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 the threat of competition and of competition on innovation in the postal sector. We restrict ourselves to the analysis of end-to-end competition. The effect of public ownership and letter volume on the incentives to innovate are 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 with the purpose of measuring 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. Contrarily to what was expected, there is evidence that the percentage of private ownership has a positive effect on innovation. GDP per capita turns out to be significant and to have a positive relationship with innovation in all the models estimated.

Keywords: Innovation, Liberalisation, Competition, Postal sector

JEL Classification: K23, L19, L99, O31

1. Introduction

The European postal sector has been undergoing a process of reform over the past decade. The progressive liberalisation of the sector is definitely the most relevant aspect of this reform. One of the major motivations for liberalising the sector was the belief that competition stimulates process innovation (development of new technologies), product innovation (development of new products and services), encourages efficiency, and drives prices down.

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 seems to be undisputable.

In this paper a clear distinction is made between liberalisation and competition. In the scope of this paper, liberalisation is understood as the relaxation or abolishment of previous entry barriers. 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. There is also a debate on this issue, where the most widespread theory is the one on contestable markets, which argues that the threat of competition on its own induces a monopoly to be efficient (Baumol et al., 1982, Baumol, 1982, Baumol and Willig, 1986).

To our knowledge, neither the effects of competition, nor the effects of liberalisation on innovation have ever been assessed empirically in the postal sector. This paper aims at

filling this gap by empirically assessing the effect of competition and of the threat of competition on innovation in the postal sector. Due to the lack of quantitative data on upstream and downstream access we restrict ourselves to the analysis of end-to-end competition. Other results from Felisberto (2007), namely the effect of public ownership and of the letter volume on the incentives to innovate, are also tested.

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: (1) the percentage of market liberalized (based on the evolution of the reserved area); (2) the market shares of the new entrants; (3) the percentage of public ownership; and (4) letter volume. We control for Gross Domestic Product (GDP) per capita and for population density. Regarding the data on innovation, seventeen critical innovations were identified and postal 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 market liberalisation 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. Contrarily to what was expected, there is evidence that the percentage of private ownership has a positive effect 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

Liberalisation *per se*, i.e. not necessarily accompanied by competition, may have an impact on innovation different from that of liberalisation accompanied by competition.

The theory of contestable markets gives evidence that the threat of competition *per se* is enough for firms to become more efficient. In the absence of competition, firms do not loose market share nor economies of scale 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. Hence, liberalisation *per se* is expected to have a positive effect, larger than that of 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 the incumbent 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 author compares the incentives to innovate under monopoly and duopoly and shows that the incumbent has greater incentives to innovate under monopoly than under duopoly, when its market share duopoly decreases significantly. The size of the decrease in market share required to trigger lower innovation in the face of competition depends in a complicated manner on all the model parameters. Of course, even when levels of investment in innovation are higher under monopoly, there

is a price to pay in form of the usual deadweight losses of monopoly. How large these are will depend on the "commercial orientation", i.e., objective function, of the incumbent. In particular, when all the weight is given either to revenue or profit maximisation, prices are higher under monopoly than under duopoly while the quantity supplied and social welfare are smaller. If the market share of the incumbent is above a certain level, then it is duopoly that gives rise to more incentives to innovate (except when welfare maximisation is the sole objective or has a sufficiently high weight in the incumbent's objective function).

It is also proven by the Felisberto (2007) 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.

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

Hypothesis 1: Liberalisation has stimulated operators to be more efficient and therefore, more innovative.

Hypothesis 2: When the incumbents preserve a relatively high market share competition favours innovation. Therefore, and since the incumbents analysed here kept market shares of at least 90 a positive effect of end-to-end competition on innovation and efficiency is expected.

Hypothesis 3: Felisberto (2007) 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 the investment in innovation. If we assume that the ownership structure that is more likely to promote welfare maximisation is public ownership, then a decrease in public ownership is expected to have a negative impact on innovation.

Hypothesis 4: The greater the size of the market, i.e. the quantity supplied (or letter volume), the more efficient and innovative the operator is.

Next, the data used is described and analysed.

3. Data

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 innovation in the postal sector in the last decade.

Data to measure the innovativeness of the operators (including the letter mail volume and the average number of employees) and the degree of liberalisation and competition in the market were collected. Some additional variables, namely the percentage of capital owned by the state, population density, and Gross Domestic Product (GDP) per capita were also collected.

All these variables were collected for the period between 1995 and 2005 (some were also collected for 2006), for seventeen European countries and operators: Bulgaria (Bulgarian Posts plc), Croatia (Hrvatska pošta d.d.), Estonia (Eesti Post Ltd), Finland (Itella Oyj), France (La Poste), Germany (Deutsche Post AG), Ireland (An Post), Italy (Poste Italiane S.p.A.), Latvia (Latvijas Pasts), Poland (Poczta Polska), Portugal (CTT - Correios de Portugal, S.A.), Romania (C.N. Posta Romana S.A.), Spain (Correos y Telégrafos S.A.), Sweden (Posten AB), Switzerland (Die Post/La Poste/La Posta), The Netherlands (TNT Post) and United Kingdom (Royal Mail Group PLC).

The data needed to build the innovation index, one of the measures of innovation, were collected through a survey (see Annex 1). In that survey the incumbents were inquired about the date of introduction of 17 critical innovations.

The data used to build the liberalisation index is available in the several studies mandated by the European Commission, the regulators' reports, the annual reports of the operators and the IPC regulatory database. The same sources were used to collect the data on the degree of competition, i.e. market shares.

The different measures of innovation used and the liberalisation index are analysed first. After, the remaining variables are examined.

3.1 Measures of innovation

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

The innovation index developed in this paper to measure innovativeness in the postal sector 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 we are analysing did not introduced that innovation yet, then the latter will be penalised with the number of years that elapsed since the year the innovation was first introduced until the year we are analysing. On the contrary, if the country we are analysing already introduced a certain innovation, then the country is beneficed with the number of years that elapsed since the year that country introduced the innovation until the year we are analysing.

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

The pioneer country is identified among the seventeen countries plus the United States of America[1]. For each of the innovations we may have a different pioneer country.

For the sample at study 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 recent 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 with one year. Hence, in order to ensure a symmetric treatment of the innovations that were already introduced relatively to the ones that were not, we need to benefit the country for each year that elapses since the introduction of an innovation.

The incumbents were asked about the date of introduction of the following seventeen critical innovations:

- Optimisation of collection routes (using a 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 all front side of the letter
- Automated sorting machines using OCR that can read hand-written whole addresses

[1] Although the USA are not included in the econometric analysis the date of the USA was considered when deciding the date of introduction by the pioneering country.

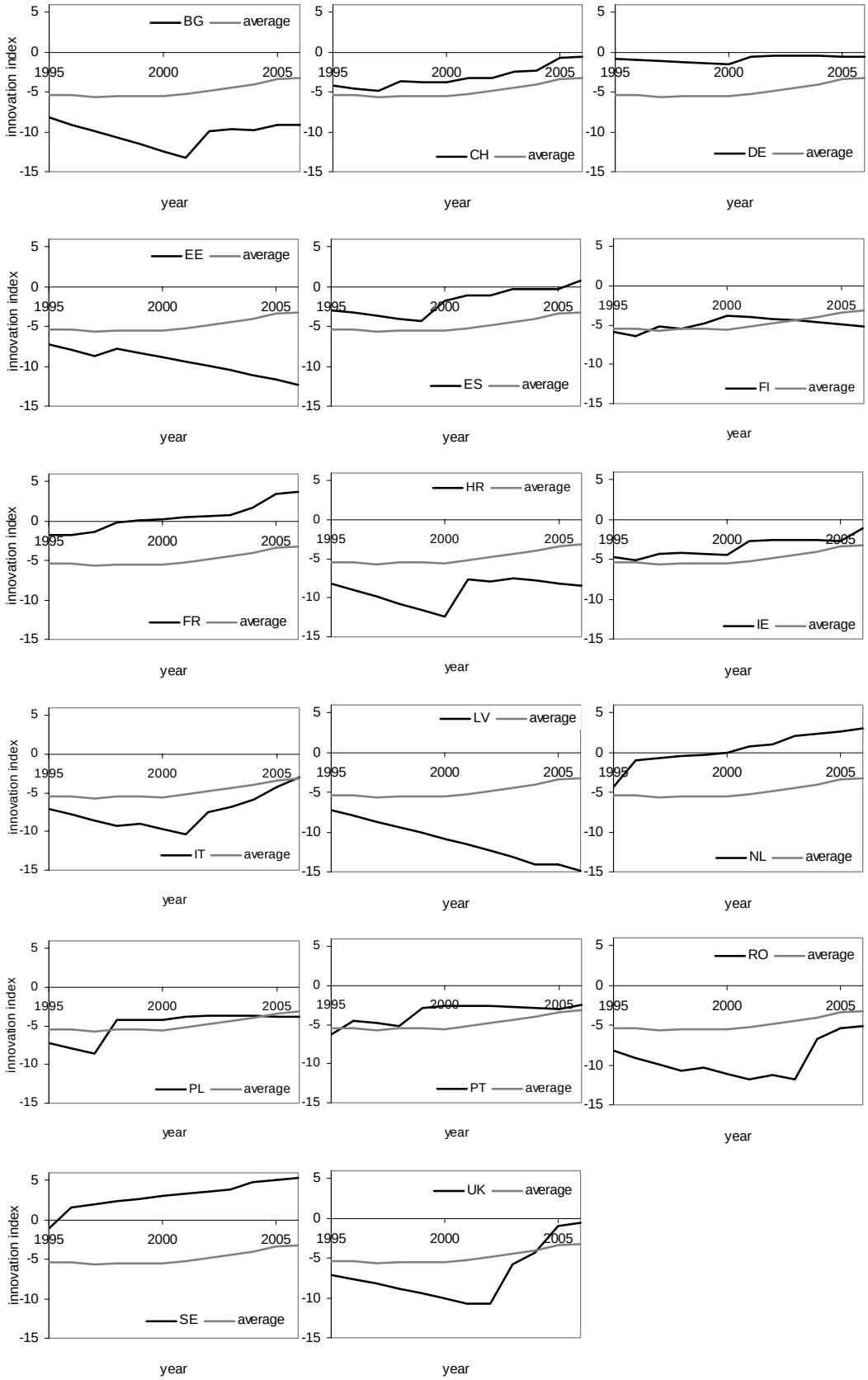
- Automated sorting machines using OCR that can read hand-written postal codes
- Automated sorting machines using OCR that can read machine written postal codes and whole addresses
- Video coded address reading equipment: online coding
- Video coded address reading equipment: scanning and remote coding (off-line video coding equipment)
- Automated sequence sorting to delivery route
- Automatic tray handling systems
- Automated guided vehicles (AGV)
- Route planning and 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 through interviews with experts in the postal sector[2]. Firstly, the ensemble of the more significant innovations was listed and then 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 Lützelschwab, Responsible REMA project, Swiss Post; Mr. Pedro Saldanha, Business Strategy and Development, CTT Correios de Portugal, S.A.

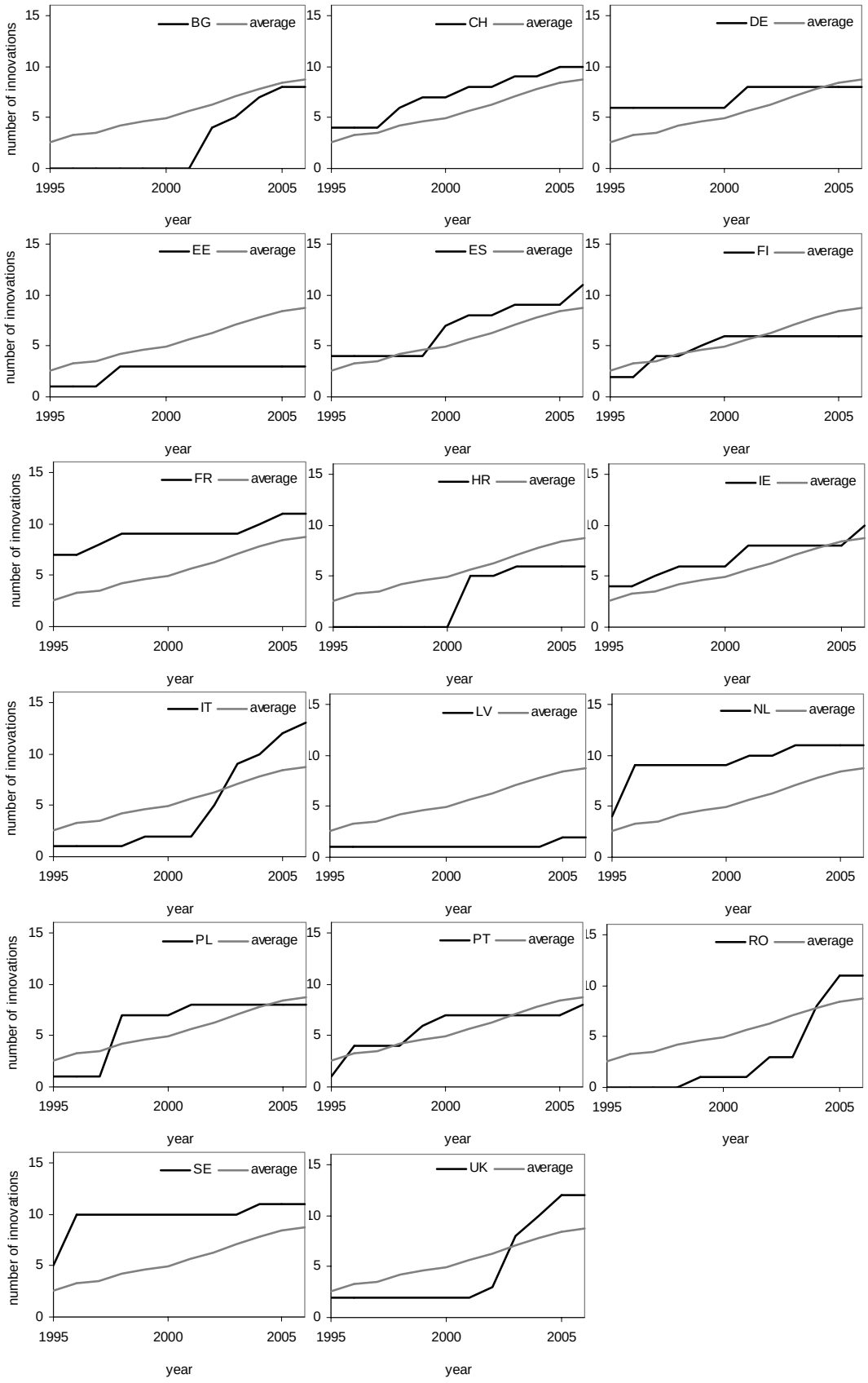
Figure 1: Innovation index



The countries with a larger technological delay are Bulgaria (BG), Estonia (EE), Croatia (HR), and Latvia (LV). Italy (IT), Romania (RO), and the United Kingdom (UK) used to have an innovation index much lower than the average. However, in 2003 both UK and IT invert the negative trend and in 2004 RO does it too. Today UK is above the average, IT just reached the average and RO is very close to it. The innovation delay/advance, introducing the critical innovations, of the incumbents from Switzerland (CH), Finland (FI), Ireland (IE), Poland (PL), and Portugal (PT) have been around the average through out the period at study. Spain (ES), Germany (DE), France (FR), The Netherlands (NL), and Sweden (SE) have registered an innovation index above the average.

The accumulated number of innovations in a certain year corresponds to the number of innovations that were implemented until that year, among the critical innovations the operators were asked about. 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.

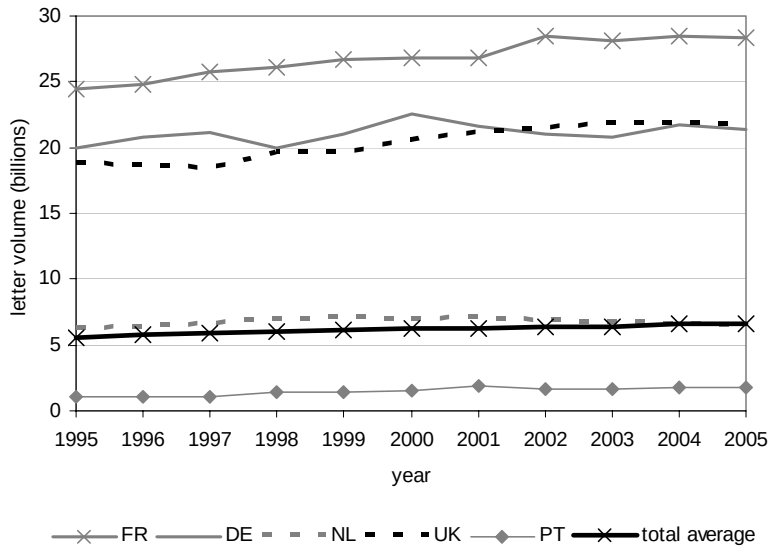
Figure 2: Accumulated number of innovations



Labour productivity is equal to the letter mail volume (in thousands) divided by the average number of employees.

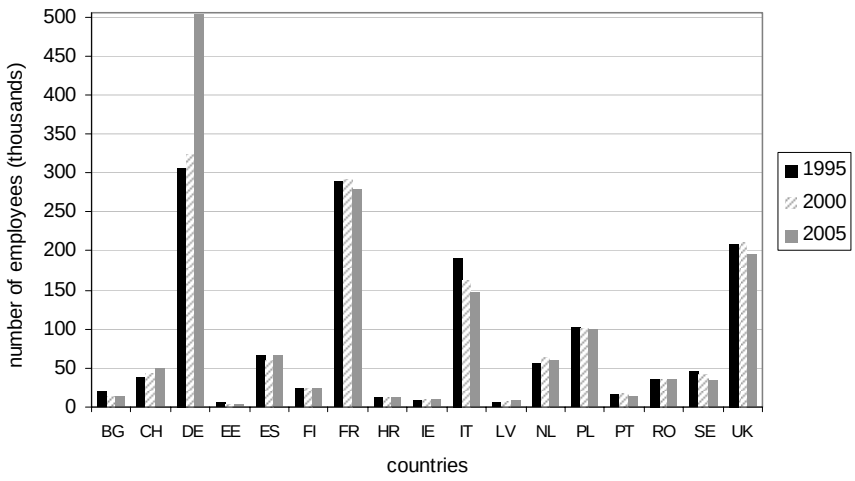
The data on the volume of letter mail in billions of items (***tvolume***), which includes domestic and international correspondence, registered items, insured letters, newspapers, and addressed and unaddressed advertising items, is available at the UPU database. Figure 3 shows that there have been some small fluctuations in the volumes but not significant ones. The impact of electronic substitution on mail volumes has been less strong than predicted by some operators. The expectations are that letter post will become a medium for distribution of direct mail and less a medium 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. FR, UK, and PT have experienced growing mail volumes. The total average has also been increasing slightly.

Figure 3: Evolution of the letter mail volumes



The average number of employees (includes permanent employees and employees with a contract with a term) 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 larger number of employees are Germany, France and UK (Figure 4). These three countries are the ones with larger volumes as observed before. Italy calls attention 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 group 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 these are that a postal operator where there is a large diversification of products and

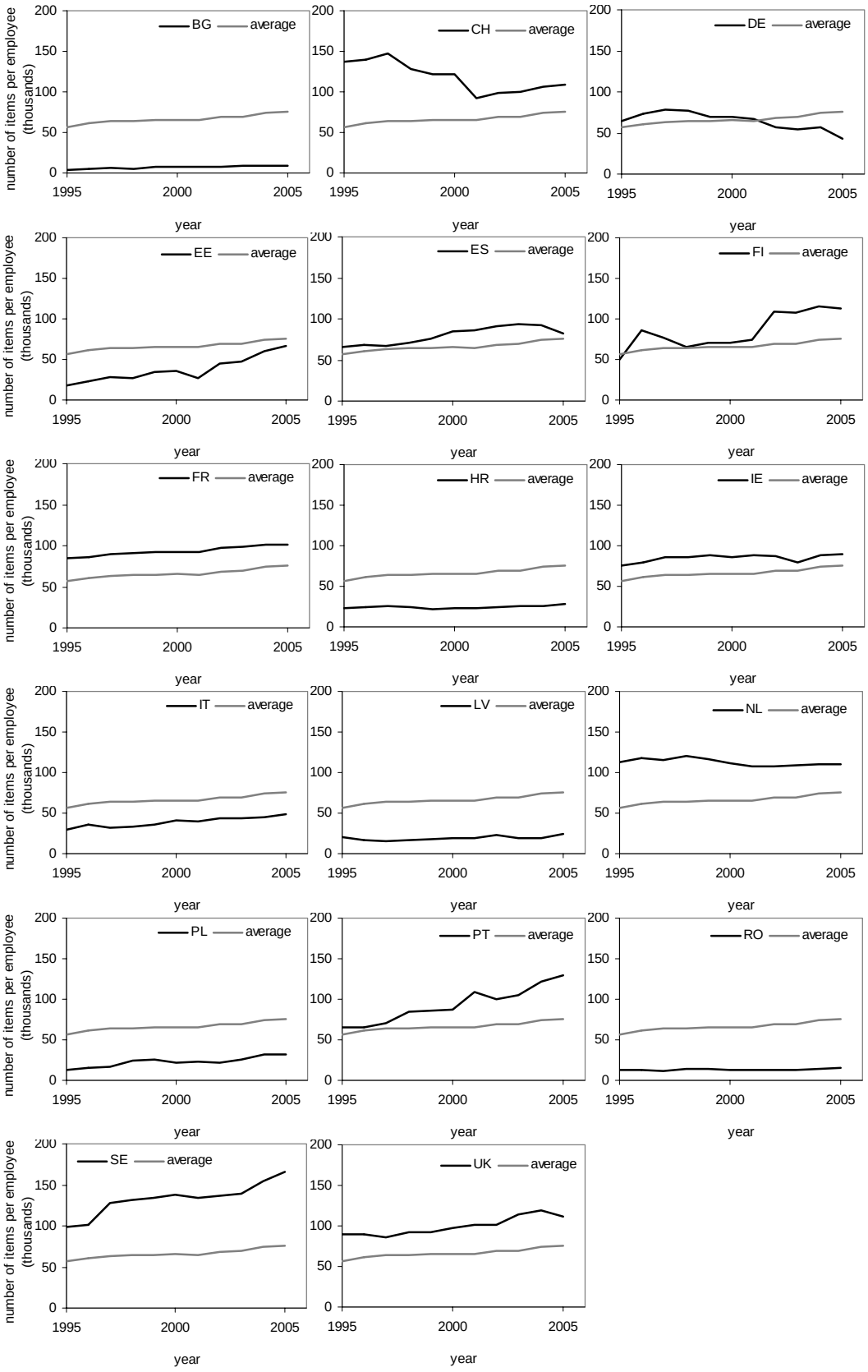
where financial services, for instance, have a large weight will have a smaller labour productivity.

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.

We also have to consider 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.

BG has a labour productivity below the average, which is consistent with the technological delay introducing the seventeen innovations observed before. In the same situation are: EE, HR, IT, LV, and RO. In EE, however, the innovation index is deviating more and more from the average while labour productivity is approaching the average. In LV, 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, Swedish, Spanish, 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 FI, and IE both measures of innovation have been always very close to the average.

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

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

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

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

3.2 Measuring the degree of liberalisation

In 1998 it was implemented the European Postal Directive 97/67/EC, 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 the 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 alter the full market opening to January 1st 2011. The new member states and posts that work within 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 in four categories: items of correspondence, addressed printed matter, newspapers, and un-addressed printed matter (i.e. un-addressed direct mail). The items of correspondence are the letters and postcards, and the transaction mail like 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 from the reserved area the collection and transportation of mail to a post office for final delivery. France, Germany, Italy, 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 paper 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 if the following categories make part of the reserved area: domestic and inbound cross-border correspondence (weight criteria transformed in percentage of mail liberalised according to Table 1); local intra-city mail; direct mail; and outbound cross-border correspondence. Each category was given a weight according to the composition of the mail market in physical terms (Table 2).

Table 1: 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 2: Composition of the mail market in physical terms

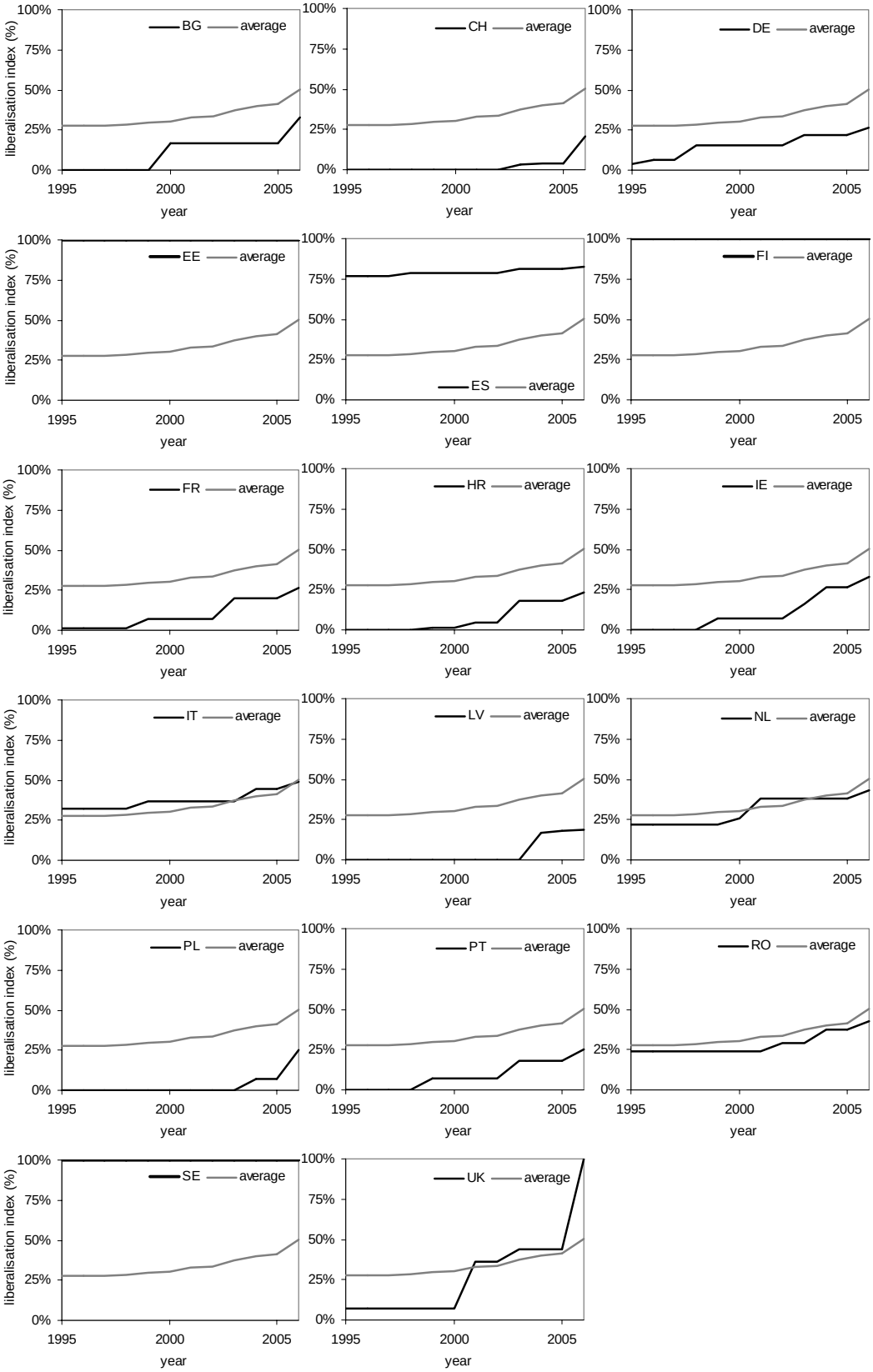
	Domestic and inbound CB	Direct mail	Outbound CB
FR	74%	23%	2%
DE	62%	37%	2%
ES	75%	21%	4%
SE	73%	23%	4%
CH	66%	31%	3%
NL	76%	20%	4%
UK	69%	28%	3%
US	73%	26%	0%
PT	81%	15%	4%
BG	88%	10%	1%
CZ	76%	21%	3%
HR	62%	37%	1%
EE	85%	11%	4%
FI	77%	22%	1%
IE	82%	7%	11%
IT	67%	32%	1%
LV	93%	4%	4%
PL	92%	5%	3%
RO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

Source: Ecorys (2005)

Before the Postal Directive 97/67/EC the incumbents retained monopolies for letters, generally up t 1 or 2 kilograms. It was assumed that the maximum reserved area for domestic and incoming cross-border mail is 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 1960's 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 costumer 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 the 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 UK, the Postal Services Act 2000 abolished the reserved area and as from 1 January 2006, the Postal Services Comission ("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 operator 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[3]. 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).

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

In Germany, letter items weighting more than 200 grams were 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 we can observe substantial competition 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).

3.3 Data analysis

The degree of competition is measured through the market share of the competitor postal operators (in terms of volume) in addressed mail delivery including both reserved and non-reserved areas (***mktshareE***). *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. The sources of the market share of the entrants are the followings: Ecorys (2005), Wik (2004), Bundesnetzagentur (2006), and the Swedish regulator. Figure 7 illustrates the evolution of the market share of the entrants between 1995 and 2005.

In the majority of the countries the entrants' market share does not exceed the 2%. Spain is the country where competition is higher, followed by Sweden. Although

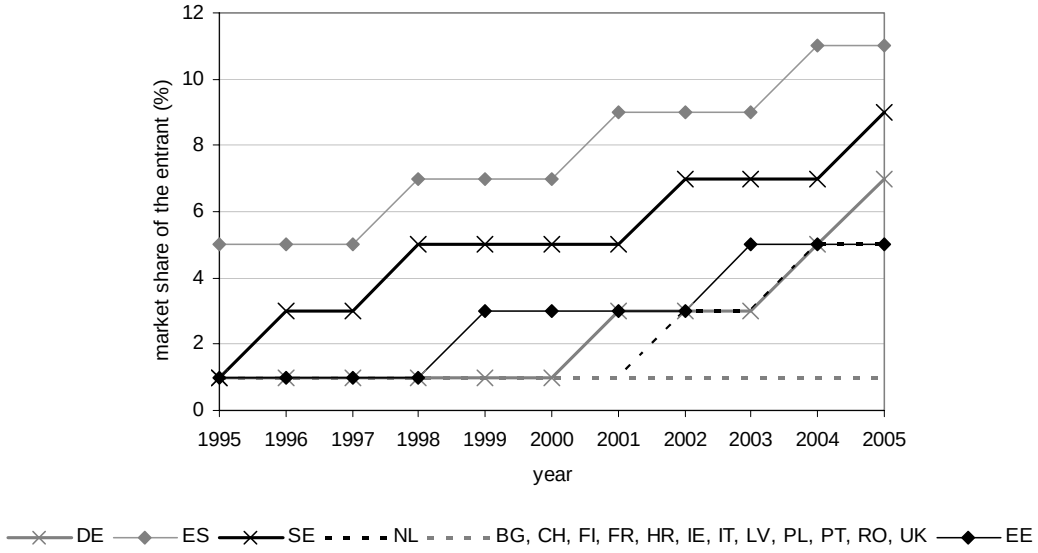
Finland and Estonia liberalised their mail markets some years ago, the restrictive licence conditions and taxation policy restricted the development of competition. In both countries, potential entrants are required to provide postal services in the whole territory of the country[4]. In Finland, potential 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, competition has not developed a lot and the incumbent still has a very dominant position nowadays. This slow development of competition can be 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 more developed are Germany, Estonia, and The Netherlands.

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

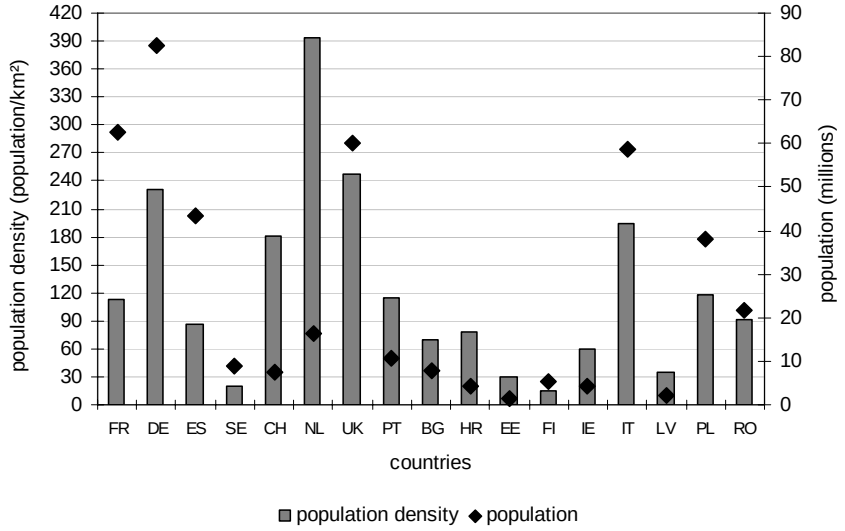
Figure 7: Evolution of the market share of the entrants



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.

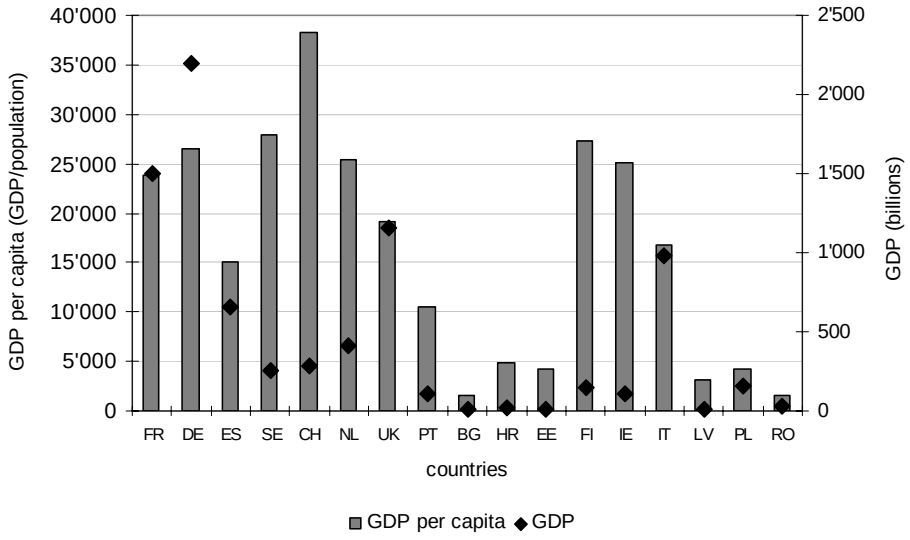
Population (in millions) was collected from Eurostat and countries' area is available at the UPU database. These two variables were used to build the variable population density (***popdens***), which is plotted in Figure 8, together with population. Population density is in number of habitants per squared kilometre. France, Germany, UK, and Italy are the countries with more population. These countries, except France, are among the four countries with larger population density. The Netherlands is the country with more population density.

Figure 8: Population and population density in 2005



The Gross Domestic Product (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 euro per habitant. Figure 9 displays the GDP per capita and GDP in 2005. The countries with higher GDP are Germany, France, UK, and Italy whereas the countries with larger 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.

The detailed descriptive statistics is presented in Annex 2, Table 1.

4. The model

The general form of the model estimated is:

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

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 the followings: *mktliberalised*, *mktshareE*, *publick*, and *tvolume*. Vector C_{it} contains the control variables *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 2. 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, we have to be alert for the fact 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, we should also be cautious when including both variables in the same model. All the other variables have a correlation with *mktliberalised* smaller than 25% and, hence, it 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. 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, we have to be alert to the possible impact of this 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 3, 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 are different across countries and the dispersion is also different. 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 conclude about 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 heteroskedasticity, correlation across panels, and serial autocorrelation the most appropriated estimation procedures are GLS and PW-PCSE. Models 1 until 13, in Annex 2, were estimated by GLS and models 14 until 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 we are in. Otherwise, OLS estimates are provided. As with GLS, with PCSE estimation the coefficient of the AR(1) process can be specified 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 part, the results are presented and discussed. A total of forty two models were estimated and reported in Annex 2 (Tables 4 until 9). Tables 4, 5, and 6 report the results of GLS estimation. Tables 7, 8, and 9 report the PW-PCSE estimation. In the models included in Tables 4 and 7 the dependent variable is the innovation index. Tables 5 and 8 contain the models that have the accumulated number of innovations as dependent variable. Finally, Tables 6 and 9 report the models that use labour productivity as proxy for innovation. Each table contains seven models. In all the models estimated the explanatory variables are found to be jointly significant.

In the models estimated by GLS that include all the contemporaneous explanatory variables (including the control variables), the percentage of market liberalised turns out not to be significant (Models 1, 8, and 15). However, once we take out of these regressions the population density, which is correlated with $mktliberalised_t$, $publick_t$, and $tvolume_t$, $mktliberalised_t$ becomes statistically significant in two of the models (Model 2 and 16). In Model 9, only when we take out of the regression $gdppercap_t$ (that is correlated with $tvolume_t$ and $popdens_t$) $mktliberalised_t$ becomes statistically significant. In Model 2, $tvolume_t$ is not statistically significant but when we exclude $gdppercap_t$ (Model 3) $tvolume_t$ becomes statistically significant at a 1% level.

With Model 4 and 5 we aim to test if the correlation between $mktliberalised_t$ and $marketshareE_t$ is affecting significantly the t-statistics. As we 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 $mktliberalised_{t+1}$. We can observe that both variables are statistically significant but they have a smaller impact on the innovation index than $mktliberalised_t$. Hence, regarding this set of models estimated using GLS and where innovation is measured through the innovation index we select Model 3 as the one that best fits the data. In Model 3, the $marketshareE_t$ and $publick_t$ are also statistically significant at a 1% level.

In Model 10, $tvolume_t$ also becomes statistically significant at a 1% level when we exclude $gdppercap_t$ from the vector of explanatory variables. $marketshareE_t$ remains statistically significant at a 1% level. However, $publick_t$ that was significant becomes not significant. When we estimate Model 11 and 12, which exclude $mktliberalised_t$ and $marketshareE_t$ from the explanatory variables respectively, we can see 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 found to be both statistically significant at a 1% level (Model 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 not anymore statistically significant in Model 14 (probably because the correlation between $mktliberalised_{t-1}$ and $marketshareE_t$). Concerning this set of models, which have the accumulated number of innovations as dependent variable and that are estimated using GLS, it is Model 10 that seem to fit better 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 we compare Model 10 with 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 and that use labour productivity as proxy for innovation (Table 6) it is Model 16 that seems to fit the data better. We see that when we include $mktliberalised_t$ and $marketshareE_t$ separately (Model 18 and 19) both varibables 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 not anymore statistically significant in Model 21 (again, probably because the correlation between $mktliberalised_{t-1}$ and $marketshareE_t$).

When we compare Models 15, 16, 17, and 18 using a likelihood-ratio tests we obtain that: (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 our perception that Model 16 is the one that fits the data better.

We now turn to the estimations using PW-PCSE. We start with the models that have the innovation index as dependent variable (Models 22 until 28). In all these models $mktliberalised_t$ and $marketshareE_t$ are statistically significant at at least a 5% level. $mktliberalised_{t+1}$ and $mktliberalised_{t-1}$ are also found to be statistically significant (Model 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 we eliminate $popdens_t$ 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. Model 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 higher R-squared.

Models 29 until 35 correspond to PW-PCSE estimation with the accumulated number of innovations as 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 until 35. Again, the correlation between $mktliberalised_t$ and $marketshareE_t$ does not affect notably 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 not statistically significant whereas $mktliberalised_{t+1}$ (Model 34) is statistically significant. Models 31 and 34 have a high R-square and seem to be the models that fit the data better.

The last group of models (Model 36 until 42) have labour productivity as 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 we exclude $gdppercap_t$, $marketshareE_t$ 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 quite high explanatory power (R-square=0.78). For the first time, $publick_t$ is not statistically significant in the selected model, i.e. Model 37.

From the results presented before we can conclude that the answer 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, i.e. 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 than of the contemporaneous answer. It may happen that some of the investments in innovation are decided in advance but they are only observable in the following(s) year(s).

If we compare the models that better fit the data (selected models), i.e. Model 3, 10, 16, 23, 31, 34, and 37, we see that the models estimated by GLS give rise to stronger results. The use of one innovation measure instead of another one does not originate significantly different results. This shows that the innovation index developed is a good measure of innovation and gives us warranties about the quality of the models

estimated. If we would find different results depending on the measure of innovation used we would not know which model (if any) was correct.

All the selected models point out to the positive effect that liberalisation has on innovation. In all 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 has also 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 contrarily to what was expected, the percentage of public ownership is negatively related to innovation. This does not necessarily mean that concerns with welfare maximisation do not stimulate innovation. It can also mean that the hypothesis that the ownership structure more likely to promote welfare maximisation is public ownership is wrong. 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 might not be always true.

Concerning the letter volume handled by the operators there is strong statistic 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 is in line with the theory of contestable markets that argues that the threat of competition (or potential competition) on its own induces a monopoly 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 loose 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.

Contrarily to what was expected, there is evidence that the percentage of private ownership has a positive effect on innovation.

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.

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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 a 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 of 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 manoeuvre 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

Table 3: 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

Table4: 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 5: Summary of the heteroskedasticity and correlation tests performed

Dependent variable	**Explanatory varibles**	**Likelihood-ratio test for heteroskedasticity**		**Modified Wald test**		**Wooldridge test**	
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 6: 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	0.017	0.037	0.040			
	(1.07)	(1.79)*	(3.74)***	(3.81)***			
$mktshareE_t$	0.351	0.375	0.478		0.645	0.525	0.388
	(4.83)***	(4.26)***	(6.37)***		(8.21)***	(6.68)***	(4.43)***
$publick_t$	-0.108	-0.093	-0.087	-0.094	-0.073	-0.075	-0.072
	(4.80)***	(26.89)***	(11.97)***	(11.07)***	(9.97)***	(8.77)***	(11.36)***
$tvolume_t$	0.084	0.090	0.298	0.259	0.252	0.384	0.237
	(1.46)	(1.37)	(8.88)***	(7.25)***	(12.17)***	(3.82)***	(7.25)***
$popdens_t$	-0.021						
	(2.94)***						
$gdppercap_t$	0.304	0.192					
	(3.84)***	(2.51)**					
$mktliberalised_{t+1}$						0.016	
						(2.02)**	
$mktliberalised_{t-1}$							0.019
							(1.64)*
Constant	2.436		-1.127	0.142	-0.895	-1.492	-0.591
	(0.97)		(1.91)*	(0.26)	(1.68)*	(1.83)*	(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 7: 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 8: 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 9: 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

Table 10: 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 11: 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