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**Evidence on the effect of liberalisation and
competition on innovation in the postal sector**

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Abstract

This paper empirically assesses the effect of liberalisation and competition on innovation in the postal sector. The analysis is restricted to end-to-end competition. The effect on the incentives to innovate of public ownership, letter volume, and other control variables is also tested. Data on liberalisation, competition and innovation in the postal sector is collected for seventeen European countries, over ten years. Three measures are used as proxies for innovation: (1) an innovation index based on a survey conducted for this purpose; (2) the accumulated number of innovations (based on the same survey); and (3) labour productivity. We also develop a liberalisation index in order to measure the percentage of market liberalised (in terms of letter volume). Several models are estimated by GLS and using PW-PCSE. In general, the models estimated have a high explanatory power. We find evidence that market liberalisation has a positive effect on innovation and 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. Letter volume is also significant and has a positive impact on innovation. GDP per capita turns out to be significant and to have a positive relationship with innovation in all the models estimated.

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1. INTRODUCTION

The European postal sector has been undergoing a process of reform over the past decade. The progressive liberalisation of the sector is the most important feature of this reform. One of the major motivations for liberalisation is the belief that competition stimulates process innovation, product innovation, encourages efficiency, and drives prices down.

In this paper a clear distinction is made between liberalisation and competition. Liberalisation is understood as the relaxation or abolishment of previous legal barriers to entry. We are not only concerned with the relationship between competition and innovation, but also with the impact of liberalisation per se on the incentives to innovate.

The literature on the relationship between competition and innovation does not have a clear answer as to whether competition stimulates innovation or not. Increased competition is said to have both positive and negative effects on innovation. The positive effect is a result of the firm's quest to optimize profits through increasing its efficiency and reducing its cost of production. Profitability pushes the development and adoption of more efficient technologies and processes. At the same time, 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 are also likely to encounter more difficulties when trying to recover potential investment into new technologies and new processes (not sufficient economies of scale). The lack of consensus is more apparent when the theoretical results are compared with the empirical results. The need for empirical evidence is undisputable.

Regarding the effect of liberalisation on innovation, we argue that it depends on 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. If there are barriers to entry yet there is regulation capable of overcoming those barriers and making the threat of competition real, then 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.

To our knowledge, neither the effects of competition, nor the effects of liberalisation on incumbent's innovation have ever been assessed empirically in the postal sector. This paper aims at filling this gap. Due to the lack of quantitative data on upstream and downstream access the analysis is restrict to end-to-end competition.

To this end data on liberalisation, competition and innovation in the postal sector was collected for seventeen European countries over ten years. An econometric analysis was then performed. The explanatory variables of interest are the percentage of market liberalised (based on the evolution of the reserved area) and the market shares of the competitors. We control for letter volume, percentage of public ownership, Gross Domestic Product (GDP) per capita, and population density. Regarding the data on incumbent's innovation, seventeen critical innovations were identified and the historical operators were inquired, through a survey, about their date of introduction. Based on this information

an innovation index and the accumulated number of innovations were computed. Additionally, labour productivity was also computed.

Several models were estimated by Generalised Least Squares (GLS) and using Prais-Winsten estimation with Panel Corrected Standard Errors (PW-PCSE). The three innovation proxies mentioned above were used as dependent variable and the results were compared. In general, the models estimated have a high explanatory power. We find that the percentage of market liberalised is statistically significant and has a positive effect on innovation. Regarding competition, the market share of the competitors is also significant and has a positive relationship with the investment in innovation. This result is valid at least until the market share of the competitors reaches a certain threshold, which was not attained yet in the postal sector. Letter volume is also significant and has a positive impact on innovation. GDP per capita turns out to be significant and to have a positive sign in all the models estimated.

The structure of this paper is as follows. Firstly, the related literature is summarised and the hypotheses being tested are presented. Then, the data used is described in detail. Particular attention is given to the measures of innovation used, namely to the innovation index and to the liberalisation index. Next, the model and the estimation procedures are presented. Finally, the results are discussed. Section 7 concludes.

2. THE IMPACT OF LIBERALISATION AND COMPETITION ON INNOVATION

As already mentioned, increased competition is likely to have both positive and negative effects on innovation. On the one hand, competition obliges firms to increase its efficiency and to reduce its cost of production in order to optimize profits (the positive effect). On the other hand, competition decreases the rents of the monopolist and may reduce its market share, which leaves fewer resources available to invest in new processes and technologies and creates more difficulties to recover investments.

Felisberto (2007) develops and analysis a model of incumbent network operator 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 on the investment in new technologies. 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. The main results are that the difference between the investment in innovation under monopoly and duopoly is governed by the incumbent's market share under duopoly and by the incumbent's elasticity of demand under monopoly and duopoly. For a certain market share interval, duopoly provides more incentives than monopoly. This interval depends on the other model parameters and, in particular, on the elasticity of demand of the incumbent. Outside this interval, it is the monopoly that generates more investment in innovation by the incumbent. 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 decrease as the weight given to revenue and/or to profit increase. In other words, the more regulation can move the incumbent to act as a welfare maximiser, the larger the investment in

innovation is. This conclusion (that regulatory intervention which motivates the incumbent to act like a welfare-maximising firm favours innovation) is independent of the market share of the incumbent.

The debate about the influence of the intensity of market competition on technical progress started with Schumpeter (1942) and continued with Arrow (1962). Schumpeter argues that monopoly favours the development of 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 intuition behind this result is that under monopoly, part of the benefits coming from innovation serve only to replace the monopolist's rents earned before innovating, i.e. the monopolist has greater opportunity costs of innovating. Grossman and Helpman (1991) and Romer (1990) support Schumpeter's view that monopoly is a precondition for innovation by arguing that firms innovate because they seek profitable opportunities that arise from monopoly. On the contrary, Nickell (1996) and Boone and Dijk (1998) support the existence of a positive relationship between competition and innovation.

Other authors have elaborated on the relationship between competition and innovation, introducing additional factors like the value of the innovation and the level of fixed and variable costs. Kamien and Schwartz ((1975), (1976)) show that for inventions of small value, the absence of rivalry leads to the most rapid development, while a positive level of rivalry will achieve this for more valuable innovations. Loury (1979) finds that, under certain conditions, the incentives to invest in R&D of individual firms decrease as competition increases. The work developed by Lee and Wilde (1980) reaches rather different conclusions from Loury (1979). The authors conclude that an increase in rivalry increases the equilibrium individual R&D effort. In an attempt to reconcile this conclusion with Loury's earlier work, the authors show 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.

Other authors have made a 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).

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 and technological advance found by some authors in the empirical studies. Scherer (1967) observes that the speed of technological research accelerates with rivalry, provided that the number of firms competing is not excessive. Scherer is the first to suggest an inverted-U relationship between competition and innovation. Later on, Boone ((2000), (2001)) and Aghion et al. (2005) also find a nonlinear relationship between competition and innovation. Aghion et al. (2005) confirm the inverted-U relationship between intensity of competition and R&D incentives.

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. 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. When the threat of competition is not real, liberalisation has no effect on innovation. Liberalisation results in no potential or actual competition (threat of competition is not real) when there are strong barriers to entry on the supply side and no mechanisms are put in place to overcome those barriers.

This paper tests the following hypotheses that follow from the literature and in particular from Felisberto (2007):

Hypothesis 1: Liberalisation in the postal sector has stimulated operators to be more efficient and therefore, more innovative. Behind this hypothesis it is the assumption that there are no strong barriers to entry, namely sunk costs, on the supply side of the postal sector.

Hypothesis 2: When the incumbents preserve a relatively high market share competition favours innovation. 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.

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

In the following section, the data used is described and analysed.

3. 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 variables, namely the percentage of capital owned by the state, population density, and GDP per capita, were also collected.

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

Table 1: 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 is available in 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. 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 1). In that survey the 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.

3.1 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 benefited with the number of years that elapsed from the year that country introduced the innovation until the year in question.

In this way, it was 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 America¹.

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 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

¹ 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.

- 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 optimization 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 sector². 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 1 shows the evolution of the innovation index for the ensemble of the countries.

² 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 Lützel Schwab, Responsible REMA project, Swiss Post; Mr. Pedro Saldanha, Business Strategy and Development, CTT Correios de Portugal, S.A.

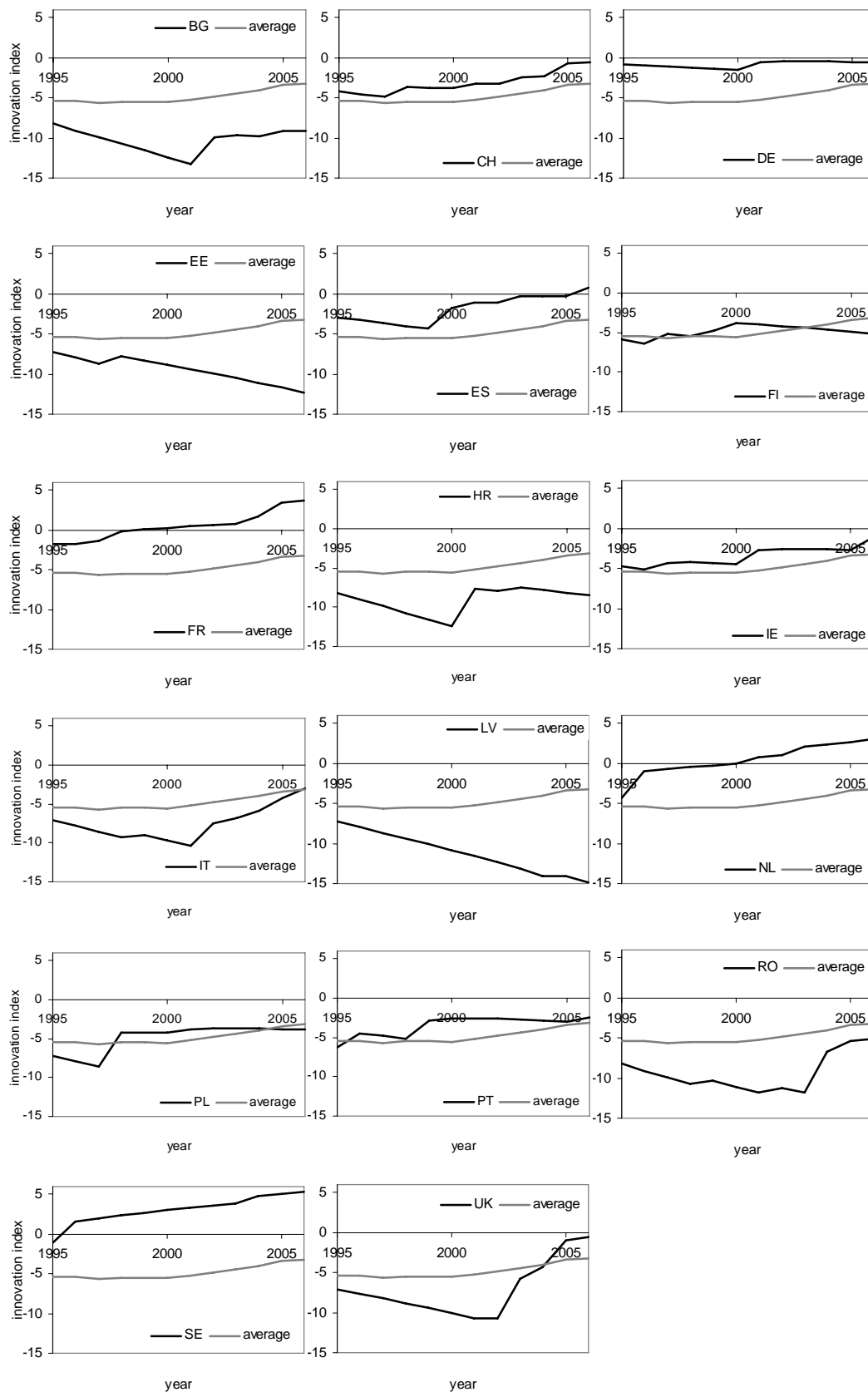


Figure 1: Innovation index.

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 invert the negative trend and, in 2004, Romania does 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 2 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.

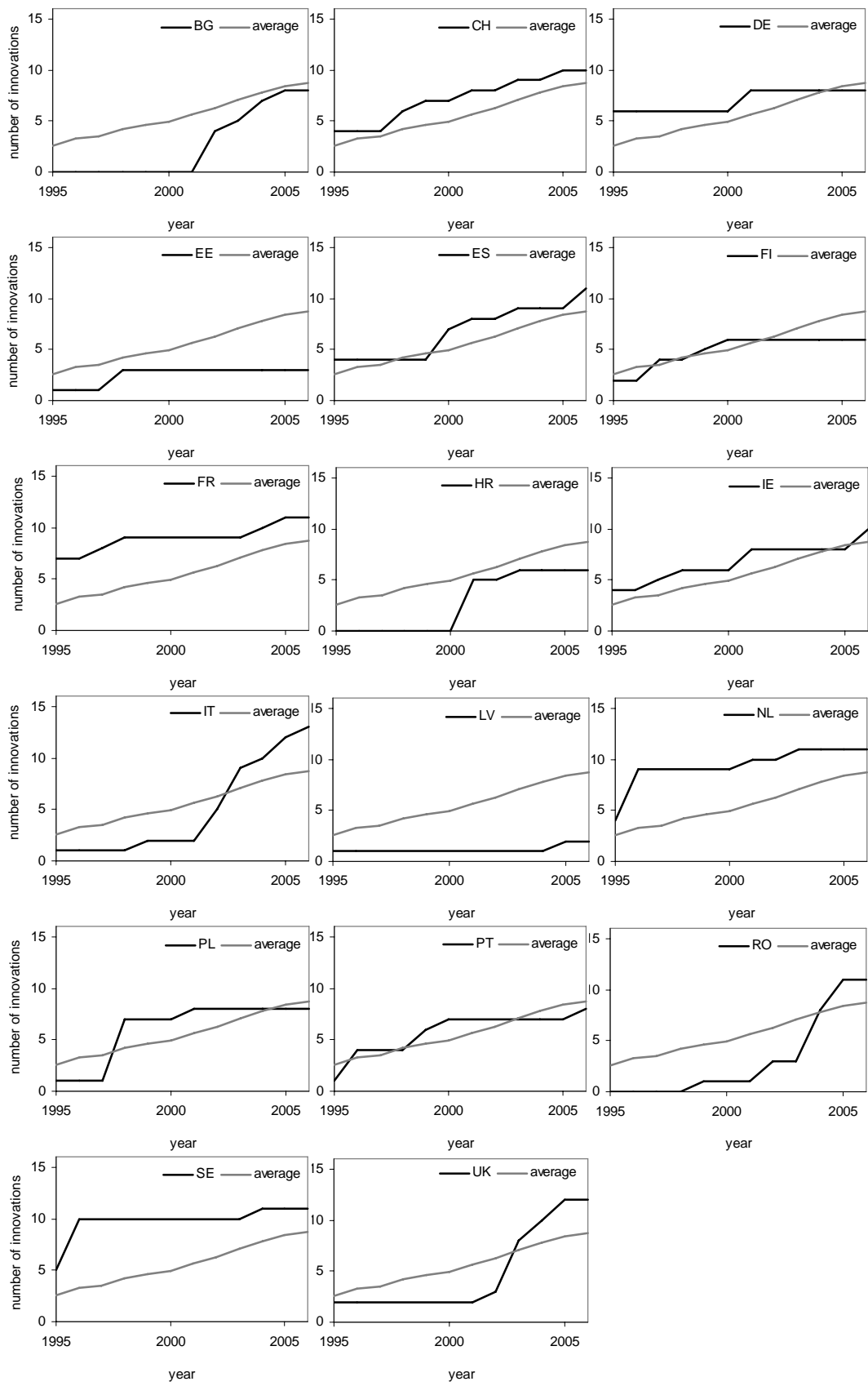


Figure 2: Accumulated number of innovations.

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 UPU database.

Figure 3 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.

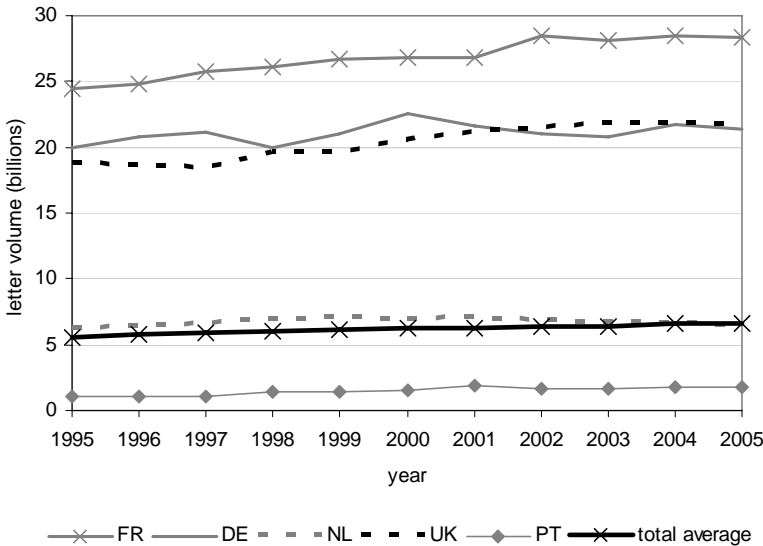


Figure 3: Evolution of letter mail volumes.

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 the largest number of employees are Germany, France and the United Kingdom (Figure 4). 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.

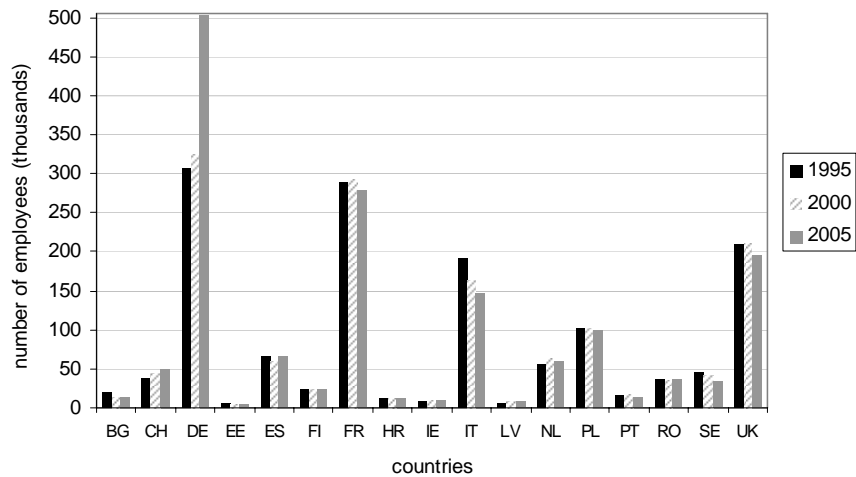


Figure 4: Average number of employees for the years 1995, 2000, and 2005.

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. The consequences 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 5.

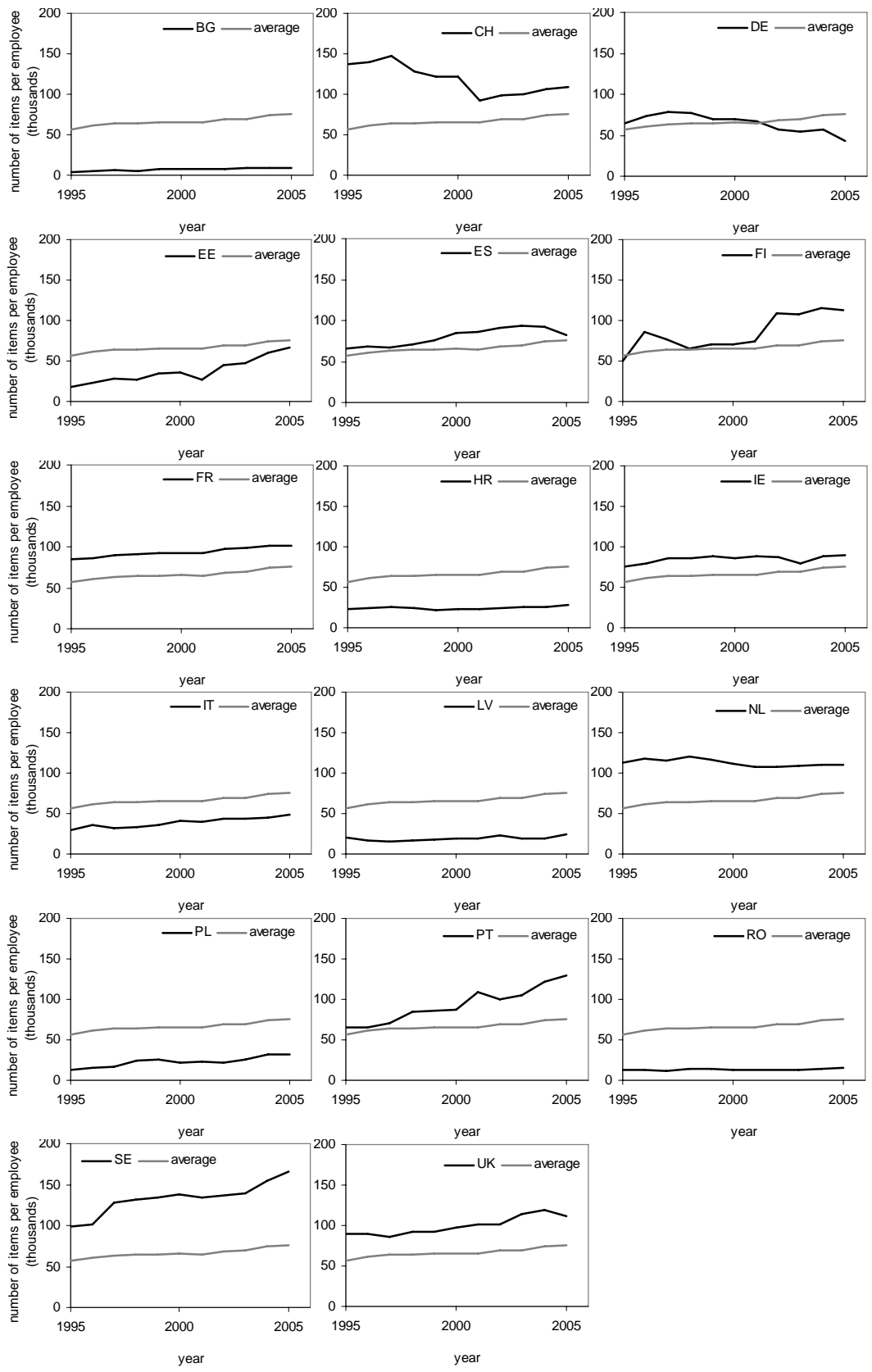


Figure 5: Labour productivity (thousands of items per employee).

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.

3.2 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 aim of the European Commission is the gradual market opening of the postal sector within the European Union. Besides the definition of the maximum reserved area 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, the harmonisation of technical standards. Moreover, directive 97/67/EC required the creation of independent national regulatory authorities.

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 2)
- 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 3).

Table 2: 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)

Table 3: 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)

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 6 displays the evolution of the liberalisation index for the seventeen countries.

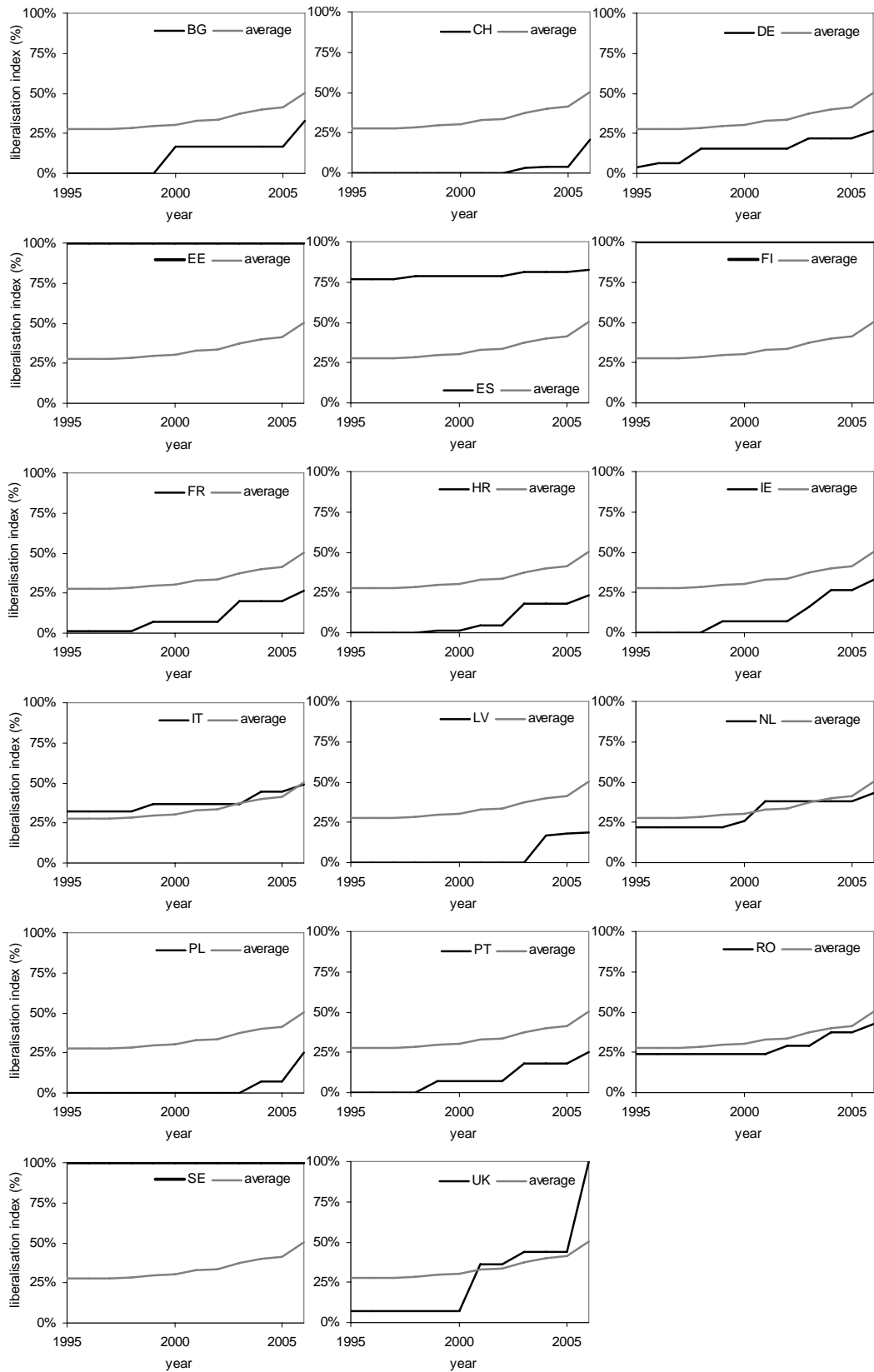


Figure 6: Liberalisation index.

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 (Price Waterhouse, 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 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 Netherlands³. 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).

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).

³ « Postal Memorandum » available at <http://www.ez.nl/content.jsp?objectid=20863> [8/10/2007].

3.3 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 7 illustrates the evolution of the market share of the entrants between 1995 and 2005.

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 country⁴. 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.

⁴ With the exception of the Aland islands in Finland.

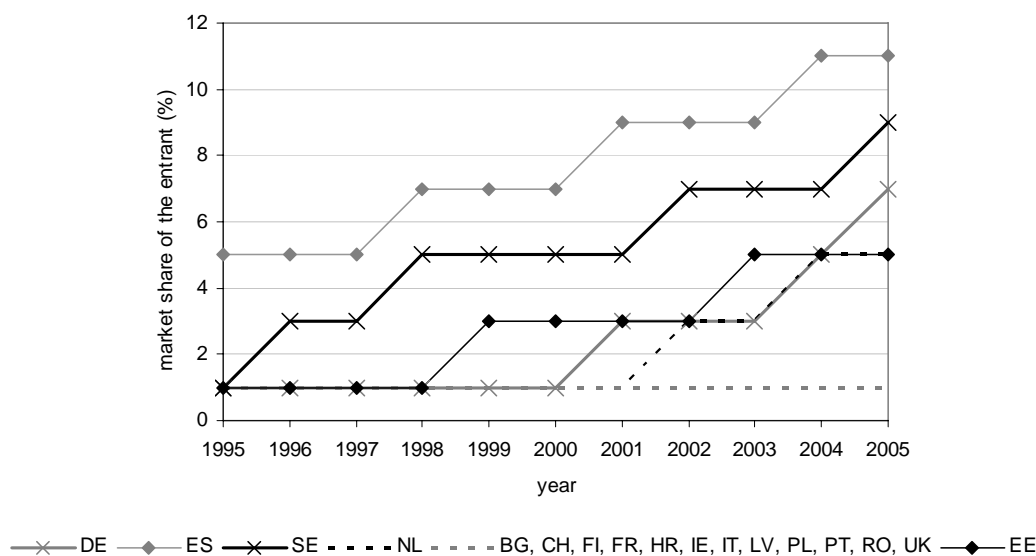


Figure 7: Evolution of entrants' market share.

3.4 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 8, together with population. Population density is in number of habitants per squared kilometre. France, Germany, UK, 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.

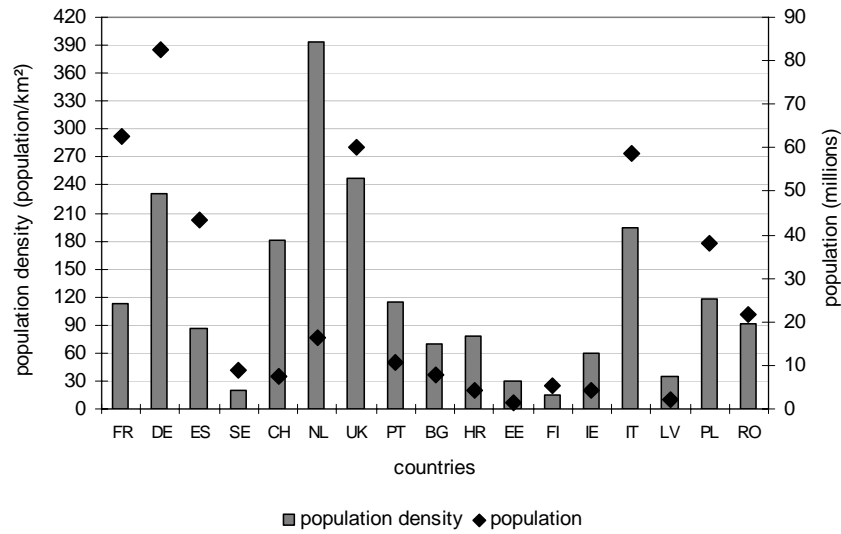


Figure 8: Population and population density in 2005.

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 9 displays the GDP *per capita* and GDP in 2005. The countries with the highest GDPs 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.

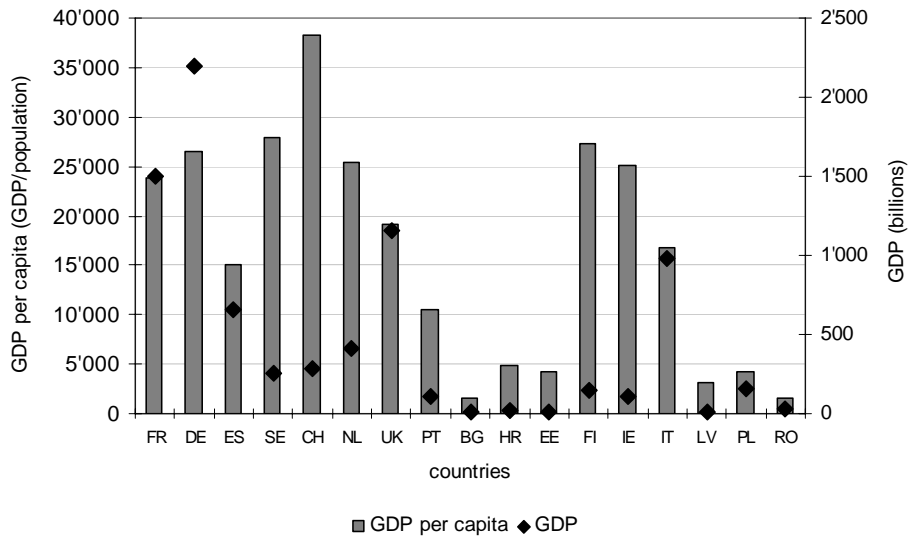


Figure 9: GDP per capita and GDP in 2005.

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

Table 4 summarises and describes the variables involved in this study.

Table 4: Variables' description.

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

The detailed descriptive statistics are presented in Annex 2, Table 6.

4. THE MODEL

In this section we present the econometric model estimated in order to test the hypotheses presented in section 2. Its general form is:

$$\text{Innovation}_{it} = \alpha + \beta_1 X_{it} + \beta_2 \text{mktliberalised}_{i,t-1} + \beta_3 \text{mktliberalised}_{i,t+1} + \beta_4 C_{it} + e_{it}$$

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 the market liberalisation, respectively.

The correlation matrix between independent variables is displayed in Annex 2, Table 7. 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. ESTIMATION PROCEDURES

Firstly, the models were tested for the presence of heteroskedasticity and correlation between and within panels. Table 8, in Annex 2, 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 heteroskedasticity.

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 13, in Annex 2, were estimated by GLS and models 14 through 19, in Annex 2, 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 Ordinary Least Squares (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.

6. RESULTS

In this section, the results are presented and discussed. A total of forty two models were estimated and reported in Annex 2 (Tables 8 through 13). Tables 8, 9, and 10 report the results of GLS estimation. Tables 11, 12, and 13 report the PW-PCSE estimation. In the models included in Tables 8 and 11 the dependent variable is the innovation index. Tables 9 and 12 contain the models that have the accumulated number of innovations as dependent variable. Finally, Tables 10 and 13 report the models that use labour productivity as proxy for innovation. Each table contains seven models. Schematically the models are as follows:

Table 5: Scheme of the models estimated.

Estimation procedure		Dependent variable		
		<i>inindex</i>	<i>accuminno</i>	<i>itemperempl</i>
GLS	table number	4	5	6
	model number	1-7	8-14	15-21
PW-PCSE	table number	7	8	9
	model number	22-28	29-35	36-42

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

6.1 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 $\chi^2(2)=5.50$ and $\text{Prob}>\chi^2=0.064$). When compare Model 10 is compared to Model 11, the

likelihood-ratio test indicates that Model 10 fits the data better (LR $\chi^2(2)=4.43$ and $\text{Prob}>\chi^2=0.035$).

In the set of models estimated by GLS which use labour productivity as proxy for innovation (Table 11) 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 $\chi^2(2)=-5.51$ and $\text{Prob}>\chi^2=1$); (2) Model 16 is preferable to Model 17 (LR $\chi^2(2)=62.98$ and $\text{Prob}>\chi^2=0.000$); and (3) Model 16 fits the data better than Model 18 (LR $\chi^2(2)=180.76$ and $\text{Prob}>\chi^2=0.000$). This confirms the perception that Model 16 is the one that best fits the data.

6.2 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.

From the results presented above, it can be concluded 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 always statistically significant 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.

7. 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 have not been assessed yet.

This paper aims at contributing to the literature with empirical evidence on the effect of both liberalisation and competition on innovation in the postal sector. The impacts of private ownership and of market size are also analysed.

To this end a dataset, 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, is put together. The dataset embraces data for seventeen European countries, over ten years. Three measures are 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 develop a liberalisation index, which allows us to measure the percentage of market liberalised (in terms of letter volume).

Several models are estimated by GLS and using PW-PCSE. In general, the models estimated have a high explanatory power. We find evidence that market liberalisation has a positive effect on innovation. This finding supports the idea that the threat of competition (or potential competition) on its own induces firms to be efficient.

We also find evidence 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, it is also found evidence 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.

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

Further work could introduce work-sharing (upstream access) and downstream access, as explanatory variables in the model. It would also be interesting to replicate this study for other network industries, in particular the ones where competition is more developed.

REFERENCES

- [1] 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.
- [2] 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.
- [3] ARTHUR D. LITTLE LIMITED, 2004. Technology and innovation in the postal sector - a competitive market review.
- [4] BAUMOL, W., 1982. Contestable markets: an uprising in the theory of industry structure. *American Economic Review*, 72, 1-15.
- [5] BAUMOL, W., PANZAR, J. C. & WILLIG, R. D., 1982. *Contestable markets and the theory of industry structure*, New York, Harcourt Brace Jovanovich.
- [6] BAUMOL, W. J. & WILLIG, R. D., 1986. Contestability: developments since the book. *Oxford Economic Papers*, 38, 9-36.
- [7] 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.
- [8] BOONE, J., 2000. Competitive pressure: the effects on investments in product and process innovation. *The RAND Journal of Economics*, 31, 549-569.
- [9] BOONE, J., 2001. Intensity of competition and the incentive to innovate. *International Journal of Industrial Organization*, 19, 705-726.
- [10] BOONE, J. & DIJK, T. V., 1998. Competition and innovation. *De Economist*, 3, 445-461.
- [11] BUNDESNETZAGENTUR, 2006. Ninth market study - Letter market. Mainz.
- [12] 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.
- [13] 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*.
- [14] ECORYS, 2005. Development of competition in the European postal sector. Rotterdam.
- [15] FELISBERTO, C., 2007. The effect of competition on innovation in the network industries. *6th Conference on Applied Infrastructure Research*. TU Berlin.
- [16] GROSSMAN, G. M. & HELPMAN, E., 1991. *Innovation and growth in the global economy*, Cambridge, MIT Press.

- [17] IPC, 2007. Postal Regulatory Database, Country Directory 2007 - Version 6.
- [18] KAMIEN, M. I. & SCHWARTZ, N. L., 1975. Market structure and innovation: a survey. *Journal of Economic Literature*, 13, 1-37.
- [19] KAMIEN, M. I. & SCHWARTZ, N. L., 1976. On the degree of rivalry for maximum innovative activity. *The Quarterly Journal of Economics*, 90, 245-260.
- [20] LEE, T. & WILDE, L. L., 1980. Market structure and innovation: a reformulation. *The Quarterly Journal of Economics*, 94, 429-436.
- [21] LOURY, G. C., 1979. Market structure and innovation. *The Quarterly Journal of Economics*, 93, 395-410.
- [22] NERA, 2004. Economics of postal services. London.
- [23] NICKELL, S. J., 1996 Competition and corporate performance. *The Journal of Political Economy*, 104, 724-746.
- [24] PRICE WATERHOUSE, 1997. Employment trends in the European postal sector.
- [25] PRICEWATERHOUSECOOPERS, 1997. Employment trends in the European postal sector.
- [26] ROMER, P., 1990. Endogenous technological change. *Journal of Political Economy*, 98, S71-S102.
- [27] SCHERER, F. M., 1967. Research and development resource allocation under rivalry. *The Quarterly Journal of Economics*, 81, 359-394.
- [28] SCHUMPETER, J., 1942. *Capitalism, socialism and democracy*, New York, Harper.
- [29] WIK, 2004. Main developments in the European postal sector. Bad Honnef.
- [30] WIK, 2005. The evolution of the regulatory model for European postal services. Bad Honnef.
- [31] WIK, 2006. Main developments in the postal sector (2004-2006). Bad Honnef.

ANNEX 1 - Questionnaire

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 2- Results

Table 6: Descriptive statistics.

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

Table 7: Correlation matrix.

	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 8: Summary of the heteroskedasticity and correlation tests performed.

Dependent variable	Explanatory variables	Likelihood-ratio test for heteroskedasticity		Modified Wald test		Wooldridge test	
		LR chi(16)=		chi2(17)=		F(1,16)=	
inindex	X_{it}	LR chi(16)=	88.38	chi2(17)=	5720.62	F(1,16)=	85.61
		Prob>chi2=	0	Prob>chi2=	0	Prob>F=	0
accuminno		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 9: Results of GLS estimation with *inindex* as dependent variable.

	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6	Model 7
<i>mktliberalised_t</i>	0.009 (1.07)	0.017 (1.79)*	0.037 (3.74)***	0.040 (3.81)***			
<i>mktshareE_t</i>	0.351 (4.83)***	0.375 (4.26)***	0.478 (6.37)***		0.645 (8.21)***	0.525 (6.68)***	0.388 (4.43)***
<i>public_t</i>	-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)***
<i>tvolume_t</i>	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)***
<i>popdens_t</i>	-0.021 (2.94)***						
<i>gdppercap_t</i>	0.304 (3.84)***	0.192 (2.51)**					
<i>mktliberalised_{t+1}</i>						0.016 (2.02)**	
<i>mktliberalised_{t-1}</i>							0.019 (1.64)*
<i>Constant</i>	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 10: Results of GLS estimation with *accuminno* as dependent variable.

	Model 8	Model 9	Model 10	Model 11	Model 12	Model 13	Model 14
<i>mktliberalised_t</i>	0.006 (0.58)	-0.016 (1.57)	0.019 (2.05)**	0.031 (2.97)***			
<i>mktshareE_t</i>	0.439 (5.79)***	0.517 (7.60)***	0.534 (4.56)***		0.550 (6.00)***	0.387 (4.24)***	0.051 (0.81)
<i>publick_t</i>	-0.056 (2.76)***	-0.022 (2.15)**	0.000 (0.01)	0.018 (2.78)***	0.011 (2.63)***	0.007 (1.10)	0.012 (1.49)
<i>tvolume_t</i>	-0.032 (0.52)	0.066 (1.22)	0.274 (7.87)***	0.196 (1.98)**	0.236 (2.64)***	0.278 (8.38)***	0.238 (5.86)***
<i>popdens_t</i>	0.039 (2.25)**						
<i>gdppercap_t</i>	0.398 (5.65)***	0.354 (7.31)***					
<i>mktliberalised_{t+1}</i>						0.020 (2.95)***	
<i>mktliberalised_{t-1}</i>							0.063 (7.75)***
<i>Constant</i>							
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 11: Results of GLS estimation with itemperempl as dependent variable.

	Model 15	Model 16	Model 17	Model 18	Model 19	Model 20	Model 21
<i>mktliberalised_t</i>	0.020 (0.92)	0.051 (2.06)**	0.021 (0.64)	0.081 (2.67)***			
<i>mktshareE_t</i>	1.944 (7.51)***	2.168 (6.59)***	1.056 (2.63)***		1.728 (5.47)***	1.194 (7.12)**	0.615 (1.51)
<i>publick_t</i>	-0.251 (6.69)***	-0.253 (6.04)***	-0.257 (4.95)***	-0.282 (7.21)***	-0.413 (7.37)***	-0.368 (13.25)***	-0.751 (18.77)***
<i>tvolume_t</i>	2.412 (7.97)***	1.735 (5.91)***	2.074 (7.57)***	2.261 (9.51)***	2.640 (12.37)***	2.664 (20.28)***	2.512 (11.59)***
<i>popdens_t</i>	0.032 (2.18)**						
<i>gdppercap_t</i>	2.180 (16.33)***	2.346 (16.07)***					
<i>mktliberalised_{t+1}</i>						0.006 (0.58)	
<i>mktliberalised_{t-1}</i>							0.221 (5.71)***
<i>Constant</i>	38.482 (9.60)***	43.261 (9.54)***	77.393 (10.82)***	79.528 (12.06)***	78.790 (12.60)***	74.990 (18.29)***	105.667 (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 12: Results of PW-PCSE estimation with inindex as dependent variable.

	Model 22	Model 23	Model 24	Model 25	Model 26	Model 27	Model 28
<i>mktliberalised_t</i>	0.032 (2.71)***	0.030 (2.25)**	0.040 (2.59)***	0.032 (2.56)***			
<i>mktshareE_t</i>	0.276 (2.97)***	0.290 (3.20)***	0.265 (2.97)***		0.388 (3.95)***	0.285 (3.24)***	0.254 (2.86)***
<i>publick_t</i>	-0.021 (1.06)	-0.038 (3.33)***	-0.071 (4.26)***	-0.088 (7.08)***	-0.062 (3.75)***	-0.072 (4.50)***	-0.063 (3.96)***
<i>tvolume_t</i>	-0.050 (0.35)	0.045 (0.28)	0.225 (1.38)	0.242 (4.37)***	0.248 (1.59)	0.203 (1.38)	0.228 (1.39)
<i>popdens_t</i>	0.002 (0.38)						
<i>gdppercap_t</i>	0.284 (7.71)***	0.252 (5.57)***					
<i>mktliberalised_{t+1}</i>						0.035 (2.47)**	
<i>mktliberalised_{t-1}</i>							0.036 (2.18)**
<i>Constant</i>	-8.438 (3.69)***	-6.616 (6.39)***	-1.452 (0.99)	0.357 (0.39)	-1.094 (0.75)	-1.283 (0.96)	-2.291 (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

Table 13: Results of PW-PCSE estimation with accuminno as dependent variable.

	Model 29	Model 30	Model 31	Model 32	Model 33	Model 34	Model 35
<i>mktliberalised_t</i>	0.020 (1.44)	0.011 (1.00)	0.023 (1.74)*	0.027 (2.16)**			
<i>mktshareE_t</i>	0.356 (3.30)***	0.326 (3.15)***	0.264 (2.44)**		0.328 (2.94)***	0.266 (2.51)**	0.160 (2.24)**
<i>publick_t</i>	0.003 (0.16)	-0.033 (2.81)***	-0.056 (3.68)***	-0.070 (5.46)***	-0.049 (3.37)***	-0.060 (4.06)***	-0.048 (2.80)***
<i>tvolume_t</i>	0.238 (1.20)	0.281 (1.57)	0.290 (1.99)**	0.196 (2.72)***	0.301 (2.05)**	0.246 (1.90)*	0.265 (1.94)*
<i>popdens_t</i>	0.009 (1.79)*						
<i>gdppercap_t</i>	0.171 (4.87)***	0.174 (5.24)***					
<i>mktliberalised_{t+1}</i>						0.024 (1.82)*	
<i>mktliberalised_{t-1}</i>							0.018 (1.41)
<i>Constant</i>	-1.596 (0.51)	3.240 (2.55)**	7.732 (5.78)***	9.452 (11.51)***	7.931 (5.92)***	8.064 (6.77)***	7.586 (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 14: Results of PW-PCSE estimation with itemperempl as dependent variable.

	Model 36	Model 37	Model 38	Model 39	Model 40	Model 41	Model 42
<i>mktliberalised_t</i>	0.094 (1.70)*	0.109 (1.76)*	0.161 (1.63)*	0.210 (2.36)**			
<i>mktshareE_t</i>	1.505 (2.11)**	1.122 (1.78)*	0.849 (0.94)		1.047 (1.04)	0.901 (1.02)	0.781 (0.82)
<i>publick_t</i>	0.165 (1.06)	0.161 (1.38)	-0.167 (1.12)	-0.163 (1.21)	-0.214 (1.31)	-0.150 (1.05)	-0.231 (1.61)*
<i>tvolume_t</i>	5.816 (4.28)***	5.418 (4.79)***	2.210 (5.46)***	2.393 (5.83)***	2.546 (7.85)***	1.976 (3.88)***	1.961 (5.00)***
<i>popdens_t</i>	-0.013 (0.35)						
<i>gdppercap_t</i>	2.307 (8.47)***	2.366 (8.20)***					
<i>mktliberalised_{t+1}</i>						0.030 (0.48)	
<i>mktliberalised_{t-1}</i>							0.060 (0.65)
<i>Constant</i>	-5.368 (0.31)	-7.181 (0.57)	62.565 (3.92)***	65.875 (4.60)***	61.457 (4.04)***	71.041 (4.70)***	77.299 (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