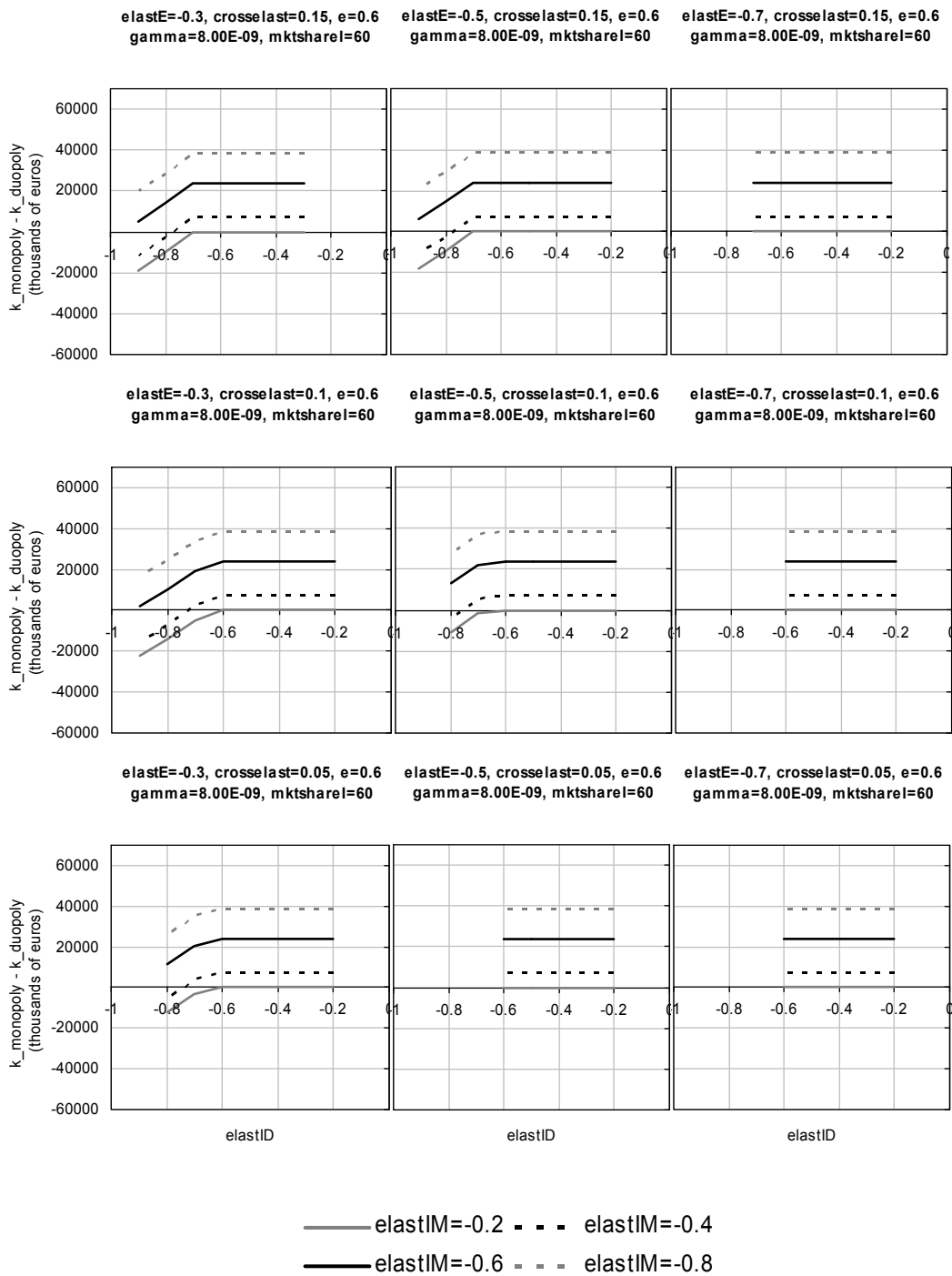
Figure 81: Results for e=0.6, γ =8E-9 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

Figure 82: Results for e=0.6, γ =8E-9 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

Annex 4 – Results for Sweden
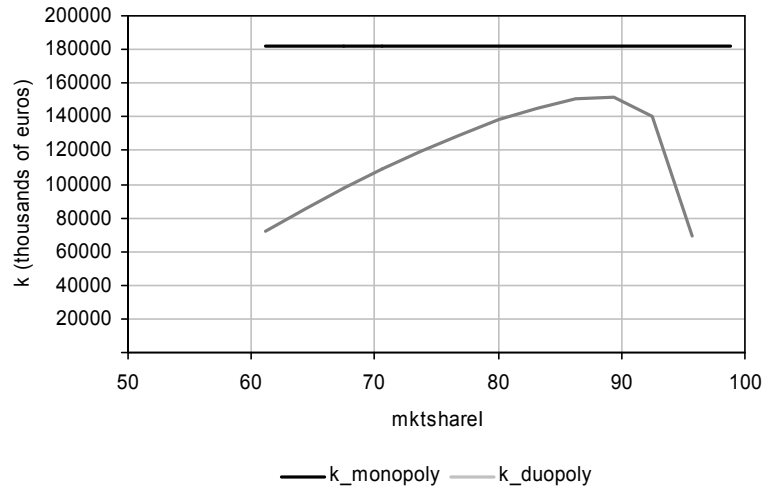
Figure 83: Effect of the incumbent's market share on k (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-9, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
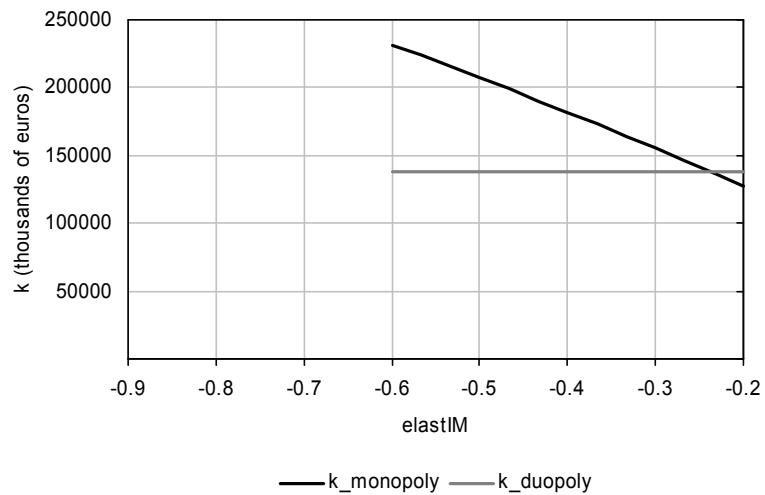

Figure 84: Sensitivity analysis for elastIM (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-9, mktshareI=80%, elastID=-0.5, elastE=-0.6, crosselast=0.1)
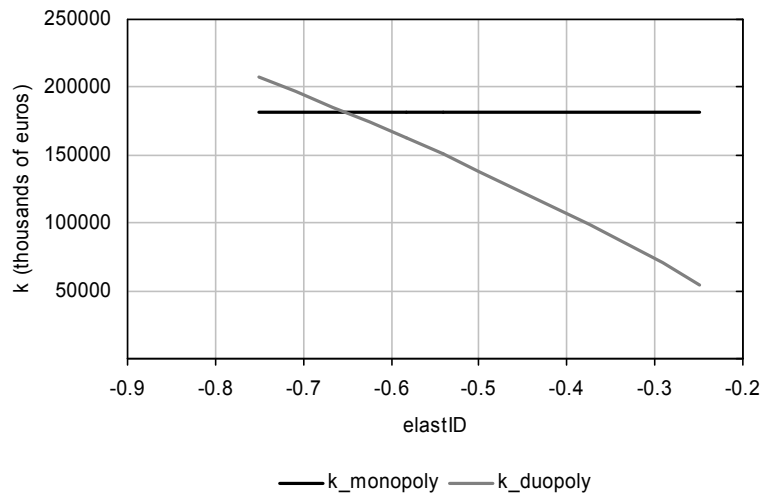
Figure 85: Sensitivity analysis for elastID (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-9, mktshareI=80%, elastIM=-0.4, elastE=-0.6, crosselast=0.1)
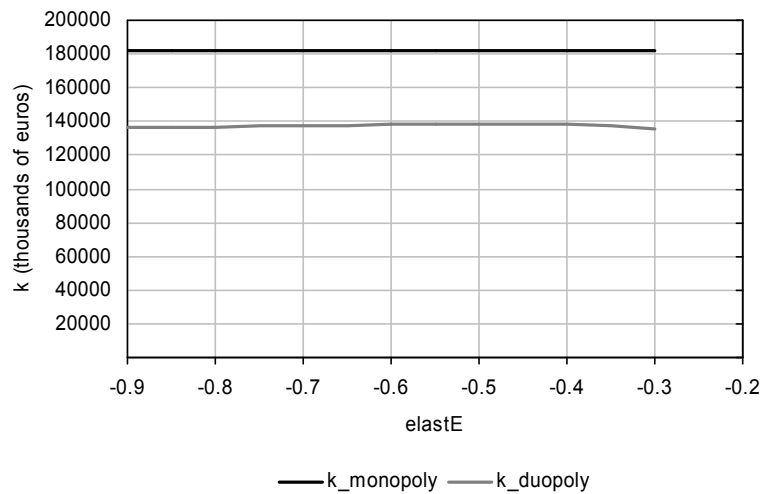
Figure 86: Sensitivity analysis for elastE (α_1=0.2, α_2=0.6, α_3=0.2, e=0.8, γ=2.5E-9, mktshareI=80%, elastIM=-0.4, elastID=-0.5, crosselast=0.1)
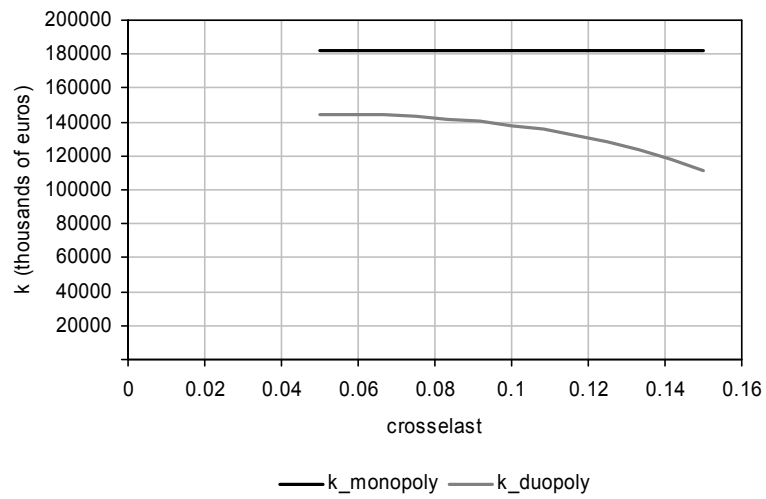
Figure 87: Sensitivity analysis for crosselast (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =2.5E-9, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6)
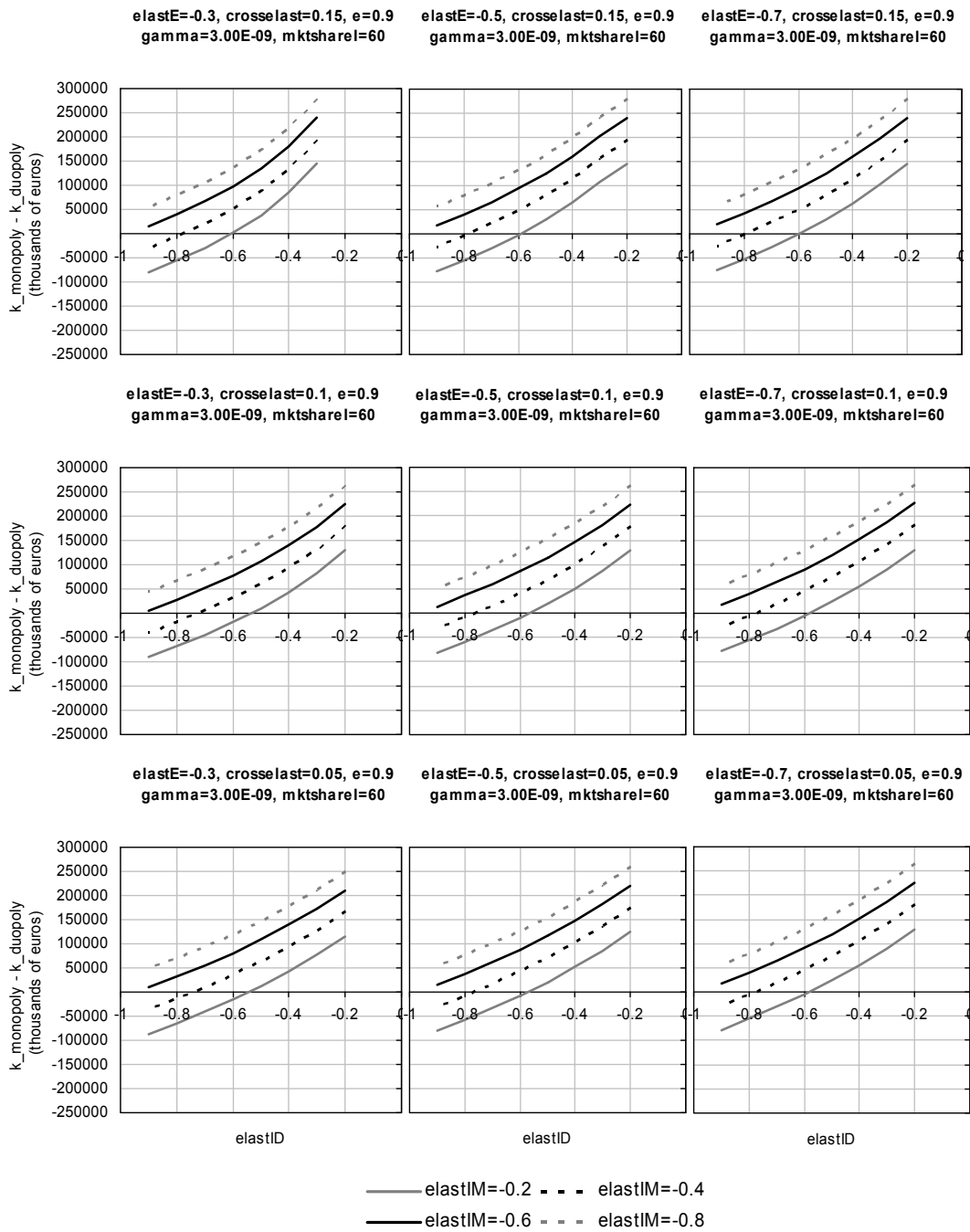
Figure 88: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.9, γ =3E-9, and mktshareI=60%)
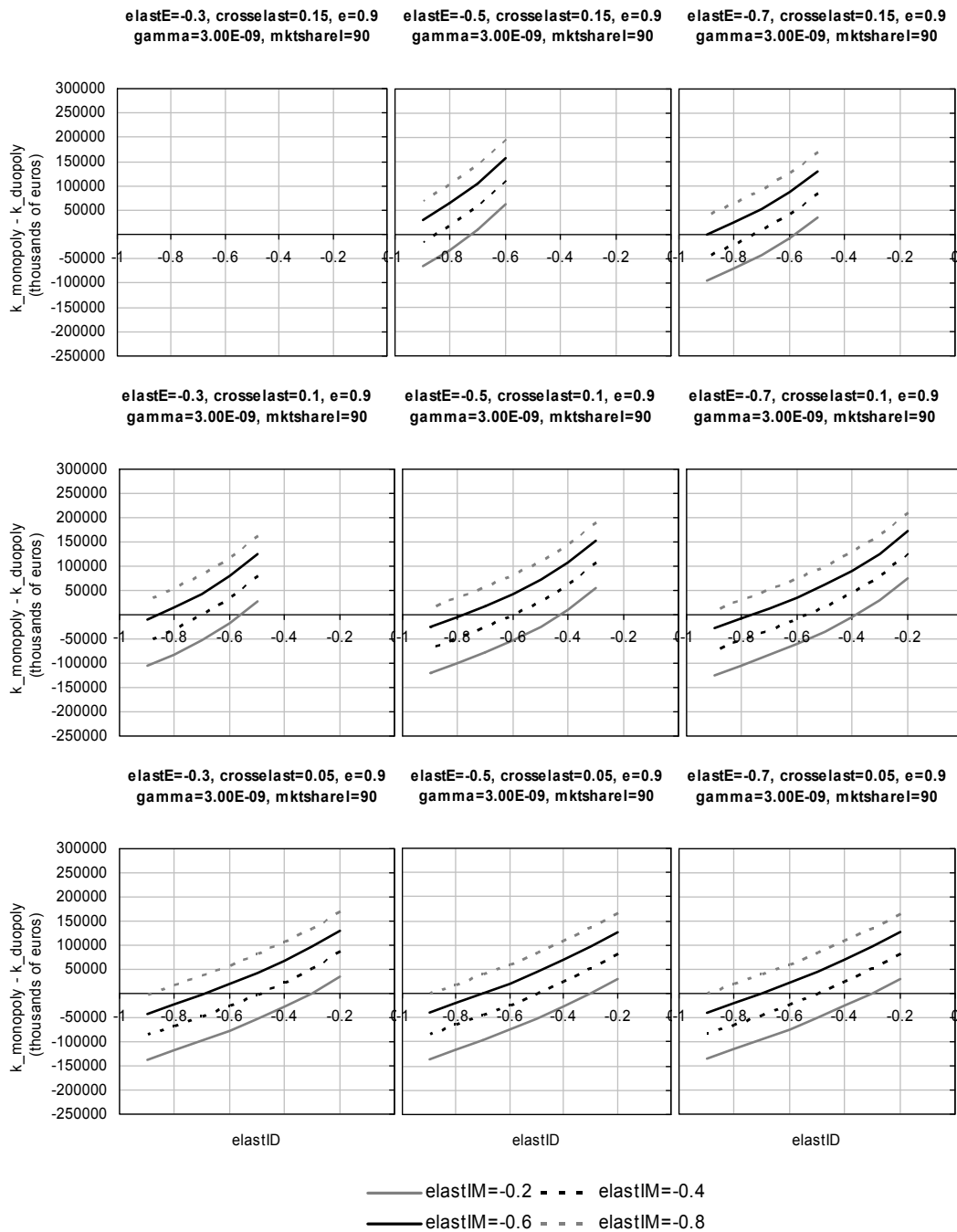
Figure 89: Effect of simultaneous changes in elastIM, elastID, elastE, and crosselast on innovation (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.9, γ =3E-9, and mktshareI=90%)
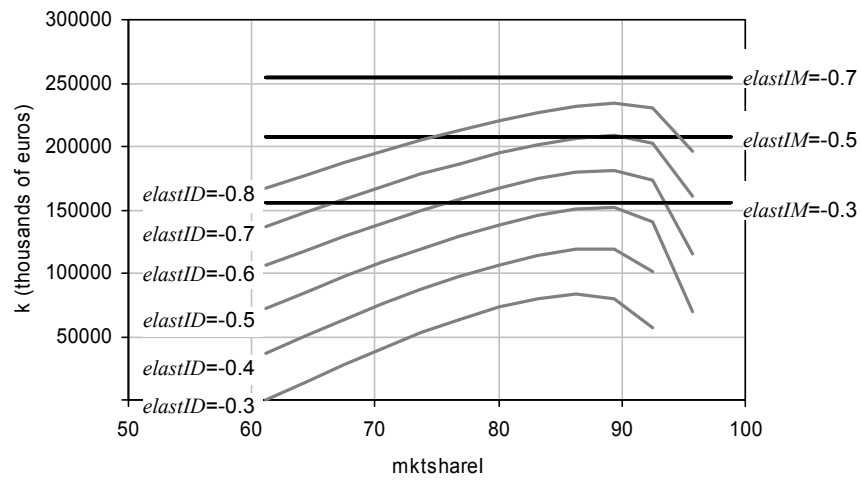
Figure 90: Combined effect of the incumbent's market share, elastIM, and elastID on k under monopoly and duopoly (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, γ =5E-10, elastE=-0.6, and crosselast=0.1)
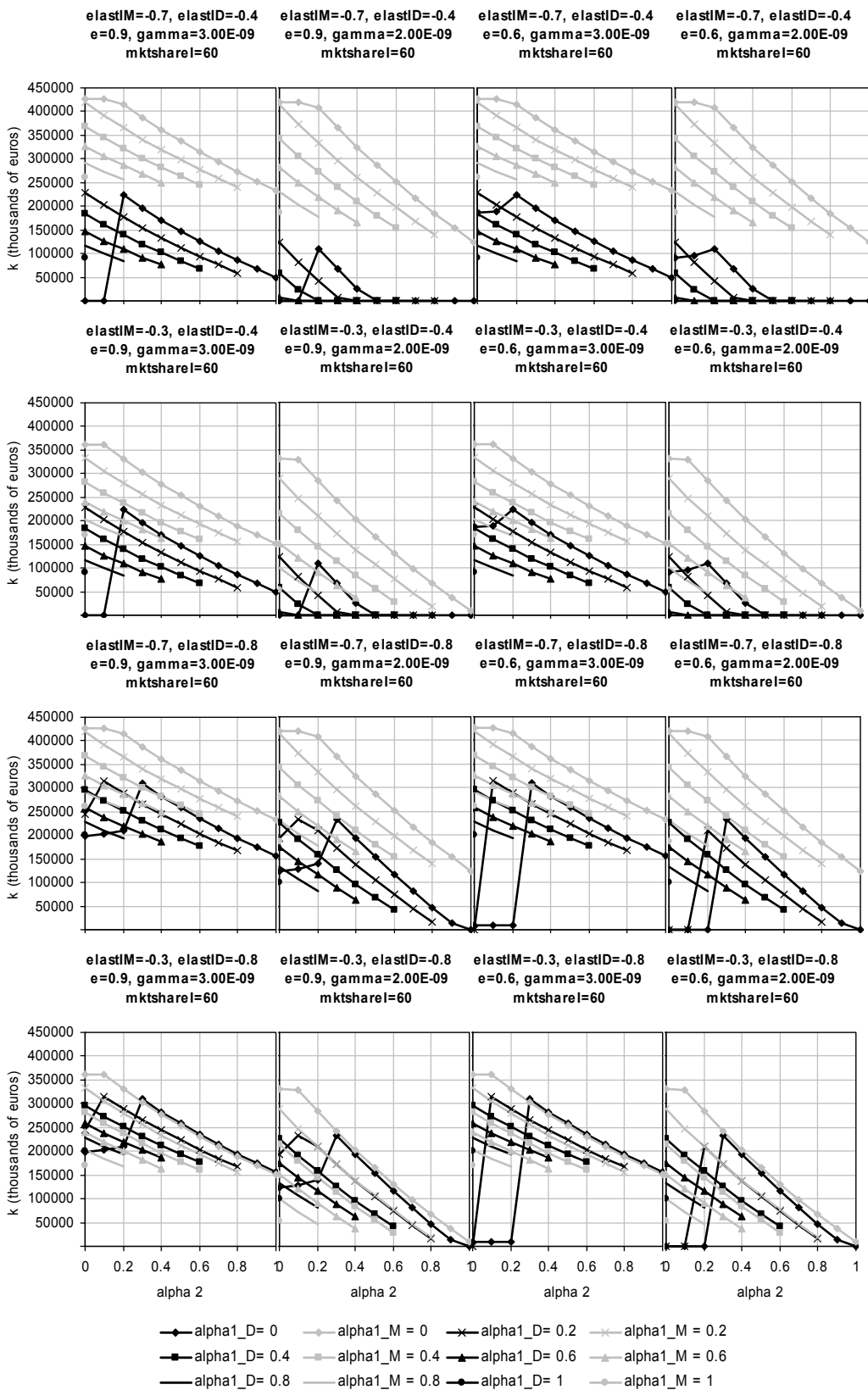
Figure 91: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=60%)
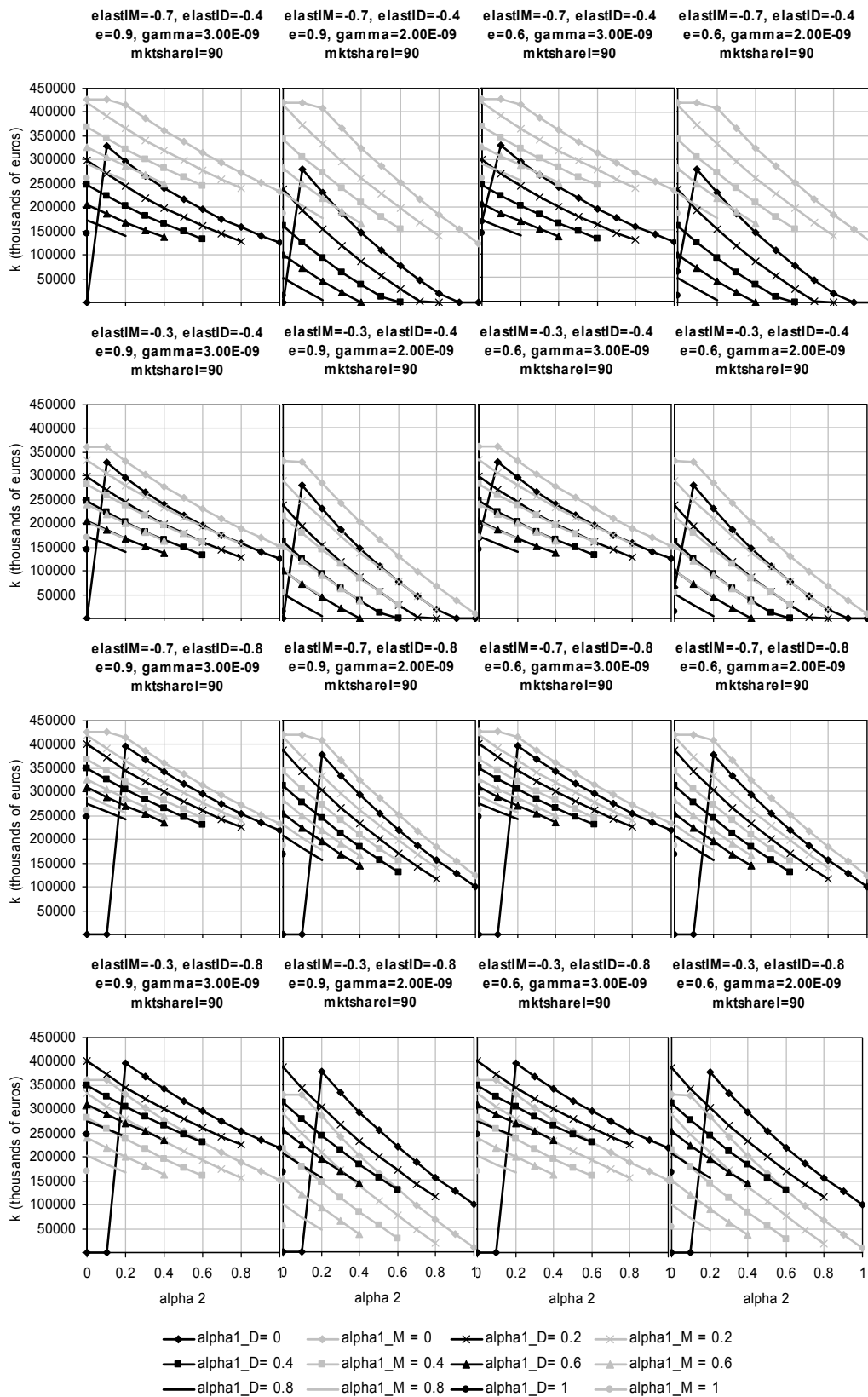
Figure 92: Effect of changes in α_1, α_2 and α_3 on k (elastE=-0.6, crosselast=0.1, mktshareI=90%)
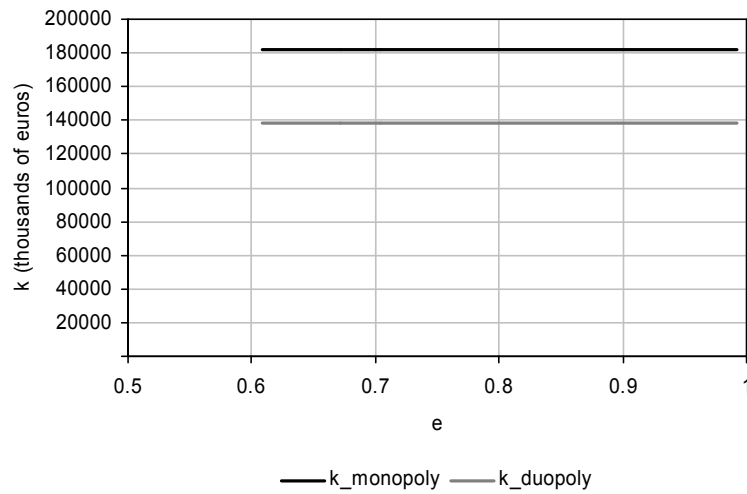
Figure 93: Sensitivity analysis for e (α_1 =0.2, α_2 =0.6, α_3 =0.2, γ =2.5E-9, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
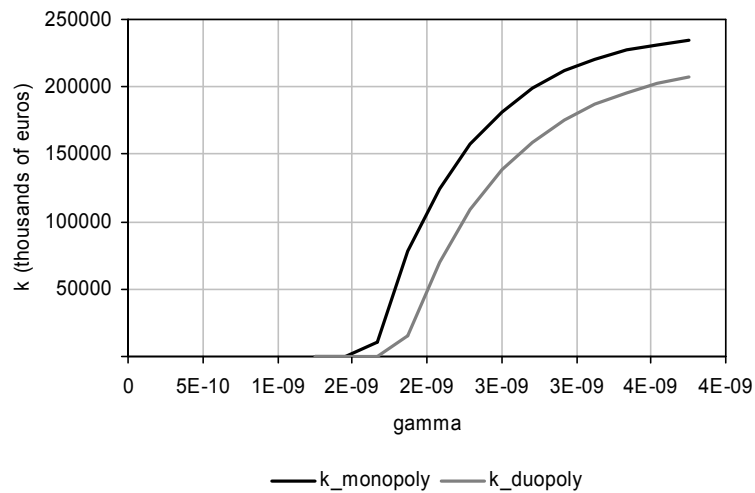
Figure 94: Sensitivity analysis for γ (α_1 =0.2, α_2 =0.6, α_3 =0.2, e=0.8, mktshareI=80%, elastIM=-0.4, elastID=-0.5, elastE=-0.6, crosselast=0.1)
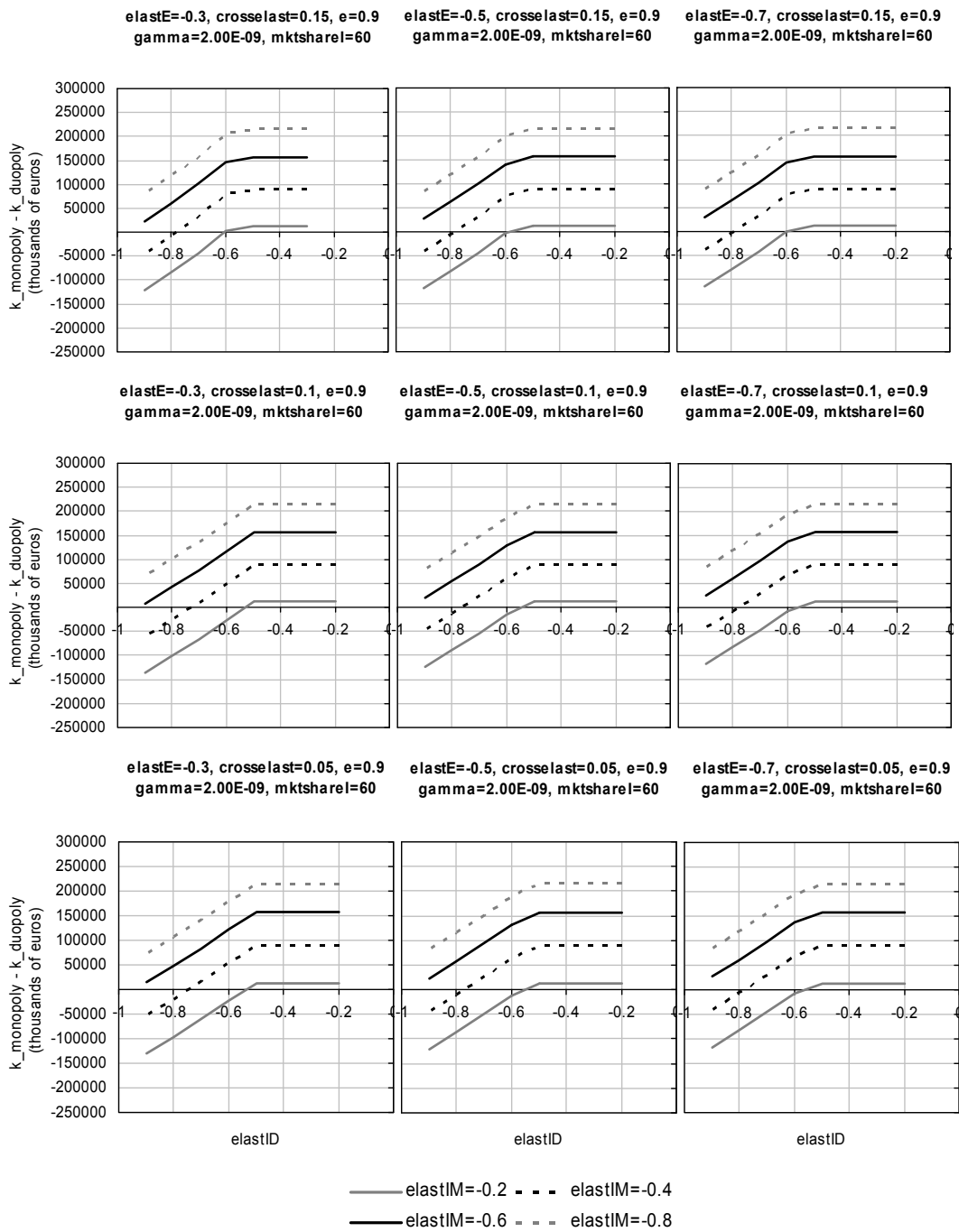
Figure 95: Results for e=0.9, γ =2E-9 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)

216

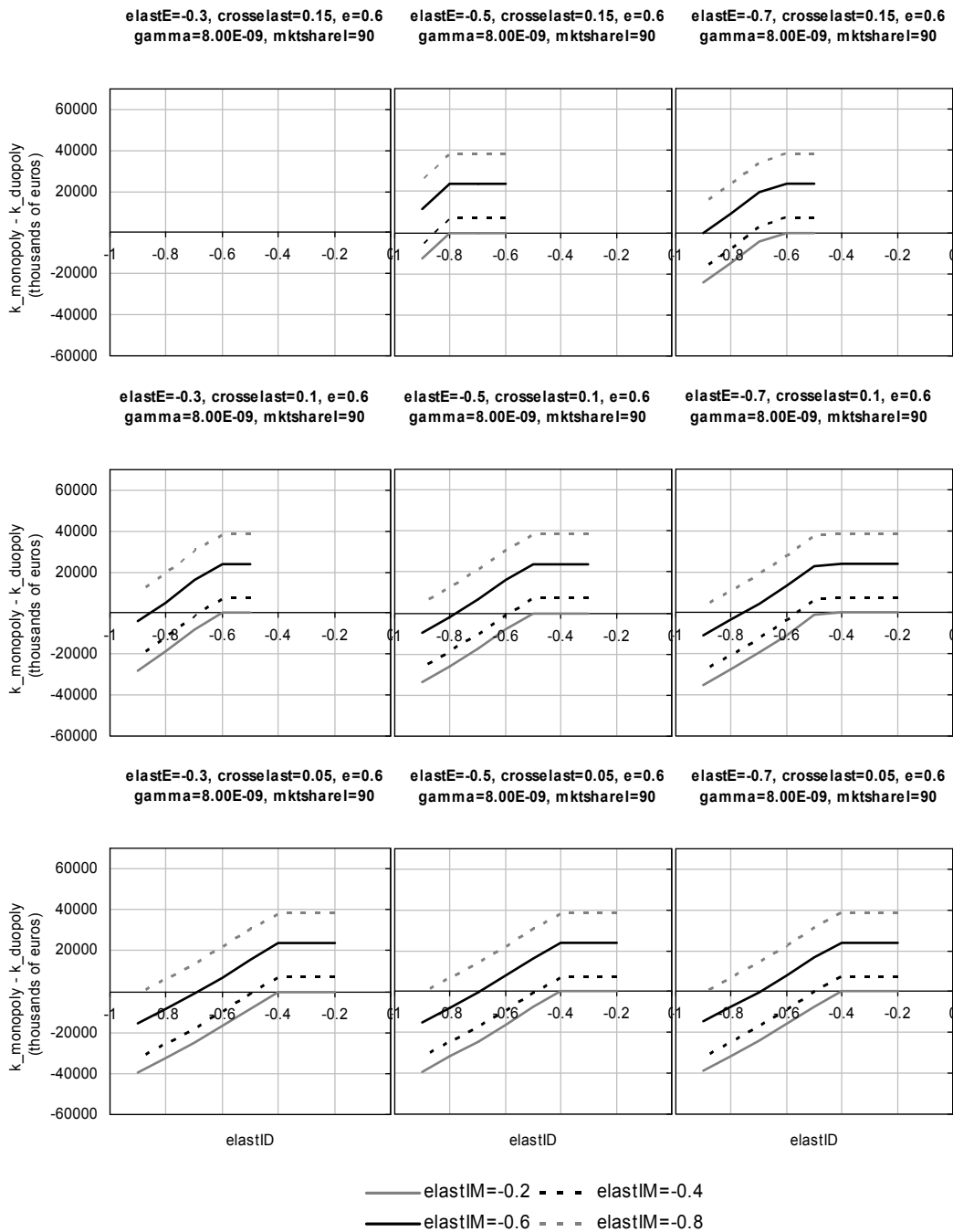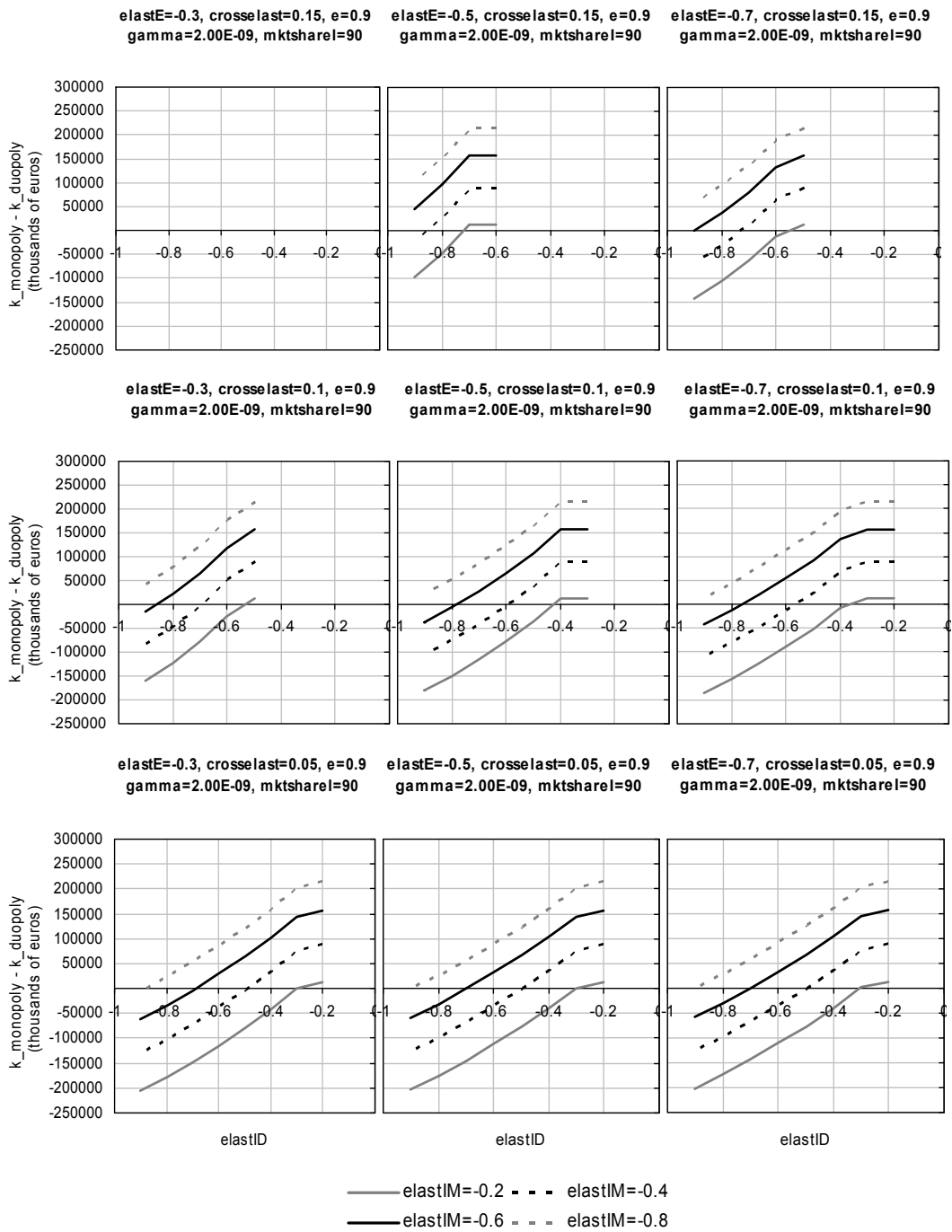*Figure 96: Results for e=0.9, γ =2E-9 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)*
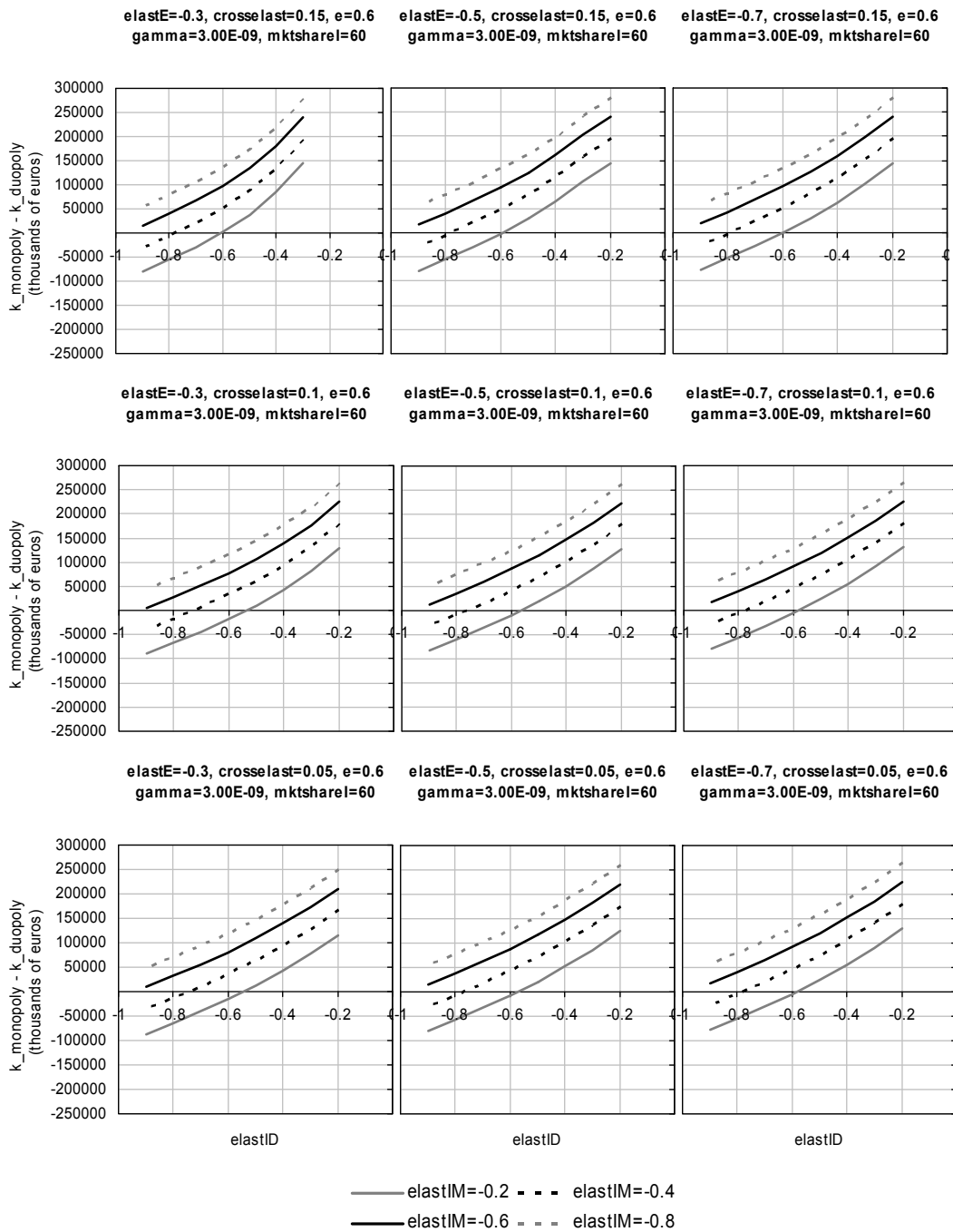
Figure 97: Results for e=0.6, γ =3E-9 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)

218
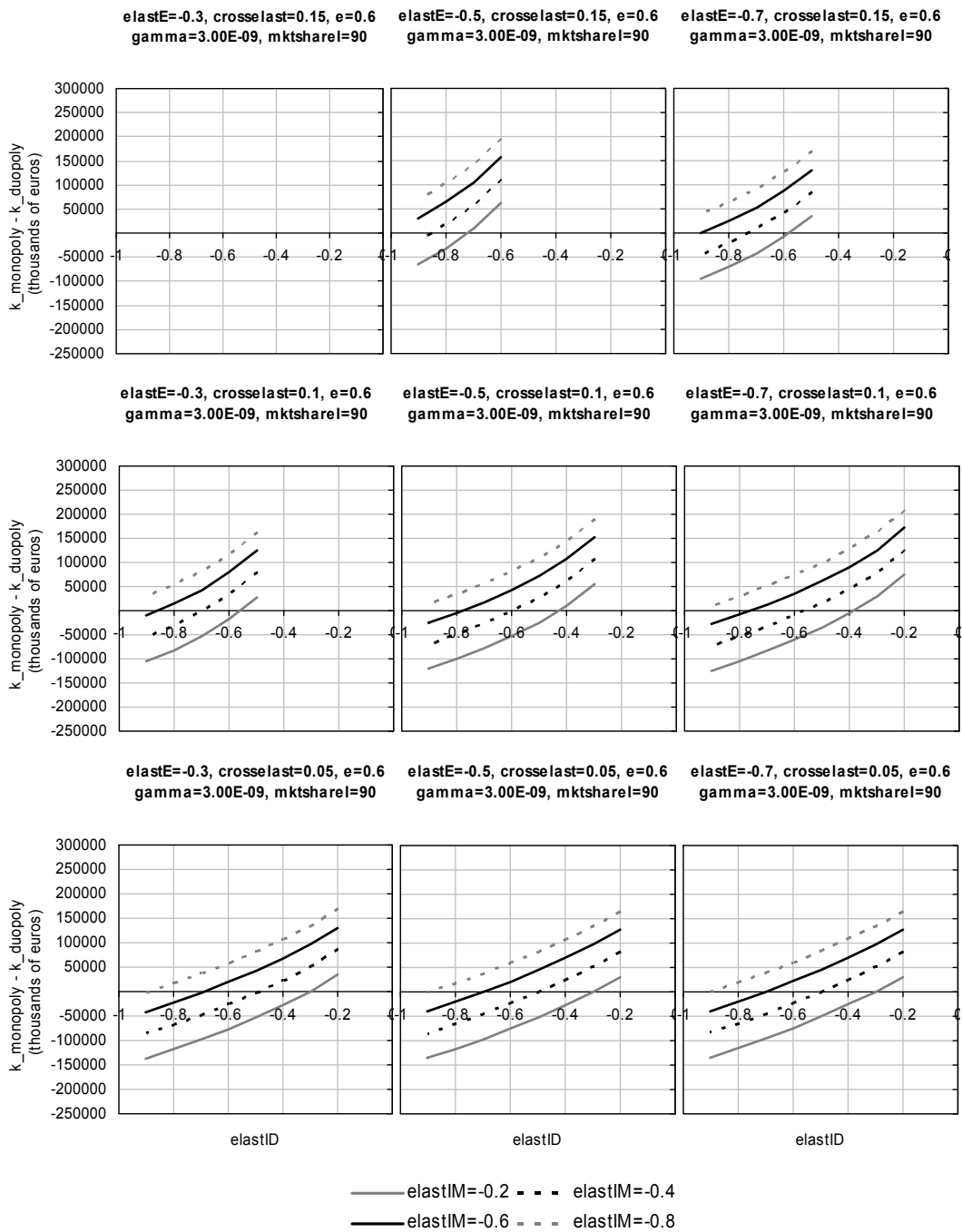
Figure 98: Results for e=0.6, γ =3E-9 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)
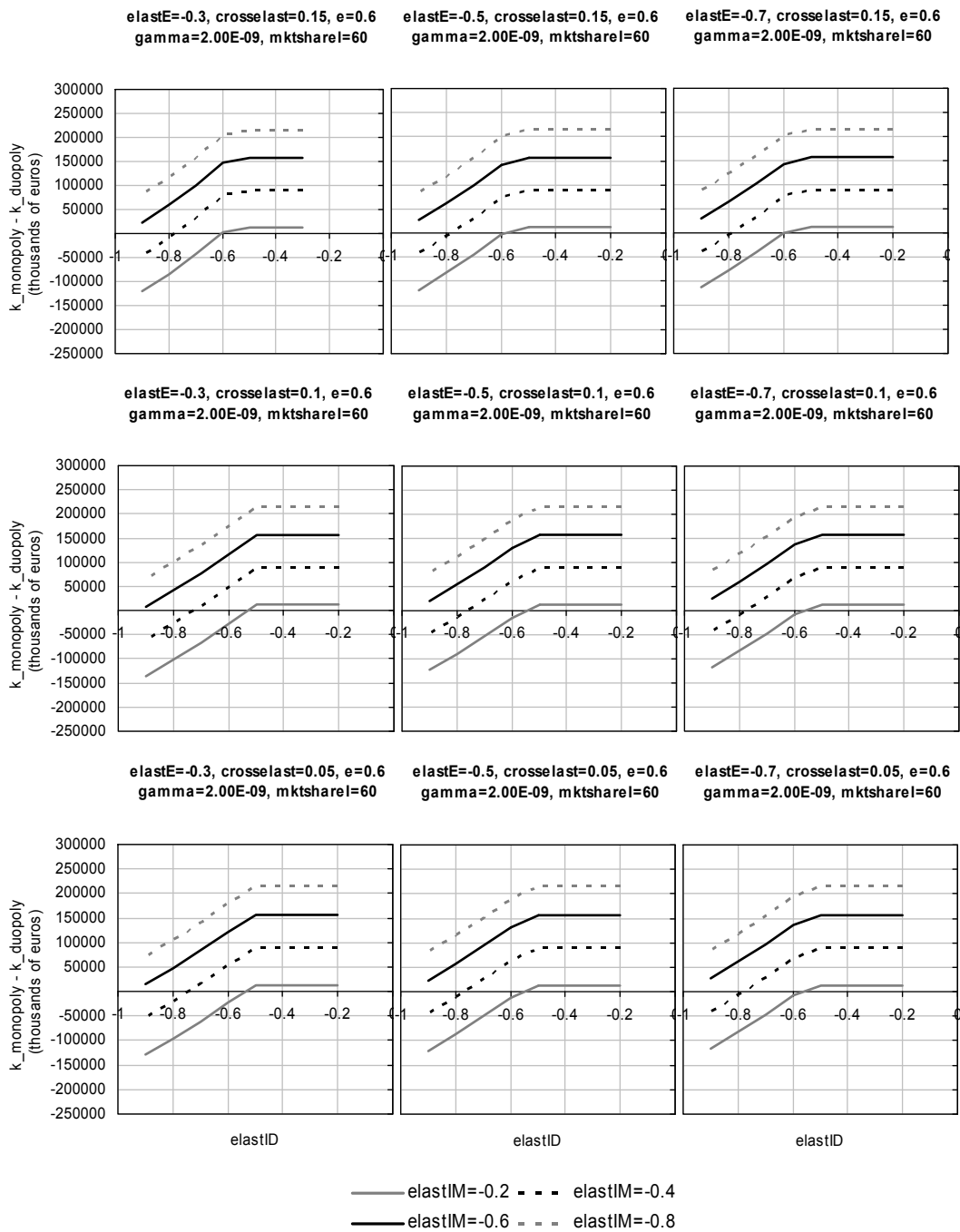
Figure 99: Results for e=0.6, γ =2E-9 and mktshareI=60% (for different values of elastIM, elastID, elastE, and crosselast holding α_1 =0.2, α_2 =0.6, and α_3 =0.2)
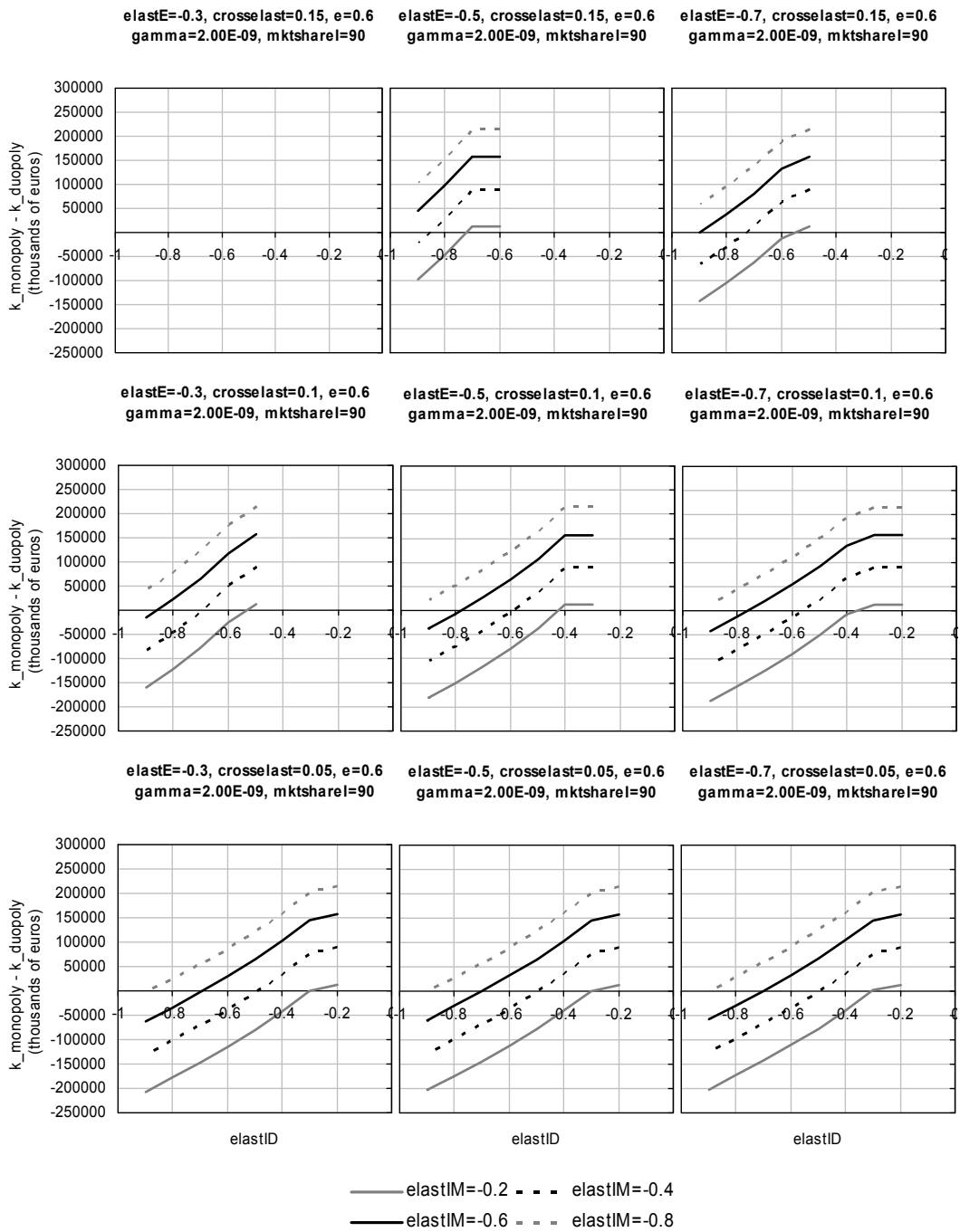
Figure 100: Results for e=0.6, γ =2E-9 and mktshareI=90% (for different values of elastIM, elastID, elastE, and crosselast holding α₁ =0.2, α₂ =0.6, and α₃ =0.2)

Annex 5 – List of sources for the data collection

ARCEP (2005) Rapport public d'activité

ARTHUR ANDERSEN (1998) Study on the impact of liberalisation of direct mail.

BUNDESNETZAGENTUR (2006) Ninth market study on licensed postal services

CONSIGNIA (2001) Annual report and accounts 2000/2001

CONSIGNIA (2002) Annual report and accounts 2001/2002

CORREOS Y TELÉGRAFOS (1998) Annual report 1998

CORREOS Y TELÉGRAFOS (1999) Annual report 1999

CORREOS (2000) Annual report 2000

CORREOS (2001) Annual report 2001

CORREOS (2002) Annual report 2002

CORREOS (2003) Annual report 2003

CORREOS (2004) Annual report 2004

CORREOS (2005) Annual report 2005

CTCON (1998) Study on the impact of weight and price limits of the reserved area in the postal sector.

CTT (2005) Relatório e contas 2005

CTT (2004) Relatório e contas 2004

CTT CORREIOS (2003) Relatório e contas 2003

CTT CORREIOS (2002) Relatório e contas 2002

CTT CORREIOS (2001) Relatório e contas 2001

CTT CORREIOS (2000) Relatório e contas 2000

CTT CORREIOS (1999) Relatório e contas 1999

CTT CORREIOS (1998) Relatório e contas 1998

CTT CORREIOS (1997) Relatório e contas 1997

CTT CORREIOS (1996) Relatório e contas 1996

CTT CORREIOS (1995) Relatório e contas 1995

CTT CORREIOS (1994) Relatório e contas 1994

DEUTSCHE POST AG (1995) Annual Report 1995

DEUTSCHE POST AG (1996) Annual Report 1996

DEUTSCHE POST AG (1997) Annual Report 1997

DEUTSCHE POST AG (1998) Annual Report 1998

DEUTSCHE POST WORLD NET (1999) Annual Report 1999

DEUTSCHE POST WORLD NET (2000) Annual Report 2000

DEUTSCHE POST WORLD NET (2001) Annual Report 2001

DEUTSCHE POST WORLD NET (2002) Annual Report 2002

DEUTSCHE POST WORLD NET (2003) Annual Report 2003

DEUTSCHE POST WORLD NET (2004) Annual Report 2004

DEUTSCHE POST WORLD NET (2005) Annual Report 2005

ECORYS (2005) Study on the development of competition in the European postal sector.

GROUPE LA POSTE (2002) Rapport Annuel 2002

GROUPE LA POSTE (2003) Annual Report 2003

GROUPE LA POSTE (2004) Annual Report 2004

GROUPE LA POSTE (2005) Annual Report 2005

IPC (2004) Postal Regulatory database – Country Directory

IPC (2005) Postal Regulatory database – Country Directory

IPC (2006) Postal Regulatory database – Country Directory

IPC (2007) Postal Regulatory database – Country Directory

LA POSTE (1996) Rapport Annuel 1996

LA POSTE (1997) Rapport Annuel 1997

LA POSTE (1998) Rapport Annuel 1998

LA POSTE (2000) Rapport Annuel 2000

MMD (1999) Modelling and quantifying scenarios for liberalization.

NERA (2004) Study about the economics of postal services.

OMEGA PARTNERS (2001) Study on the impact of certain aspects of the application of the Directive 97/67 EC on the postal sector.

PLS Rambøll (2002) Study on employment trends in the European Postal sector.

POSTEN (2005) Posten year end report 2005

POSTEN (2004) Posten annual report 2004

POSTEN (2003) Posten annual report 2003

POSTEN (2002) Posten annual report 2002

POSTEN (2001) Posten annual report 2001

POSTEN (2000) Posten annual report 2000

POSTEN (1999) Posten annual report 1999

POSTEUROP (2000) PostEurop Annual Review

POSTEUROP (2001) PostEurop Annual Review

POSTEUROP (2002) PostEurop Annual Review

POSTEUROP (2003) PostEurop Annual Review

POSTEUROP (2004) PostEurop Annual Review

POSTEUROP (2005) PostEurop Annual Review

POSTCOMM (2006) Competitive market review

POSTCOMM (2004) The UK letters market 200-2003

POSTCOMM (2005) Postcomm's brief on developments in liberalising countries Sweden, Germany, Netherlands, Denmark and Norway

POSTCOMM (2005) Giving customers choice: a fully open postal services market, A decision document

POSTDIENST (1990) Annual Report 1990, Deutsche Bundespost

POSTDIENST (1991) Annual Report 1990, Deutsche Bundespost

POSTDIENST (1992) Annual Report 1990, Deutsche Bundespost

POSTDIENST (1993) Annual Report 1990, Deutsche Bundespost

PTT (1996) Annual Report 1996

PTT (1997) Annual Report 1997

PRICEWATERHOUSE (1997) Employment trends in the European postal sector.

PRICEWATERHOUSECOOPERS (2006) The impact on Universal service of the full market accomplishment of the postal internal market in 2009.

ROLAND BERGER, R. (2004) Monitoring developments in the postal market – market survey

ROYAL MAIL GROUP PLC (2003) Annual Review 2003

ROYAL MAIL GROUP PLC (2004) Annual Review 2003-04

ROYAL MAIL GROUP PLC (2005) Annual Review 2004-05

ROYAL MAIL GROUP PLC (2006) Annual Review 2005-06

STEVEN-JONES, N. (2004) The implications and consequences of introduction of competition

SWEDEN POST (1998) Annual report 1998

SWEDEN POST (1997) Annual report 1997

SWEDEN POST (1996) Annual report 1996

SWEDEN POST (1995) Annual report 1995

SWISS POST (1998) Annual Report 1998

SWISS POST (1999) Annual Report 1999

SWISS POST (2000) Annual Report 2000

SWISS POST (2001) Annual Report 2001

SWISS POST (2002) Annual Report 2002

SWISS POST (2003) Annual Report 2003

SWISS POST (2004) Annual Report 2004

SWISS POST (2005) Annual Report 2005

THE POST OFFICE (1994) Annual Report and Accounts 1993/94

THE POST OFFICE (1996) Annual Report and Accounts 1995/96

THE POST OFFICE (1997) Annual Report and Accounts 1996/97

THE POST OFFICE (1998) Annual Report and Accounts 1998

THE POST OFFICE (1997) Annual Report and Accounts 1996/97

THE POST OFFICE (1999) Annual Report and Accounts 1998/99

THE POST OFFICE (2000) Annual Report and Accounts 1999/2000

TPG (2000) Annual report 2000

TPG (2001) Annual report 2001

TPG (2002) Annual report 2002

TPG (2003) Annual report 2003

TPG (2004) Annual report 2004

TPG (2005) Annual report 2005

USPS (1974) Annual report 1974

USPS (1978) Annual report 1978

USPS (1982) Annual report 1982

USPS (1995) Annual report 1995

USPS (1986) Annual report 1986

USPS (1996) Annual report 1996

USPS (1997) Annual report 1997

USPS (1998) Annual report 1998

USPS (1999) Annual report 1999

USPS (2000) Annual report 2000

USPS (2001) Annual report 2001

USPS (2002) Annual report 2002

USPS (2005) Annual report 2005

WIK (2003) Survey on some main aspects of postal networks in EU adhesion candidate countries.

WIK (2004) Study on main developments in the European postal sector.

WIK (2005) Study on the evolution of the regulatory model for European postal services.

WIK (2006) Main developments in the postal sector (2004-2006).

Annex 6 - Survey

INSTRUCTIONS: Please fill in the dates when each of the innovations was introduced into operation. If the innovation was not introduced yet please write "NA".

Innovation	Specificities	Part of value chain concerned	Year of introduction into operation (not test or pilot)	Remarks (Please write here any remarks or notes regarding your answers)
Optimisation of collection routes (using software)		Collection/ Transportation		
Hybrid mail [1]		Collection/All value chain		
Digital stamp [2]		Franking		
Radio frequency identification (RFID):	Used to identify trucks	Upstream/ Transportation		
	Used to identify trolleys	Upstream/ Transportation		
	Used to identify trays or bags	Upstream/ Transportation		
	Used to monitor the performance of the letter post [3]	Upstream/ Transportation		
Automated sorting machines using Optical Character Recognition (OCR):	That can read all front side of the letter	Sorting		
	That can read hand-written whole addresses	Sorting		
	That can read hand-written postal codes	Sorting		
	That can read machine written postal codes and whole addresses	Sorting		
Video coded address reading equipment [5]:	Online coding	Sorting		
	Scanning and remote coding (off-line video coding equipment)	Sorting		
Automated sequence sorting to delivery route [4]		Sorting/ Delivery		
Automatic tray handling systems		Material handling		
Automated guided vehicles (AGV) [6]		Material handling		
Route planning and optimization software for delivery		Delivery		

[1] Customers digitally send the information to be printed to the Postal Service Provider, which then sorts the mail electronically, prints it and dispatches it in physical form into the conventional mail stream from the site closest to the delivery point. Conversely, hard copy mail can be scanned in and sent on directly to an online account. Hybrid mail offers particular advantages for direct-marketing and large-scale mailings. Most of the costs involved in the physical handling of traditional paper mail are cut, since the data is handled in real time in electronic form until the final phase of the process, when it is printed on paper and physically delivered to the recipient.

[2] A digital stamp, in mail or philately, is similar to a conventional postage stamp except it is resident on or in a computer. A digital stamp can typically be downloaded and printed onto envelopes or packages by authorized individuals.

[3] RFID tags monitor test letters at key points in the mail processing pipeline. It highlights bottlenecks so that postal operators can free them and speed up the mail flow. Test letters with RFID tags in them are seeded into normal mail flow and operators do not know which have the tags in them, ensuring objectivity and reliable results.

[4] This is a letter sorting system to extend mechanization to delivery route sequencing, the last operation in the processing cycle. The goal of sequencing systems is to automatically sort mail into delivery point sequence with an aim to significantly cut back on the amount of time a letter carrier needs to spend in the office casing mail.

[5] Video coded address reading equipment:

Unreadable addresses, e.g. cursive not distinguished by the OCR, unreadable machine print or unmatchable to the address database, are digitally imaged and 1) processed by human operators online (online coding), or 2) sent on to a Remote Encoding Centre (REC) and processed by human operators there (scanning and remote coding) (Arthur D. Little Limited, 2004).

[6] Automated guided vehicles (AGVs):

AGVs are transport systems capable of functioning without driver operation. AGVs are used within sorting offices to move mail around. AGVs find their way without a person behind the wheel by using laser guidance, wall-mounted reflectors, and a computer-based human controller running the routing software. They can also be run on magnetic paths; this does leave less flexibility for maneuver but can be safer when interacting with employees. While the vehicles can be programmed to follow a set route, it is also possible for employees to divert the AGVs if required. The vehicles can determine if there are loads waiting at set points by the change in area contrast and load monitor systems preclude uneven or overloading. Robotics can also be used to sleeve, lid, unsleeve and unlid mail packages at each end of the transportation process (Arthur D. Little Limited, 2004).

Annex 7 – Econometric results

Table 11: Descriptive statistics for the variables

Variable		Mean	Std. Dev.	Min	Max	Observations
country	overall	9	5	1	17	N=204
	between		5	1	17	n=17
	within		0	9	9	T=12
year	overall	2001	3	1995	2006	N=204
	between		0	2001	2001	n=17
	within		3	1995	2006	T=12
mktliberalised	overall	34	37	0	100	N=204
	between		37	3	100	n=17
	within		9	12	105	T=12
mktshareE	overall	2	2	1	11	N=187
	between		2	1	8	n=17
	within		1	-2	6	T=11
publick	overall	95	17	10	100	N=204
	between		17	34	100	n=17
	within		6	64	118	T=12
tvolume	overall	6	8	0	29	N=187
	between		8	0	27	n=17
	within		1	4	8	T=11
popdens	overall	120	95	15	393	N=187
	between		97	15	383	n=17
	within		2	109	130	T=11
gdppercap	overall	15	11	1	38	N=187
	between		11	1	36	n=17
	within		1	9	19	T=11
inindex	overall	-5	5	-15	5	N=204
	between		4	-11	3	n=17
	within		2	-10	2	T=12
accuminno	overall	6	4	0	13	N=204
	between		3	1	10	n=17
	within		3	0	14	T=12
itemperempl	overall	66	41	4	166	N=187
	between		41	7	133	n=17
	within		12	31	103	T=11

Table12: Correlation matrix for the independent variables

	mktliberalised	mktshareE	publick	tvolume	popdens	gdppercap
mktliberalised	1					
mktshareE	0.5438	1				
publick	0.0409	-0.1267	1			
tvolume	-0.1522	0.0063	-0.1549	1		
popdens	-0.3423	-0.1162	-0.7258	0.462	1	
gdppercap	0.1220	0.1336	-0.2803	0.4819	0.3787	1

Table 13: Summary of heteroskedasticity and correlation tests

Dependent variable	Explanatory varibles	Likelihood-ratio test for heteroskedasticity		Modified Wald test		Wooldridge test	
inindex		LR chi(16)=	88.38	chi2(17)=	5720.62	F(1,16)=	85.61
		Prob>chi2=	0	Prob>chi2=	0	Prob>F=	0
accuminno	X_{it}	LR chi(16)=	113.16	chi2(17)=	682.77	F(1,16)=	67.11
		Prob>chi2=	0	Prob>chi2=	0	Prob>F=	0
itemperempl		LR chi(16)=	312.75	chi2(17)=	87332.65	F(1,16)=	95.70
		Prob>chi2=	0	Prob>chi2=	0	Prob>F=	0

Table 14: Results of GLS estimation with inindex as dependent variable

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
$mktliberalised_t$	0.009 (1.07)	0.017 (1.79)*	0.037 (3.74)***	0.040 (3.81)***			
$mktshareE_t$	0.351 (4.83)***	0.375 (4.26)***	0.478 (6.37)***		0.645 (8.21)***	0.525 (6.68)***	0.388 (4.43)***
$publick_t$	-0.108 (4.80)***	-0.093 (26.89)***	-0.087 (11.97)***	-0.094 (11.07)***	-0.073 (9.97)***	-0.075 (8.77)***	-0.072 (11.36)***
$tvolume_t$	0.084 (1.46)	0.090 (1.37)	0.298 (8.88)***	0.259 (7.25)***	0.252 (12.17)***	0.384 (3.82)***	0.237 (7.25)***
$popdens_t$	-0.021 (2.94)***						
$gdppercap_t$	0.304 (3.84)***	0.192 (2.51)**					
$mktliberalised_{t+1}$						0.016 (2.02)**	
$mktliberalised_{t-1}$							0.019 (1.64)*
Constant	2.436 (0.97)		-1.127 (1.91)*	0.142 (0.26)	-0.895 (1.68)*	-1.492 (1.83)*	-0.591 (1.33)
Observations	187	187	187	187	187	187	170
Log likelihood	1192	-	-	1171	-	1215	1264
Wald chi2	379	1108	219	213	192	210	148
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 15: Results of GLS estimation with accuminno as dependent variable

	Model 8	**Model 9**	**Model 10**	**Model 11**	**Model 12**	**Model 13**	**Model 14**
mktliberalised$_t$	0.006	-0.016	0.019	0.031			
	(0.58)	(1.57)	(2.05)**	(2.97)***			
mktshareE$_t$	0.439	0.517	0.534		0.550	0.387	0.051
	(5.79)***	(7.60)***	(4.56)***		(6.00)***	(4.24)***	(0.81)
publick$_t$	-0.056	-0.022	0.000	0.018	0.011	0.007	0.012
	(2.76)***	(2.15)**	(0.01)	(2.78)***	(2.63)***	(1.10)	(1.49)
tvolume$_t$	-0.032	0.066	0.274	0.196	0.236	0.278	0.238
	(0.52)	(1.22)	(7.87)***	(1.98)**	(2.64)***	(8.38)***	(5.86)***
popdens$_t$	0.039						
	(2.25)**						
gdppercap$_t$	0.398	0.354					
	(5.65)***	(7.31)***					
mktliberalised$_{t+1}$						0.020	
						(2.95)***	
mktliberalised$_{t-1}$							0.063
							(7.75)***
Constant							
Observations	187	187	187	187	187	187	170
Log likelihood	1184	1179	1181	1179	-	1158	1266
Wald chi2	1031	1286	263	19	145	745	298
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 16: Results of GLS estimation with itemperempl as dependent variable

	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
$mktliberalised_t$	0.020	0.051	0.021	0.081			
	(0.92)	(2.06)**	(0.64)	(2.67)***			
$mktshareE_t$	1.944	2.168	1.056		1.728	1.194	0.615
	(7.51)***	(6.59)***	(2.63)***		(5.47)***	(7.12)**	(1.51)
$publick_t$	-0.251	-0.253	-0.257	-0.282	-0.413	-0.368	-0.751
	(6.69)***	(6.04)***	(4.95)***	(7.21)***	(7.37)***	(13.25)***	(18.77)***
$tvolume_t$	2.412	1.735	2.074	2.261	2.640	2.664	2.512
	(7.97)***	(5.91)***	(7.57)***	(9.51)***	(12.37)***	(20.28)***	(11.59)***
$popdens_t$	0.032						
	(2.18)**						
$gdppercap_t$	2.180	2.346					
	(16.33)***	(16.07)***					
$mktliberalised_{t+1}$						0.006	
						(0.58)	
$mktliberalised_{t-1}$							0.221
							(5.71)***
Constant	38.482	43.261	77.393	79.528	78.790	74.990	105.667
	(9.60)***	(9.54)***	(10.82)***	(12.06)***	(12.60)***	(18.29)***	(19.49)***
Observations	187	187	187	187	187	187	170
Log likelihood	920	923	891	832	-	-	916
Wald chi2	7026	2031	95	146	261	741	856
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 17: Results of PW-PCSE estimation with inindex as dependent variable

	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27	Model 28
mktliberalised$_t$	0.032	0.030	0.040	0.032			
	(2.71)***	(2.25)**	(2.59)***	(2.56)***			
mktshareE$_t$	0.276	0.290	0.265		0.388	0.285	0.254
	(2.97)***	(3.20)***	(2.97)***		(3.95)***	(3.24)***	(2.86)***
publick$_t$	-0.021	-0.038	-0.071	-0.088	-0.062	-0.072	-0.063
	(1.06)	(3.33)***	(4.26)***	(7.08)***	(3.75)***	(4.50)***	(3.96)***
tvolume$_t$	-0.050	0.045	0.225	0.242	0.248	0.203	0.228
	(0.35)	(0.28)	(1.38)	(4.37)***	(1.59)	(1.38)	(1.39)
popdens$_t$	0.002						
	(0.38)						
gdppercap$_t$	0.284	0.252					
	(7.71)***	(5.57)***					
mktliberalised$_{t+1}$						0.035	
						(2.47)**	
mktliberalised$_{t-1}$							0.036
							(2.18)**
Constant	-8.438	-6.616	-1.452	0.357	-1.094	-1.283	-2.291
	(3.69)***	(6.39)***	(0.99)	(0.39)	(0.75)	(0.96)	(1.68)*
Observations	187	187	187	187	187	187	170
R-squared	0.64	0.65	0.34	0.40	0.31	0.39	0.41
Wald chi2	139	140	58	94	39	59	50
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

236

Table 18: Results of PW-PCSE estimation with accuminno as dependent variable

	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34	Model 35
$mktliberalised_t$	0.020	0.011	0.023	0.027			
	(1.44)	(1.00)	(1.74)*	(2.16)**			
$mktshareE_t$	0.356	0.326	0.264		0.328	0.266	0.160
	(3.30)***	(3.15)***	(2.44)**		(2.94)***	(2.51)**	(2.24)**
$publick_t$	0.003	-0.033	-0.056	-0.070	-0.049	-0.060	-0.048
	(0.16)	(2.81)***	(3.68)***	(5.46)***	(3.37)***	(4.06)***	(2.80)***
$tvolume_t$	0.238	0.281	0.290	0.196	0.301	0.246	0.265
	(1.20)	(1.57)	(1.99)**	(2.72)***	(2.05)**	(1.90)*	(1.94)*
$popdens_t$	0.009						
	(1.79)*						
$gdppercap_t$	0.171	0.174					
	(4.87)***	(5.24)***					
$mktliberalised_{t+1}$						0.024	
						(1.82)*	
$mktliberalised_{t-1}$							0.018
							(1.41)
Constant	-1.596	3.240	7.732	9.452	7.931	8.064	7.586
	(0.51)	(2.55)**	(5.78)***	(11.51)***	(5.92)***	(6.77)***	(5.40)***
Observations	187	187	187	187	187	187	170
R-squared	0.56	0.61	0.53	0.60	0.49	0.55	0.19
Wald chi2	114	125	53	50	43	52	34
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

Table 19: Results of PW-PCSE estimation with itemperempl as dependent variable

	Model 36	**Model 37**	**Model 38**	**Model 39**	**Model 40**	**Model 41**	**Model 42**
mktliberalised$_t$	0.094	0.109	0.161	0.210			
	(1.70)*	(1.76)*	(1.63)*	(2.36)**			
mktshareE$_t$	1.505	1.122	0.849		1.047	0.901	0.781
	(2.11)**	(1.78)*	(0.94)		(1.04)	(1.02)	(0.82)
publick$_t$	0.165	0.161	-0.167	-0.163	-0.214	-0.150	-0.231
	(1.06)	(1.38)	(1.12)	(1.21)	(1.31)	(1.05)	(1.61)*
tvolume$_t$	5.816	5.418	2.210	2.393	2.546	1.976	1.961
	(4.28)***	(4.79)***	(5.46)***	(5.83)***	(7.85)***	(3.88)***	(5.00)***
popdens$_t$	-0.013						
	(0.35)						
gdppercap$_t$	2.307	2.366					
	(8.47)***	(8.20)***					
mktliberalised$_{t+1}$						0.030	
						(0.48)	
mktliberalised$_{t-1}$							0.060
							(0.65)
Constant	-5.368	-7.181	62.565	65.875	61.457	71.041	77.299
	(0.31)	(0.57)	(3.92)***	(4.60)***	(4.04)***	(4.70)***	(5.33)***
Observations	187	187	187	187	187	187	170
R-squared	0.76	0.78	0.48	0.59	0.40	0.62	0.54
Wald chi2	212	207	35	37	63	17	25
Prob>chi2	0	0	0	0	0	0	0

Absolute value of z-statistics in parentheses
* significant at 10% level; ** significant at 5% level; *** significant at 1% level

238

Curriculum Vitae

CÁTIA FELISBERTO

Date of birth: 08/08/1977
Nationality: Portuguese
E-mail: catia.felisberto@gmail.com

EDUCATION

1/2005-5/2008   **Doctorate in Sciences (PhD) - Economics**
Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland
Dissertation: "The effect of liberalisation on incumbent's innovation. The case of the postal sector"

1/2005-2/2007   **Swiss Program for Doctoral Students in Economics**
Study Center Gerzensee, Foundation of the Swiss National Bank
Courses: Microeconomics, Macroeconomics and Econometrics (full program)

10/2002-10/2003   **Master of Science in Economics**
Université de Lausanne, Switzerland - Ecole des Hautes Etudes Commerciales (HEC)
Specialization: Macroeconomics and Finance
Dissertation: "The Impact of Immigration on Social Security: the case of Switzerland"

9/1995-9/1999   **Diploma in Economics** (4 years diploma)
Universidade Técnica de Lisboa, Portugal - Instituto Superior de Economia e Gestão (ISEG)

PROFESSIONAL EXPERIENCE

Since 1/2004   **Ecole Polytechnique Fédérale de Lausanne (EPFL), Switzerland**
Chair, Management of Network Industries, Research Associate
- Researcher on the project "The effects of regulation on innovation in the postal sector." funded by the Swiss National Science Foundation
- External consultant on projects related to the Postal Sector
- Taught at the doctoral course "Deregulation and re-regulation of the network industries"
- Taught at the master's course/seminar "Management Public II" (University of Geneva)
- Supervised student projects at the undergraduate level

8/2000-7/2002   **ExxonMobil – Esso Portuguesa, Lda, Portugal**
Industrial and Wholesale (I&W) business line, Bulk/Piped LPG department, Economist III

Core responsibilities:
- Administration of a major project involving the inaugural implementation of computing system software designed to manage twenty thousand domestic clients (representing approximately 700 thousands of Euros per month)
- Performing business analysis
- Contract negotiation and client management
- Coordinating the daily administrative matters of the department

9/1999-7/2000   **KPMG, S.A., Portugal**
Audit assistant
Commerce, Industry and Services department

OTHER ACTIVITIES

Reviewer   International Journal of Production Economics

RESEARCH GRANTS AWARDED

Since 1/2005   **PhD Scholarship** from Fundação para a Ciência e a Tecnologia, Portugal

OTHER SKILLS

Languages   Portuguese – Mother tongue
English – Fluent
French - Fluent

Computer skills   Microsoft Office, Stata, E-Views, VBA, Matlab

LEISURE AND HOBBIES

Handicrafts, reading, swimming and jogging.

LIST OF PUBLICATIONS

Chapters in books — Pricing the Last Mile in the Postal Sector (with B. Friedli, M. Finger, D. Krähenbühl and U. Trinkner), 2006, in *Progress toward Liberalization of the Postal and Delivery Sector* (chapter 15), editors: Michael A. Crew and Paul R. Kleindorfer, publisher: Spring Science and Business Media.

Peer reviewed articles — The Effect of Entry regulation on Process Innovation in the Swiss Mail Industry (with H. Dietl, A. Grütter, M. Lutzenberger and M. Finger), 2008, Swiss Journal of Economics and Statistics, Vol.144 (1).

Non-peer reviewed publications — The effect of competition on innovation in the network industries, 2007, Proceedings 6th Conference on Applied Infrastructure Research, TU Berlin, Germany.

Evidence on the effect of liberalisation and competition on the Postal Sector, 2007, 11th Seminar ANACOM, Lisbon, Portugal.

Economic regulation in the Network Industries: where does it stand? (with P. Manso), 2006, CDM working papers series.

Historical operators and new technologies (with M. Finger and F. Abdallah), 2006, Joint MIR and SAP publication.

Towards an intelligent franking system (with F. Abdallah, M. Finger, and P. Rossel), 2006, MIR Report.

Mise en perspective critique du project de révision de loi sur les télécomminications en Suisse (with M. Finger and P. Rossel), 2005, MIR Report.

On the importance of labour productivity growth: Portugal vs. Ireland, 2003, Cours de Modèles macroéconomiques – Recueil des recherches, Université de Lausanne, Ecole des HEC, DEEP.

Modelling emigration from Portugal to Switzerland and a wage equation for emigrants, 2003, Applied Econometrics II course, Université de Lausanne, Ecole des HEC.

Determinants of individual trade-policy preferences in France, 2003, Political Economy of Trade Policy course, Université de Lausanne, Ecole des HEC.

Thesis — The impact of immigration on social security: the case of Switzerland, 2003, Master's thesis, Université de Lausanne, Ecole des HEC.