ECONOMIC EFFICIENCY OF AIR NAVIGATION SERVICE PROVIDERS: AN ASSESSMENT IN EUROPE

by

Rui Neiva
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Public Policy

Committee:

_______________________________________ Kenneth Button, Chair

_______________________________________ John Earle

_______________________________________ Lance Sherry

_______________________________________ John Strong, External Reader

_______________________________________ James P. Pfiffner, Program Director

_______________________________________ Mark J. Rozell, Dean

Date: __________________________________ Spring Semester 2014
George Mason University
Fairfax, VA

Economic Efficiency of Air Navigation Service Providers: An Assessment in Europe

A Dissertation submitted in partial fulfillment of the requirements for the degree of Doctor of Philosophy at George Mason University

by

Rui Neiva
Bachelor in Engineering Sciences
University of Porto, 2007
Master in Civil Engineering
University of Porto, 2009

Director: Kenneth Button, University Professor
School of Public Policy

Spring Semester 2014
George Mason University
Fairfax, VA

DEDICATION

To my Parents.

ACKNOWLEDGEMENTS

I would like to thank my dissertation committee chair, Professor Ken Button, for all the support and guidance throughout the entire doctoral program. I would also like to thank the other two members of the committee, Professors John Earle and Lance Sherry, for their help during the field and dissertation stages of the program, and to Professor John Strong for accepting to be my external reader.

I am also thankful to all my friends on both sides of the Atlantic for their continuous friendship throughout the entire program. In the United States, Rebecca Mao, Robin Skulrak, and Tameka Porter; special thanks to Carla Cerqueira for making the last weeks of writing much more enjoyable. Back in Portugal, André Domingues, Maria João Saleiro, Manuela Carvalho, Marina Carneiro, and Tiago Tarrataca.

Finally, and most of all, I am grateful to my family, especially my Parents and my sister Filipa for their support.

This dissertation and my doctoral studies had the financial support of the Fundação para a Ciência e Tecnologia, with the scholarship SFRH/BD/64730/2009, funded under the POPH and QREN Portugal programs.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF EQUATIONS

LIST OF ABBREVIATIONS AND SYMBOLS

Advance Automation System ....AAS
Air Navigation Service Provider... ANSP
Air Navigation Services.. ANSs
Air Traffic Control...ATC
Air Traffic Controller...ATCo
Air Traffic Flow Management.. ATFM
Air Traffic Management ....ATM
Air Traffic Organization .... ATO
Area Control Centers .... ACC
ATM Cost-Effectiveness ....ACE
Automatic Dependent Surveillance – Broadcast ....ADS-B
Banker, Charnes, and Cooper (DEA model) ....BCC
Charnes, Cooper, and Rhodes (DEA model) ....CCR
Civil Aeronautics Board .... CAB
Civil Air Navigation Services Organisation ....CANSO
Communications, Navigation and Surveillance...CNS
Consumer Price Index.. CPI
Corporación Centroamericana de Servicios de Navegación Aérea ....COCESNA
Cost-Benefit Analysis .... CBA
Data Envelopment Analysis.. DEA
Decision Making Unit... DMU
Differences-in-Differences .... D-i-D
Dollar ....$
Euro..€
European Aviation Safety Agency... EASA
European Union .... EU
Federal Aviation Administration ....FAA
Flight Information Region .... FIR
Functional Airspace Block...FAB
Instrument Flight Rules .... IFR
Interstate Commerce Commission..ICC
Key Performance Indicator.. KPI
L'Agence pour la Sécurité de la Navigation aérienne en Afrique et à Madagascar..............
……………………………………………………………………………………..ASECNA
Maastricht Upper Area Control Centre..MUAC
National Air Traffic Services Ltd ....NATS

Nautical Miles .... NM
Next Generation Air Transportation System .... NextGen
Performance Review Report .... PRR
Professional Air Traffic Controllers Organization .... PATCO
Public-Private Partnership .... PPP
Single European Sky ATM Research .... SESAR
Single European Sky .... SES
Stochastic Frontier Analysis .... SFA
Strengths, Weaknesses, Opportunities, and Threats .... SWOT
Total Factor Productivity .... TFP
United Kingdom .... UK
United States of America .... US
Upper Information Region .... UIR
US Air Traffic Services Corporation .... USATS
Vogelsang-Finsing (mechanism) .... V-F

ABSTRACT

ECONOMIC EFFICIENCY OF AIR NAVIGATION SERVICE PROVIDERS: AN ASSESSMENT IN EUROPE

Rui Neiva, Ph.D.

George Mason University, 2014

Dissertation Director: Dr. Kenneth Button

The economic deregulation efforts that have been taking place for several decades in many industries have been associated, in numerous benchmarking studies, with improvements in economic efficiency.

The aviation industry is no exception. Research on airlines and airports has demonstrated significant advantages in moving to a liberalized system of provision and regulation. However, airports and airlines are just two components of the aviation industry. The third component, air navigation service providers, links airports and airlines as well as dispenses air traffic control services. In this industry, economic deregulation has also been happening since the late 1980's. Many national systems have now been "commercialized" in attempts to improve their efficiency by separating them from their respective governments, but research on the impact of those institutional and regulatory reforms has been somewhat scarce. This gap in the literature is what this dissertation aims to address.

Using panel data from Europe, programmatic and econometric approaches will estimate if these institutional changes have been associated with improvements in the economic efficiency levels of this industry. Issues like the fragmentation of European airspace and the existence of spatial autocorrelation will also be addressed.

Results indicate that non-commercialized providers are associated with higher levels of economic efficiency. However surprising, these results might be affected by limitations of the dataset, which only runs for 10 years; causality tests were used but they did not help to further clarify the matter.

Estimates also show that a number of operational and physical variables also significantly impact the efficiency results, and there are indications to suggest that the great level of fragmentation of the European airspace is indeed impacting the overall efficiency of the system.

Keywords: Economic Efficiency, Air Traffic Management, Air Navigation Services, Air Navigation Service Providers, EUROCONTROL, Single European Sky, Data Envelopment Analysis, Stochastic Frontier Analysis

CHAPTER 1 – INTRODUCTION

The aviation industry has three basic components, with air navigation services (ANSs) and their providers, the air navigation service providers (ANSPs), being the link that connects the other components, the airlines and the airports. Their aim is, above all else, to assure the safety of operations and to promote an efficient flow of traffic.

Traditionally, ANSPs have been government owned and controlled, but this is no longer the case in many countries as nations have moved to *commercialize* ANSPs. The research presented in this dissertation will discuss the changing regulatory thinking that lead public authorities to move away from the direct provision of ANSs, how those changes have been operationalized, and estimate the possible effects, if any, of those changes in terms of economic efficiency.[1]

1.1. Motivation

1.1.1. Relevance of Research for Public Policy

This dissertation will not contribute to any discussion about how technology can improve ANSs. This dissertation will focus on policy, institutions, and regulation. With that in mind, it can provide insights and facilitate the discussion from a policy standpoint in the area of regulation and ownership. In a time when governments are reassessing their

[1] For the context of this dissertation, economic efficiency will simply be defined as the efficient use of resources in a way that maximizes the production of services. The traditional technical and allocative efficiency definitions will be considered, with the former being how efficiently a given set of inputs is transformed into outputs, and the latter being defined as using the least costly input mix to produce a given set of outputs.

role in society, the ANSs industry will not be exempt from that discussion. This dissertation will add to that discussion by presenting and examining the merits and drawbacks of the various solutions that exist. It will also use available empirical data to benchmark how systems operating under different regulatory circumstances have performed.

Comparing experiences and benchmarking can improve the discussion regarding regulation by reducing the asymmetries of information between the different stakeholders involved, thus contributing to a more informed discussion along with an improved decision-making process. Although this dissertation will focus on one specific industry – air navigation services –its relevance will not be limited to this industry. The history of regulation has shown that findings about the effects of regulation on one industry could be applicable to other industries. By adding to the body of knowledge about regulation and ownership, this dissertation will contribute to those discussions.

1.1.2. Relevance for the Literature

Most of the literature regarding ANSs is about technical aspects. Such is also the case of productivity and efficiency analysis in the industry. Since the commercialization efforts started, there have been some publications that have focused on the institutional aspects of those efforts, but mostly from an institutional perspective, not an economic/econometric one. This dissertation will add to that body of literature by performing an economic analysis of industry efficiency as well as an institutional analysis. The main addition to the literature will be the explicit inclusion of ownership variables in the economic efficiency assessments, which has not been done before. This will provide insights into how commercialization has been associated with different economic efficiency outcomes.

1.1.3. Research Questions

The main goal of this research is to estimate if ownership structure has been associated with different outcomes of economic efficiency of European air navigation service providers. The following research questions and hypotheses are addressed:

1. Are "commercialized" ANSPs associated with higher levels of economic efficiency than "public agency" ANSPs?

2. Is the impact of non-policy variables, namely operational and physical ones, significant in terms of explaining differences in economic efficiency?

The first question addresses the fundamental issue of the relationship between ownership structure and economic efficiency, and how it relates to the overall issue of the rationale for privatization and corporatization: it has been hypothesized and shown that it is expected that changing ownership from the public to the private sector or to private-like business models will be associated with increased economic efficiency. This seems to be due largely to the presence of pressures for the actions of management to match the goals of the owners/shareholders and to innovate (Bös, 1991; Jasiński & Yarrow, 1996).[2]

The second question relates to how operational (e.g., number of flights controlled or number of employees) and physical (e.g., size of airspace) variables are associated with the economic efficiency outcomes. This is based on the understanding that ANSPs operate in a particular industry, which is subject to a number of constraints resulting from

[2] Oum et al. (2008) performs a survey with some contradictory findings, suggesting that in some cases privatization did not results in increased efficiency.

the specificities of the air navigation systems themselves that cannot be easily changed, if at all, by management, namely their physical characteristics (size of airspace, location of airports, etc.), and the operational environment in which the systems operate (e.g., number of flights using the airspace). The hypothesis will assess the extent to which those non-policy variables are associated with economic efficiency.

1.2. Overview of the Dissertation

The dissertation begins with an overview of regulatory changes in the past few decades and the move to deregulation[3], from both a theoretical (Chapter 2) and practical application (Chapter 3) perspective, with the latter being focused on applications in the aviation industries.

The dissertation will then discuss air navigation services and air navigation service providers (Chapter 4). First, a few historical and technical notes about the ANSs will be presented (Chapter 4.1), followed by an examination of commercialization practices in the industry (Chapter 4.2). Current developments in the industry will also be presented (Chapter 4.3), with a focus on the United States and Europe.

The next chapter, Chapter 5, will present and discuss the proposed qualitative and quantitative methodologies, along with the data sources.

The following three chapters present the results, with the first (Chapter 6) being dedicated to the qualitative assessments, and the other two to the quantitative ones (Chapter 7 and 8). Finally, Chapter 9 presents and discusses the conclusions.

[3] Or liberalization as it is often called in Europe.

CHAPTER 2 – REGULATION: THEORY

This dissertation is part of a long tradition of the study of the effects of economic regulation. This chapter will provide some background on the issue of regulation and why, in some cases, it has been deemed necessary throughout history.

In addition to the general historical perspective, a more detailed examination of the aviation industry will take place. This industry has seen major changes in the past few decades, which have been accompanied by a plethora of studies assessing the outcomes of those changes. The dissertation will study those regulatory changes in a particular industry of the aviation sector: the air navigation services industry.

2.1. The Rationale for Economic Regulation

Regulation has been seen as the "government's necessary and beneficial response to market failure" (Coppin & High, 1999, p. 8) to "induce firms […] to act in a way that is compatible with social goals" (Train, 1991, p. xi), i.e., maximize (or at least not harm) social welfare. For those reasons, regulation becomes *needed*[4] when the presence of a market along with Adam Smith's *invisible hand* is not enough of a guarantee of socially desirable outcomes and the public interest is not protected (Train, 1991).[5]

[4] In case it is believed that one of the roles of government is to deal with market failures, as it also can be argued that should not be a role of government.

[5] This is mostly a modern definition. McCraw (1984, p. 301) expands on the purposes of regulation along the decades: disclosure and publicity, protection and cartelization of industries, containment of monopoly and oligopoly, promotion of safety for consumers and workers, or legitimization of the capitalist order.

While a simple concept in principle, the practical applications of regulation have followed the predominant economic concepts, the political thinking that backed them up, and the economic conditions of each period. This resulted in regulation being applied with significant differences along the decades, from the presence of economic regulation in a wide range of industries in the post-World War II markets, to the deregulation efforts of the late 20th century.

After this introduction, this section will look at the historical background and the changes in the concept and implementation of regulation, with a focus on some of the seminal works in the area, namely the works of Alfred E. Kahn and the economists of the University of Chicago – the "Chicago School". Although economic regulation has a long history, dating at least since the 19th century[6], this chapter will focus on the period of time since the middle of the 20th century, as the developments made in this realm during that period are the most relevant for the present regulatory environment and the scope of this dissertation.

2.2. The Changes in Regulatory Paradigm

2.2.1. Alfred E. Kahn

Alfred E. Kahn was an American economist that played a pivotal role in the development of regulatory thinking in the 1960's and 1970's, both in academia and in public service as the chairman of the New York Public Service Commission and the Civil Aeronautics Board (CAB) (McCraw, 1984).

[6] Posner (1971) traces back economy regulation in the United States to 1827 in Illinois' ferries, turnpikes, and toll roads. For more on the history of regulation see, among others, Kolko (1963), McCraw (1984), High (1991), Coppin & High (1999), and Glaeser & Shleife (2003).

To the theoretical treatment of economic regulation, Kahn's contributions are perhaps best represented in his two-volume seminal book "The Economics of Regulation: Principles and Institutions" (Kahn, 1970, 1971), where issues relating to the economic and institutional implementation of regulation were explored in great detail.

The first volume underscores the need for and implementation of economic regulation. The volume is a presentation of the main concerns regarding the regulatory frameworks of the time and is also a discussion of the economic principles that could be used to improve them.

Kahn's criticism of the regulatory procedures fell into three main categories: quality of service, rate levels, and the rate structure.

The lack of market competition under regulation, especially for those, like public utilities, that enjoyed a market monopoly, did not provide many incentives[7] for the firms to pay attention to quality of service. Since the regulators were concerned with rate levels, quality of service was often seen as being the responsibility of the firm. As those firms had no incentives to improve quality of service, it remained subpar[8]. On the other hand, the regulatory framework did offer some indirect incentives in terms of quality of service, namely because the prevailing rate-of-return regulation that was put in place offered an incentive for overinvestments in capital[9]. As such, firms could invest on improving service, knowing that the regulators would allow them to reap benefits from it.

---

[7] The issue of incentives and how the regulatory structure of the time did not create them permeates the two volumes of the book.

[8] That was not the case in all industries. As it will be discussed later, a criticism of the airline regulation put in place at the time was that since airlines could not compete on price, they had to compete by offering more perks than their competitors.

[9] The rate-of-return regulation and how it leads to overinvestments by firms will be discussed in Chapter 3.1.

Additionally, the public was critical about the failures of regulated firms in providing adequate service, so the firms would act to avoid intervention of the regulators in response to those criticisms.

Regarding rate level and how it should be established, the author points to several issues. First, there is the issue of the asymmetry of information. Since companies know much more about their own business than the regulators, there are incentives for the firms to disclose the information that would work best for their own benefit – for example, by exaggerating their costs, in order for rate increases to be allowed. In turn, regulators have to spend great amounts of resources in order to try to close that information gap. For the regulators to have access to the same level of information, they would have to run the company themselves or almost[10].

In addition, established rates-of-return regulation was supposed to allow firms to charge prices and have a rate of return on its capital that would allow them to operate successfully, attract capital for new investments, and reward their investors with an appropriate rate of return on their investment. Nevertheless, as regulators were not privy to all the firms' information, it would have not been known if the rate chosen would create incentives for the companies to reduce costs. Moreover, the goods or services being regulated did not have a competitive market most of the time[11], thus creating another level of "blindness" for the rate-setting regulators.

---

[10] Which they sometimes did in government-owned companies.

[11] An exception were intrastate aviation services, which were not regulated and competition existed, compared with interstate services that were regulated. The study of these two situations was used as an example that regulation failed to keep prices low, and eventually airlines were deregulated in the late 1970's.

Finally, the issue of rate structures – what rates can be charged to a specific group of users – was mainly a problem in the transportation industries[12], with the public utilities having more discretion in setting their own rate structure. For the transportation firms, however, regulators, as well as the courts, intervened to avoid “unfair discrimination” among customers, firms, modes, etc. The author argues that those decisions were a mixture of economic principles along with political and social considerations that from an economic standpoint might not have been the most efficient: i.e., prices should equal marginal costs, and are “unfair” if they do not do so.

As a possible solution for those problems, the author argues that marginal cost pricing should be used. Marginal cost can be defined as “the cost of producing one more unit [or] the cost that would be saved by producing one less unit” (I, 65[13]). Since production is limited, there is an opportunity cost associated with consuming a good. Thus, it can be argued that the most welfare-maximizing way for the society to allocate the resources necessary to produce that good, would be to charge the price that maximizes the utility of the consumer[14]: the marginal cost. Setting marginal pricing has its own set of issues, because it is not only impractical but also expensive for firms to establish the true marginal cost of each additional unit they produce. Also, ever-changing prices would confuse consumers and increase their costs to keep informed about them. As

[12] At the time, trucking companies, canals, railroads, and airlines, where all subject to economic regulation in the US.

[13] Since both volumes of Kahn (1970, 1971) do have continuous numeration, when quoting, the Roman numeral indicates the volume (I or II), and the Arabic numeral the page.

[14] This of course is a purely economic argument, and does not take into consideration non-economic considerations like equality or social issues, or national security, for example, but as the author puts it “this, too, is an ethical judgment, not an economic one” (I, 68) and the issue was being looked at from an economic perspective.

a result, compromises had to be made between charging true marginal costs and keeping pricing feasible.[15]

The second volume has a more practical approach, dealing with institutional and governance issues related to the implementation of economic regulation. These issues are important because, even if practical ways of implementing the economic theories of the first volume are found, that might be irrelevant without means, i.e. an institutional framework, to put them into practice.

According to the author, two features characterize regulation: protectionism and conservatism. Even though regulatory schemes are “vigorous, imaginative, and enthusiastic” (II, 11) when they are put in place, after a certain amount of time, bureaucracies become engrained. Firms learn how to deal with their regulators and have regulation working for their best interest[16] (protectionism); any changes to the *status quo* are considered to be potentially risky and destabilizing (conservatism).

As mentioned before, the lack of incentives for regulated firms to improve their performance is an issue of concern when setting a regulatory structure. For the author, performance can be assessed in five different ways: efficiency, i.e., cost; the relationship between prices and cost (marginal pricing); improved efficiency over time and passing of those savings to consumers; quality of service; quality of service improvements over time. The question then arises on how to measure the relevant variables in each one of

[15] For a discussion of possible ways of implementing marginal costs see chapters 4, 5, and 6 of the first volume.

[16] This would be known as “regulatory capture”, an issue that will be discussed in Chapter 2.2.2.

these categories, and for that benchmarking[17] can provide helpful tools to achieve those goals.

For companies to keep improving in the goods or services they offer – by providing ever cheaper, ever better, goods or services – they need to have incentives. For a company operating in a competitive market, the big incentive in existence is the maximization of profit, and for that they have to offer goods and services that customers want. For a company operating under regulation, there is also that incentive to maximize profits; however, the regulatory scheme put in place can distort that goal by imposing limits on what levels of profits are deemed “acceptable” or “just”.

Regulated firms also have an additional incentive to keep costs under control and provide quality service: being under public scrutiny. Managers have an incentive to provide good service and to avoid asking for rate increases; otherwise, their image with the public could be hurt. Also, elastic markets also provide incentives. If the prices are set too high, consumers will not buy their products so, the more elastic the market is, the more incentives there are for the products to be sold at a purely competitive level. In many countries with more interventionist governments, there is the additional incentive of a possible government takeover. If the regulator believes that the firm is producing at higher costs than they should, the government can either take the operation in their own hands, or give the monopoly to another company.

For the author, the need of regulation or not comes from a simple question: “does it do more good than harm?” (II, 111). And the answer is (at least) two-fold. When a

[17] The subject of Chapters 3.4 and 5.

company can exercise a great deal of monopoly power (because it is too large in proportion of its markets, for example), effective regulation can help to protect consumers, fight inefficiencies, and decreases in the quality of service. In this scenario, the benefits outweigh the costs. On the other hand, in markets where regulation imposes restriction on competition that otherwise would exist, regulation may do more harm than good, as regulation is much less effective than competition in promoting innovation[18] and decreasing costs.[19] Even “excessive competition” – which has been used as the rationale to impose regulation in many non-monopolistic industries – can be welfare maximizing.[20]

Kahn’s contributions did not come to existence in a bubble, but rather in a moment of history when the regulatory structure that had been put in place several decades earlier began to been seen in a different light from economists. This was the case, for example, in the telecommunication industry, which had been considered as a natural monopoly[21] for decades, mainly due to its high fixed costs. It was either provided by a public enterprise (the case in most of the world) or a private regulated corporation (the case of AT&T in the United States). However, these companies were believed to be quite inefficient, over-investing and investing poorly, which lead to higher prices than

---

[18] As Kahn stated: “If I knew what was the most efficient and rational arrangement, I'd continue to regulate” (cited by Button, 2013).

[19] Not to mention the costs of creating and maintaining the regulations themselves.

[20] However, as Rose (2012, p. 379) notes, “deregulation does not mean ‘laissez-faire’”, and firms that operate in markets without economic regulation, can still be subjected to certain standards, for example in terms of safety or quality of service (as is with the case of the airlines, for example, with the extensive set of safety regulations that they have to comply with, as well as many quality of service standards) – the caveat in that those standards can be so burdensome that they might lead to many firms not being able to stay in the market, thus creating a situation where even without economic regulation that are still barriers to entry and competition is affected.

[21] A natural monopoly can be defined as existing when the production costs in a market are such that, due to economies of scale and/or scope, the lowest cost of production for the entire industry is achieved by having only one firm supplying the market. This concept of natural monopoly is of extreme importance in the regulation realm, and has justified many regulatory efforts (Train, 1991).

could be expected. They also had distorted price structures, with costs being allocated arbitrarily between the different users, and cross-subsidies not being delivered in the most socially desirable manner (i.e., subsidizing those who need it the most) (Laffont & Tirole, 2000).

The same economic thinking, but applied to airlines, was becoming prevalent when Kahn became the chairman of the CAB[22]. Several publications and studies[23] claimed that the regulatory scheme in place created a *de facto* cartel in the American airline industry[24], resulting in competition not on prices (because that was not allowed), but on service (better food and drinks, in-flight entertainment, etc.), over-scheduling of flights[25] and, consequently, low load factors. In fact, although Kahn was at the helm when deregulation took place, some levels of deregulation had already been put in place by his predecessor John Robson, including the creation of "peanut" fares at discounted prices as well as the deregulation of cargo services in the year before passenger services were deregulated (Button, 2013; McCraw, 1984; Vietor, 1991).

[22] A job he had for only 18 months, and which he did not want in the first place, as he rather wanted to be the chairman of the Federal Communications Commission (Button, 2013).
[23] And several lobby groups.
[24] For example, McCraw (1984, p. 268) cites a General Accounting Office study that actual airline customers were paying an estimate of $1.4 to $1.8 billion more per year during the years 1969-1974 than they would pay if there was competition in the interstate market. Considering that lower prices would attract more customers, savings would accrue to over $2 billion annually. Experiences with unregulated intra-state aviation markets, especially in California (Levine, 1964) and Texas (Thornton, 1977) had also demonstrated what deregulation would bring in terms of ticket prices. Additionally, in the 1960's, Caves (1962) had already demonstrated that airlines were not a natural monopoly, so the regulators fears of too much or too little competition were unfounded. For more studies on the issue see both McCraw (1984) or Vietor (1991).
[25] Companies believed – and empirical evidence proved their point – that by offering as many flights as possible, they would attract more passengers, because they would find their schedules convenient, and the airline market share would increase at greater rates than the increase in capacity share – for a review of published material about this subject see Wei &Hansen (2005).

Both telecommunications and airlines went through extensive changes in regulation, and in fact the same happened to many other industries in the Western world in the 25 years that followed the publication of Kahn's volumes, either by means of complete deregulation, or by re-arrangements of the economic regulation schemes previously in place.[26]

2.2.2. The Chicago School and the Capture Theory

In the perspective of the "Chicago School", epitomized by academics like Stigler (1971), regulation ends up not being used to protect and benefit the public/consumer, but to protect the industry being regulated. This is considered regulatory capture.[27]

According to Stigler, industry profited from the status quo (on the expense of consumers) by a process of rent seeking aimed at increasing their profits, and that "as a rule, regulation is acquired by the industry and is designed and operated primarily for its benefit" (p. 3). This was done, Stigler argues, via four types of policies: direct subsidies, control over entry of new rivals, control over industries that produce substitutes or complements, and price-fixing. [28]

A subsidy is the most obvious form of benefit that a company can receive from a government. Nonetheless, Stigler argues that this benefit is not normally the one that an industry is most eager to seek for if there are no barriers to enter the market, the pool of money available will have to be given to a growing number of companies, thus

[26] Winston (2012, p. 391) summarizes Kahn's contributions by claiming that Kahn "became known as the father of one of the largest Pareto improvements during the postwar period – economic deregulation".
[27] Stigler has not the first author to explore the idea of regulatory capture, and these ideas can be traced at least as far back as Karl Marx in the 19th century (Laffont & Tirole, 1993).
[28] For a generalization of Stigler's model of regulation see Peltzman (1976), who suggested that legislators select regulatory policies that maximize the legislator's support.

diminishing the amount each company receives. This leads to the second type of policy: control over entry of new rivals, creating *de facto* oligopolies where entering is either impossible (because the regulators simply do not allow it), or where the barriers are so numerous that the costs of entry are prohibitively expensive.

The third policy, control over industries that produce substitutes or complements, is the case where the state protects an industry either by hindering the prospects of industries that produce substitutes[29] or by helping industries that produce complements[30]. Finally, price-fixing is the case where the prices are administratively set, instead of being set by the market. Price-fixing is desirable by the firms because it can be used to achieve excessive rates of return.

Stigler argues that this state of affairs, in which an industry receives benefits that are smaller than the damages incurred by the rest of the community, are a direct result of the political process in democracies. The state has the "power to coerce" (which the market or any of the state citizens do not have) and its decisions are infrequent, universal and simultaneous (i.e., if the state decides to regulate an industry, that decision affects all the users and all the non-users of the services of that industry, present and future). Since it would be impractical (not to mention extremely expensive) for the citizens to vote on every single matter, they have to vote on representatives that will vote on those matters for them. Because those representatives have a wide range of voting preferences, voters need to choose a representative by giving their preference to a number of topics on which they agree, even if they disagree with a number of others. Also, there is a high cost (and

[29] Stigler used the example of butter producers who wish to suppress margarine.
[30] butter producers would want the state to encourage the production of bread.

not many incentives) to acquire knowledge on every single topic on which a representative will potentially vote, so even the most informed voter will not have the knowledge to vote consciously on many matters. These intrinsic characteristics create political processes that are “gross or filtered or noisy” which “disregard the lesser preferences of majorities and minorities”, creating a system where industries seeking regulation can focus their attention on candidates/political parties that will help them achieve their goals at the expense of the rest of the community, thus benefiting both the industries and the candidates.

Coppin & High (1999) argue that the regulatory capture theory, in which regulated firms gain control over the process by which they are regulated, does not always hold true, with numerous examples existing[31] in which regulation is not captured by the regulated industry[32]. Laffont and Tirole (1993) add to this argument by discussing that this is because of the theory’s methodological limitation of dealing only with the “demand side” (i.e., the regulated firm/interest group), and not the “supply side”: the political and regulatory institutions, and the voters and legislators that have a level of control over them.[33]

[31] Like the Hepburn Act of 1906 that gave the Interstate Commerce Commission (ICC) the power to set maximum railroad rates, and was opposed by almost all railroads.
[32] On the other hand, Kolko (1963) suggested that during the 1870’s and 1880’s railroads had a pivotal role in lobbying for the creation of the ICC, because it would isolate them from state regulations, and stabilize price levels in competing markets.
[33] Adding to this point, Gómez-Ibáñez (2003) argues that the Chicago School authors view regulatory agencies has being controlled by one “political master” (the politician who had the most votes), while in reality, regulatory agencies can be influenced by a great number of elected and unelected officials (along with other interest groups) at different levels of government, making it harder for one group of interests to influence decisions decisively.

Another important author of the Chicago School was Harold Demsetz, who, in a 1968 paper attempted to deconstruct many of the arguments that at the time were used to justify regulating public utilities and natural monopolies.

One of the main arguments of the paper is that although there might be such economies of scale that the production of a given good is undertaken by only one producer (i.e., a natural monopoly), it does not automatically mean that monopoly prices will necessarily ensue. According to the author, if a bidding process (or an auction) is implemented, the existence of many bidders that are aware that unless they have the lowest price they will not win the auction, the price of the good or service will not be a monopoly price, and it will indeed be "very close to per-unit production cost".[34]

Despite the relevance of the discussion about the disconnection between the presence of natural monopolies and monopoly prices, Demsetz's paper falls short on the details. Auctioning monopolies has become increasingly common in the decades that followed the publication of Demsetz's paper, which can be a sign that the author's general idea has been proven its relevance over the years. Nevertheless, the author's assessment of these ideas can be deemed as somewhat incomplete. For example, the example chosen as a natural monopoly, production of license plates for automobiles,[35] does not in any way involve the complexity of providing services like electricity or air traffic control (ATC). Although issues like right of way and utilities' distribution systems are discussed, though with no regard to transactions costs and judicial disputes that might arise if new entrants into the market decided to build new overlapping distribution

[34] This "auctioning monopolies" method of regulation is discussed in greater detail in Chapter 3.1.3.
[35] Which, in many countries, is not a natural monopoly.

systems in totally unregulated markets, other concerns like sunk costs or the duration of franchises are not discussed or even mentioned[36]. While making license plates might not entail investing significant amounts of capital that are not recoverable and a new provider can be chosen every year, that is probably not the case of services like sewage treatment or natural gas distribution.

[36] Besides a brief note on page 57, in which the “durability of distribution systems”, along with “uncertainty, and irrational behavior”, are seen as “irrelevant complications”.

CHAPTER 3 – REGULATION: PRACTICE

3.1. Different Forms of Regulation

Train (1991) compiled the state of the art of the different regulatory frameworks that existed at the time, with applications mainly to natural monopolies[37,38] but also to other situations where it is deemed that regulation is needed. This section will discuss some of the methods present in that book[39], using mainly the concepts described in it, unless otherwise noted.

3.1.1. Rate-of-Return Regulation

Under the scheme[40] – which was the most used regulatory scheme used for private monopolies for many decades (Laffont & Tirole, 2000) –, the regulator defines a rate-of-return on the firm's investment in capital that is considered to be "fair" and does not result in "excessive" levels of profits. Besides that limitation, companies can choose their levels of inputs, outputs, or the prices of their products.

The rate-of-return on capital is defined by Equation 1:

---

[37] A choice the author made in order to not introduce an unnecessary level of complication in a book the author pretended to be accessible, and also because the author believed that competition is "clearly inappropriate" when dealing with natural monopolies.

[38] Demsetz (1968, p. 56) defines a natural monopoly as follows: "if, because of production scale economies, it is less costly for one firm to produce a commodity in a given market than it is for two or more firms, then one firm will survive; if left unregulated, that firm will set price and output at monopoly levels; the price-output decision of that firm will be determined by profit maximizing behavior constrained only by the market demand for the commodity". A more comprehensive definition and discussion of natural monopolies can be found on volume II (chapter 4) of Kahn (1970, 1971).

[39] A couple of regulation methods (like surplus subsidy schemes or Sibley's mechanism) are not discussed in this dissertation because they were not considered to be relevant for the analysis being conducted here.

[40] Which can also be called "cost-of-service" regulation.

Equation 1

$$Rate - of - return\ on\ capital = \frac{P.Q - w.L}{K}$$

With $P.Q$ being price and outputs (i.e., revenues), $w.L$ being wages and other non-capital inputs (i.e., costs for noncapital inputs), and K being the level of capital investment.

In a rate-of-return regulatory scheme, this rate defined in Equation 1 has to be lower than the "fair" rate f, defined in Equation 2:

Equation 2

$$f \geq \frac{P.Q - w.L}{K}$$

From Equation 2, f has to be higher than the cost of capital: if it is below the cost of capital, the company will make more profit by closing operations and selling its capital – assuming the regulators allow that, otherwise it will reduce its capital as much as possible, possibly resulting in less output and higher prices; if it is the same as the cost of capital, there is no profit maximizing solution, and the company will have no incentive to act in the way the regulators intended – no matter what level of inputs or outputs, or what input mix it had, it would always have the same profit.

Besides the problem of setting an appropriate "fair" rate, this scheme has two other disadvantages: it promotes X-inefficiency and the "Averch-Johnson effect". X-inefficiency (Leibenstein, 1966) occurs when companies do not minimize the costs needed to produce a given output. Under rate-of-return regulation, there are no incentives for the companies to do so, since when a firm's production costs increase they might be able to request a price increase in order to maintain their rate-of-return. However, the existence of regulatory lag – the time it takes before a requested new price is approved – helps to countervail this problem. This is because if a firm increases its costs and requests a price increase, which might not even be approved, in the time it takes between making the request and being able to charge the new price, the firm will be earning a rate-of-return that is less than expected; similarly, if the firm manages to reduce costs, until the regulator approves a price decrease it will be earning a rate-of-return that is higher than expected (Waldman & Jensen, 2007).

The issue of the "Averch-Johnson effect"[41] under this regulatory scheme – which in theory had the advantage of guaranteeing that companies would be able to recover their costs and that the absence of risk would attract capital at low prices – comes from the fact that firms have incentives to use more capital than needed[42] and to use inefficiently high capital/labor ratios. To be sure, outputs could be produced more cheaply if the firm used more labor and less capital. These two flaws in the structure of this type of regulation create an incentive system based on the amount of capital that the firm invests, and does not lead the firm to operate efficiently and produce at minimum cost, once again leading to X-inefficiency.

---

[41] After a 1962 paper by Averch and Johnson (Averch & Johnson, 1962), one of the seminal works in the literature of the behavior of regulated firms.

[42] In some cases "prudency reviews" were put in place were the regulator had to approve the goodness of new investments, but issues about asymmetric information and concerns about the independence (or lack of it) of companies when regulators micro-managed them lead to limited use of these sort of reviews (Laffont & Tirole, 2000). For some empirical analysis on firms in which the Averch-Johnson effect seem to have existed see Waldman & Jensen (2007, p. 613).

3.1.2. Price-Capping

A more recent form of regulation, developed in the 1980's in the UK, is price-cap regulation. Under this scheme – which has replaced rate-of-return regulation in many markets in order to try to overcome its shortcomings – the firm has to become increasingly efficient (one of the aims of this sort of regulation is the removal of existing inefficiencies) and lower the prices (in real terms) of its services continuously. This is done by setting a price cap under the formula "CPI-X[43]", in which *CPI* is the inflation rate (consumer price index) and *X* is the expected efficiency gains. If the savings fall above the predicted rate (i.e., if the firm can produce at a price lower than the regulator demands), the extra profits can be passed to the shareholders, which creates an incentive to achieve greater levels of efficiency. However, sometimes regulators impose some restrictions and if the firms become "too efficient" – i.e., if they are deemed to have more profits than is acceptable – the savings might have to be passed, at least partially, to the consumers.[44]

One of the main problems with this form of regulation is the determination of *X*: it should be a proxy for a competitive market, and be based on the firm's past performance as well on the performance of other firms that live in the same industry – a proxy for its determination could be the improvements of total factor productivity (TFP)[45] – but, as the

[43] In the United Kingdom this is known as "RPI-X", with RPI being a measure of inflation used in the UK: retail price index.
[44] For example, in 1995 in the United Kingdom, due to political and consumer pressure (who believed the companies had excessive profits), the prices caps that the regional electricity companies were operating under were revised and lowered, ahead of the planned review process (Laffont & Tirole, 2000). Gómez-Ibáñez (2003) concludes that is mainly a result of political meddling in the regulatory process.
[45] TFP, as opposed to single-factor or partial-factor productivity, i.e., using a single input (labor, capital, etc.) or some combination of inputs to assess how efficiently the company produces outputs – uses a combination of observable inputs to estimate the efficiency of producing outputs. Having a fixed set of

efficiency increases, *X* approaches a normal profit margin and price-capping essentially becomes rate-of-return regulation (Button, 2010).

Other problems can also be identified in this method of regulation (Laffont & Tirole, 2000): quality concerns, regulatory capture, and regulatory taking. Quality concerns appear when the company reduces the quality of services in order to be able to supply the service at a price equal (or below) the price cap. This price cap acts as an incentive to save whenever possible to maximize its profits (i.e., while rate-of-return regulation provides incentives for overinvesting, price-capping regulation provides incentives for underinvesting). To address this problem, some sort of regulation over quality control is needed. Regulatory capture *à la* Stigler and regulatory taking are both related to the issue of the power of discretion that regulators have: when there is regulatory capture, the regulator is deemed to be "too soft" and allows companies to have inflated rents. On the other hand, when there is regulatory taking, the regulator is "too harsh" and reduces compensation to the company to very low levels, not giving enough compensation for its investments and efficiency improvements. Both these situations are strong cases for regulatory independence from politicians, regulated companies, consumer lobbies, and other stakeholders and interest groups.

3.1.3. Auctioning Monopolies

As previously discussed, this is a method that, paradoxically, should allow for the presence of a monopoly without the corresponding monopoly price. In recent years, it has

---

inputs, companies with higher TFP will produce more outputs than companies with lower TFP (Syverson 2011).

become widely used, for example, when attributing franchises for the operation of mass transit services like rail and bus lines or transit networks.

With this method, a regulator decides that a service must be provided. Due to the nature of the service, it must be provided as a monopoly. Since by definition a monopoly does not allow competition, the regulator creates an auction, where the different companies interested in providing the service can bid for the right to do so. Auction systems vary.[46] They can have simultaneously or sequential bidding; bids can be public or secret, etc. Regardless of the system implemented, the goal should be similar: create competition in order to incentivize companies to bid the lowest price for the product possible[47] (i.e., the price for which the company has zero profits[48]).

For this model of regulation by auction to result in lowest possible per-unit cost and not a monopoly price, Demstez (1968) presents two major requirements: the inputs required to enter production have to be available at market prices to many potential bidders, and the cost of collusion between bidding rivals has to be "prohibitively high". These two requirements to avoid monopoly prices are the same as in any market,

[46] The most common are English auctions, where the price is raised until there is one bidder left, Dutch auctions, where the price starts at a high price and then is lowered continuously until a bidder accepts it (therefore, the first bidder wins the auction), first-price sealed-bid auctions, where the bidders have to make a bid without knowing what are the other bids are, and then the auction is awarded to the highest bidder, and Vickrey, second-price, auctions, similar to the last one, but the winning bidder only has to pay the second highest price (Klemperer, 1999). For a discussion of auction design and the issues of favoritism and regulatory capture in auctions see Laffont & Tirole (1993).

[47] Alternatively, the bidding can be for the lowest cost of production, not for the price of the product, but the end goal should be the same. This is the case, for example, in some mass transit systems, where the regulator pays the franchise owner a fixed amount to provide the service, and then collects the fare revenue for itself – this method is used in transit systems because many times their pricing is subsidized because of social concerns, and does not result merely from marginal cost principles. This method offers the advantage that, no matter the changes in production costs, this becomes a problem of the monopolist company, with prices to the consumers not being affected, and creates an incentive for the monopolist company to become more efficient because that will increase their profits.

[48] The expression "zero profits" is used as a synonym of "zero economic profits", not the "accounting profits" used in day-to-day parlance.

regardless of the existence of economies of scale that lead to the emergence of natural monopolies or not.

One of the major problems with this kind of regulation is that the lowest, optimal, price is only true at the moment of bidding, and it can change during the period for which the company has the monopoly: if production prices increase during the period, and the company is not allowed to raise the price it charges its consumers, it can become insolvent; if production prices decline and prices stay the same, consumers are, in essence, being overcharged[49]. Contracts can have clauses to deal with this situation, but then we can be in the presence of *de facto* rate-of-return and price-cap, depending on how the contracts deal with changes in production costs. Additionally, it might not be ideal to allow renegotiation of rates when production costs decline, as that provides an incentive for the monopolist company to become more efficient and keep the additional profits. When the contract ends, a new auction will likely result in lower prices.

A possible solution to this problem would be to run a new auction, allowing competitors to bid for the new lowest prices, but this solution would be impractical because prices can change several times in a short period of time and complicated from a legal standpoint because of the existence of existing contracts. A more feasible solution is to sign contracts that are neither too short (not giving companies enough time to develop their market and have incentives to reap the benefits of improved efficiency) nor too long (not allowing consumers to also gain from the improved efficiency of the service

[49] Asymmetry of information might play a significant role in here, because companies do not have an incentive to share with the regulators that they were able to reduce costs and are charging consumers the same, and when production costs rise they are more likely to inform the regulator immediately and request changes in prices if allowed by the contract.

provider). After each contract ends, a new action is set up and, in theory, bidders would present a new price based on the gains in efficiency that the industry has achieved since the last auction, and a new contract would be signed with the company that now offers the lowest prices.[50]

3.1.4. Ramsey Pricing

Created by Frank Ramsey in 1927 in the context of "optimal taxation", Ramsey pricing would become an important contribution to regulation theory, namely regarding the issue of pricing of multi-product[51] monopolies.

When companies that have the goal of achieving zero profits, as is the case of regulated natural monopolies, sell more than one product, achieving zero profits is a problem with multiple solutions. Ramsey pricing deals with this issue by trying to find the combination of prices that maximizes the total consumer surplus while allowing the provider to break even. At the Ramsey price equilibrium, the amount by which price exceeds marginal cost, expressed as a percentage of price, is bigger for products with less elastic demand (the "inverse elasticity rule").[52]

Having the result of maximizing total consumer surplus while allowing the provider to break even, Ramsey pricing does not take into consideration the distribution of that surplus. This can create a problem of social welfare and inequity, when one

[50] Which can certainly be the incumbent, because due to their knowledge of the production system, they have access to more detailed information, and due to this information asymmetry they can bid a price that mirrors the production costs more exactly (Laffont & Tirole, 1993).
[51] Multi-product can mean either two different goods (say, a utility company that sells both natural gas and electricity), or the same good with different characteristics (for example, a utility company that sells electricity can price it electricity at different prices according to the time of day – off-peak, peak-hour, peak-of-peak, etc.).
[52] It has been argued that the charging system put in place in the European ANSs until recently was a surrogate for Ramsey pricing (Golaszewski, 2002)

provider, like an ANSP, serves very distinct consumers, say general aviation and commercial aviation, and might lead to a situation where the strict application of Ramsey pricing leads to one group of consumers subsidizing other groups, and equity issues can arise as a result[53]. The regulator has the possibility to act in order to achieve a more equitable redistribution, but that can also affect the demand on the products, thus creating non-Ramsey prices.

3.1.5. Vogelsang-Finsinger Mechanism

The Vogelsang-Finsing (V-F) mechanism was proposed in 1979 by the authors that give the mechanism its name. The goal of the mechanism is to induce companies to charge Ramsey prices, and it does that while dealing with asymmetry of information issues on the part of the regulator: with this mechanism the regulator does not need to know the demand and cost functions to achieve "optimal pricing".

The mechanism works as follows:

- A company produces certain amounts of goods (outputs), using certain levels of inputs, and sells them at a given price. This accounts for one period of time (it can a month, semester, year, etc., whatever is deemed appropriate for that particular industry) – the *current* period;

[53] In fact, this is a direct consequence of the creation mechanism of Ramsey prices, which raises the costs of goods with lower elasticity above marginal costs, which means that people who buys those goods are likely to keep buying them even if they are more expensive. In some types of services, say mass transit (which is the example Train uses), the people who are more inelastic to its price are lower income people (because they do not have any other mobility options – this might also be the case of the younger and older cohorts of the population), thus raising the price of those inelastic consumers is in fact subsidizing the ticket of more elastic, probably better-off, consumers that could choose to use the personal automobile for those trips.

- For the *next* period of time, the company is able to charge whatever they want for their product. But, those prices multiplied by the company's output in the *current* period cannot exceed the company's costs in the *current* period;
- Over several iterations, i.e., after several periods have passes, Ramsey pricing will be achieved.

If a company reports costs that are higher than the actual costs, it can charge higher prices that it should, so the V-F mechanism creates an incentive for companies to misreport their costs. The same can also be done if the company spends more than it should. Although in this case the company does not get to keep the difference between what it reports, and what it actually spends, so the incentive is not as significant. In the long run Ramsey pricing should be achieved nonetheless, although it might take longer if wasteful spending is being done. To avoid this, regulators need to audit the company, which has costs in itself. Still, it can be argued that if the regulator has the power to levy fines whose amounts are high enough to deter companies from misreporting, and if the auditing is done on an irregular basis, the company never knows when it will be audited. Since on each period of time it can be audited (hence paying a huge fine if it gets caught misreporting), the incentive to misreport basically disappears, leading to a situation where even with auditing being done very sporadically, companies should behave honestly.

3.2. Regulatory Changes in the Transportation Sector

In a market under perfect competition there would be, among others, no barriers to entry, perfect information, no transactions costs, well defined property rights, no externalities, and such a number of buyers and sellers that prices would equal marginal costs (which in their turn would equal marginal revenue). However, there are markets in which one or several of these assumptions do not hold true, and thus that market experiences market failures. When the production costs in a market are such that, due to economies of scale and/or scope, the lowest cost of production for the entire industry is achieved by having only one firm supplying the market, the market is said to be in the presence of a natural monopoly (Train, 1991).

When that natural monopoly exists (or is believed to exist), the rationale to justify the application of economic regulation has been that without it, monopoly prices would be imposed, leading to a decrease in social welfare. The regulation is hence used as a replacement for competition in order to achieve a socially optimal outcome, and from a microeconomics standpoint, that socially optimal outcome would be the one in which the greatest possible total surplus is achieved and the firm prices at marginal cost (Train, 1991) [54].

Some of the industries in which this rationale has been traditionally applied have been public utilities like electricity and natural gas, telecommunications, and transportation.

[54] This definition does not take into account issues like equity and or the fact that a firm pricing at marginal costs might be operating on a loss (not to mention the difficulties of operationalizing true marginal pricing) (Kahn, 1970, 1971; Train, 1991).

In the transportation industry, government intervention has been evolving for several decades, with the levels and types of economic regulation imposed accompanying those trends. The types of market failures that the industry (and its varied sub-industries) is said to experience is extensive and include, among others (Button, 2010):

- The presence of economies of scale and scope, and network economies that lead to natural monopolies and the need to curb the monopoly power that might ensue;
- The eventual existence of excessive competition that leads to instability in the industry, waste of resources due to multiplication of provision, and underservice to segments of the public that are deemed to need it – the regulation of the aviation and the rail industry in the United States was based on this rationale;
- The presence of externalities (pollution, for example) that negatively affect the society at large;
- Lack of capability by the industry to provide high-cost infrastructure (roads, airports, seaports, etc.);
- Issues of equity and social justice (no service to the poor, minorities, or isolated areas, for example);
- The presence of (high) transaction costs (when acquiring right of way, for example).

How governments have dealt with these market failures has varied, and has included measures such as[55] (Button, 2010):

- price controls (to curb monopoly pricing);
- auctioning franchises (to introduce competition for the right to produce the service and curb monopoly pricing);
- barriers to entry (to avoid excessive competition);
- direct provision of the infrastructure or the service by the government (when the market is deemed to not to be able to do so; or if it is able to do so but only in a natural monopoly the government decides to provide it itself in order to safeguard social welfare and protect specific members of the society – the poor and the disenfranchised, for example);
- taxation and subsidies (to affect modal split, to address inequality issues, or simply to raise funds either for the provision of transportation – infrastructure or service –, or for the general budget);
- creating laws and regulations (for dealing with issues like competition, externalities, safety, etc.).

For a multitude of reasons, the history of regulation has always included many examples from the transportation sector, from the price controls of the railroad industry in the late 19th in the United States, to the extensive regulatory framework (on entry, prices, and routes) imposed on the airline industry until the late 1970's in the United States and the 1990's in Europe. As these examples show, the rationales to do so and the measures

[55] All this measures are here presented assuming their goal is to correct market failures. This is not always strictly the case, as the capture theory tries to demonstrate.

taken as a result of those rationales have been varied. Nowadays, in the Western world, it is now considered that although with failures, markets can nevertheless be more efficient in increasing social welfare than many of the regulations that were put in place, and thus many transportation industries (trucking, airlines, railroads) have been deregulated. In contrast, there are areas where regulation has been increasing, for example in the case of externalities, namely environmental externalities, with increasing amounts of regulation aimed at reducing noise or air pollutants, just to mention two examples. Finally, in other areas, the rationale and implementation of regulation has remained largely unchanged, as is the case of measures to deal with equity issues. Governments still have measures to provide access to transportation for members of society that would not be able to have it in a free market, and this is normally done either by subsidizing the provision of services below the cost of production (as is the case of many mass transit systems[56]), or by subsidizing the creation of routes (and this is done not only on mass transit, but also on airline service to remote areas, for example) that would not exist in a competitive market[57]. One aspect of this that has changed in recent decades is that many of those services were traditionally provided directly by governmental agencies. Currently, many of them are operated by private companies that have been awarded (via an auction, for example) a franchise.

[56] Another rationale used for the subsidization of mass transit is that it reduces road congestion and the need for more road expansion

[57] This is not done only in mass transit; for example, the US has an *Essential Air Services* program that subsidizes air service to over 150 small airports in the country.

3.3. Regulatory Changes in the Aviation Industry

The aviation industry provided some of the most widely and known examples of deregulation worldwide[58], from the deregulation processes of cargo and passenger airlines in the late 1970's in the United States, to the Open Skies agreement between the United States and the European Union (EU) that became in place in 2008.[59]

3.3.1. Airlines

The two major economic blocks in the world, the US and the EU, along with other places like Canada, all went through complete economic deregulation of their airlines. However, the time of implementation and the processes that lead to deregulation were quite different.

In the US, deregulation of the airline industry, which was already discussed in chapter 2.2.1, came as what would have become known as the "big bang approach", with cargo being deregulated in 1977, and passengers in 1978 with the passage of the "Airline Deregulation Act". This act followed some small steps that had been happening since 1976, with the CAB[60] allowing some discounted fares in off-peak times, and more competition in selected routes. With the new rules set in place by the 1978 act, by January 1st 1983, entry barriers were totally removed[61], and airlines could schedule as

[58] Telecommunications provided one of the other most widely discussed examples. For more on that see, for example, Laffont & Tirole (2000), Peltzman & Winston (2000) or Kahn (2004). Other industries, like electricity utilities also suffered deregulation processes in some parts of the world, including the United States, but considering the scope of this dissertation, the focus will be on the aviation industry.

[59] This chapter will deal with airlines and airports. Changes in ANSP regulation will be discussed in Chapter 4.2.

[60] Which, as previously mentioned, had the responsibility of economic regulation in the airline industry.

[61] In 1980 the CAB stopped regulating routes, in 1983 it stopped regulating fares completely, and it was eventually disbanded the following years. The airlines had to continue to fulfill the technical and safety standards though, and anti-trust laws remained in place

many flight to wherever they want to, and price those flights at whatever prices the airlines saw fit (Button, 2004; Kahn, 2004).

In Europe, the deregulation process was more gradual[62]. It followed the "incremental" approach with the EU[63] implementing it in three different stages, from 1987 to 1997, in a process that would have become known as the "Three Packages" (Button, 2004)[64]. As in the US, these processes were also a result of the general trend of liberalization in the economy, with the aggravating circumstance of the existence of the 1957 Treaty of Rome that created the European Economic Community. The Treaty, on its Article 3, precluded the "the adoption of a common policy in the sphere of transport", and "the institution of a system ensuring that competition in the common market is not distorted" (European Economic Community, 1957). As is it can be seen by looking at the 40 years that took from the signature of the Treaty of Rome, until the airline industry was completely deregulated, the mere existence of the Treaty was not enough to advance liberalization quickly. It would take several studies comparing the prices in liberalized vs. non-liberalized routes within Europe during the 1980's, the direct election of the European Parliament in 1979, and a decision by the European Court of Justice to "force" the European Commission and the member states to act on these issues (Button, 2004).[65]

---

[62] And as a result the explanation of the processes that lead to it is also significantly larger than its American counterpart.

[63] Formally, the European Union only exists since the signature of the Maastricht Treaty in 1993, and it replace the European Economic Community that existed since 1957 but, for the sake of simplicity, the term "European Union" will be used to represent the political and economic entity that has existed since 1957, regardless of the formal name it had in a specific moment in time.

[64] Before these EU-wide policies, there were several different types of bilateral agreements with different levels of liberalization between the different EU members, including some were there was freedom of scheduling and pricing (Button, 2004).

[65] The focus of this section is on airlines. For a more general analysis of the regulatory situation in Europe see Henry et al. (2001)

With this institutional backing, the European Commission started to act, even though some state members were not so eager to have their airlines facing competition (Button, 2004). The “First Package” was passed in 1987. With it, a number of measures intending to liberalize inter-state travel were enacted, but it did not include any measures relating to not intra-state travel or travel between member states and third countries. Member states could still maintain certain bilateral agreements, dealing with issues like joint planning and coordination of capacity, revenue sharing, computer reservation systems, and ground handling services. Greater pricing freedom for airlines was now allowed. Member states still could regulate fares, but only if they had a rationale for it (prevent dumping or the need for a given level of return on capital, for example), not simply because it was lower than the price offered by another carrier. Regarding access to air market, some liberalizing measures were also enacted. Agreements between two countries could not remain to allow only 50/50 splits of traffic between the two countries[66]; a ratio of 55/45 was now being allowed, and it would become 60/40 after September 1989.

In December 1989, the “Second Package” was ratified (Button, 2004). This new package stipulated that a fare could only be rejected if both countries affected rejected it, i.e., no single country could unilaterally reject a fare proposed by an airline. Fares that fell into a certain percentage from the reference fare (30 to 105%, depending on the type of fare) were now approved automatically. Again, there were also changes in the division of traffic rules – they were to disappear completely. The Second Package also included

[66] That is, in an agreement between country A and country B, 50% of traffic had to be carried by airlines from country A and 50% form airlines from country B.

provisions against discrimination of foreign, but from an EU member state, carriers[67], and removed the ownership rules that limited where an airline could fly based on its ownership – with these rules, any airline registered within the EU had to be treated as a "national" airline, regardless who owned the shares[68] or where their planes were registered.

Finally, in 1992, a "Third Package" was approved. Enacted in 1993, it would gradually eliminate the remaining regulations. By 1997, the frameworks in which EU airlines operate was similar to the one that existed since 1978 in the United States, with full cabotage[69] permitted, unregulated fares, and barriers to entry removed.[70]

Both the "big bang" and the "incremental" approaches have their virtues and drawbacks. The "big bang" approach had the advantage of leading to a more efficient production frontier more quickly and is also less likely to be subject to regulatory capture as compared to an incremental approach; on the other hand, short term disruptions can be significant as a new economic reality is created and personnel, equipment, and management all have to adapt quickly to the new situation. The incremental approach allows for these adaptation costs to be dispersed for a longer period of time and it can be possible to create a "smoother" transition between the two realities, but it does so by not allowing the society at large to reap the benefits of the new structure quickly, and by creating a situation where the regulated companies might have the possibility of capturing

[67] As long as they met the safety and technical requirements set by the civil aviation authorities.
[68] There was, and there still is, a limit on how much non-EU companies or nationals can own for the airline to be still considered as an EU airline in bilateral agreements with third countries.
[69] Cabotage is the carriage of passengers or goods between two points in one country by a carrier registered in another, for example, when an airline from country A operates a flight between two cities in country B.
[70] As long as technical, financial and safety requirements were fulfilled.

the process in the timespan between the implementation of each incremental (de)regulation. In the case of the EU, the political reality of having to deal with different 12 countries (15 when the process finished) also made the incremental approach the most viable solution for the implementation of airline deregulation (Button & Johnson, 1998).

3.3.2. Airports

The airport industry in Europe has seen a considerable amount of innovation in terms of regulatory and ownership structure[71]. Traditionally, airports were owned and operated by the different layers of government (local or regional authorities, or central governments), but since the United Kingdom sold its stake at seven major airports in 1987, there has been a worldwide trend of privatization (Figure 1), granting concessions, and other forms of private involvement (see Table 1) to private operators in a great number of airports (Oum et al., 2006).

[71] The same happened in other places like Australia, New Zealand, and some Asian countries. However, in the United States, airports still are mostly government owned and operated (there are some privatization initiatives though), but they do have extensive private sector participation in the form of terminal ownership and financing, for example (Oum et al., 2006), which makes some authors like de Neufville (1999, p. 24) consider that "U.S. airports are among the most privatized in the world". In Canada the situation is similar, with the national government having ownership, and signing long-term contracts with local authorities for the operation of airports (Oum et al., 2008).

Table 1 Possible models of private sector involvement in infrastructure provision.

Private sector involvement	Description	Asset ownership
Public work contracts	Private sector only performs pre-determined tasks to the service provider, with no responsibility for the final service quality	Public
Technical assistance contracts	Continuum contracts between private and public sectors to ensure an adequate quality level in a sub-system	Public
Sub-contracting or outsourcing	The public sector contracts a private company to ensure a certain service, for which the private sector is entirely responsible	Public
Management contracts	Based on a set of objectives and targets, the private sector manages the service for the "owner"	Public
Leasing	The private sector assumes as its own risk the provision of the service, for which the public sector pays a lease fee. It is not responsible for making investments	Public
Concession (build-operate-transfer or other schemes)	The private sector is responsible for providing the service, and also, for financing the investments required. After the concession period, the assets return to the public sphere	Public
Build-own-operate	Same as above, but without the transfer at the end of the period	Private
Divestiture	Complete transfer of assets from the public sector to a private entity	Private

Source: Cruz & Marques (2011). Note that these can apply to different types of infrastructure other than airports.

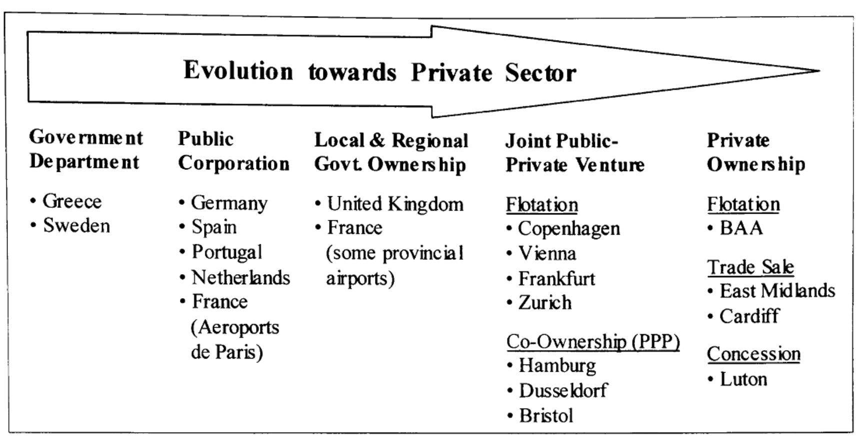


Figure 1 Different levels of government involvement in airports.

Source: Vogel (2004)

The reasoning for these privatization efforts is rooted in the rationale for privatizing government assets in order to improve efficiency. Public ownership of infrastructure had been used as a mean to correct market failures, provide infrastructure that the private sector could not or would not provide on its own, or simply because it was considered of strategic importance to the authorities[72]. Unlike private firms, which have profit-maximizing goals (along with shareholder value), government-run enterprises might have a plethora of undefined goals, from maximizing social welfare, to maximizing personal political gains for the bureaucrats involved. Those goals might change with the political cycle. Using principal-agent and public choice theories, it has been hypothesized that under private ownership, there are more incentives for management to match the goals of the owner/shareholders and to innovate more, thus leading to better chances of producing more efficient outcomes (Boardman & Vining, 1989; Jasiński & Yarrow, 1996; Nett, 1994). However, empirical studies have shown contradictory results in terms of the gains in efficiency resulting from privatization (Bös, 1991; Oum et al., 2008).

Table 2 summarizes some of the main influences promoting privatization.

[72] Other issues like political preferences, redistribution intentions, or ideological standpoints (communism, socialism) also played their role. Savas (2000) lists some of the main issues that have been brought to serve as rationale for privatization: inefficiency, overstaffing, and low productivity; poor quality of goods and services; continuing losses and rising debts of for-profit government enterprises; lack of managerial skills or sufficient managerial authority; unresponsiveness to the public; under-maintenance of facilities and equipment; insufficient funds for needed capital investments; excessive vertical integration; obsolete practices or products, and little marketing capability; multiple and conflicting goals; misguided and irrelevant agency missions; underutilized and underperforming assets; illegal practices; theft and corruption. For a more complete treatment of the issue of privatization see Bös (1991) and Yarrow & Jasiński (1996); for an overview of the issues see Jasiński &Yarrow (1996).

Table 2 The influences promoting privatization

Influence	Effect	Reasoning
Pragmatic	Better government	Prudent privatization leads to more cost-effective public services
Economic	Less dependence on government	Growing affluence allows more people to provide their own needs, making them more receptive for privatization
Ideological	Less government	Government is too big, too powerful, too intrusive in people's live and therefore is a danger in democracy. Government's political decisions are inherently less trustworthy than free-market decisions. Privatization reduces government's role.
Commercial	More business opportunities	Government spending is a large part of the economy; more of it can and should be directed toward private firms. State-owned enterprises and assets can be put to better use by the private sector.
Populist	Better society	People should have more choice in public services. They should be empowered to define and address common needs, and to establish a sense of community by relying less on distant bureaucratic structures and more on family, neighborhood, church, and ethnic and voluntary associations.

Source: Savas (2000).

Regardless of ownership structure, the issue of the regulation of airport charges and fees has also deserved some attention. Due to their role in the local economies, combined with the monopolistic nature of airports in many markets[73], has led to fears of loss of social welfare that the abuse of market power by those airports might create[74]. That has led many governments and other public authorities to impose restrictions on that market power, preventing the operator from having "excessive profits" (Forsyth, 2001).

That economic regulation may take the form of price-caps or rate-of-return regulation. It can be used to regulate the revenues of both the aeronautical (use of the runways and terminals by the airlines, for example) and the non-aeronautical/commercial

[73] Thus creating captive markets.
[74] For a discussion on why that might not hold true see Forsyth (2001).

(shopping venues, parking, etc.) activities of the airports. When only the operational activities are regulated, we are in the presence of “single till”[75] regulation; when both activities are regulated, “dual till” regulation is imposed. The single till model is normally the one that airlines desire, because in it commercial activities can subsidy landing and terminal charges; on the other hand, dual till regulation is normally preferred by airport operators, because with it they can have no profit restrictions regarding the (potentially) very lucrative non-aeronautical commercial activities[76]. The dual till model also provides an incentive for airport operators to become more efficient in order to attract more airlines, so the passengers that they fly can generate revenue in the commercial activities, like stores and car parks[77] (Czerny, 2006; de Neufville & Odoni, 2002; Forsyth, 2001; Oum et al., 2004).

3.4. Benchmarking and Benchmarking Studies in the Airport Industry

With the changes in the regulatory framework that have swept much of the world in the last few decades, there has been a growing interest in measuring the effects of those changes, namely their effects on the productivity levels and the economic efficiency of the affected industries. For example, how efficiently do these industries turn their inputs into outputs? This section will analyze the literature on the theoretical

[75] According to the *Merriam-Webster’s Unabridged Dictionary*, a till is “a money drawer in a store or bank”.
[76] For example, in the US 25% of airport’s revenue come from car parking.
[77] Dual till might suffer the problem of determining exactly what activities should be regulated and what activities should not.

concepts of productivity and economic efficiency[78], as well as studying some applications of those concepts on airports[79].

Benchmarking[80,81] and efficiency analysis can be used as a means of reducing information asymmetry[82] by comparing the performance (pricing, efficiency, quality, safety record, etc.) of firms operating under similar situations, thus being able to assist improving the decisions made regarding the regulatory schemes that are put in place. For instance, it measures firms (or any other entities) performance, compares it to the performance of other similar firms, and extracts "best practices" from it (Laffont & Tirole, 2000). An example, drawn by the research carried out in this dissertation, can be an ANSP operating in one European country, compared to another ANSP operating in a different European country: both ANSPs have the same goal (fly planes safely and effectively), operate with similar, sometimes even the same, technology, under similar regulatory environments, and thus useful comparisons can possible be made. Although having the potential for being important in the definition of regulatory schemes,

---

[78] In this dissertation *productivity* and *efficiency* will be used interchangeably, but one must be aware that some authors do not consider these terms to be synonyms, with *productivity* being the ratio of outputs over inputs, and *efficiency* being a measure that compares observed inputs and outputs to optimum usage of inputs and outputs (Fried et al., 2008a).

[79] The third component of the aviation industry are airlines, and they have been the subject of numerous benchmarking and productivity studies, especially since the deregulation efforts of the last decades of the 20th century, but it was considered that the experiences with airports and ANSPs were more relevant for the purposes of this dissertation. For studies about the performance of airlines see, for example, Tae & Yu (1995). For a survey of the productivity effects of regulation on other, non-aviation industries, see, for example, Fried et al. (2008a) and Syverson (2011). Studies on ANSP efficiency will be discussed in Chapter 5.

[80] Robert Camp is often credited as the inventor of benchmarking, while he worked at Xerox. See, for example, Camp (1993).

[81] Sometimes also called "relative performance evaluation" or, when in the context of regulation, "yardstick competition". For the importance of benchmarking in other settings other than regulation see Bogetoft & Otto (2011).

[82] As mentioned in the section about the works of Kahn, information asymmetry is many times a major problem in establishing regulatory regimes, since the firms being regulated normally possessing an amount of information about the industry that regulators cannot expect to have.

benchmarking is not many times put explicitly in contracts, and ends up being used only informally by regulators to increase their awareness of the environment in which the regulated companies operate (Laffont & Tirole, 2000).

While useful in reducing information asymmetries and in suggesting best practices, these benchmarking studies can have the problem of being too general in scope, only indicating where to look to know how an "efficient" firm in that industry behaves, but not aiding firms (and regulators) in the micro-level details, such as the time scale of changes, i.e., if a best practice is adopted, how long will it take for the firm to achieve higher level of efficiency?, and what the effects of individual changes are on the productivity and efficiency levels (Davies & Kochhar, 2002).

With all the changes in ownership and regulatory structure of airports that have been happening around the world, along with the continuous development of tools to analyze efficiency[83], there has been a growing interest in analyzing the effects of those changes[84]. Merkert et al. (2012), for example, list 53 of such studies in the period from 1997 to 2012[85]. The scope of those studies vary widely, some studying only a handful of airports in a specific country, while others do international time-series analyses with more than 100 airports. In terms of methods[86], Data Envelopment Analysis (DEA)[87] is by

[83] What also helped was the increased availability of computer processing power at ever cheaper prices, along with the availability of packages that allow the use of these tools by many researchers that are not proficient in programming.
[84] For a review of benchmarking studies on other industries see Dattakumar & Jagadeesh (2003).
[85] The studies mentioned in this paper are mostly studies published in academic journals. These are not the only benchmarking initiatives that exist. For example, the Air Transportation Research Society publishes since 2001 a (paid) annual "Global Airport Benchmarking Report" that analyzes almost 200 airports throughout the world (www.atrsworld.org/publications.html). For another review of benchmarking studies on airports see Schaar (2010).
[86] For a discussion of how the choice of benchmark model can have significant impacts on results see Schaar & Sherry (2008).

far the most widely used technique, with 39 out of the 53 studies using it in their analyses. Both Stochastic Frontier Analysis (SFA) and TFP are less-used methods, with only 8 studies using each of the methods[88]. Given the extensive literature available on this subject, this section will focus on a selected number of studies that deal with the issue of regulation and ownership of airports.[89]

Oum, along with other co-authors, has made several contributions to the discussion regarding ownership and regulation. (Oum et al., 2006, 2008, 2004). Using TFP (2004 and 2006 studies) and SFA (in the 2008 paper), 60 airports were analyzed in the 2004 study, and more than 100 in the two more recent ones.

The oldest study (2004) dealt mainly with the issue of regulatory schemes, regardless of ownership, and concluded that airports under dual till price-cap regulation performed significantly better than airports under single till rate-of-return regulation; airports under single till price-cap performed better than under single till rate-of-return, but these results were not statistically significant[90]. Another finding of this study is that there were economies of scale and/or scope in the presence of higher numbers of passengers processed and that airports used as hubs tend to have decreased TFP. More congested airports (which is the case of many hub airports) tend do have higher TFPs, often at the price of imposing delays costs at both passengers and airlines. A dummy variable regarding ownership was also included, but it was deemed as non-significant.

---

[87] A discussion of these methods is present in Chapter 6.
[88] The total is more than 53 because some studies use more than one method.
[89] For a discussion of the usefulness of these analyses for regulation of airports see Reinhold et al. (2010).
[90] There were no airports in the sample operating under dual-till rate-of-return regulation, so it was not possible to make any comparison involving that particular form of regulation.

In the other two studies (2006 and 2008) private ownership was correlated with improved efficiency in some instances. The 2006 TFP study showed that 100% privately-owned airports perform better than 100% government-owned airports, but the differences are very small. The caveat with this result is that it could be biased by the presence of innumerous 100% government-owned airports in the US that operate in a much more corporation-like environment than 100% government-owned airports in other parts of the world. In fact, the situation in the US deserved an analysis of its own, and it was found that there were no statistically significant differences in the levels of efficiency between American airports operated by port authorities and American airports operated directly by governmental branches. Finally, this 2006 study found that airports operated under public-private partnerships (PPP) agreements are less efficient than airports either 100% privately-owned or 100% government-owned, which might indicate that it is better to either privatize completely the assets, or let them remain in public hands.

The 2008 SFA study reached some different conclusions: different forms of ownership result in different levels of efficiency, with the privately-owned airports achieving higher levels of efficiency. Like in the 2006 TFP study, PPP-operated airports perform worse than either privately or publicly owned airports. These differences in results can be either a result of actual changes in efficiency, the change in the benchmarking method use for the analysis, and the parameterization of each method in both studies.

In a less comprehensive study, Domney et al. (2005), compared the performance of six private airports in the 1993-2001 period operating under two different regulatory settings: four airports in Australia, subjected to *ex-ante* CPI-X price-capping regulation (what the authors called "heavy-handed regulation"), and two airports in New Zealand, subjected to *ex-post* "light-handed regulation", where airports have information disclosure requirements, and can be subjected to intervention by the regulators if they are deemed to be exploiting their monopoly positions. Although it cannot be said that one country can be considered a control group for the other, this analysis is interesting, because both countries share similar political, economic[91], and social characteristics, and both are islands, where air access is of primordial importance for many trips. Another contribution of this paper is that the analysis is conducted for the periods before and after privatization[92], allowing analyses not only of regulatory schemes, but also of ownership form.

Using a DEA framework, some interesting results were uncovered. Efficiency decreased after privatization, and in the post-privatization environment, "heavy-handed" regulated airports were more efficient than "light-handed" regulated airports. Profitability levels in the less regulated airports were much higher, in contrast with the findings in Oum et al (2006). The authors conclude that these airports were enjoying the benefits of more unrestricted market power, while disregarding efficiency. These results can be affected by the very small sample size, the relative short periods of time before and after privatization considered (especially the latter, not leaving much time for companies to adjust), and by the choice of variables in the DEA model. For this last point, the output

[91] Although Australia's economy was, in 2013, over 8 times as large as New Zealand's.
[92] For example, the study by Assaf (2010), also analyzed Australian airports, but focused on the post-privatization period. The study found out that efficiency improved during the 2002-2007 period considered in the paper.

side of the DEA model included fairly standard measures (annual passenger and aircraft movements), but did not consider issues like airport-induced delays, and on the input side the variables included were total length of runways, aircraft parking slots, and operating expenses, without consideration for issues like employment, and since operational aspects like length of runways and parking slots were used, other variables like number of gates should have also be included.

CHAPTER 4 – AIR NAVIGATION SERVICES

4.1. Historical and Technical Notes

In its current form[93], ANSs emerged from the post-World War II world and the new international arrangements that were put in place in many areas of society. For ANSs the defining moment was the "Convention on International Aviation" held in Chicago in late 1944, better known as the "Chicago Convention". From that meeting, a new set of rules and guidelines regulating ANSs, and aviation in general, came to be. A new United Nations organization to coordinate and regulate international air travel was also to be established, the International Civil Aviation Organization (ICAO), which was done so in 1947 (Nolan, 1998; Oster & Strong, 2007).

Article 28 of the Chicago Convention is the most relevant for ANSs provision (International Civil Aviation Organization, 2006):

"*Air navigation facilities and standard systems*

"Each contracting State undertakes, so far as it may find practicable, to:

"a) Provide, in its territory, airports, radio services, meteorological services and other air navigation facilities to facilitate international air navigation, in accordance with

[93] For an account of pre-World War II history of ANSs see Nolan (1998) and Kraus (2011). As a summary, it all started with bonfires lit to guide airplanes in the 1920's, while in the 1930's the increase in levels of traffic and the airplanes abilities to fly faster, at night, and during bad weather lead to more formalized ways of air traffic control – it was during this period, for example, that the federal government became involved in providing ANSs in the US..

the standards and practices recommended or established from time to time, pursuant to this Convention;

"b) Adopt and put into operation the appropriate standard systems of communications procedure, codes, markings, signals, lighting and other operational practices and rules which may be recommended or established from time to time, pursuant to this Convention;

"c) Collaborate in international measures to secure the publication of aeronautical maps and charts in accordance with standards which may be recommended or established from time to time, pursuant to this Convention."

The Chicago Convention thus gives states the complete and exclusive sovereignty to control the airspace above their land and their territorial waters. Each country then divides its airspace in the way they see fit, with each country having one or several Flight Information Regions (FIR)[94], either continental or oceanic, to roughly control airspace over land and sea, respectively[95]. The Chicago Convention also allows the possibility that regional agreements may be signed in order to provide services over international waters. This is case, for example, of the North Atlantic, whose international waters are controlled by Portugal, Ireland, and Iceland (Nolan, 1998; Oster & Strong, 2007).

In Europe, the approach to provide ANSs was on a nation-by-nation paradigm following national borders, a situation that mostly persists today. However, the introduction of jet aircraft that could fly much faster and at much higher altitudes than the

[94] In fact, these are *flight control regions*, not merely informational, but the name is a legacy from a period when ANSs only provided information, and did not control airspace movements (Cook, 2007)
[95] A map of the FIRs in Europe in presented in Chapter 4.3.1, Figure 3.

turboprop planes they started to replace meant that transitions between national systems were becoming an issue. That led to efforts to try to create some sort of pan-European ANSs arrangement that would provide a better flow of traffic. Those efforts culminated in the 1960 creation of EUROCONTROL, an international organization whose aim was to, according to its founding convention, achieve "common organisation of the air traffic services in the upper airspace" through standardization of concepts, technical means and personnel. However, that original vision never came to be, and EUROCONTROL was afterwards emptied out of that goal of being an ANSP for upper European airspace[96], and became more of an organization to enhance cooperation, planning, and research and coordination activities among member states – a change most visible in the tweaking of the wording in the founding convention from "an air traffic services Agency" to "Agency for the safety of air navigation". The organization would later re-gain a more prominent role with the decision to go ahead with the Single European Sky (SES) initiative[97] in the early 20th century (McInally, 2010).

From a technical standpoint, Figure 2 summarizes the main components of an ANSs system[98]. Although ANSPs are normally referred in common language as "air traffic control" providers, as the figure shows that is only one of several services that ANSPs provide.

---

[96] Initial plans were for EUROCONTROL to operate three upper airspace centers, one in the Netherlands, one in Germany, and one in Ireland, with plans to eventually extend those control responsibilities to more countries, but only the first one ever came to be, and the other two became part of their respective national ANSPs (McInally, 2010).

[97] The subject of Chapter 4.3.1.

[98] As expected, ANSs operations are highly technical, and a thorough description of the topic is outside the scope of this dissertation. For a mostly non-technical description see Oster & Strong (2007), for a more technical one see Nolan (1998); Cook (2007) also provides an overview but with a focus on European procedures.

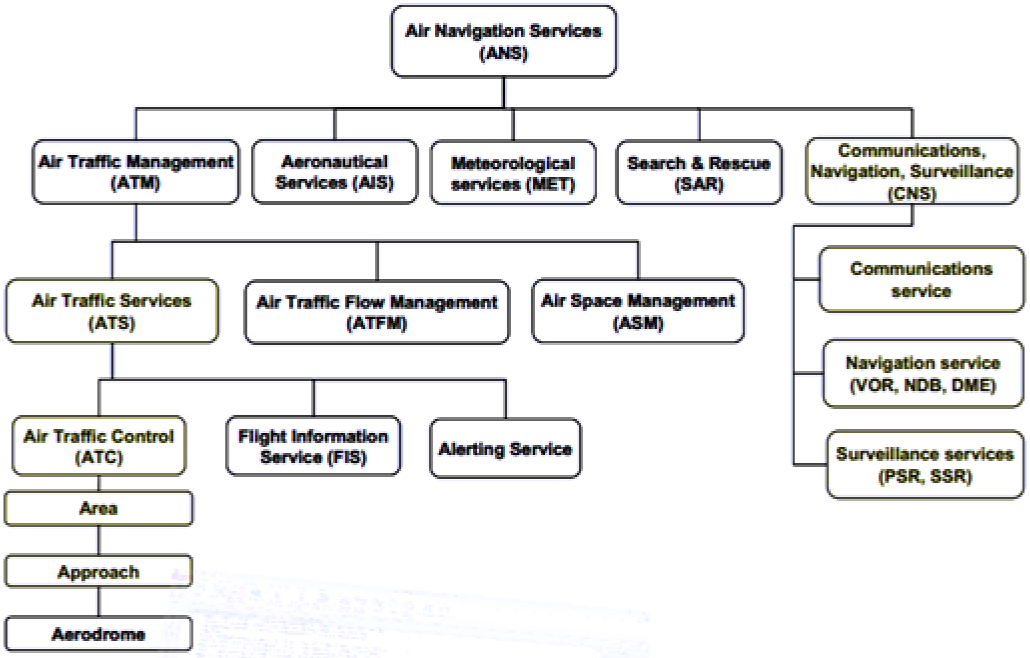


Figure 2 The different components of air navigation services
Source: Helios Economics and Policy Services (2006b)

ATC is responsible to control traffic in order to (Helios Economics and Policy Services, 2006b):

- prevent collisions between aircraft;
- prevent collisions between aircraft and obstructions on the ground;
- maintain and orderly an efficient flow of air traffic.

Airport traffic is controlled in towers in their immediate surroundings and its immediate adjacent airspace is controlled by approach units, while en-route traffic in the upper airspace is controlled in Area Control Centers (ACC), which are further divided into en-route sectors, which have at least one air traffic controller (ATCo) manning each one of them. These ATCos use a range of technological facilities, including radar and satellite based location equipment, and air/ground communication equipment to safely locate and separate traffic.

In terms of regulation, air traffic management procedures are regulated internationally by ICAO, under "Doc 4444, Procedures for Air Navigation Services – Air Traffic Management", with Europe having a special setting of specific procedures, published in "Doc 7030, Regional Supplementary Procedures" (Cook, 2007).

4.2. Commercialization and Privatization

Similar to the case of airports, ANSPs also began a transition in the 1980's, although at a much slower pace, towards different forms of regulation and ownership. Also like airports, they had traditionally been operated directly by governments, which under the Chicago Convention have sovereignty over the airspace in their territory and the responsibility, "so far as it may find practicable" (article 28), to ensure that the airspace is served by air traffic control. That did not mean, however, that governments have to directly provide the services. They could be delegated, for example, to a firm (like in Canada) or a supranational authority like EUROCONTROL. Now, there are a range of different ownership structures and different types of regulation schemes (Button & McDougall, 2006). This trend has become known as the "commercialization"[99] of ANSPs.

[99] According to mbs ottawa (2006, p. 16), commercialization is "the range of organizational options and regulatory frameworks that introduce business practices into what is, or traditionally was, the province of a government department" , with "corporatization" and "privatization" being "considered as options within

From an operational viewpoint[100], commercialization was seen as needed due to a number of factors. First, the issue of financing and budgets constraints, as ANSPs were generally dependent on government budget for their capital and operational expenses, and there was need for them to be able to generate their own revenue, either by charging for their services, or by incurring into debt. Second, the issue of the need to become a customer-oriented industry, serving their customers, i.e., the airlines, first, not the governments and their lobbies or the unions, and to be free to establish their own agendas. Finally, a range of other issues that derive from the fact of being part of the government bureaucracy, from difficult, expensive, and slow procurement problems, to difficulties in implementing new technologies, and labor issues. From this perspective, commercialization can be considered a success, as most commercialized ANSPs, even those 100% government-owned, have at least some level of independence from their national governments. However, many non-commercialized ANSPs have achieved the same level of independence, for example in terms of financing[101] or safety regulation[102], without having to leave the umbrella of their respective governments, so it might be argued that greater levels of independence could happen in the industry regardless of the underlying organizational structure.(Button & McDougall, 2006; Charles & Newman, 1995; Majumdar, 1995; United States Government Accountability Office, 2005)

---

the umbrella concept of commercialization", and that an essential condition of the definition of commercialization is "the introduction of some form of financial autonomy into the ANSP".. Another, similar, definition is provided by the United States Government Accountability Office (2005, p. 1): "commercialization is the ability of an organization to operate like a commercial business".

[100] Commercialization can also be seen from an ideological or political perspective; also, the issues regarding the rationale for the privatization of airports discussed in a previous chapter also apply here.

[101] For example, the French ANSP is still a state agency but nevertheless has the authority to go to the financial markets to finance itself.

[102] Most countries now have separate agencies to regulate safety that are totally independent from their ANSPs, even if they are still governmental agencies.

Commercialization of ANSPs began in New Zealand in 1987 with the creation of a state-owned enterprise that pays dividends to the state. This was part of an overall package of commercialization of state-owned enterprises in the country and led the way to the other systems. Australia followed suit the next year (it was again re-structured in the mid-1990's), but the real impetus of commercialization took place in the late 1990's with the privatization of NAV Canada, the Canadian ANSP, along with the commercialization of many European systems (Oster & Strong, 2007). This Canadian privatization process, which had the support of the labor unions[103], began in 1994 and concluded in 1996 with the creation of a non-share, not-for-profit corporation that is able to charge user fees[104] . The corporation has a board of directors that represent the four stakeholders of the system: air carriers, general aviation[105], federal government, and employees.

A number of other ANSPs have been commercialized since then, with most of them becoming 100% state-owned corporations (for an overview of characteristics of selected ANSPs see Table 2[106]). These corporations do not have profit-maximizing goals, being normally considered to be not-for-profit corporations, which might amount to a *de facto* rate-of-return regulation. A major exception to this rule, and in fact a unique case worldwide, is National Air Traffic Services Ltd (NATS), the British ANSP, which in

---

[103] According to Oster and Strong (2007), labor pushed for privatization because they had not been given pay rises for over six years and they had no right to strike.
[104] Including in flights that only overpass the Canadian airspace and which previously were able to do so for free.
[105] General aviation is a term that encompasses all the non-commercial and non-charter flights (private jets, recreational users, etc.).
[106] For a more detailed analysis of a number of selected commercialized refer to the studies mentioned in Chapter 5.

2001 became the only for-profit private ANSP[107]. It operates under a PPP scheme where 51% of the shares belong to the private sector and the remaining 49% to the state. Besides the form of ownership, NATS has also one characteristic that sets it apart from its peers: the form of regulation. Under the PPP agreement, charges are subjected to a price-cap regulation using the CPI-X method[108], inflation minus a factor to account to productivity, normally a positive X, in order to create an incentive for increases in productivity[109]. In the first year of operation (2001) X was set a 2.2%, 4% in 2002, and 5% in the following years (Oster & Strong, 2007). In the current 2011-2014 period, charges are expected to decline at an average rate of 1.44% per year (Civil Aviation Authority, 2011b). [110]

[107] NATS is in fact a holding that included not-for-profit and commercial arms. The part of the company that provide air traffic control services, NATS (En Route), is operating in a "not for commercial profit" basis.

[108] These charges are set by the Regulatory Policy Group of the UK Civil Aviation Authority. Charges are usually set for five years, but that time-frame can vary (EUROCONTROL Performance Review Commission, 2012).

[109] The formula is quite more complicated nowadays, see "Condition 21" at Civil Aviation Authority (2011a) for more details. Even at the beginning it also included a parameter related to quality of service, in order to try and prevent the ANSP to reduce costs exclusively by reducing quality of service.

[110] Chapter 7.2.3 will include more details on NATS. See also Goodliffe (2002) and Steuer (2010). For more current regulatory information see the Civil Aviation Authority website at www.caa.co.uk.

Table 3 Basic features of selected air navigation service providers

Country	ANSP Name	Ownership	Rate Regulation
Australia	Airservices Australia	Government corporation	Commission oversight
Canada	NAV CANADA	Not-for-profit private corporation	Legislated principles/appeals
EUROCONTROL	Maastricht Upper Area Control Centre (MUAC)	International organization	EUROCONTROL Permanent Commission
France	Direction des services de la navigation aérienne (DSNA)	State Agency	Approved by transport ministry
Germany	Deutsche Flugsicherung GmbH (DFS)	Government corporation	Approved by transport ministry
Ireland	Irish Aviation Authority	Government corporation	Commission oversight
Netherlands	Luchtverkeersleiding Nederland (LVNL)	Government corporation	Approved by transport ministry
New Zealand	Airways Corporation of New Zealand	Government corporation	Self-regulating/appeals
Switzerland	Skyguide	Government corporation	Approved by transport ministry
UK	NATS Ltd.	Public-private partnership	Price capping
US	FAA's Air Traffic Organization	State agency	Financing from taxation

Notes: All ANSPs are financed by user fees except for the US Federal Aviation Administration that is funded by taxation.
Source: Button and McDougall (2006) and EUROCONTROL Performance Review Commission (2013a).

4.3. Current Developments

4.3.1. Europe – Single European Sky

While sharing a similar geographical area, the US has only one single ANSP, the Federal Aviation Administration (FAA), while Europe has several dozen. Despite the similarity in size, the European system handles fewer flights, uses more centers and airports, and is more labor intensive than the American system to which it is often compared (Table 4)[111]. Although there might be a number of technical reasons that can

[111] Golaszewski (2002) outlines the nature of the US air navigation system and gives a comparative analysis of the interactions between ANSPs and airport regulations in the US and Europe.

explain the differences, a particular issue is the lack of coordination across the European systems, and that the small scale of many of the national European systems prevents economies of scale from being exploited.

Table 4 US and European Air Navigation Systems (2012)

	Europe	US	Difference: US vs. Europe
Area (million km^2)	11.5	10.4	–10%
Number of air service navigation providers	37	1	
Number of air traffic controllers	17,200	13,300	–23%
Total staff	58,000	35.500	–39%
Controlled flights (million)	9.5	15.2	+59%
Share of flights to/from top 34 airports	67%	66%	-
Share of general air traffic	3.9%	21%	x 5.4
Flight hours controlled (million)	14.2	22.4	+59%
Relative density (flight hours per km^2)	1.2	2.2	x 1.8
Average length of flight (within respective airspace)	559NM	511NM	–11%
Number of en-route centers	63	20	-42
Number of approach control units (Europe) and terminal facilities (US)	260	162	-98
Number slot controlled airports	>90	4	
ATM provision costs (billions of €2011)	8.4	7.8	-12%

Note: NM is nautical miles
Source: EUROCONTROL Performance Review Commission & US Federal Aviation Administration (2013)

This fragmentation of the airspace[112], with its boundaries mimicking the national borders on land (Figure 3) and frequent handing-over of traffic, is estimated to have significant impacts on the overall efficiency of the system and its costs. This has resulted in a an estimated €4.0 billion in annual delay costs in 2011, significant environmental damage, and flights that are, on average, 49 km longer that they would need to be if the

[112] Fragmentation can be defined as having operational units that are smaller than what is the operational optimum, and as such this could happen not only because different national ANSPs are involved, but even within a single ANSP.

airspace was optimized and more modern technologies were utilized (European Commission, 2012b)[113].

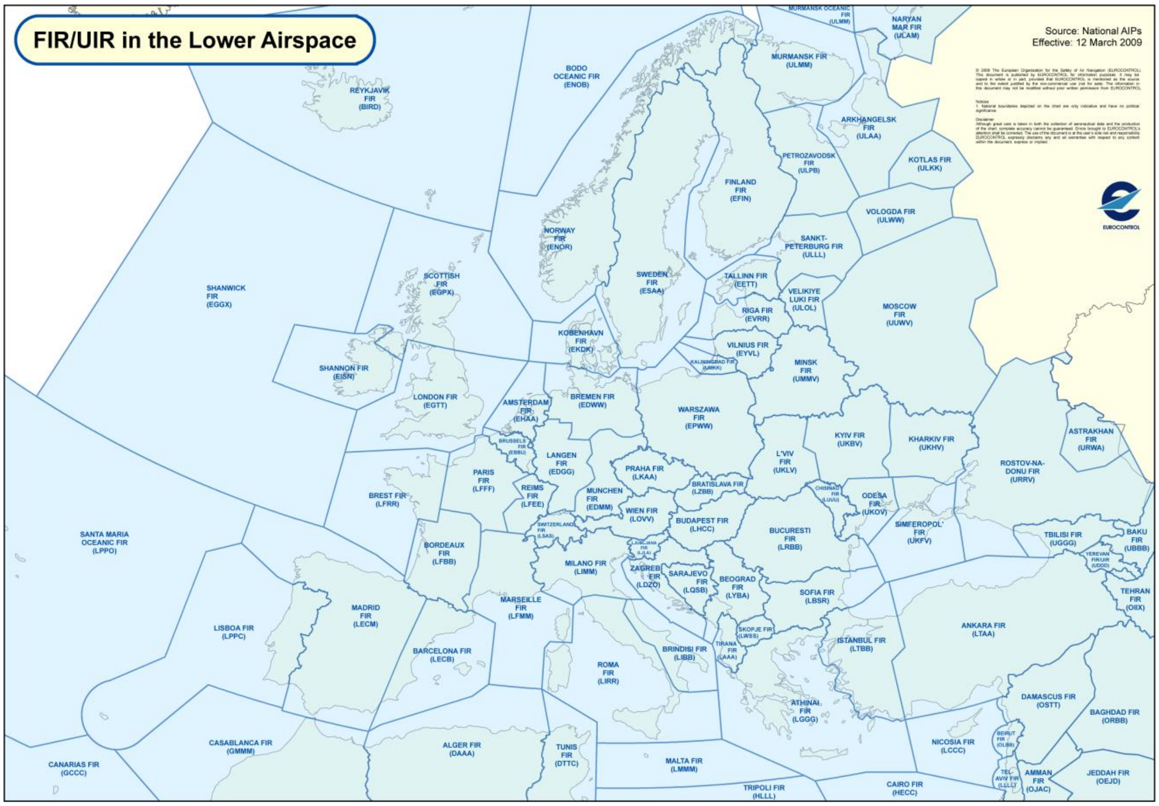


Figure 3 Flight information regions in European airspace
Source: www.eurocontrol.int

A report commissioned by EUROCONTROL (Helios Economics and Policy Services, 2006b) found out that fragmentation result not only from un-optimized subdivision of airspace, but also from fragmented planning, piecemeal procurement, and

113 There is also a wide dispersion in the size of ANSPs, with the five largest European ANSPs handling 54% of the traffic and incurring 60% of the costs, with the remaining 46% of the traffic being handled by over 30 different providers (EUROCONTROL Performance Review Commission, 2013a).

duplication of support activities. These problems are exacerbated by the life cycles of systems and facilities. Though technology improvements might change the optimum scale of operations, the sunk costs invested in facilities might impede new investments to move into a more optimized scale of operations. Figure 4 lists the areas where fragmentation costs derive from.

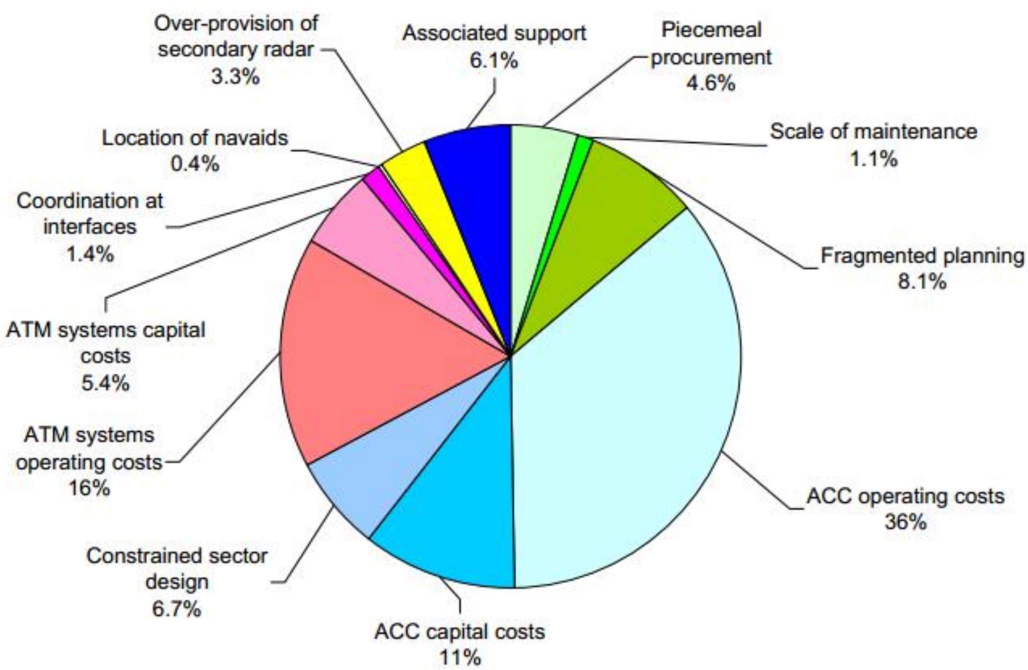


Figure 4 Details about the costs of fragmentation in the Europe ANSs system

Note: ATM is Air Traffic Management and ACC are Area Control Centers.
Source: Helios Economics and Policy Services (2006b)

An area where the report identified significant costs due to fragmentation was in procurement processes, because although there a few standards throughout Europe, and more are being developed, national, and sometimes even regional, idiosyncrasies in their implementation means that the costs of development are higher, thus leading to higher implementation costs. If there were a set of European-wide common procurement specifications for technologies, there is a potential for significant cost reductions.

Planning investment appraisal is also identified as having considerable importance in terms of increased costs. This is because this type of activity is done at the national level, without concerns about how it affects the overall efficiency of the system. Examples of this are the duplication of investments that could be done transnationally with a better cost-benefit, and perpetuation of the existence of non-interoperable systems across ANSPs, even after several product life-cycles where the issue could have been addressed when updating those systems.

As a summary, the report concludes that there is no indication that fragmentation significantly impacts either on safety or capacity; it simply increases the costs of providing those levels of safety and capacity.

It is against this background that the European Commission created the Single European Sky initiative with the aim of treating upper European airspace as a single entity instead of being a patchwork of all the different national systems, thus creating a European-wide Upper Information Region (UIR)[114]. Unlike NextGen in the US[115], which is mostly a technological initiative, SES includes not only technological initiatives, but also policy and regulatory ones. Because of the complexity of the systems, their diversity,

[114] UIRs are simply FIRs that only control the upper parts of airspace.
[115] Discussed in Chapter 4.3.2.

and the inability to simply undergo a "big bang" style reorganization, a phased approach to reform was initiated,

First proposed by the European Commission in 1999[116], the SES was put into law in 2002 with enactment in 2004[117]. It made ANSs a responsibility of the European Union instead of its individual member states and has the main goal is improving the efficiency and the capacity of ANSs in Europe. This is intended to be done by promoting airspace restructuring and rationalization, consolidation of facilities, and harmonization of systems and procedures (Helios Economics and Policy Services, 2006b). A number of stipulations were put in place by legislation in both 2002 and 2009, including the creation of the Functional Airspace Blocks (FABs), the Single European Sky ATM Research (SESAR) technological initiative to modernize the ANS system[118], and the extension of competencies of the European Aviation Safety Agency (EASA) to include air traffic management and air navigation services[119] (European Commission, 2012a).

One of the fundamental aspects of the SES initiative are the FABs, which have the goal of reducing the inefficiencies – in terms of safety, capacity, and cost – that result from the fragmentation of European airspace[120]. FABs are seen as an explicit bottom-up

[116] At the time, a *High-Level Group* was formed by the European Commission to study the issue.
[117]Implementation involves a number of institutions and initiatives involving; the European upper information region (EUIR), functional airspace blocks (FAB), flexible use of airspace (FUA), National Supervisory Authorities (NSA), certification of ANSPs, air traffic controllers licensing, interoperability, SESAME, and extensions to third party countries.
[118] SESAR could be considered as the European counterpart of US' NextGen.
[119] Essentially forcing the separation of provision and safety oversight for the systems that have not done so already.
[120] The criteria for the creation of FABs are strictly to do with:

- safety;
- optimum use of airspace, taking into account air traffic flows;
- overall added value, including optimal use of technical and human resources, on the basis of CBA;
- ensuring a fluent and flexible transfer of responsibility for air traffic control;

approach to the ultimate integration of European airspace.[121] They seek to improve ANS for a number of national airspaces by better coordination of their ANSPs. The underlying philosophy being that, "each FAB is different and faces different political, operational, technical, and economic challenges. (…) FAB initiatives show wide differences in scope, timescales and approaches. It is clear that a flexibility of approach needs to be maintained, as long as improvements are delivered." (EUROCONTROL Performance Review Commission, 2008, p. v).

The concept was established in 2002 in the first SES legislative package and further developed in 2009 in the second legislative package, the so-called SES II (European Commission, 2012b). The initial idea was that they were to be based on the experience of States/ANSPs when being set with the European Commission developing binding general principles for establishment and modification of FABs. The extension of FABs to lower airspace below 28,500 feet was to be studied by the Commission before the end of 2006, with the Commission reviewing the functioning of the bottom-up approach by early 2009 and to propose additional measures, if necessary. The aim was that by 24 June 2012, the consultation material of all FABs shall be submitted to the European Commission, a target that was not met.

- ensuring compatibility between upper and lower airspace;
- complying with regional agreements concluded within ICAO;
- respecting regional agreements, in particular those involving European third countries.

[121] Strictly a FAB is defined in the SES legislative package, namely Regulation (EC) No. 1070/2009 amending Regulation (EC) No. 549/2004, as an airspace block based on operational requirements and established regardless of State boundaries, where the provision of air navigation services and related functions is performance-driven and optimized through enhanced cooperation among ANSPs or, when appropriate, an integrated provider (European Commission, 2012a).

The phasing in of the SES is almost inevitable, but there are often issues when changes are made sequentially rather than as a single “big bang”[122]. In particular, major changes often occur when there is a crisis in the existing regime and a consensus, or at least a dominant coalition of interests emerge for change; it is also useful to have what is seen as a more favorable alternative available. A comprehensive, rapid change, while often painful to many parties in the short-term, yields subsequent positive results for the system as a whole at about the same time. Gradual changes often affect different groups differently during the change, leading to reluctance for some parties to move forward. *Ex ante*, those likely not to be early winners are often reluctant participants. The SES initiative inevitably entails differential changes by the various ANSPs at different times, leading to the potential of simply moving from one sub-optimal situation to another and remaining stuck there[123].

With the FABs, operational concerns would supersede national boundaries in the handling of traffic. The rationale behind this is that it will lead to an optimized use of the airspace and will facilitate the handing out of traffic between operators, thus reducing the inefficiencies of the system. To be established, the proposed FABs have to report to the European Commission on a number of topics, including safety, consistency with European Union-wide performance targets, and be justified by their overall added value, on the basis of cost-benefit analyses (CBA) (European Commission, 2012a).

[122] As discussed in Chapter 3.3.1, one can compare the different ways in which airline deregulation was approached, with the US basically adopting a big-bang approach, and the EU adopting the “three packages” staged approach over a decade.

[123] A similar situation is occurring with the NextGen technological initiative that aims to improve ANS in the United States. It is also been implemented in a staged approach, and like in Europe many stakeholders (namely airlines) have also been reluctant to jump in, fearing that the realized gains will take too long to materialize. Next Gen will be discussed in Chapter 4.3.2.

Nine FABs have been proposed, but only the first two have been declared established and notified to the European Commission[124]:

- UK-Ireland FAB
- Danish-Swedish FAB
- Baltic FAB (Lithuania, Poland)
- BLUE MED FAB (Cyprus, Greece, Italy and Malta)
- Danube FAB (Bulgaria, Romania)
- FAB CE (Austria, Bosnia & Herzegovina, Croatia, Czech Republic, Hungary, Slovak Republic, Slovenia)
- FABEC (Belgium, France, Germany, Luxembourg, the Netherlands and Switzerland)
- North European FAB (Estonia, Finland, Latvia, and Norway)
- South West FAB (Portugal, Spain).

Figure 5 shows the FABs in their geographical context, and Table 5 presents some basic statistics relating to the individual ANSP aggregated at the FAB level.

Table 6 presents the financial and economic KPIs[125] for the FABs as estimated by EUROCONTROL for the year 2011.

[124] All the FABs produce periodic reviews of progress that contain quasi CBA of their activities, embracing some environmental as well as operational performance assessments e.g. for the UK-Ireland FAB, see Irish Aviation Authority & NATS (2012). These contain performance data, but no rigorous assessment of economic efficiency.

[125] Key Performance Indicator. These are a measure of performance estimated by EUROCONTROL, with lower being better. More details are discussed in Chapter 5.

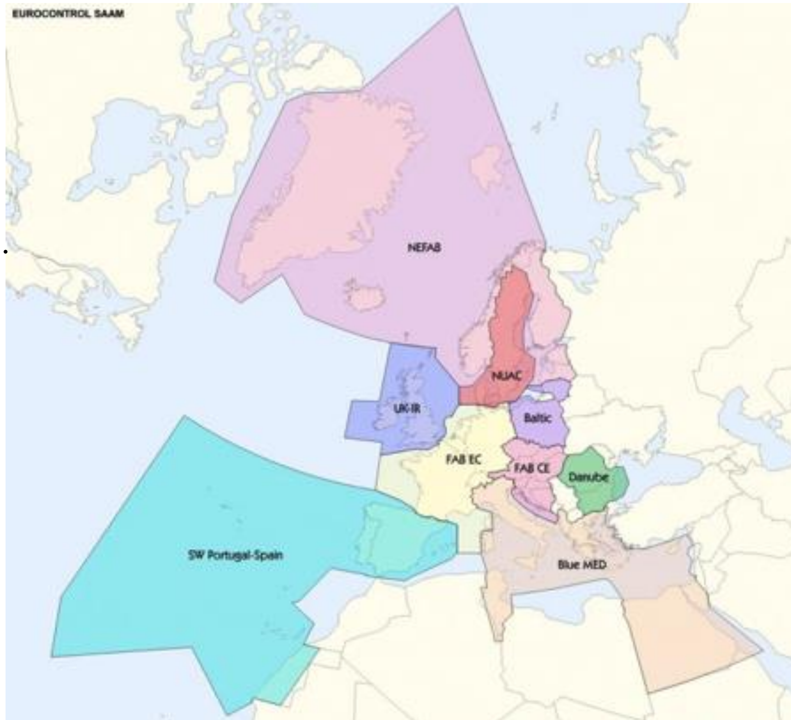


Figure 5 The functional airspace blocks.
Source: www.eurocontrol.int

Table 5 Basic statistics of the FABs (2011)

FAB	Area (million km²)	IFR[126] flight-hours controlled (thousands)	IFR airport movements controlled (thousands)	Staff	Air traffic controllers	En-route sectors	Revenues (€ million)	Costs (€ million)
BALTIC FAB	0.4	394	326	1,994	486	10	172	171
BLUE MED	1.7	1,751	1,428	5,141	1,992	78	940	994
DANUBE	0.4	453	255	2,800	635	14	265	250
DEN-SWE	0.8	606	836	1,825	728	28	295	333
FABCE	0.5	1,016	807	3,933	1,063	43	589	586
FABEC	1.8	4,581	5,080	16,908	5,370	242	3,341	3,115
NEFAB	0.7	431	686	1,617	513	18	200	221
SW FAB	2.9	1,598	2,097	4,859	2,064	77	1,191	1,168
UK-IRE	1.3	1,511	1,911	5,029	1,608	82	925	846

Note: Luxembourg and Bosnia and Herzegovina are not included in the figures for their respective FABs. Airspace area does not include oceanic airspace.
Source: adapted from EUROCONTROL Performance Review Commission (2013a).

Table 6 Financial and economic KPIs for the FABs (2011)

FAB	Financial KPI (€)	Economic KPI (€)
Baltic FAB	315	384
BLUE MED	423	547
Danube	399	404
Denmark-Sweden	364	378
FAB CE	444	489
FABEC	466	566
UK-Ireland	462	424

Values are in 2011 euros.
Source: EUROCONTROL Performance Review Commission (2013a).

Although the implementation of the FABs was supposed to be underway in late 2012 and to start having practical results some time after that point, by that date the process was stalled. While the agreements to form the FABs were in place, only two of

[126] Following the United States Federal Aviation Administration (2008), Instrument Flight Rules (IFRs) are "rules and regulations established to govern flight under conditions in which flight by outside visual reference is not safe. IFR flight depends upon flying by reference to instruments in the flight deck, and navigation is accomplished by reference to electronic signals". All commercials flights are subjected to IFRs.

them (DEN-SWE and UK-IRE) have been declared established and notified to the European Commission, and the consolidation of air traffic control has yet to take place (European Commission, 2012b).[127]

Another way in which the European system is changing is in the way it collects charges for ANSs. Charges are collected for both airport movements, i.e., landings and departures, and en-route, i.e., while the plane is in flight. Charges, which account for around 6% of the prices of airline tickets in Europe, are set a national level, but they are regulated at the European level. Until recently, under Regulation (EC) 1794/2006, European regulations imposed full cost recoveries mechanisms, in which any shortfalls in revenue lead to charges going up, and any profits had to be redistributed back to the airspace users (Casteli et al., 2012).

This charging scheme created two perverse effects. One, when traffic is declining, rates have to go up, potentially exacerbating the problem. Two, any productivity and efficiency increases to lead to increase profits had to be returned in full to the airspace users, thus reducing the incentives for good management and procedures. To change this paradigm, Regulation (EC) 1191/2010 was published. Under this new scheme two new concepts were introduced: a traffic risk sharing mechanism that tries to mitigate unexpected increases in costs or declines in traffic[128], and financial penalties or bonus for productivity and efficiency changes are now allowed. In practice, this will result in a system were costs do not have to be fully recovered each year, and it will also allow

[127] For example, the two FABs already established still maintain separate rates for each of the ANSPs that are part of them (Casteli et al., 2012).
[128] A scheme already in use in the regulated arm of UK's NATS.

ANSPs to keep at least a portion of eventual profits. This new regulatory framework was started to be implemented in 2012, and should finished by 2014 (Castelli et al., 2012).

4.3.2. United States – NextGen

Efforts to modernize the technology in use at the FAA[129] have been recurrent for decades. In the late 1980's, the FAA started the implementation of the Advanced Automation System (AAS), which aimed at increasing capacity by completely revamping the hardware and software system in place at the FAA, including a major consolidation of facilities and the introduction of many automated capabilities. However, the program in its entirety never came to fruition, and only a few of the planned improvements were implemented, a total of $1.5 billion were spent, with estimates that around two-thirds of that investment was wasted, and only the remaining $500 million did anything to improve the ANSs system (Office of Inspector General, 1998).

More recently, in 2004, a new plan was envisioned: the Next Generation Air Transportation System, now simply marketed as NextGen. With this plan, which shares some similarities with the SESAR program being implemented in Europe, by the mid 2020's the US ANSs system will move from the current ground radar-based control system, to a satellite-based one. For the most part, the need for this comes from capacity and cost concerns. The current system relies on expensive ground infrastructure that is a legacy from World War II-era technology, and the move to satellite based control would increase accuracy, thus allowing controllers to *squeeze* more planes into the same

[129] This chapter will analyze US' ANSs mainly from a technological perspective. For an institutional treatment see the US' case study in Chapter 7.2.4.

airspace and increase capacity this way – a must, given predictions that traffic will double or triple in the next two decades. This is mainly due to the implementation of Automatic Dependent Surveillance – Broadcast (ADS-B), a system, already implemented in Alaska and the Gulf of Mexico[130] that allows airplanes to be aware of the traffic around them without having to rely on information transmitted to them by ATCos. Moving to a satellite-based system also makes possible, or at least more feasible, other enhancements like "free flights"/4-D trajectories in which the airplanes follow direct routes between two points instead of relying in the series of ground-based waypoints they have to follow with the current system (Federal Aviation Administration, 2013; Oster & Strong, 2007).

Implementation has been the major concern with NextGen for two reasons: cost overruns and equipage. The AAS experience had shown the risks of trying to implement such large scales projects, and the fiscal situation in the US combined with the reliance of the FAA from Congress appropriations makes implementation difficult and cost overruns could happen (Table 7). In terms of equipage, the risk is that until most if not all airspace users make the necessary investments to equip their airplanes the lowest common denominator, in terms of separation, for example, must be adopted to maintain safety levels. This leads to a situation where airspace users are not eager to make the necessary investments to equip their airplanes while knowing that many of the benefits in terms of savings will take a long time to materialize and will only come when a majority of users has adopted the technology.

[130] And that will be mandatory for most airplanes in both Europe and the US by the end of the decade.

That concern has lead Robyn (2007) to suggest that the implementation should move from the current "big bang" approach that would deliver significant results only when all new systems are put in place, which should happen by mid-2020's, to a more staged approach that would start to deliver benefits sooner, thus increasing the incentives for airlines and other stakeholders to take part in the process.[131]

Table 7 Selected NextGen projects with cost and schedules performance

Program	Description	Start date	Original completion date	Projected completion date	Difference between original and projected completion dates (in months)	Original cost	Projected cost as of July 2012	Difference between original and projected cost
Automatic Dependent Surveillance Broadcast (ADS-B)	A satellite-based information broadcasting system to enable more precise control of aircraft	Aug. 2007	Sept. 2014	Sept. 2014	0	$1,682	$1,726	$45[a]
Collaborative Air Traffic Management (CATM)- includes work packages 1-3	Encompasses the development of systems to manage airspace and flight information	Aug. 2005	Dec. 2015	Dec. 2015	0	561	561	0
Data Communications- includes segment 1 phase 1	Provides data transmissions directly to pilots and their flight management systems	May 2012	Fiscal year 2019	Fiscal year 2019	0	1,519	1,519	0
System Wide Information Management (SWIM)-includes segment 1	The information management architecture for the national airspace system	July 2009	Sept. 2015	Sept. 2015	0	310	310	0
System Wide Information Management (SWIM)-includes segment 2A	The information management architecture for the national airspace system	July 2012	Dec. 2017	Dec. 2017	0	120	120	0
Time-Based Flow Management (TBFM)	Modernizes the Traffic Management Advisor (TMA) system aimed at integration of airport and air traffic control information	April 2010	Nov. 2014	Nov. 2014	0	115	115	0
En Route Automation Modernization (ERAM)	A new enroute air traffic control system for high altitude traffic	June 2003	Dec. 2010	Aug. 2014	44	2,155	2,485	330

Costs in millions of dollars.
Source: United States Government Accountability Office (2012b)

[131] The United States Government Accountability Office has been producing a number of reports on the challenges in implementing NextGen. See, for example, United States Government Accountability Office (United States Government Accountability Office, 2010a, 2010b, 2011a, 2011b, 2012a, 2012b, 2013).

CHAPTER 5 – BENCHMARKING AIR NAVIGATION SERVICES: LITERATURE REVIEW

With the commercialization efforts that have been underway in many systems, the efficiency of ANSPs has also been attracting some attention in the literature. The number of published research is not near as extensive as the one dealing with airport efficiency though, and the scope is also normally quite different, with most of them being case study-like approaches, with little in-depth economic analysis. The reasons for this "lack of interest" might have several explanations, from unavailability of data, the relative recentness of the changes in many systems, or simply because ANSPs and air traffic control do not draw as much attention as airports and airlines.

EUROCONTROL has been one of the most active in producing benchmarking studies, and for the last 15 years they have had a department, the EUROCONTROL Performance Review Commission[132], that has been publishing a number of reports a part of their mission to monitor performance and propose targets for improvements. These reports include the annual "ATM Cost-Effectiveness (ACE) Benchmarking Report" (with EUROCONTROL Performance Review Commission, 2013a being the most recent), hereafter referred as ACE, and the also annual "Performance Review Report" (with EUROCONTROL Performance Review Commission, 2013b being the most with), hereafter referred as PRR.

[132] For the history on how and why the Performance Review Commission was created see McInally (2010).

The ACEs provide a number of performance indicators relating to cost-effectiveness and productivity, the analyses of past trends, and forecasts for the future. This analysis in conducted at the European level and also at the individual ANSP level. The main outputs of this report are the “financial gate-to-gate cost-effectiveness KPI” and the “economic gate-to-gate cost-effectiveness KPI”[133], with the latter being the former plus measures of air traffic control-induced delays. There are also a number of intermediate indicators (employment costs, provision costs, capital expenditures, productivity levels, etc.) that are used in the calculation of these KPIs.

In terms of financial cost-effectiveness, a “composite flight-hour”[134] in 2011 cost an average of €423 in Europe, with a wide variation of cost among ANSPs, from €175 in Estonia to almost €700[135] in Belgium, four times more. Analyzing the evolution along the years, costs in real terms have decreased a modest 0.2% per annum between 2007 and 2011. Looking into more detail, it can be seen that in 2009 costs have increased 8.7% in real terms compared to 2008, followed by a decreased of 6.8% the next year and a further decline of 2.1% in 2011. This is most likely a result of the decrease in traffic that resulted from the 2008 financial crisis. Since the ANSPs did not have time to adjust and maintained a structure that was ready for a certain level of traffic, the decline in traffic lead to increased costs per flight, and in the next year, they started to adjust to the new

[133] For a discussion of the development of these indicators see EUROCONTROL Performance Review Commission (2001).

[134] This is a composite measure created by EUROCONTROL that takes into account both airport movements and actual flight-hours, in order to allow for the creation of a single performance measure (EUROCONTROL Performance Review Commission, 2012).

[135] All these monetary values are not adjusted for the different purchasing power in each country. The reports have more info on how monetary issues – exchange rates and purchasing power parities – are dealt with.

traffic levels, and thus a steep decline in costs followed. The latest report included some analysis at the FAB level. Levels of dispersion are half of what they are at the individual level, with the financial KPI ranging from €315 (Baltic FAB) to €466 (FABEC).

As for economic cost-effectiveness, the European average for 2011 was €502 per composite flight-hour, also with the same levels of variation, although with the added variable, of having ANSPs in which delays are almost non-existent[136] and other in which delays are a considerable part of the cost[137]. The evolution along the years shows a 0.8 decrease in real terms per annum since 2007, but this all results of a sharp decline of 10.2% from 2010 to 2011, as in the four years prior there had been an increase every year that totaled 7% in real terms. As there was a decrease in the financial cost-effectiveness during the same period, all of this increase can be attributed to an increase in the costs associated with delays, but in the last year, a large decline in the amount of delays reported brought the KPI down 10.2%. At the FAB level, dispersion is also much smaller like it was in the case of the financial KPI, ranging from the €375 per composite-hour of NEFAB to €602 per composite-hour of the South West FAB. Table 8 presents the values for the financial and economic KPIs for 2011 for the individual ANSPs, and Table 9[138] the same values for the FABs. Table 10 presents the performance ratios[139] for the individual components that are used to estimate the financial KPI, along with employments costs per hour.

---

[136] Malta, Slovenia, Romania, etc.
[137] Cyprus or Greece, for example, with the latter being the most extreme example, where taking delays into account inflates the price per composite flight-hour from €303 to more than €701, more than double.
[138] This is the same table as Table 6.
[139] Defined as being the relationship between the value for an ANSP of an indicator and the value for the entire European system – i.e., values greater than one (the European average) indicate that particular ANSP performs better than average on that indicator, and vice-versa.

Table 8 Financial and economic KPIs for the individual ANSPs (2011)

ANSP	Financial KPI (€)	Economic KPI (€)	ANSP	Financial KPI (€)	Economic KPI (€)
Albania	414	581	Latvia	253	253
Armenia	357	357	Lithuania	350	350
Austria	469	555	Malta	248	248
Belgium	699	748	Moldova	377	377
Bulgaria	366	379	Netherlands	589	725
Croatia	357	456	Norway	383	420
Cyprus	250	507	Poland	310	388
Czech Rep.	441	448	Portugal	374	405
Denmark	367	376	Romania	419	419
EUROCONTROL	229	238	Serbia	354	364
Estonia	175	180	Slovakia	549	549
Finland	316	389	Slovenia	513	514
France	436	496	Spain	479	640
FYROM	454	454	Sweden	363	379
Germany	499	677	Switzerland	600	713
Greece	303	701	Turkey	283	336
Hungary	429	430	UK	385	430
Ireland	385	386	Ukraine	586	586
Italy	495	505			

Values are in 2011 euros.

Source: EUROCONTROL Performance Review Commission (2013a)

Table 9 Financial and economic KPIs for the FABs (2011)

FAB	Financial KPI (€)	Economic KPI (€)
Baltic FAB	315	384
BLUE MED	423	547
Danube	399	404
Denmark-Sweden	364	378
FAB CE	444	489
FABEC	466	566
UK-Ireland	462	424

Values are in 2011 euros.

Source: EUROCONTROL Performance Review Commission (2013a).

Table 10 Performance ratios for the different components of the financial KPI and employment costs for the individual ANSPs (2011)

	Performance ratios				
ANSP	ATCO-hour productivity	Employment costs per ATCO-hour	Support cost per ATCO-hour	Employment costs per CFH	Support costs per CFH
Albania	0.72	3.63	0.39	2.62	0.81
Armenia	0.24	8.08	0.6	1.97	1.01
Austria	1.18	0.65	1.17	1.77	0.97
Belgium	0.88	0.78	0.88	0.69	0.58
Bulgaria	0.93	1.97	0.63	1.82	1
Croatia	0.84	1.22	1.16	1.02	1.27
Cyprus	0.91	1.85	1.01	1.68	1.7
Czech Rep.	1.17	1.11	0.74	1.29	0.86
Denmark	1.28	1.08	0.83	1.39	1.07
EUROCONTROL	2.45	0.65	1.17	1.58	1.99
Estonia	0.96	2.67	0.94	2.57	2.35
Finland	0.85	1.44	1.09	1.22	1.39
France	0.93	1.1	0.95	1.02	0.95
FYROM	0.28	3.57	0.92	1.01	0.9
Germany	1.29	0.66	0.99	0.85	0.84
Greece	0.94	1.28	1.16	1.2	1.5
Hungary	1.03	0.93	1.03	0.96	1
Ireland	1.2	1.07	0.86	1.28	1.04
Italy	0.91	0.95	0.99	0.86	0.85
Latvia	0.96	3.36	0.52	3.23	1.38
Lithuania	0.62	2.69	0.72	1.67	1.08
Malta	0.92	3.3	0.56	3.04	1.43
Moldova	0.29	8.36	0.47	2.39	0.91
Netherlands	1.19	0.74	0.81	0.88	0.66
Norway	0.99	0.87	1.28	0.86	1.25
Poland	1.22	1.05	1.06	1.29	1.4
Portugal	1.17	0.63	1.52	0.75	1.45
Romania	0.75	1.75	0.77	1.31	0.92
Serbia	0.96	2.01	0.62	1.93	1.02
Slovakia	0.83	1.38	0.68	1.14	0.68
Slovenia	0.58	1.24	1.15	0.72	0.88
Spain	0.99	0.62	1.45	0.61	1.09
Sweden	0.85	0.92	1.48	0.78	1.47
Switzerland	1.24	0.69	0.77	0.92	0.64
Turkey	1.01	2.39	0.62	2.41	1.28
UK	1.25	0.96	0.91	1.2	1.06
Ukraine	0.41	4.53	0.39	1.86	0.57

	Employment costs (€)	
ANSP	Per ATCO-hour	Per CFH
Albania	28	49
Armenia	13	65
Austria	156	166
Belgium	130	185
Bulgaria	51	70
Croatia	83	125
Cyprus	55	76
Czech Rep.	91	98
Denmark	94	92
EUROCONTROL	157	81
Estonia	38	50
Finland	70	104
France	92	125
FYROM	28	126
Germany	154	149
Greece	79	106
Hungary	109	133
Ireland	95	99
Italy	106	147
Latvia	30	39
Lithuania	38	76
Malta	31	42
Moldova	12	53
Netherlands	136	144
Norway	116	147
Poland	96	99
Portugal	160	171
Romania	58	97
Serbia	50	66
Slovakia	73	112
Slovenia	82	178
Spain	164	209
Sweden	110	162
Switzerland	148	138
Turkey	41	53
UK	106	106
Ukraine	22	68

Performance ratios are relative to the system-wide average, monetary values are in 2011 euros.
Source: EUROCONTROL Performance Review Commission (2013a)

The PRRs expand on the ACEs by including not only analysis of cost-efficiency, but also analysis of safety, capacity and delays, and environment and flight efficiency. While the ACEs provide both a global analysis of the European ANSs system and an individual breakdown of issues for every ANSPs, these PRRs have a much more global focus, with almost all the analysis being done on an European-wide level.

The main findings in the last report in the three areas not covered by the ACEs are:

- In terms of safety, ANSs continue to not be a problem in Europe. However, the report points out that a high number of incidents, probably in the tens of thousands, remain unreported every year, and that policies are needed to address that issue with every ANSP; this is specially the case of Turkey and Ukraine which do not provide EUROCONTROL with an annual summary of incidents, and some other countries also have problems in data reporting;
- As for capacity and delays, there have been positive improvements, with delays accruing to 0.63 minutes per flight in 2012 – 11 years earlier it was 3.1 minutes per flight, and in 2011 it was still at 1.1 minutes. Thus, this was the first year in which the target of 1 minute of delays per flight has been achieved. As for delays at major airports, the levels of delay have been stagnant in the last five years considered in the report;
- From the environmental and flight efficiency perspective, which is measured by comparing the direct route between origin and destination, and the actual route that airplanes have to fly, there has been an increase in efficiency, albeit rather modest: in 2009 on average flights were 3.5% bigger than they needed to be – i.e., for every 100 kilometers of direct

path, planes had to fly 103.5 kilometers –, as value that had decreased to 3.2 kilometers in 2012. This figure is affected significantly by exogenous factors, be it natural disasters, like the Icelandic volcano eruption of 2010, or other things like industrial actions – strikes – or military exercises that make planes to have to re-route and deviate from the most direct flight path.

Besides these annual endeavors, EUROCONTROL has published a few more studies, including a TFP analysis (EUROCONTROL Performance Review Commission, 2005b) , an econometric stochastic frontier analysis (Competition Economists Group, 2011), and comparisons with the North-American system (EUROCONTROL Performance Review Commission & Federal Aviation Administration, 2009, 2012, 2013; EUROCONTROL Performance Review Commission, 2005a; EUROCONTROL, 2013).

The TFP report analyzed the performance of 29 European ANSPs in the three-year period from 2001 to 2003. The results showed an overall increase of 2% of the productivity levels over the period, but the individual analysis of ANSPs showed variations from -21 to +37 percent. Comparing the results of this study with the partial productivity indexes of the ACEs showed high levels of correlation, with a R^2 of 0.74.

The more recent econometric SFA study[140] applied a cost function with a Cobb-Douglas specification with the inclusion of several explanatory variables, ranging from operational factors to socio-economic conditions of each individual countries – one

[140] Before this study, NERA (2005) also used a SFA framework to compare the efficiency of European ANSPs between 2001 and 2004, but due to lack of data, results were considered to be poor, and no major conclusions were drawn.

variable that was not included, though, was the ownership status of the ANSP. Results from the different models tested showed an average level of inefficiency ranging from 13 to 60%, with the authors concluding (p. 25) “It is likely that the “real” level of inefficiency is within the threshold provided by these two different models”. Other findings include the presence of economies of scale in the provision of ANSs, and that the “quality of the business environment”, a variable which (p. 16) “reflects the risk to invest in a given country taking into account the local business and institutional environments” is associated with lower costs of provision.

The comparisons with the situation in the US are useful because of the differences between the two systems (Table 4, previous chapter). While the United States has a single system to control 10.4 million km^2 and almost 16 million annual flights, in Europe, almost 40 systems control an area that is only slight larger and has much fewer flights in it – less than 10 million in fact.

Besides discussing differences in how the systems conduct operations, these reports have shown that while ATCos in the US control more flight-hours per annum, that is offset by higher labor costs, making the levels of labor productivity similar. Regarding delays provoked by the ANSs system, the reports found that the total amounts of delays attributable to them are similar in both cases, but the stage of flight when these delays occur are different. In the US, they occur most often at the airports, due to the levels of congestion at those airports and over-scheduling of flights by airlines. In Europe, they happen during the flight because of the fragmentation of the European airspace that leads to less-optimal routes. In terms of costs, they have increased at greater rates in the US compared to Europe, with provision costs being 35% higher in real terms in 2011 when compared to 2002 in the US, while they were only 21% higher in Europe for the same period of time. This evolution meant than while in 2002 costs per flight-hour were 55% lower in the US, by 2011 they were only 34% lower.

More recently than EUROCONTROL, the Civil Air Navigation Services Organisation (CANSO), an international industry association of ANSPs, has also begun to benchmark some aspects of its members' operational efficiency. So far, three reports have been released (CANSO, 2010, 2011, 2012).

These reports cover the operations of around 30 ANSPs around the world in five-year periods: 2005-2009 in the 2010 study; 2006-2010 in the 2011 one; and 2007-2011 in the 2012 study. The main interest of these reports is the inclusion of systems that are normally not studied as much, like the ones from Mexico, Dubai, Thailand, or South Africa; however, the ANSPs included vary between the reports, and some of them are included in the older reports and not in the most recent. Even within each report, there are variations in the ANSPs that are included in each study undermining the usefulness of the reports for a more thorough long-term analysis[141].

The main outcomes of the reports are three indicators: flight-hours per controller, costs per flight-hour, and revenues per flight-hour, which are measures of productivity, cost-effectiveness, and revenue, respectively. However, the reports do not present any data on safety, air traffic complexity, or quality of service. All reports reach similar

[141] This is also affected by the relative recentness of the reports and the consequent short span of data availability.

conclusions: a recovery trend is present, but it remains fragile due to the uncertainties regarding the global economy.

Table 11, Table 12, and Table 13 present some of the findings from the last report in terms of productivity and cost-effectiveness along with some basic statistics regarding these results. The results show the disparities in the levels of productivity and cost-effectiveness achieved by the different ANSPs.

Table 11 IFR flight-hours per ATCo in operations (worldwide data)

ANSP	2007 ($)	2008 ($)	2009 ($)	2010 ($)	2011 ($)	Annual average change
Canada	1624	1733	1631	1613	1683	1.0%
Czech Rep.	1194	1240	1186	1223	1213	0.4%
Denmark	943	1158	1045	1066	1106	4.7%
Estonia	1792	1647	1326	1046	964	14.1%
Finland	-	-	559	591	660	8.7%
Georgia	376	362	347	384	363	-0.7%
Hungary	1072	1103	1144	1151	1119	1.1%
Ireland	1245	1269	1124	1210	1250	0.4%
Latvia	1022	1052	834	790	918	-1.7%
Mexico	1653	1529	1350	1394	1351	-4.8%
New Zealand	814	872	802	747	718	-2.9%
Portugal	1397	1418	1290	1275	1422	0.7%
Romania	498	523	520	652	681	8.6%
Serbia	764	927	928	934	904	4.7%
Slovakia	658	715	689	824	875	7.7%
South Africa	1161	1128	1080	969	884	-6.5%
Spain	740	720	649	730	748	0.6%
Sweden	812	881	784	767	775	-0.9%
UK	1028	1092	948	922	1081	1.9%
USA	1934	1995	1882	1902	1800	-1.7%
Average	1091	1124	1006	1010	1026	1.8%
Minimum	376	362	347	384	363	-6.5%
Maximum	1934	1995	1882	1902	1800	14.1%
Standard deviation	423	406	371	353	346	4.9%

Monetary values are in 2007 dollars.

Source: CANSO (2012) and calculations by the author.

Table 12 Cost per IFR flight-hour (worldwide data)

ANSP	2007 ($)	2008 ($)	2009 ($)	2010 ($)	2011 ($)	Annual average change
Canada	358	344	344	352	340	-1.3%
Czech Rep.	743	718	732	735	697	-1.6%
Denmark	639	725	805	769	802	6.1%
Estonia	228	262	277	294	285	5.9%
Finland	-	-	776	738	691	-5.6%
Georgia	792	849	455	454	615	-1.0%
Hungary	412	491	611	756	791	18.0%
Ireland	542	573	607	647	687	6.1%
Latvia	431	452	498	569	501	4.3%
Mexico	97	108	126	123	125	6.9%
New Zealand	323	325	357	378	396	5.3%
Portugal	730	780	763	660	648	-2.7%
Romania	781	882	905	811	824	1.7%
Serbia	581	563	625	710	794	8.4%
Slovakia	706	741	893	872	888	6.2%
South Africa	263	282	307	369	434	13.5%
Spain	1117	1178	1291	972	910	-4.0%
Sweden	551	542	676	751	744	8.3%
UK	806	739	867	892	1000	6.0%
USA	336	363	403	425	433	6.6%
Average	549	575	616	614	630	4.4%
Minimum	97	108	126	123	125	-5.6%
Maximum	1117	1178	1291	972	1000	18.0%
Standard deviation	247	257	270	224	227	5.7%

Monetary values are in 2007 dollars.

Source: CANSO (2012) and calculations by the author.

Table 13 Employment costs for ATCo in operations per IFR flight-hour (worldwide data)

ANSP	2007 ($)	2008 ($)	2009 ($)	2010 ($)	2011 ($)	Annual average change
Canada	103	103	111	114	113	2.3%
Czech Rep.	173	145	142	142	157	-1.9%
Denmark	181	169	232	232	188	2.8%
Estonia	51	70	70	70	84	15.0%
Finland	-	-	246	246	230	-2.9%
Georgia	39	49	51	51	61	13.0%
Hungary	114	124	150	150	239	21.4%
Ireland	144	156	177	177	175	5.2%
Latvia	65	69	69	69	74	3.4%
Mexico	25	27	35	35	39	12.4%
New Zealand	110	112	129	129	149	8.0%
Portugal	200	240	263	263	296	11.1%
Romania	234	239	240	240	191	-4.3%
Serbia	109	100	112	112	135	5.9%
Slovakia	154	146	172	172	181	4.5%
South Africa	41	50	60	60	97	24.5%
Spain	657	702	736	736	391	-10.0%
Sweden	159	202	255	255	304	18.2%
UK	194	186	241	241	243	6.5%
USA	88	86	94	97	102	3.7%
Average	150	157	179	180	172	6.9%
Minimum	25	27	35	35	39	-10.0%
Maximum	657	702	736	736	391	24.5%
Standard deviation	133	142	147	147	89	8.5%

Monetary values are in 2007 dollars.

Source: CANSO (2012) and calculations by the author.

There have been at least two studies (mbs ottawa inc., 2006; United States Government Accountability Office, 2005, the former analyzed 5 commercialized ANSPs, and the latter 10 - the total number of commercialized ANSPs is close to 50 now) that have considered the issue of the commercialization of ANSPs. These studies concluded, albeit from small samples, that changes were either neutral or positive, with improvements in customer service, more modernization efforts undertaken, and that financial stability was maintained, while costs were, in the worst cases, kept in check or even reduced. McDougall & Roberts (2008) reported similar results. An older case study (Majumdar, 1995) conducted when commercialization was in its infancy, examined two at-the-time-recent commercialization processes (New Zealand and Germany) and other two that were proposed at the time (UK and US, with only the former being successfully commercialized since then). It concluded that the biggest risk of commercialization would inevitable be safety, as the mindset of reducing costs under commercialized ANSPs would put pressure on safety levels and ultimately (p. 122) "the debate is as to how much 'less safe' can an operation be before it becomes 'unsafe'".

Other studies include a large overview of issues related to ANSPs (Oster & Strong, 2007), in which some analysis of commercialization experiences are also included[142]; and a similar approach but with a focus on Europe and also a more detailed technical analysis of ANSs (Cook, 2007), while others analyze the rationale behind commercialization (Charles & Newman, 1995; Dempsey, Janda, Nyampong, Saba, & Wilson, 2005; Morrison & Winston, 2008; Robyn, 2007).

Besides being studied with varied levels of depth in virtually every study pertaining to ANSP commercialization, UK's NATS have seen a number of publications dedicated to this system, including academic papers (Goodliffe, 2002; Steuer, 2010) and

[142] The book followed a report by the same authors about commercialization efforts in the UK and Canada (Oster & Strong, 2006).

a plethora of regulatory policy analysis made public by UK's Civil Aviation Authority[143]. The report by Helios Economics and Policy Services (2006a) may be the most relevant for the scope of this dissertation.

There are still a number of issues that still have not been developed in the literature. For example, pricing and pricing regulation also vary significantly across ANSPs, from taxes on tickets (with the most notable case being the United States) to user charges. Among user charges, those can be set independent civil aviation authorities, by the respective governments, or being subjected to price-capping (as is the case of the British ANSP, NATS), and are a subject that have deserved little or no research – an exception being Castelli et al. (2012), although this is mostly a study about rate optimization from a mathematical perspective, not from an economic/regulatory standpoint. Issues like the role of disruptive events that change the predicted traffic patterns (recessions, volcanoes, epidemics, etc.) in the economic efficiency of ANSPs (i.e., how prepared are ANSPs to operate efficiently from an economic perspective when in the presence of traffic variations beyond the usual seasonal variations[144]) are also an area worthy of research in which published work is still not abundant. Other examples of topics worthy of investigation could certainly be found.

Since the changes in ownership and regulatory structures are somewhat recent in most systems, having mostly happened in the last 15-20 years, it can be expected that in the next few years that gap in the literature will start to be filled with new research,

---

[143] These reports can be accessed at http://www.caa.co.uk/default.aspx/default.aspx?catid=5&pagetype=90&pageid=586. Last accessed in November 2013.

[144] Indeed, analyzing how ANSPs deal with the "regular" seasonal variations is another area where the literature has not provided many insights.

conducted by academics from various fields (engineering, economics, public policy, etc.), the industry itself and its suppliers (technology firms, consultants, etc.), or regulators (FAA, EUROCONTROL, etc.).

Regarding ANSPs, due to their intrinsic complex characteristics they provide an interesting case to analyze the role of regulation, and how it relates to economic efficiency. Some of these characteristics include the fact they are a private good[145], where change within their systems is slow and faces several layers of opposition. Additionally, redundancy and 24/7 operational capability are indispensable, interlinks with other systems (airlines and airports) are their purpose of existence, and, although being civilian, they have to interact with the military and the operational constraints they impose on airspace. Being a market in which several types of structures co-exist, from public agencies to government-owned corporations and PPPs, allows for different types of analysis, with different scopes and different goals, to be performed.

The research presented in this dissertation will build on these previous works, and will do both an institutional and economic analysis of the industry. From an institutional perspective, the added value of the dissertation will probably not be extensive, as it will

---

[145] This is because the use of the airspace cannot be neither non-rival nor non-excludable. Despite this it has been long considered by some to be a public good (Button & McDougall, 2006), with perhaps the notion of Coase (1974) of a club good, being a compromise between the two: it can be argued that it is difficult to exclude planes from using airspace and that one plane's use has minimal effect on others. While the former may have some applicability to air transportation, some parts of the European airspace are congested suggesting rivalness at least on some corridors. Coase's main interest, however, is in excludability. Those favoring the public good concept argued that it is difficult to recover the costs of navigation services unless there is some "crown patent" forcing aircraft to pay. Coase, however, argues that the British system of lighthouses is privately funded from fees collected at ports, and hence the market has the features of a club good; a model that can presumably be applied to aircraft . Radar makes it easy to track aircraft and payments may be extracted on landing; over-flightscan be monitored and without payment of ANSs fees future flights "refused". Considering these circumstances, the notion of ANSs being a club good would seem reasonable.

mostly compile and update results that have already been previously presented. On what it will add value is on the economic analysis, and that value will come not only by being the first study to do a programmatic analysis of the economic efficiency of ANSs systems in Europe, but also because it will be the first to explicitly include considerations about ownership in the analysis, thus departing from more “traditional” productivity studies which mainly focus on technological and operational variables, not institutional or regulatory ones.

CHAPTER 6 – METHODOLOGY

This section outlines the methodologies that were used to discuss the research questions. Although the main focus will be the "hard" economic modeling using data for a number of European systems that will be presented in the last part of this section, the qualitative assessments, besides providing a review of previous research in the area, offer a "soft" approach to the problem.

The rationale for this multipronged approach resides in the fact that since this is a field where research is still scarce, the use of several methods allows for more robust results and findings.

6.1. Qualitative Assessments

6.1.1. SWOT Analysis

Although often overlooked as not being up to par with current academic standards[146], qualitative, "soft", equations-free, approaches can be useful to provide insights on a topic (e.g., policy variables) that economic modeling alone cannot capture.

On this section of the dissertation a strength, weakness, opportunity and threat (SWOT) analysis approach will be used to study the different institutional and regulatory arrangements put in place in the industry. SWOT analysis is a decades-old technique mainly used in business and marketing analysis to provide information that is helpful in

[146] Borts (1981) discusses, from an editorial perspective, why there is a bias towards the publication of papers with a "harder", math-heavy, content in economics.

matching a firm's resources and capabilities to the economic environment in which it operates. In addition, its application can be extended to embrace policy assessment and efficiency as a sort of soft economic benefit-cost analysis that involves treating the government as a firm and its policies as its products to be appraised. While not as technically rigorous as some approaches, it allows both for the introduction of qualitative information and for a flexible way of assessing several aspects of alternative ownership frameworks. This is important given the diverse national systems of providing air navigation services and the softer considerations that come into assessing their relative economic merits, and it might become useful in a time when governments and regulators are discussing the options for the future of their systems.

The components of the acronym "SWOT" are divided into internal (strengths and weaknesses) and external (opportunities and threats) factors[147]. With appropriate knowledge regarding the internal and external worlds in which they function, organizations can create strategies to act. Table 14 summarizes the main concept behind SWOT analysis.

[147] To quote Sun Tzu (2005), "So it is said that if you know others and know yourself, you will not be imperiled in a hundred battles; if you do not know others but do know yourself, you win one and lose one; if you do not know others and do not know yourself, you will be imperiled in every single battle."

Table 14 The basis of SWOT analysis.

	Strengths	**Weaknesses**
Opportunities	Achieve opportunities that greatly match the company's strengths	Overcome weaknesses to attain opportunities
Threats	Use strengths to reduce the company's vulnerability to threats	Prevent weaknesses to avoid making the company more susceptible to threats

Source: Chermack & Kasshanna (2007).

Although widely adopted in business, SWOT analysis has not been extensively used in academic studies. In 2010, Helms & Nixon (2010) did a survey and literature review of published academic papers using or studying SWOT analysis and found just 141 papers published over 11 years in the more than 3,000 scholarly publications examined. None of these were related to the air navigation services industry, but some have analyzed entire industries in a given region, country, or group of countries[148]. One of the reasons for the lack of use of SWOT analysis in academic research is perhaps that, given its flexibility and "soft", qualitative, rather than "hard", technically rigorous nature (basically there are no equations) the method is viewed as not being up to par with current academic standards. Nevertheless, the tool can be useful for an initial analysis of internal and external factors that might affect the performance of an organization, be it a company or something else, and from that highlight the broad direction for actions that can create value for the organization (Chermack & Kasshanna, 2007). It also allows for a multicriteria approach to be adopted, which would seem appropriate for undertakings such as ANSPs that are not strict profit maximizers but largely, even in corporatized and

[148] Most of the studies deal with the analysis of companies, either analyzing only one, or by comparing two or more. There were also some studies analyzing entire countries.

public private forms, pursue objectives more akin to Simon's (1956) notions of satisficing. Indeed, the very idea of them not making a profit, or being price capped, that are increasing the objectives set ANSPs means that they are not maximizers in the neo-classical economic sense.

The method has its limitations, and it has been criticized from several perspectives, ranging from being poorly used[149] to making the strategy development process too formal and not allowing creativity. Chermack and Kasshanna (2007), in particular, have argued that the use of SWOT analysis is vulnerable to misappropriation, because it can easily be used by decision-makers to "cherry pick" whatever they want to include and avoid topics in which they are not comfortable, thus becoming not a tool to help in the decision-making process, but to reinforce a pre-determined conclusion about the path along which to proceed. This misuse can not only result from an deliberate attempt to "game" the system, but also because whomever is doing the analysis lacks information, it has a particular problem in analyzing the external factors, or is exercising poor judgment that does not allow a more complete analysis.

In some cases, when efforts are made to sum or in some other way quantitatively compare elements in a SWOT analysis, an inappropriate and illusory degree of exactitude can be introduced. Koch (2000) argues that these flaws are not because of the properties of SWOT analysis, but rather result from misconceptions about the method, the poor quality of inputs, and lack of knowledge in many attempts to use it. Here, while accepting the inevitable caveats, this latter line of argument is followed and SWOT analysis is

[149] A critique that can be made about virtually every method in existence.

treated as a method of systematically representing information is a sort of quasi-accounting framework that allows for qualitative assessment.

6.1.2. Case Studies

In addition to the SWOT analysis, this section of the dissertation will also include a number of descriptive case studies about selected ANSPs. This will add value to the dissertation by providing practical examples on how some systems have evolved, how changes in regulation have been operationalized, and what forces lead them to their current state[150]. The systems studied will include the main outliers in terms of service provision: the United States, the world's biggest system, and one of the few that still is funded by taxation, not user fees; Canada, the only private system in existence; United Kingdom, the only public-private system in the world. New Zealand, as it was the first system to be commercialized will also be studied.

6.2. Quantitative Assessments

Productivity and efficiency measures deal with the question of how many inputs are needed to produce a given quantity of outputs. Although simple in concept, several problems can be identified (Fried, Lovell, & Schmidt, 2008a):

- Which outputs and inputs should be included in the analysis?
- If in the presence of multiple inputs and/or multiple outputs, should they be weighted in comparison to one another?

[150] This case study approach was also used by Oster & Strong (2007). The book includes analysis on a number of other systems, including in Africa and Eastern Europe that will not be discussed in this dissertation.

- How should the technical and economic potential of the producer be determined?

Several ways to deal with these questions have been proposed in the literature, and the possible solutions (discussed in more detail in both Syverson (2011) and Fried et al.(2008b)) involve looking at the data available in each the specific case – including the availability, or not, of market prices, regulatory schemes and incentives, ownership structure, etc. – and apply models that can deal effectively with the limitations of that data, since even modest differences in parameterization can lead to significant changes in the results.

This section presents the two methods that are used to study the economic efficiency of European ANSs. The first is a linear programming approach, Data Envelopment Analysis (DEA), and the other an econometric one, Stochastic Frontier Analysis (SFA). They both stem from the notion of efficiency frontiers first proposed by Farrel (1957) and are two different approaches for this same problem.

A discussion of the methods and their application on this research will end the chapter.

6.2.1. Data Envelopment Analysis

DEA is a nonparametric method[151] that was developed by Charnes et al. (1978) after work conducted by Farrel (1957). This nonparametric characteristic of the method is perhaps its greatest advantage because there is no need to stipulate a form for the

[151] That is, the method does not assume any particular structure for the model, leading to a structure that is not predetermined and a result of the data alone.

production function, leaving the researcher without the burden of having to make assumptions about it (Post, 2001).

DEA is a linear programming tool that can estimate the relative levels of efficiency[152] of multiple firms, called Decision Making Units[153] – DMUs – in the literature, compared to the others. That is, the results can only be used to assess the relative efficiency between the firms and when interpreting DEA results one can only infer that the firms that the method estimates as being more "efficient" are only more efficient when compared to its peers. It is not known what its absolute level of efficiency is.

Besides the aforementioned advantage of not having to make assumptions about the production model, DEA also has the advantage of being useful when market prices are not available. Another advantage of the DEA framework is that it allows for the presence of a larger number of outputs and inputs, and, unlike other methods where at least the outputs have to be either quantities or monetary values and are reduced to one single variable, it can deal with very different units and measurements scale. In fact, DEA efficiency estimates are independent from the units or scales chosen. However, that advantage also brings some disadvantages along with it. Because the results are sensitive to the selection of inputs and outputs, outliers can affect the results disproportionately,

[152] DEA allows the estimate of both technical and allocative efficiency – as a reminder, the former being how efficiently a given set of inputs is transformed into outputs, and the latter being defined as using the least costly input mix to produce a given set of outputs, i.e., a given DMU can be "technical efficient" because it uses its inputs efficiently when compared to its peers, but it is possible that it is not "allocative efficient", because it is not using those inputs into optimal proportions and the same "technical efficiency" could be achieved using a different, less costly, mix. Usually, when one is referring to "DEA efficiency" it is technical efficiency that is being referred to.

[153] Depending on the context, this can be as varied as a firm, a piece of machinery, a region or a political party, for example.

and the number of DMUs that are considered to be efficient tend to increase with the number of inputs and outputs considered. Also, DEA assumes that all deviations from the efficiency frontier are a result of inefficiency and does not take into account other possible explanations like sample noise (Coelli et al., 1998; Cooper et al., 2007).

The original model proposed by Charnes et al. (1978) (Equation 3[154]), is known as the *CCR model*[155] after its authors. This model assumes constant returns to scale in production.

Equation 3

$$\begin{aligned}
\max_{\mu, v} \quad & \theta = \mu_1 y_{1o} + \cdots + \mu_s y_{so} \\
\text{subject to} \quad & v_1 x_{1o} + \cdots + v_m x_{mo} = 1 \\
& \mu_1 y_{1j} + \cdots + \mu_s y_{sj} \leq v_1 x_{1j} + \cdots + v_m x_{mj} \\
& \qquad (j = 1, \ldots, n) \\
& v_1, v_2, \ldots, v_m \geq 0 \\
& \mu_1, \mu_2, \ldots, \mu_s \geq 0
\end{aligned}$$

[154] Both this CCR model and the BCC model presented next are the simplified version presented on Cooper et al. (2007). The original papers present both the complete versions of the models and all the demonstrations, proofs, and assumptions.

[155] This is the input-oriented version of the model, i.e., it is a model that tries to minimize the inputs based on a given set of outputs. Since the output-oriented model (a model that tries to maximize the outputs based on a given set of inputs) is very similar it was decided to just present this version of the BCC model. Both definitions are from Cooper et al. (2007, p. 115).
The choice between the two should be derived from the characteristics of the DMU's being studied: for example, when in the presence of a firm that has access to a limited amount of resources, the output-oriented model should be preferred, as the goal is to maximize outputs given those limited resources; on the other hand, if the firm has a particular number of orders to fill, the goal would be to use as little resources as possible to fulfill that order. Due to the linear programming nature of DEA, the choice of orientation should result in the same efficient frontier, and thus the firms identified as efficient should be the same, and the only changes in results should be the efficiency measure associated with inefficient firms (Coelli et al., 1998). Another consideration with choosing orientation, is that the CCR model requires non-negative elements as inputs (with at least with one positive element) regardless of orientation, while the BCC model requires non-negative elements as inputs (with at least with one positive element) when in the presence of an input-oriented model (the outputs can be either negative, zero or positive), and non-negative elements as outputs (with at least with one positive element) when in the presence of an output-oriented model (the inputs can be either negative, zero or positive) (Cooper et al., 2007).

Where x and y are, respectively, the inputs and outputs of the DMU, and υ and μ are, respectively, the input weights and output weights[156]. The first restriction is set to avoid having an infinite number of solutions.

In the years that followed the creation of the CCR model, other models were developed, with one of the more relevant being the *BCC model* by Banker et al. (1984), also named after its authors. The major contribution of this model (Equation 4[157]) was the addition of variable returns to scale.

Equation 4

$$\min_{\theta_B, \lambda} \quad \theta_B$$

$$\begin{aligned} \text{subject to} \quad & \theta_B x_o - X\lambda \geq 0 \\ & Y\lambda \geq y_o \\ & e\lambda = 1 \\ & \lambda \geq 0, \end{aligned}$$

where;

θ_B is a scalar ≤ 1
λ is a column vector the weights for all firms
x_o is input data (≥ 0) for DMUo
y_o is output data (≥ 0) for DMUo
X is the matrix of inputs
Y is the matrix of outputs
e is a row vector with all elements equal to one

Figure 6 shows the differences between the CCR and the BCC model in a simple one-input and one-input industry. If only the CCR model were used, DMU B would fall into the frontier and would be the only one considered to be efficient. If the BCC model

[156] "Weights" are the ratios between the different outputs considered and between the different inputs considered (for output weights and input weights, respectively). Using DEA these weights (that in the most common DEA models are between zero and one) are not pre-determined (although they can be, for example when have a weight of zero is implausible), and are derived from the data. Each DMU has a "best" set of weights, and those weights can vary between each DMU in the sample (Cooper et al., 2007).

[157] Like the previous CCR model, the version of the model presented here is also the input-oriented model.

were used, the variables returns to scale assumption would create a different efficiency frontier and DMUs A, B, and C would be considered efficient.

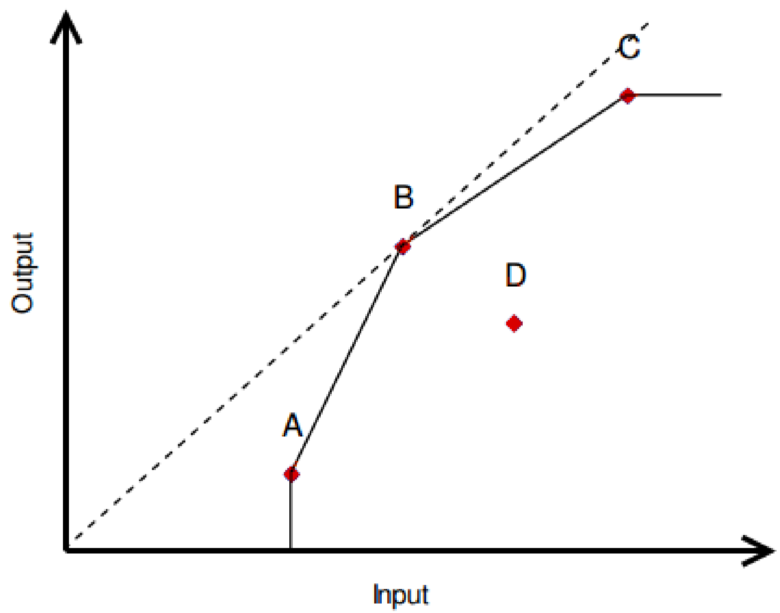


Figure 6 CCR vs. BCC models comparison

The BCC model is normally the preferred model, as the constant returns to scales assumptions of the CCR model only hold true when all firms are operating at an optimal scale.[158] However, by using both models, it is possible to estimate the level of “scale efficiency”, which is a measure of the distance between actual production and optimal

[158] Several other variations of DEA have been proposed since the original model – see, e.g., Bogetoft & Otto (2011), Coelli et al. (1998), and Cooper et al. (2007). They can be used to refine the analysis to include more realistic assumptions, but also have the potential of allowing more ways to manipulate the data to reach a desirable outcome. On the other hand, if that is the goal, it can be done with even the simplest DEA models, as changing the quantities of inputs and outputs and/or DMUs can possible have great effects on the efficiency scores (Coelli et al., 1998).

scale. Another feature of DEA is that it estimates the levels of *slacks*, which are nothing more than the amount of each output and input that could be increased or reduced, respectively, without it affecting the efficiency level (Bogetoft & Otto, 2011).

When dealing with panel data[159], DEA also can be used to study productivity changes over time. This can be done using a measure of TFP applied to DEA efficiency results: the Malmquist productivity indices (D. W. Caves, Christensen, & Diewert, 1982a, 1982b)[160].

Finally, with DEA, statistical analysis is also possible. However, since DEA is a nonparametric method, bootstrapping[161] (or some other method[162]) is needed to allow that (Simar & Wilson, 1998). The method proposed by Simar & Wilson (1998, Equation 5), allows the creation of bootstrapped results that the can be used in further statistical analysis.

With observations(x^1, y^1),…., (x^K, y^K) and Farrel efficiency measures E^1, …., E^K, bootstrapped DEA estimated efficiency scores can be obtained from Equation 5

Equation 5

$$\hat{E}^k = \min\left\{\theta \in \mathbb{R} \middle| (\theta x^k, y^k) \in \hat{T}\right\} \qquad (k = 1, \dots\dots, n)$$

where $\hat{T}$ is the estimated technological set for the technology set T (Equation 6):

[159] Panel data is a set of data that includes observations across different individual (*cross-sections*) and over different periods of time (*time series*)

[160] For more details on TFP, TFP indices, and TFP applications see Syverson (2011). For more details on the technical details of Malmquist indices and their use in DEA analysis see Coelli et al. (1998), Fried et al. (2008b), and Cooper et al. (2007)

[161] According to Simar and Wilson (1998, 49), "is based on the idea of repeatedly simulating the data-generating process, usually through resampling, and applying the original estimator to each simulated sample so that resulting estimates mimic the sampling distribution of the original estimator".

[162] Although bootstrapping has become a common way to introduce stochastic behavior into DEA, other methods exist, for example, "chance-constrained DEA". For more on that see see Fried et al. (2008a).

Equation 6

$$\hat{T} = \left\{(x, y) \middle| x \geq \sum_{k=1}^{K} \lambda^k x^k, y \leq \sum_{k=1}^{K} \lambda^k y^k, \lambda \geq 0, \sum_{k=1}^{K} \lambda^k = 1, \right\}$$

Bootstrapping has become widely used in the literature to allow secondary analysis of DEA results and to assess how exogenous factors might explain the firm's performance, but according to Simar and Wilson (2007) many of the published works in the area that use two-stage DEA with bootstrapping reveal some flaws that might undermine its scientific soundness and produce invalid results.

This ability to do statistical analysis on DEA efficiency results might be useful when in the presence of exogenous variables that DMU management cannot control, like for example, ownership form, regulation, or physical attributes (the airspace area controlled by an ANSP, for instance). Besides second-stage statistical analysis, there have been several ways to try to include these variables in the analysis, for example by dividing the sample in different groups and analyzing the efficiency of these subgroups separately, but this approach can have the disadvantage of creating subgroups that are too small, and makes comparisons between DMUs in each subgroup difficult. Certain variables can also be included as inputs or outputs, but this cannot be done with categorical variables, and an assumption about the influence of the variable (positive or negative) has to be done *a priori* (Coelli et al., 1998). Two-stage analysis is an attempt to solve these problems by allowing the use of statistical analysis and hypothesis testing (the second stage) on the results of the DEA model (first stage), and bootstrapping has become the most widely used method of doing that (Fried et al., 2008b). This dissertation will follow this approach.

6.2.2. Stochastic Frontier Analysis

SFA is a parametric econometric technique first developed (independently) in 1977 by Aigner et al. (1977) and Meeusen & van den Broeck (1977). Together with DEA, SFA has become one of the dominant approaches in benchmarking analyses (Bogetoft & Otto, 2011).

Being parametric, it is necessary to make a number of assumptions regarding the specification of both the distributional forms for the inefficient term and the functional form for a production or cost function, which adds to the complexity of the problem when compared to using the DEA framework and also adds a level of arbitrariness to the technique since it is not independent from the distributional assumption. Also, the treatment of multiple outputs is not as sophisticated as with DEA, as with many specifications, one has to combine multiple outputs into one. On the other hand, SFA deals with noise (measurement errors, for example) more efficiently, and conventional hypothesis testing can be used straightforward, while DEA efficiency estimates, being deterministic, need to be treated (by means of bootstrapping, for example) before hypothesis testing can be done (Bogetoft & Otto, 2011; Coelli et al., 1998).

The model is presented in Equation 7 (Coelli et al., 1998):

Equation 7

$$\ln(y_i) = f(x_i, \beta) + v_i - u_i \qquad , i = 1,2, \dots, N$$

Where,

$\ln(y_i)$ is the logarithm of the scalar output for the i-th firm;

x_i is a vector of input quantities used by the i-th firm;

β is a vector of unknown parameters to be estimated,

v_i is the random error, it can be positive or negative, and accounts for measurement errors and other factors on the value of the output variable, along with the combined effects of unspecified input variables in the production function; it is a normal distribution,

u_i is a non-negative random variable, associated with technical inefficiency in production; it is a truncated, half-normal, distribution. The two error terms are assumed to be distributed independently from each other.

The problem is one of maximum likelihood estimation and it is normally solved by maximizing the log-likelihood using numerical methods. Like DEA, it also gives out the relative technical efficiency values for each firm. In addition, it also allows the estimation of the percentage of total variation of the error term that is due to inefficiency and due to random variation (Equation 8):

Equation 8

$$Percentage\ of\ total\ variation\ due\ to\ inefficiency = \frac{\lambda^2}{\lambda^2 + 1}$$

Where,

λ^2 is the ratio of variances σ_u^2/σ_v^2

σ_u^2 is the variance of the error term,

and σ_v^2 the variance of the random error.

When comparing efficiencies obtained by both DEA and SFA estimations, it is expected that DEA estimations are relatively higher than their SFA counterparts and it should not be expected that all firms that are relatively efficient in the DEA approach have necessarily to be so in an SFA analysis. Additionally, several firms/DMUs with an efficiency of 100% are to be expected while using DEA. While under SFA, they are not.[163]

6.2.3. Identification Issues

An issue that relates to all these methods, and indeed to all economic modeling, is the issue of causality and causal relationships, or as it is called in the context of econometrics, the issue of identification. In economic and econometric analysis, it is possible to envision many theoretical models using the same dataset, and since natural experiments are most of the times not possible, establishing causation is a serious concern[164]. In the specific context of this dissertation, since its goal is to estimate if changes in ownership and other variables are associated with different levels of economic performance of ANSPs, this identification problem assumes great importance, as not dealing correctly with it might jeopardize the soundness of the results.

Heckman & Vytlacil (2007) discuss how the main source of identification problems when studying causation in econometric models are unobserved variables, including missing data, and methods to control for the unobserved relevant variables must be devised and statistically tested.

[163] In fact, the probability of having an efficiency of 100% in a SFA estimation is zero (Bogetoft & Otto, 2011).

[164] Black (1982, p. 29) argues that establishing causation in econometrics is so problematic that it might even undermine the entire econometrics science: “The trouble with econometric models is that they present correlations disguised as causal relations. The more obvious confusions between correlation and causation can often be avoided, but there are many subtle ways to confuse the two; in particular, the language of econometrics encourages this confusion. The problem is so serious that econometric models are usually ineffective even for estimating supply and demand curves (…).It is doubtful, though, that traditional econometric methods will survive.”

When in the presence of panel data in which some observations are exposed to a certain event and some are not – this is the case of this dataset, with some ANSPs having changes in their regulatory schemes and some not –, there is an approach, differences-in-differences (D-i-D), that tries to capture the effects of changing economic or policy conditions (Angrist & Krueger, 1999). Figure 7 summarizes the basic concept behind the D-i-D estimation and Equation 9 formalizes it using ordinary least squares (Bertrand et al., 2004).

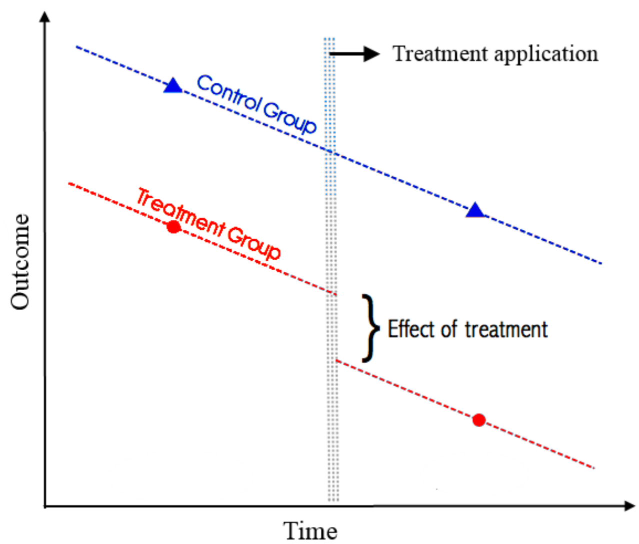


Figure 7 Differences-in-differences

Equation 9

$$Y_{ist} = A_s + B_t + cX_{ist} + \beta I_{st} + \epsilon_{ist}$$

Where,

Y_{ist} is the outcome of interest for individual *i* in group *s* by time *t*

I_{st} is a dummy for whether the intervention has affected group s at time t

A_s are fixed effects for group s

B_t are fixed effects for time t

X_{ist} are relevant individual controls

ϵ_{ist} is an error term

β is the estimated impact of the intervention

A major criticism of the D-i-D approach is that it assumes that interaction terms are zero in the absence of an intervention. That is, the evolution of the outcome would have been the same in the different groups if not for the application of the treatment. However, due to the fact that models are a simplification of reality, it might be the case that some underlying cause that is influencing the outcomes in the different periods of time is not being captured. The D-i-D estimate might then be a measure not of the effect of variable of interest, but some other variables that are not being studied (Angrist & Krueger, 1999)[165].

Applied to this dissertation, the application of D-i-D will compare ANSPs that have had changes in ownership during the time period considered with others that did not. Nevertheless, limitations in the dataset might present a problem, as only a very limited number of systems[166] experienced changes during the 2002-2011 period considered: most systems that were commercialized did so in the years prior to 2002. As such, the sample might be too limited to draw meaningful conclusions. Additionally, the

[165] For a more technical discussion of the drawbacks of D-i-D estimates see Bertrand et al. (2004).
[166] Four in total, with three of them (Macedonia, Slovenia, and Sweden) moving from public to commercialized ownership, and one (Poland) in the other way around.

fact that the observations operate in 36 different countries, making them somewhat different between each other, there are possible numerous outside variables that might be influencing the results – from socio-economic conditions in the overall economy of each country, to labor laws specific to the industry – thus making the interpretation of the D-i-D estimates more difficult.

6.2.4. Discussion of Quantitative Methodologies

Although the need to use this different approaches can be discussed, and it can even be considered that the methods are used just for the sake of using them, it is believed that a comprehensive study of the effects of ownership in the economic efficiency of European ANSPs – like this dissertation aims to be – cannot rely on a single method in order to draw sound conclusions. Each method and its variations have their own merits and drawbacks. Although dealing with the same basic concept (efficiency), that concept is approached from different perspectives, which can add value to the research.

For the particular case of ANSPs, the characteristics of DEA offer some advantages that make it a practical and viable tool for assessing relative levels of efficiency:

- No need to assume functional form.
- It can be used to compare the relative levels of efficiency of different ANSPs (for example, the different ANSPs in Europe), specific parts within the ANSPs or across different ANSPs (for example, en-route centers), or other components of the industry (the FABs that will

aggregate the operations of different European ANSPs under the SES initiative, for example).

- It can be used to estimate Malmquist TFP indices and allocative and scale efficiencies.
- ANSPs have a great number of standardized (at least in Europe) inputs and outputs (costs, revenues, flights controlled, delays, safety indicators, area controlled, en-route sectors (number and area), total staff, total ATCos, etc.), and DEA allows for them to be incorporated in the model, either on the first stage of analysis (i.e., estimating efficiency), or in the second stage (statistical analysis and hypothesis testing).
- The main caveats of using DEA is that being in the presence of so many variables, one as to pay attention to the fact that choosing too many variables will increase the number of "efficient" DMUs in the first stage analysis, and using too many independent variables in the statistical analysis might artificially increase the fitness of the model (R^2). Another important aspects to pay attention to is what variables are to be chosen in each stage, for example, deciding on the appropriateness of mixing monetary (costs and revenues) and physical (flights controlled, area, etc.) variables either in the outputs or the inputs of the model.

The case for SFA is not so straightforward. It requires the specification of production or cost functions, which need to be parameterized and have specific requirements in terms of data that are not present when using DEA specifications. More details will be discussed when the model specification for the SFA analysis is presented. Given the dataset available, which lacks prices – needed for the specification of cost functions – and is incongruent in some of the inputs (e.g., labor data is more detailed for ATCos than for the rest of the staff – for the former there are data available of both the number of workers and number of hours worked, while for the latter there are only data for the number of workers), it is believed that the flexibility that DEA offers makes the method a potentially more relevant approach for this particular study. Considering this, the main analysis will be done using the DEA approach[167], with the SFA estimates being used as robustness checks for the "main" models of ANSP technical efficiency.

6.2.5. Data Sources

The main source of data for these analyses will be a set of annual reports that have been released by EUROCONTROL in the past decade: the ATM Cost-Effectiveness (ACE) reports, being EUROCONTROL Performance Review Commission (2013a) the most recent. These reports are part of an effort by EUROCONTROL to benchmark the European ANSs using reliable qualitative data about each individual system's operation, and with that, improve efficiency and promote a smooth transition into the SES. Although each system remains independent from each other, EUROCONTROL has been mandating that its member states provide annual information about their systems financial and operational situation, following a set of mostly standardized[168] procedures

[167] It will include not only estimates of individual efficiency results for the ANSPs along the ten years of the dataset, but will also include a study of spatial autocorrelation issues, TFP Malmquist indices, and causation tests.

[168] Each system still has some leeway in the way they choose to present some variables. This is specially the case of financial information, which does not follow the same accounting standards in all countries.

for reporting data[169]. These have been released since 2002, providing now data for a period that spans ten years (2002-2011), for a total of 36 countries[170] and a supra-national operator[171]. Although the period for which data is available is not especially large, considering how long it takes for changes to take place in this particular industry[172], it should at least allow for a discussion to begin about how the different components of the sector have been affecting the levels of economic efficiency.

The reports provide a number of performance indicators relating to cost-effectiveness and productivity, analyses of past trends, and forecasts for the future. In addition, and more importantly for this dissertation research, they also present a number of variables about each individual ANSP. These include financial (different sets of costs and revenues, including capital expenditures and assets, etc.), operational (staff, en-route centers, delays, flights, flight-hours, and airport movements controlled, etc.), and physical (size of airspace controlled, etc.) variables, that provide a wide range of useful information to be included in the models. In 2011, these 37 operators employed 58,000 people, 17,200 of which were ATCos, had revenues of €9.3 billion, costs of €8.7 billion,

---

169 Recent reports include a section on the status of individual ANSP's annual reports and their shortcomings in terms of data reporting.

170 Albania, Austria, Belgium, Bulgaria, Croatia, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Republic of Macedonia, Germany, Greece, Hungary, Ireland, Italy, Latvia, Lithuania, Malta, Moldova, Netherlands, Norway, Poland, Portugal, Romania, Serbia, Slovenia, Slovakia, Spain, Sweden, Switzerland, Turkey, United Kingdom, and Ukraine. Data for some countries is not available for all years.

171 The MUAC, which is operated by EUROCONTROL and controls the upper airspace (above 24,500 feet) of Belgium, the Netherlands, Luxembourg and north-west Germany. This was supposed to be just the first of several upper ACCs operated by EUROCONTROL – others would have included Karslruhe in Germany and Shannon in Ireland –, but the lack of support for these international initiatives lead to MUAC being the only center run by EUROCONTROL (McInally, 2010).

172 A wide-spread anecdote in the industry is that in the 1990's, forty years after the development of the transistor, the FAA still had systems that used vacuum tubes.

and controlled 9.8 million flights, 14.5 million flight-hours, and 15.4 million airport movements.

When dealing with monetary values over different years, adjustments for inflation will use the database from the International Monetary Fund[173]. Additionally, purchasing power parity data from the World Bank[174] will also be used in order to adjust for the different purchasing powers across countries. If any other indicators related to the macro-economic conditions of these countries are needed, both these institutions, along with Eurostat will be used.

---

[173] From the *International Financial Statistics* database.
[174] From the *World Bank Data* database.

CHAPTER 7 – QUALITATIVE ASSESSMENTS

7.1. SWOT Analysis

To ease exposition and follow the original underlying rationale for its development, the various elements of the SWOT analysis are divided into internal and external considerations. Except where any specific elements are referenced, the sources for the table include Button & McDougall (2006), Mbs Ottawa inc. (2006), Oster and Strong (2007), Robyn (2007), Majumdar (1995), Charles & Newman (1995), and US Government Accountability Office (2005), as well as information and comments in the annual EUROCONTROL Performance Review Commission annual reports. The results are seen in Table 15.

The methodology provides a systematic presentation of the internal and external factors associated with assessing ANS provision, and any decisions depend upon the exact criteria being of the decision maker. To assist in this, the presentation of the material is slightly different to that found in many SWOT analysis completed by private companies, in that following the quasi-CBA requirements of public policy a much wider range of considerations are taken into account, and many of these reflect a longer-term perspective. Additionally, the presentation includes reference to the rationale for inclusion of some of the elements and the ways they are treated, again at variance with the general use of SWOT by private business.

SWOT analysis is a soft approach to deal with economic benefit-cost analysis, and unlike full economic benefit-cost analysis, it does not produce a single net present value as its result. It is more akin to accountancy, where the tabulations highlight potentials and pitfalls with the aim of offering a platform for making multi-dimensional trade-offs. What trade-offs are made, and how, depends on the specifics of the exercise, and may be fuzzy. There are also the scenarios against which the assessments are made, not least of which are the future terms patterns of demand for ANSP services, the actual impacts of changes in technology (such as the NextGen initiative in the United States) and projected operational and organizational changes (as the SES initiative in Europe). Unlike airlines, the implications of changing the ownership patterns of ANSPs and, *ipso facto*, the regulatory structure under which they operate, have not emerged rapidly where it has taken place, and is unlikely to be rapid with any future changes. SWOT analysis is one of contextual and comparative analysis and only sheds limited light on this.

Table 15 SWOT analysis of ANSs provision.

Internal factors		
Strengths	**Public**	Safety • In most of the world the safety of air navigation services is not a concern, regardless of ownership. There are exceptions: for example, in parts of Africa and South America, but this is an issue of safety regulation and oversight rather than the ownership of the ANSP. Financing • If the ANSP is allowed to access financial markets with the government as the guarantor of debt, the ANSP can be in a position where it has wide access to capital (assuming the government has a good standing with creditors). • A private provider of ANSs normally uses user fees as a source of revenue. Given the dangers in inherent with any monopoly provider, these fees are often regulated; this may be through judicial revenue of their reasonableness of by direct measures as is the UK case (Goodliffe, 2002).
	Private	Safety • In most of the world the safety of ANSs is not a concern, regardless of ownership. There are exceptions: for example, in parts of Africa and South America, but again the issue is safety regulation and oversight rather than the ownership of the ANSP. Fears that commercialization would eventually lead to declines in the levels of safety have failed to materialize so far – a possible explanation is that commercialization was accompanied with increased safety oversight. Financing • Private companies are not constrained by national budgets, and as such in case there is a need for capital they can just go to the markets as any regular company would do. Capital investments • Free from political interference and public budget constraints, ANSPs should be able to make capital investments (modernization efforts, for instance) when they are needed, not when government tells them to or makes money available for them. Procurement processes • Private companies are not subjected to regulation regarding procurement processes and public contracts, being free to seek their partners without having to go through potentially lengthy and expensive procurement processes. Incentives • Privates companies have incentives to serve their customers well and to continuously innovate so

they can have more business and reward their shareholders.

Customer focus

- Free from political interference, private ANSPs can focus on serving their customers: airlines.

Weaknesses	**Public**	Financing • If the ANSP is not allowed by the government to raise capital in financial markets or from other sources of revenue, there is the chance that when it needs to raise money the budget is not able to accommodate their needs. This has been the case in the US, where the FAA budget is subjected to authorization from Congress, leading to partial shutdowns of the agency when authorizations expire (before the 2012 FAA Air Transportation Modernization and Safety Improvement Act was passed, 23 re-authorizations of 2007 legislation were needed to keep the agency functioning), and stopping the modernization efforts from going at the pace the FAA and the industry wants – the “Mineta Commission” (National Civil Aviation Review Commission, 1997) concluded that federal budget rules for the FAA were “crippling” and “inappropriate for a system controlling commercial operations that needs to be driven by demand for services” and that increasing operational costs happening under federal budget caps were stopping necessary capital investments to upgrade and modernize the system. Incentives • Unlike private firms, which have profit-maximizing goals (along with shareholder value), government-run enterprises might have a plethora of undefined goals, from maximizing social welfare, to maximizing personal political gains for the bureaucrats involved, and those goals might chance with the political cycle (Jasiński & Yarrow, 1996). Public agency mindset • Public agencies can be affected by a “bureaucracy”-like mindset that does not have their customers or the welfare of the public at large as their main concern, but only the existence of the agency for the sake of its existence. Political interference • All public agencies face the risk of changes in political attitudes towards them, political meddling, being used as a place of patronage, etc. For example, in the US the “Mineta Comission” (National Civil Aviation Review Commission, 1997)stated that there were “too many cooks” (“the FAA, the Department of Transportation, the aviation industry, the Administration, and the Congress”) meddling with the FAA, making authority and accountability too diffused.
	Private	Financing • The ANSP might need capital to invest or operate the system, but not be in a financial position that permits it to have access to the necessary amounts in the financial markets.

External factors		
Opportunities	**Public**	Non business-oriented objectives • Without the constraint of having a profit-maximizing goal, a public ANSP can have goals that a private ANSP might disregard (environmental concerns, social welfare, etc.) Independence from political agendas • Even if an ANSP remains a government agency, governments can grant a great deal of independence to it, achieving some the benefits of a private enterprise, without having to incur the expense of actually transferring ownership. This is, for example, the case of the French system, which is still a government agency but does have access to capital markets and operates independently from the government.
	Private	Business-oriented objectives • Having a profit-maximizing goal, there are more incentives for the actions of management to match the goals of the owner/shareholders and to innovate, thus leading to better chances of producing more efficient outcomes. Common objectives with airlines (the costumers) • Can possible lead to more efficient outcomes that are able to satisfy both the airlines and the ANSP. No government interference • Being free from (direct) government interference should allow a private ANSP to operate more in line with the goals of their customers and other stakeholders.
Threats	**Public**	Factor availability • Many less developed countries are short of the skills to efficiently operate ANSs and franchising offers a mechanism for bringing in not only foreign investments, but also skilled manpower (Button, 2008). “Gold plating” • Operating as non-profit agencies translates into a zero de facto rate-of-return regulation, with the possibility of the occurrence of the “Averch-Johnson effect” (Averch & Johnson, 1962), as rate-of-return regulation creates an incentive for companies to over-invest and have a sub-optimally high capital to labor ratio.

Shocks to the system

- A public ANSP may not have reserves to deal with unexpected fall in revenues as occurred with many systems after 9/11, and thus is dependent on the government to allow it to either operate with deficits or provide short term monetary support.

Regulation regarding public services

- Public ANSPs might be the subject of many laws and regulations that apply indiscriminately to all public agencies (for example, labor laws regulating pay and conditions or procurement and public contracts laws) and could affect the efficiency of the ANSP's operation. An example is procurement processes that can become too slow, expensive, and cumbersome, making it difficult to buy "off-the-shelf" and updated technology.

Threats	**Private**	Shocks to the system • Epidemic outbreaks, terrorist attacks, financial downturns, and volcanoes, all have significantly impacted the aviation industry, leading to a decline in traffic. This might cause serious problems as revenues decline concomitantly with the traffic, and a private ANSP does not have the backing of a national government to bail them out if needed. The 9/11 terrorist attacks happened shortly after the Canadian and British ANSPs had changed ownership, resulting in below-forecasted revenues, which lead to disruptions to investment plans. Lack of capital • Markets might not be willing to lend to an ANSP unless heavily underwritten by government, leading to a lack of capital either for operational or investment expenditures. Coordination between private and military agencies • The coordination of military and civilian airspaces is sometimes a complicated issue, which might be exacerbated if one of the players is a private company. Additionally, in many countries ANSPs are part of the military, and institutional issues might arise if a government decides to take those competences away from the military to privatize the system. Stakeholder involvement • There is a risk that some stakeholders in the aviation industry (unions, airlines, airports, regulators, etc.) feel exploited in the privatization process and try to jeopardize it. Monopoly power • Abuse of monopoly power, both in terms of generating allocative and X-inefficiency, i.e., technical efficiency not being achieved, is a common concern with private enterprise monopolies. Regulatory capture • It has been shown by Stigler (1971) that regulated monopolies can "capture" their regulators, making them create rules that are aimed to serve the monopolist interests and not to maximize social welfare. Competition for the market • Demsetz (1968) has shown that to lower prices in a monopolistic setting, auctions can be used whereby companies bid to provide the service. There are, however, the potential problems associated with such things as the nature of the auction adopted, the transactions costs of it implementation, the definition of the "product" to be auctioned (e.g. regulations about how the ANSs are to be provided and the charges levied on users) and, the terms of the contract (e.g. its length, and flexibility in terms of renegotiating its elements).

Threats	**Private**	Economic regulation • Concern over the monopoly position of ANSPs will likely lead to regulations of some kind. If it is rate-of-return regulation, Averch-Johnson effects might ensue, leading to suboptimal capital to labor ratios. If price-caps are introduced, the determination of the cap can be difficult (theory states that it should be a proxy for a competitive market, which in ANSs might be difficult to gauge as competition does not exist), and in the long run as efficiency improves these tend to approach a normal profit margin and price-capping essentially becomes rate-of-return regulation (Button, 2010). Other forms of regulation • ANSs are the subject of numerous forms of regulation besides economic regulation (safety, financial, environmental, consumer rights, etc.) that can impact the business model of the ANSP. Political interference • What can be privatized can be nationalized, and there is always a chance that in the future political interference might become a reality.

7.2. Case Studies of Selected Markets

7.2.1. Canada

Like in many other countries, Canada's ANSs system, the second biggest in the world in terms of airspace covered, was fully owned and operated by the national government. In addition, and this is also a constant in other countries, fiscal constraints also put pressure on the system and did not allow the necessary investments to cope with increased traffic to be made (Oster & Strong, 2007).

To tackle this problem, a consultation process, which involved airlines, unions, airports, general aviation, and other stakeholders, was initiated and the final conclusion was that commercialization would be the best approach to modernize the system while maintaining safety. A major proposal in the process was related to economic regulation. At the time, a tax was levied on the tickets to finance the system, but it was found that there was wide evidence that that system was not ideal and that user fees charged directly to airlines would allow full cost recovery and serve as leverage to access capital markets. Also, an additional source of revenue was found. Overflights in Canadian airspace, namely to and from Europe or Asia (via the North Pole) to the US were not charged for using the Canadian airspace. As such, a new charge was imposed, which in itself was able to bring the system into the black for the first time (Oster & Strong, 2007).

It was then proposed to create a non-share, i.e., with no shareholders, not-for-profit private company, that would run the system commercially and would be able to finance itself in capital markets. The firm was established in 1996; a corporate structure that involved 15 board members appointed by different stakeholders[175] was created, and the government received CAD$1.5 billion[176] in cash for the privatization. The board structure was believed to function as a form of "checks and balances" between the different interests in the ANSs system, functioning as an incentive to promote efficiency and avoid "gold-plating". As a result, economic regulation, besides the full cost recovery principle, was deemed to be only minimally necessary (Oster & Strong, 2007).

The financial situation of NAV Canada is, at the moment, considered to be stable, with revenues totaling more than CAD$1.2 billion[177], operating expenses of around CAD$1 billion[178] and interest, depreciation, and amortization expenses of around CAD$200 million[179]. Nonetheless, this has not always been the case, as serious financial setbacks with the declines in traffic occurring at the beginning and in the end of the 2000's decade. To mitigate the effects of these downturns, NAV Canada has a "rate stabilization fund" that is supposed to be replenished during periods of high growth and to be used when unpredictable events and fluctuations in traffic happen. The company has a goal of keeping the fund at 7.5% of revenues, which was achieved in 2012. NAV Canada has been able to go through these major events without ever having to increase charges significantly or needing any government support, but the fund has been depleted or almost at least twice in its history in order to avoid raising charges to keep the cost-recovery principle (NAV Canada, 2013; Oster & Strong, 2007).

[175] Four by airlines, one by general and business aviation, two by unions, three by the government, four by the previous ten members, plus the chief executive officer of the firm.
[176] Around $1.45 billion at current exchange rates.
[177] Around $1.15 billion at current exchange rates.
[178] Around $0.95 billion at current exchange rates.
[179] Around $190 million at current exchange rates.

In terms of charges, the creation of NAV Canada lead to a decline, in real terms, of more than 10% in the first few years of operation, but the financial problems that the firm endured in the beginning of the century lead to significant increases during the time. After that turbulent period, they started to decline in real terms slightly, and have been maintained stable since 2007. In real terms charges were by the end of 2012 5% higher than in March 1999, while during the same period total inflation in the Canadian economy was more than 30% (NAV Canada, 2013).

7.2.2. New Zealand

New Zealand, as it was the first system to have been subjected to commercialization, is a prominent case study in the field of ANSP commercialization.

The system is a small one in terms of traffic controlled, with around 1 million flights controlled per year[180] and around 1,000 employees. Nevertheless, it covers a wide airspace, both continental and oceanic, of around 30 million square kilometers, which is roughly three times the area of continental airspace in both Europe and the US (Airways New Zealand, 2013).

Until it was commercialized the system was in direct control of the government. This was a situation that was believed to be extremely bureaucratic, lack accountability, and to exist not to serve the airlines, but the government and the Minister of Transport (Majumdar, 1995).

The new company was formed as part of a wide range of reforms in the transportation sector and in the economy in general, that were put in place in a period

[180] Which compares to less than 10 million in Europe and around 16 million in the US.

when New Zealand was going through a series of macroeconomic and fiscal difficulties (Oster & Strong, 2007). The company was created in 1987 after 1985 legislation, and had the following objectives (Majumdar, 1995, p. 113).

- “provide safe air traffic, aeronautical information, rescue and related services to airports and users of the airways in New Zealand and the Pacific Basin;
- “achieve adequate profitability and an appropriate return on investment with a focus on prudent overall management and commercial purpose use resources effectively to achieve efficiency and safety consistent with international practice, ICAO standards and MOT[181] Civil Aviation Division (now CAA[182]) requirements;
- “ensure that its staff are appropriately motivated, trained and rewarded and that its human resource policies are sensitive and fair in harmonizing the needs of the Corporation, its shareholders and its personnel adopt pricing policies which reflect the cost and worth of its services and which have regard to comparable international levels of pricing while being user-oriented and market responsive;
- “foster the most favourable aviation industry environment within which the Corporation can function, encourage rationalization within the industry and maintain a special relationship with the Royal New Zealand Air Force.”

The new company, Airways New Zealand, has two shareholders, the Minister of Finance, and the Minister of State-Owned Enterprises, which appoint the eight-member board of directors. With the creation of the company, a few new features were included in

[181] Ministry of Transport.
[182] Civil Aviation Authority.

the system: the company moved to a user fees charged directly to the airlines and other airspace users, it now had direct access to private capital markets, and it paid dividends to the state (Oster & Strong, 2007).

After losing more than NZ$120 million[183] in the five years prior to commercialization, the system managed to pay NZ$82.5 million[184] in the form of dividends in the first seven years of operation, while at the same time reducing charges to airspace users. General aviation users had their charges increased though: before commercialization they could use the airspace for free, but afterwards charges were imposed on them. The system managed to go through the several difficulties that the aviation industry faced in the last 25 years without ever becoming non-profitable. It managed to avoid raising user charges for a period of more than a decade. It went through extensive modernization projects totally financed from their own revenues, and it did that while paying a total amount of dividends back to state of over NZ$200 million[185] in nominal prices (Airways New Zealand, 2013 and other years; Majumdar, 1995; Oster & Strong, 2007).

Table 16 presents some financial information on the last years of operation of the system.

[183] Around $100 million at current exchange rates.
[184] Around $68 million at current exchange rates.
[185] Around $165 million at current exchange rates.

Table 16 Financial information on Airways New Zealand.

Year	Operating profit (NZ$ million)	Dividends paid (NZ$ million)
2006-07	6.9	6.0
2007-08	10.6	6.0
2008-09	7.6	6.0
2009-10	5.1	5.0
2010-11	4.7	5.0
2011-12	9.3	5.0
2012-13	21.8	2.0

Note: Monetary values are in nominal prices
Source: Airways New Zealand (2013 and other years).

7.2.3. United Kingdom

Since the 1970's, the UK had a system similar to the one in existence in the US with the FAA. In conjunction with the military, the CAA was responsible for operating and regulating the system from a safety and economic perspective. Although having service provision and safety regulation of that same service under the same umbrella, the system was considered to be a great achievement from a safety perspective. However, like many other systems around the world, by being a *de facto* government agency, even though it fully recovered its costs[186], it was subjected to a number of restrictions in terms of borrowing capital for capital investments that were hindering its development. With increasing levels of traffic being expected it would ultimately lead to declining levels in the quality of service if the governments did not step up to provide the necessary investment funds. At the same time there no were incentives to control operating expenditures (Goodliffe, 2002).

[186] A requirement imposed in the 1980's.

The situation began to evolve in the 1990's, when the government proposed the privatization of the system. Still, that would not happen and instead, in 1996, NATS Ltd. was created, a company that was owned in its entirety by the CAA. The situation changed again in 1998 when the new government proposed that the system should have a new institutional arrangement in order to be able to bring the necessary capital to invest on the system, separate service provision from safety regulation, and to be more attentive to its clients' needs. At the time, available options included creating a public corporation, privatize and regulate like other utilities (electricity, for example), and non-profit trust like Canada, or a PPP (Oster & Strong, 2007). The PPP was eventually chosen because it was believed that it would achieve the goals of budget separation from the government, while at the same time providing incentives for efficiency. The objectives were later set to be the following (Goodliffe, 2002, p. 15):

- "to enhance aviation safety in the UK by separating regulation from service provision;
- "to maintain NATS' contribution to national security through effective civil/military joint working;
- "to ensure that NATS has access both to the necessary project and management expertise and adequate funding for investment, so as to provide for the long-term development of a safe and efficient national ATC system;
- "to provide NATS with the commercial freedom to develop the business, within the necessary framework of incentives, regulations and other disciplines;

- “to introduce incentive-based regulation, which will replace the existing ‘‘cost-plus’’ regulation which fails to encourage either timely and productive investment or value for money for airlines and their customers;
- “to ensure value of money for the taxpayer and generate proceeds, which will help fund other transport programmes;
- “to provide capital investment without adding pressure on public-sector borrowing;
- “to ensure that the private sector bears the risk of and responsibility for funding the NATS capital programme and new business opportunities;
- “to maintain effective accountability to Government through the partnership agreement, to the regulator through the licence and to the wider public interest through the special share.”

The PPP was formed in July 2001, with a structure where 51% of the shares belonged to the private sector, and the remaining 49% to the state[187]. Initially, from the 51% of the shares of the company that were owned by the private sector, 5% belonged to NATS’ employees, and 46% to *The Airline Group*, a consortium of seven airlines – British Airways, BMI, EasyJet, Monarch Airlines, Thomas Cook Airlines, Thomson Airways and Virgin Atlantic – which won the bid against two other competitors. These 46% were bought for £758 million, a revised price (down from £845 million) after traffic forecasts were reduced as a result of the dot-com bubble burst of 2000 and the economic downturn that followed. From the £758 million, most of it came from borrowing. Only

[187] With this stake the government is able to appoint directors to NATS and remains the competent authority to deal with EUROCONTROL.

£50 million was equity from The Airline Group, which meant that the company had a highly leveraged financial position[188]. A few years later, BAA, a firm that owns several airports in the UK, bought 4% of the firm from The Airline Group for a sum of £65 million.

The drawbacks of having such high levels of financial leverage were apparent just a few months after the new PPP was formed when the terrorist attacks of September 11th, 2001 happened. After that event, traffic forecast were revised downwards[189], and NATS was now facing an estimated revenue shortfall of £230 million over the next four years. This meant that NATS' ability to finance itself was constrained. The airlines part of The Airline Group were also facing a serious financial situation, hindering their ability to provide more equity; the predicted £1 billion in capital investments could not go forward. A plan to resolve the situation was then devised. It included costs reduction of about 10% of total costs over the four-year period of 2002-2006, additional capital funding of £130 million from the government and the new shareholder BAA, and the restructuring of debt from bank borrowing to bonds. This led to a financial situation that, although still leveraged at 70% of assets in 2006, was much lower from the 117% figure that existed when the PPP was created. From that perspective, a much healthier firm emerged from the restructuring, and it has been able to remain in a stronger position ever since. It allowed the PPP to move forward with its modernization projects, which totaled more

[188] For more details on the financing details of the initial bid see Steuer (2010).
[189] NATS was especially sensitive to the evolution of traffic to and from North America, as they accounted for only 14% of flights, but 44% of revenues.

than €600 million, at 2011 prices, in the 2003-2016 period (EUROCONTROL Performance Review Commission, 2013a; Oster & Strong, 2007; Steuer, 2010).

From an economic regulatory perspective, the NATS case is also unique because its charges are subjected to a price-cap regulation using the CPI-X method[190]: inflation minus a factor to account to productivity.

The initial formula for estimation of the charges was (Equation 10) (Goodliffe, 2002):

Equation 10

$$M_t = SC_t - S_t + K$$

Where,

M_t is the maximum permitted average charge per service unit in year t,

SC_t is the base charge per service unit uplifted each year by CPI-X, where X could be either positive or negative,

S_t is a quality of service/delays term,

K is a technical correction term.

The quality of service/delays term was introduced in order to provide an incentive for the company to not cut costs at the expense of less quality of service and more delays in the system, which is a common feature of price-cap regulation (Goodliffe, 2002). In the first year of operation (2001), X for non-oceanic services[191] was set a 2.2 percent, 4 percent in 2002, and 5 percent in the following years (Oster & Strong, 2007).

---

[190] These charges are set by the Regulatory Policy Group of the UK Civil Aviation Authority. Charges are usually set for five years, but that time-frame can vary (EUROCONTROL Performance Review Commission, 2012).

[191] For the oceanic service the initial X for the first five years was 2%. For the 2011-2014 period it is set a 4%.

The formula has since been update, namely because the situation of the PPP after September 11th, 2011, when a traffic risk sharing element was introduced that allowed NATS to raise its charges automatically to recover half or more of lost revenue.

The formula is now as follows (Equation 11) (Civil Aviation Authority, 2011a):

Equation 11

$$M_t = DC_t + RS_t + Pre2011_t + INF_t + FI_t$$

Where,

DC_t are the pre-determined costs for each year,

RS_t is a traffic risk sharing parameter,

$Pre2011_t$ is a correction factor for bonus and penalties for over- or under-recoveries up to 2011,

INF_t is the correction factor in which CPI-X estimates, among other things, are included,

FI_t are the financial incentives related to performance,

In the current 2011-2014 period, charges are expected to decline at an average rate of 1.44% per year (Civil Aviation Authority, 2011b).

In terms of performance, safety is of great concern, and fears that commercialization would lead to a decrease in its levels has been used to maintain ANSPs under direct government control. So far, NATS proved those forecasts wrong. There have been no accidents that were the responsibility of NATS, and the number of cases of loss of separation has also been declining. Nonetheless, they have been declining across Europe, so the causal link between moving to a PPP and improvements in safety cannot be easily proven, but at least it can be said that safety has not deteriorated (Steuer, 2010).

Table 17 presents some data regarding the financial and operational performance of NATS since 2002.

Table 17 Some statistics for UK's ANSP

Year	Composite flight-hours ('000s)	Delays ('000s minutes)	Delays/Composite flight hours	Revenues (€ million)
2002	1707	5282	3.09	864
2003	1682	1876	1.12	792
2004	1769	1522	0.86	855
2005	1826	1635	0.90	906
2006	1903	2116	1.11	910
2007	1966	2389	1.22	903
2008	1987	2292	1.15	793
2009	1780	943	0.53	668
2010	1708	1141	0.67	683
2011	1767	971	0.55	717
Year	**Costs (€ million)**	**Air traffic controllers**	**Total staff**	**Financial KPI (€)**
2002	912	1327	4882	529
2003	783	1325	4824	461
2004	743	1314	4868	415
2005	782	1387	4932	424
2006	784	1392	5057	408
2007	806	1443	5186	407
2008	677	1377	5006	338
2009	628	1413	4709	348
2010	615	1396	4541	335
2011	577	1422	4435	322

Note: Monetary values are in €2005
Source: EUROCONTROL Performance Review Commission (2013a) with calculations by the author.

Traffic is still recovering from the downturn of the late 2000's, and it is still at the same level that it was in 2002, the first full year of the PPP operation. Delays that resulted from the ANSP operation have been reduced greatly, which resulted in great improvement in the amount of delays per composite flight-hour. In terms of revenues and costs, when measured in 2005 euros, revenues in 2011 are lower than in 2002, and significantly lower than they were in the 2005-2007 peak years. In the meantime, costs have fallen even greater, which translate in a much healthier financial situation, in terms of being able to recover its costs, for the PPP[192]. In terms of staff employed, the number of ATCos employed increased almost 8% in these ten years, which was accompanied by a similar percentage decrease of the number of total staff in the PPP. All these factors combined lead to significant improvements in cost-effectiveness financial KPI, as measured by EUROCONTROL.

When measuring economic efficiency using DEA[193] (Figure 4), results show that NATS constantly ranks among the top ANSPs in terms of relative efficiency. In fact, it is one of the few systems that is able to maintain a level of relative efficiency constantly above 80%.

[192] It should be taken into account that these variations in costs and revenues are also affected by variations in the exchange rate between the pound and the euro across the time series.
[193] The complete DEA analysis for the European system will be presented in Chapter 8.

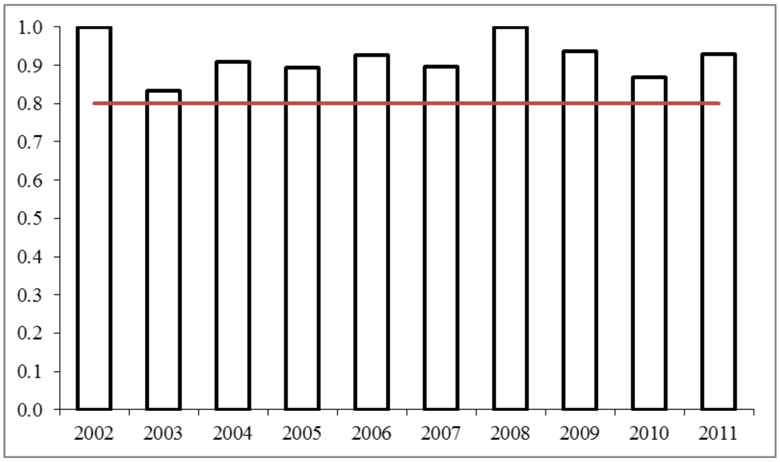


Figure 8 DEA efficiency results for UK's NATS

To summarize, although with insecure beginnings, the NATS experience can be considered to have fulfilled most of the objectives that were intended in its creation, including in terms of safety, and operational and financial performance. In this last case, it needed extensive restructuring to be able to do so, though. One area where it did not fulfill was in terms of being able to attract significant amounts of private capital, with most of the capital investments coming from borrowing underwritten by future internally generated income. Since that being able to attract that private capital was one of the primary reasons to go through with the creation of the PPP, it can be argued that, from that perspective, the PPP was not such a significant success (Steuer, 2010).

7.2.4. United States

In the US, the system is still government-owned and operated, with the FAA being both the regulator and the operator of the air traffic control system. It also remains one of the few systems that still relies on taxes, both from taxes levied on passenger tickets and from the general budget to be funded instead of user fees for their services (Oster & Strong, 2007).

This disconnect between the service provided (i.e., the costs) and sources of funding and revenue, has proved to be a constraint in providing upgrades and modernization. The FAA relies on appropriation from the federal budget to not only make capital investments, but also to simply run the system (Oster & Strong, 2007). For example, before the 2012 FAA Air Transportation Modernization and Safety Improvement Act was passed, 23 re-authorizations of 2007 legislation were needed to keep the agency functioning.

After a 1991 Transportation Research Board report that concluded that the ANSs system was falling behind, and was not capable with coping with the increases in traffic brought by airline deregulation, and a later report by the Department of Transportation that reached similar conclusions, the Clinton administration introduce legislation in 1994, to commercialize the system[194]. The proposal was to spin off the ANSs provision from FAA is to create an independent, non-profit, federal corporation, the US Air Traffic Services Corporation (USATS) (Charles & Newman, 1995; Majumdar, 1995). The main characteristics of USATS were (Charles & Newman, 1995):

[194] The issue had been discussed for at least 20 years (Charles & Newman, 1995).

- Ability to charge user fees;
- General aviation users would be exempt from those user fees;
- Ability to finance itself in financial markets;
- It would not be part of the US budget in order to avoid Congress meddling;
- Procurement procedures and regulation would be independent from the rest of the government;
- Labor strikes still would not be allowed[195].

Nevertheless, the proposal did not gain traction in Congress, which was not eager to relinquish all of the oversight it had over ANSs. USATS never came to exist (Oster & Strong, 2007).

After that failed attempt, in 1997, the so-called "Mineta Commission", chaired by the former Congressman[196] Norman Mineta, was given the task by Congress to analyze the federal role in American aviation industry; the air traffic control system was part of the analysis. This commission concluded (National Civil Aviation Review Commission, 1997):

- Federal budget rules for the FAA were "crippling" and "inappropriate for a system controlling commercial operations that needs to be driven by demand for services";

---

[195] Strikes are not allowed for governmental unions in the US. The FAA saw a famous defiance of that law when in 1981 the union of traffic controllers, the Professional Air Traffic Controllers Organization (PATCO), went into a nationwide strike after the labor contract between FAA and PATCO expired. After a court order and a presidential ultimatum demanding that the strike ended, more than 11,000 controllers, out of 16,375, were fired, leaving the FAA with a significant labor shortfall that would last for years to come.
[196] And future Secretary of Commerce under Bill Clinton and Secretary of Transportation under George W. Bush.

- There were "too many cooks" ("the FAA, the DOT[197], the aviation industry, the Administration, and the Congress") meddling with the FAA, making authority and accountability too diffused;
- Increasing operational costs happening under federal budget caps were stopping the necessary capital investments that need to be made to upgrade and modernize the system.

The Mineta Commission did not recommend the commercialization of the FAA ANSP nor the strict separation between operations and regulation. Rather, it suggested the creation of user-based fees to make the system independent from the federal budget, and the creation of an organization inside the FAA that would be responsible for the air traffic control. Although the former recommendation was not adopted, and to this day the FAA still operates with a budget funded from taxes, the latter recommendation was accepted by Congress and the President. In 2000, a new department inside the FAA was created – the Air Traffic Organization (ATO). By 2004, the ATO was fully operational, after 36,000 employees, of a total of more than 53,000 FAA personnel, were transferred to this new organization within the FAA. One major achievement of the ATO was the creation of a single budget for air traffic control expenditures, combining both operational and capital expenses, which ran against the FAA tradition of having two different budgets; this allowed the organization to have a wider perspective of its goals and capabilities. Other changes that can be attributed to the creation of the ATO include

[197] Department of Transportation.

the development of performance metrics and, based on those metrics, operational goals for the organization (Oster & Strong, 2007).

Robyn (2007) argues that creating this new entity is not enough to solve the problems with the current system because the FAA/ATO still considers Congress to be their customers, not the airlines. To solve this, the author proposes the complete separation of the ATO from the FAA, an organization which would retain their safety regulation role, and giving this new ATO borrowing authority and the ability to charge user fees instead of relying in the current tax-based system – similar to the 1994 system proposed in the USATS legislation.

CHAPTER 8 – DATA ENVELOPMENT ANALYSIS[198]

8.1. Model Specification

The model used in this DEA analysis is a standard BCC model with variables returns to scale in an input-oriented model[199]. This specification was chosen because it assumes that the amount of traffic that each ANSP controls each year is a given and that an ANSP has to minimize the inputs needed to provide those services. It considers two inputs and three outputs, with the former being monetary values (the costs of running the system), and the latter being physical outputs related to an ANSP activity. Inputs could have been divided in many more categories, but since DEA is sensitive to the number of variables considered as inputs and outputs, it was decided to use a simple measure that separates costs incurred to provide the ANSs and other costs incurred by each ANSP.

The following inputs and outputs where included in the model:

Inputs:

- Gate-to-gate air traffic management/communications, navigation and surveillance (ATM/CNS) provision costs (€ million). These constitute the costs of providing air traffic management services and the Communication, Navigation and Surveillance infrastructure, including, staff costs, non-staff operating costs

[198] A previous version of the work presented in this chapter has been published as Button, K., & Neiva, R. (2014), Economic Efficiency of European Air Traffic Control Systems, *Journal of Transport, Economics and Policy*, 48(1), 65-80.
[199] The model was estimated using the R software package with the packages "Benchmarking with DEA and SFA", version 0.23 (Bogetoft & Otto, 2011), and "nonparaeff: Nonparametric Methods", version 0.5-8 (Oh & Suh, 2013).

(rentals, energy, insurance, etc.), capital related costs (depreciation and cost of capital), and exceptional items.

- Other gate-to-gate costs of non-control services (€ million). These embrace aeronautical meteorological costs, EUROCONTROL costs, payments for regulatory and supervisory services, and payments to governmental authorities (e.g. for the use of government-owned assets).

Outputs[200]:

- IFR flight-hours controlled by ANSP (thousands). This is variable reflects one of the scale of operations of any ANSP; essentially it is the base, and generally used, unrefined measure of the traffic handled by any provider.
- IFR airport movements controlled by ANSP (thousands). EUROCONTROL/MUAC does not control air traffic in any airports, thus they have a value of zero for this output.
- 1/[Minutes of air traffic flow management (ATFM) delays exceeding 15 minutes] (thousands). The variable is a reflection of the quality of service provided by an ANSP, with the 15-minute delay factor being a widely used international

[200] One output that is not considered is safety, a major policy consideration when looking at ANSPs' performance. The challenge is that actual events are very small in number and tend to be context specific. Some statistical analysis of air transport safety use near air misses whereby aircraft go closer to each other than regulations permit, but this measure does not seem to be a good proxy for actual incidents (Button & Drexler, 2006). Further, there seem to be a uniformly high standard of safety across system because of strict and uniform institutional structures regarding safety (Button & McDougall, 2006; United States Government Accountability Office, 2005). Additionally, as EUROCONTROL reports in their series of PRR studies, data about safety and incidents is still an area where ANSP disclosure is lacking (EUROCONTROL Performance Review Commission, 2013b).

measure[201]. The use of a reciprocal is adopted to turn the variable into a positive scale for purposes of calculation. There are thirteen missing values from the 354 observations for this output and these are replaced by the average value for the respective ANSP.[202]

The DEA efficiencies obtained from this model were then bootstrapped, and statistical analysis was conducted on those bootstrapped results to examine other influences on efficiency, such as potential X-inefficiency (Leibenstein, 1966) that is associated with different ownership arrangements. There is evidence from other transportation sectors and elsewhere that ownership can affect the incentives of management to act efficiently, and in particular that public ownership can, because of unclear objectives and a narrow funding base, lead to less efficient supply that a commercially driven undertaking.

Other independent variables include physical and operational characteristics and ratios related to the ability to cover costs in non-profit environments. The labor mix of employees was also considered to reflect the possibility of administrative overheads being involved, and figures related to the complexity of the traffic that ANSPs have to handle were also included.

[201] The issue of ATFM delays, i.e., delays that can be directly attributed by the actions of ANSs, and distinguishing between the delays that are attributable to “pure” ATFM causes or not is a difficult one. For more on that see the PRR and ACE reports, as well as Cook (2007).
[202] This variable is what in the literature is called an “undesirable output”, i.e., a production output that the DMU does not want to maximize – an assumption in the DEA framework. A common undesirable output is, e.g., pollution. This approach of using the reciprocal is only one of different possible approaches to deal with the presence of this kind of outputs, and it has been chosen for its simplicity and plausibility. For a discussion on this topic see Cooper, Seiford, & Tone (2007).

Independent variables[203]*:*

- Year (*YEAR*). This linear time trend picks up any temporal effects that exist in the provision of ANSs.
- Number of air traffic controllers in operation (*ATCO*). This is intended to pick up scale effects but may also be an indicator of X-inefficiency if the level of ATCO is larger than optimal.
- Number of air traffic controllers in operation per thousands of square kilometers (ATCO km). This reflects the spatial coverage of coverage of each controller. It provides some indication of the length of time a plane is the responsibility of a controller and adds an extra dimension to the measurement of the complexity of the airspace covered.
- Number of en-route sectors (*SECTORS*). The sign of this is not intuitively clear. A large number of sectors may indicate the possibility of congestion and the internalization of sector transfer costs within one ANSP activities, but equally there may be economies of scope and density in handling operations across a number of sectors.

[203] One variable that was not included was seasonal traffic variation. This is due to the fact although EUROCONTROL has been using it for a few years now, they have only reported the exact values of their estimation in the latest report (for 2011), and as such the number of observations would have been quite low when compared to the other variables. Another variable that was not included is military airspace: one of the reasons for that is the lack of available data for all the ANSPs in the model, but since military airspace is often deliberately in areas where commercial air services would not go anyway and, perhaps more importantly, each nation's civil aviation authority, and *ipso facto* their ANSPs tends to interact differently with the military - some have strict delineations of flight areas, but most have a variety of cooperative arrangements under the Flexible Use of Airspace regulations (Commission Regulation (EC) No 2150/2005) – a simple measure of military airspace is likely a poor proxy for differences in the ways civil and military flying co-exist and their impacts on efficiency. For an analysis of military and civilian airspace utilization and interaction in Europe, including under the SES framework, see EUROCONTROL Performance Review Commission (2007) and also the sections about the issue in the various PRR reports, as well as Cook (2007).

- Size of controlled continental airspace in thousands of km^2 (*AREA*). Again it is unclear exactly what the effects of this may be, but it is possible that if the airspace under control is large this may reduce the difficulties of handling heavily trafficked corridors by limiting congestion.
- Dummy variable for type of ownership, with one being governmental agency or department (*AGENCY*). This, and the following variable are aimed at looking the role, if any, the form of institutional structure providing the air navigation services has on the efficiency of the system.
- Dummy variable for type of ownership, with one being government or privately owned corporation/enterprise (*CORP*). This differs from *AGENCY* in that a corporatized entity has a clear managerial objective, namely cost recovery, and this holds irrespective of its ownership.
- Revenues/costs ratio (*REV_COST*). This is seen as a reflection of the financial strength of the ANSP that may affect its ability to invest in efficient technology. It is anticipated to be directly related to the relative efficiency of the provider.
- Staff/air traffic controllers in operations ratio (*STAFF_ATCO*). This captures differences in an ANSP's handling of directly productive and overhead labor in their activities.
- Adjusted density for the airspace (DENS), a measure of the concentration of traffic in a given volume of airspace.

- Structural complexity index (STRUCT), an index of the complexity of airspace that includes number and types of routes, crossing routes, and variable speeds.
- Complexity indicator (COMPLEX), the multiplication of DENS and STRUCT. The effect of these two variables is multiplicative: e.g., the impact of structural complexity is greater when traffic is denser. This variable is available since 2006 only.

Table 18 presents some basic statistics about all variables included in both the DEA estimation and the regression analysis. Note that the last three variables have much smaller number of observations. This is because EUROCONTROL only started to include complexity measures in their reports since 2006. Table 19 presents the correlation matrix for the variables used in the regressions.

Simple linear models were adopted in the regressions because there is no *a priori* expectation of functional form. Four different models were tested: 1. a comprehensive coverage of all variables (all except DENS, STRUCT, and COMPLEX, for which the number of observations is smaller); 2. exclusion of some variables (AREA and ATCO) to reduce multicollinearity problems; 3. a look at physical and external characteristics (AREA and SECTORS[204]); 4. a look at operational characteristics (ATCO, ATCOkm, STAFF_ATCO, and REV_COST).

---

[204] It can be argued that SECTORS is an operational not a physical/external variable. However, it can also be argued that the number of en-route sectors is a result of geography, location of airports, and traffic patterns, all of which are mostly outside the control of an ANSP, and this specification follows that assumption.

AGENCY and YEAR were included in all models. Each model had two different sub-models in which the first one only included AGENCY and the other included AGENCY and CORP – this is done due to the fact that UK's NATS is not like any other commercialized ANSP in Europe[205]. This will test if that different nature results in any differences.

Additionally, a number of other regressions were also conducted, namely with the inclusion of the three complexity variables (DENS, STRUCT, and COMPLEX), and the inclusion of country and year-specific dummy variables into the four models.

[205] The use of this specification with only the UK as an omitted category also makes the results very sensitive.

Table 18 Basic statistics for the variables included in the DEA analysis.

	Costs (€ million)	Provision Costs (€ million)	Revenues (€ million)	Revenues/Costs	Flight Hours (‘000s)	Airport Movements (‘000s)
Mean	219.7	194.1	0.1	220.3	366.8	421.3
Minimum	2.0	2.0	0.0	2.0	5.0	0.0
Maximum	1421.0	1214.0	1.0	1479.0	2302.0	2320.0
Standard Deviation	312.4	277.4	0.2	308.3	472.7	590.1
N	354	354	263	354	354	354

	Composite Flight Hours (‘000s)	Delays (‘000s minutes)	ATCO	Staff	Staff/ATCO	ATCOkm
Mean	476.1	458.7	459	1568	3.5	1.7
Minimum	7.0	0.0	26	100	0.3	0.2
Maximum	2800.0	7906.0	2738	9219	10.9	6.3
Standard Deviation	616.9	885.8	595.3	1947.0	1.6	1.3
N	354	340	354	354	354	354

	AREA (‘000s km^2)	SECTORS	DENS	STRUCT	COMPLEX
Mean	360.5	18.6	5.5	0.8	4.5
Minimum	19.6	1.0	0.8	0.4	0.5
Maximum	2190.0	115.0	11.6	1.4	13.7
Standard Deviation	430.9	25.8	2.8	0.2	3.3
N	354	354	219	219	219

Table 19 Correlation matrix for DEA regression

	Efficiency	YEAR	ATCO	SECTORS	AREA	AGENCY	CORP
Bootstrapped efficiency	1.000	-0.138	0.408	0.398	0.401	0.250	-0.316
YEAR		1.000	-0.013	0.001	-0.009	-0.038	0.039
ATCO			1.000	0.916	0.742	0.169	-0.266
SECTORS				1.000	0.594	0.078	-0.215
AREA					1.000	0.162	-0.235
AGENCY							-0.920
CORP							1.000

	REV_COST	ATCOkm	STAFF_ATCO	DENS	STRUCT	COMPLEX
Bootstrapped efficiency	0.150	-0.331	-0.127	-0.013	0.035	-0.013
YEAR	0.092	-0.020	-0.290	0.075	-0.011	0.034
ATCO	-0.041	0.142	-0.153	0.369	0.189	0.330
SECTORS	-0.005	0.209	-0.190	0.450	0.304	0.455
AREA	-0.076	-0.286	-0.162	0.007	0.027	-0.015
AGENCY	0.183	-0.153	0.041	0.038	-0.087	-0.030
CORP	-0.198	0.153	-0.031	-0.152	-0.013	-0.111
REV_COST	1.000	-0.058	-0.007	0.227	0.049	0.200
ATCOkm		1.000	0.102	0.657	0.526	0.734
STAFF_ATCO			1.000	-0.071	-0.117	-0.063
DENS				1.000	0.421	0.910
STRUCT					1.000	0.728
COMPLEX						1.000

8.2. Results

Figure 9 provides visual details of the DEA results for the ten years and 37 ANSPs analyzed. The columns not shaded are at least 80% as efficient as the most efficient providers[206]. Table 33 and Figure 15 in Appendix II and III, respectively, provide more detailed information.

While this 80% benchmark is inevitably arbitrary, the extent of the variability between the various providers is evident. The ANSPs that have a score of 0.8 or higher in each of the ten years are, EUROCONTROL, Estonia, Finland, France, and the United Kingdom. Some others, like Turkey, moved from outside of the benchmark to being consistently above it, while others like Greece moved the other direction. Fewer providers met the 80% criteria towards the end of the period than at the beginning.

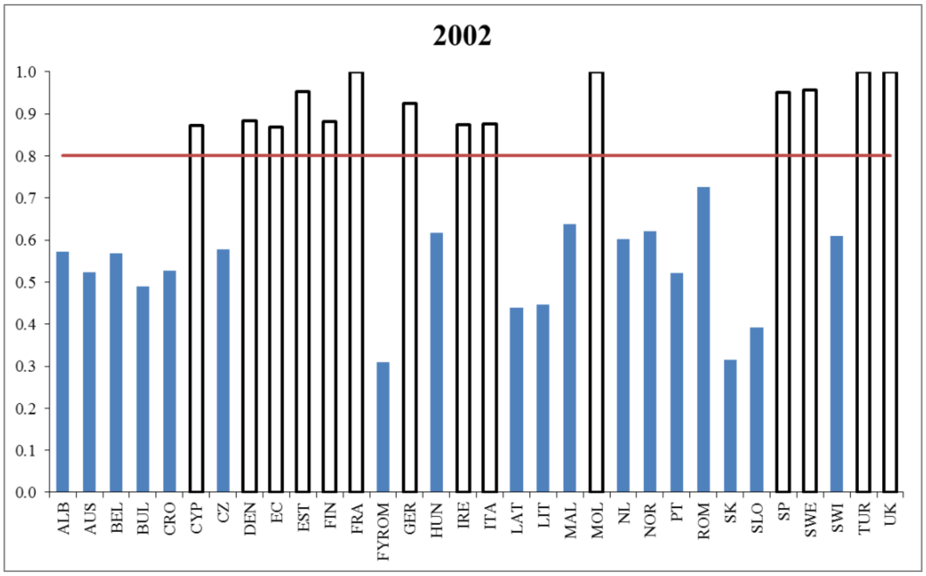
There are also some oddities in the results – for example, the sudden increases to the efficiency frontier of Portugal in 2003, Serbia in 2007, and Turkey in 2002. A look at the input and output data shows that in those years the value for the 1/delays output variable equals one in those countries, and being one the maximum value for that variable it makes the ANSP jump to the efficiency frontier. This show the sensitivity of the DEA analysis to some of the values in the model, and the different specifications tested seem to indicate that this happens mostly because of this “undesirable output” variable. Given the

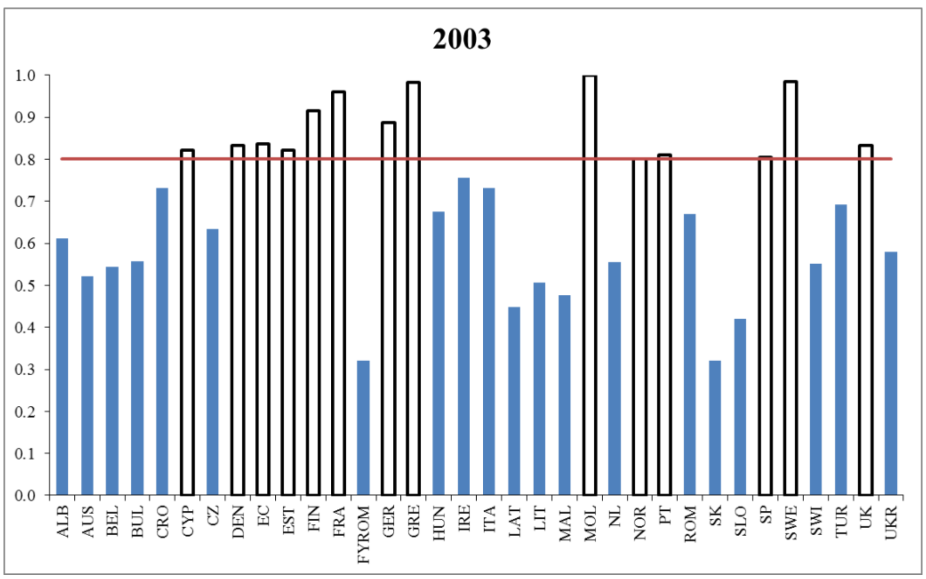
[206] DEA analysis results can be very sensitive to outliers. To test for this, the model was run removing, in one case airspace outside of the 10% and 90% percentiles for 2009, and in another traffic controlled over the same ranges. Additionally, since EUROCONTROL/MUAC is a very different ANSP from the remaining 36, a model that excluded it was also created. Results for these different models were rather similar to the basic model and no appreciable differences in results emerge.

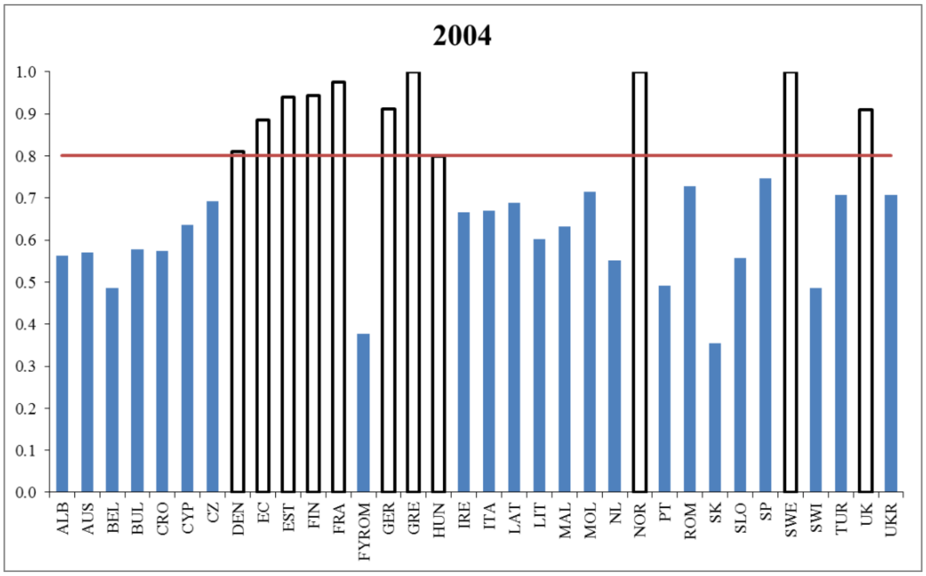
small number of cases in a dataset of more than 350 observations, this does not appear to have any significant impact in the results.

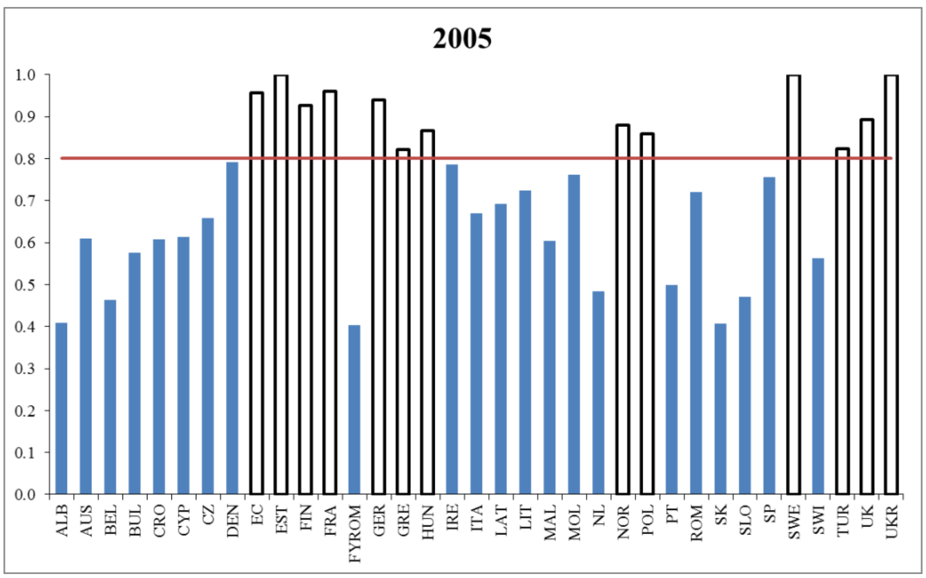
Slack analysis (Table 35 in Appendix II) shows that a large number of DMUs, more than 200, could have achieved the same level of efficiency by reducing the amount of provision costs that they incur. The same is true for the 1/delays output, with more than 200 DMUs having slack to increase this output; however, since this is a reciprocal, it means that if they reduce their amounts of delays, they would be able to maintain the same level of relative efficiency. For the other two inputs, most DMUs have a slack of zero, meaning they are operating at their optimal level. Scale efficiency estimates show that all but 11 DMUs are operating below optimal scale level, but considering the ones that operate 90% or above of optimal level, there are 107 DMUs (out of 354, 30%) in that situation.

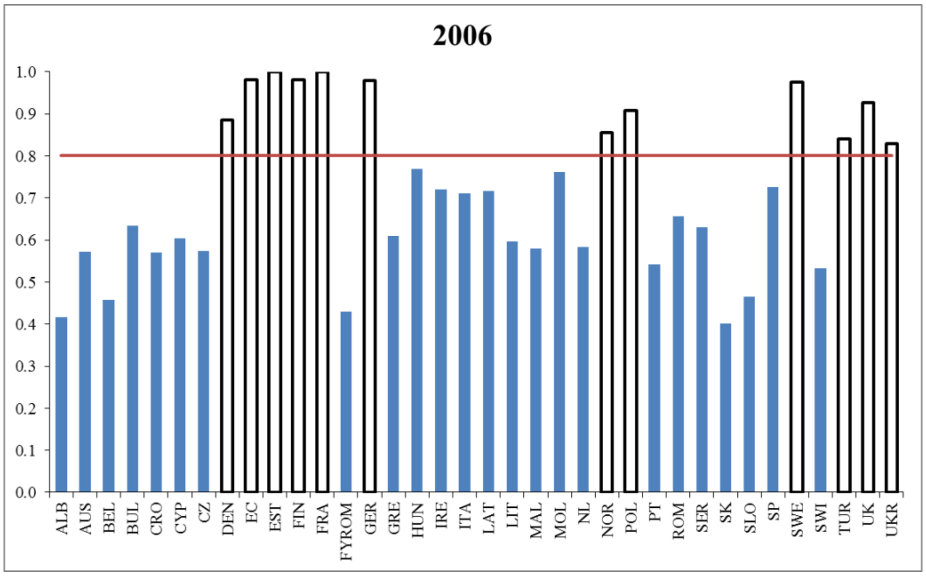
In terms of allocative efficiency (Table 34 in Appendix II), results show extremely high average levels, with an average of almost 96% allocative efficiency. This could either mean that DMUs are using their resources in a very optimized way for their level of technical efficiency, or, more likely, it might simply be a result of the specification used.

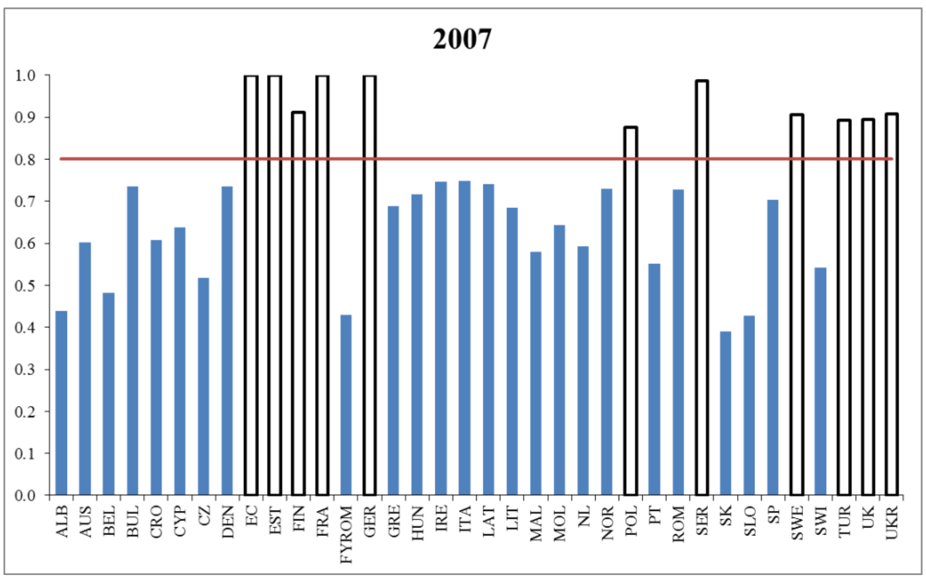

2002
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER HUN IRE ITA LAT LIT MAL MOL NL NOR PT ROM SK SLO SP SWE SWI TUR UK

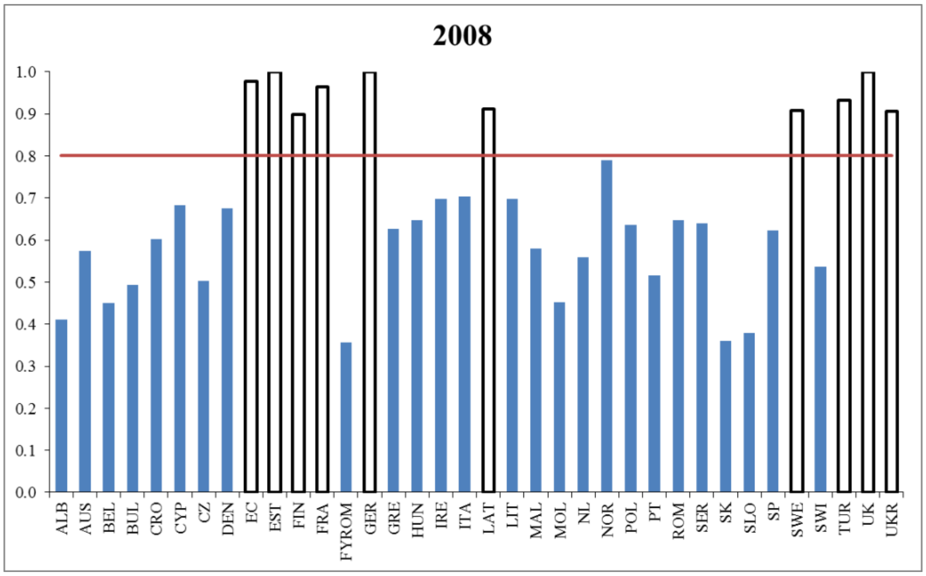

2003
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR PT ROM SK SLO SP SWE SWI TUR UK UKR

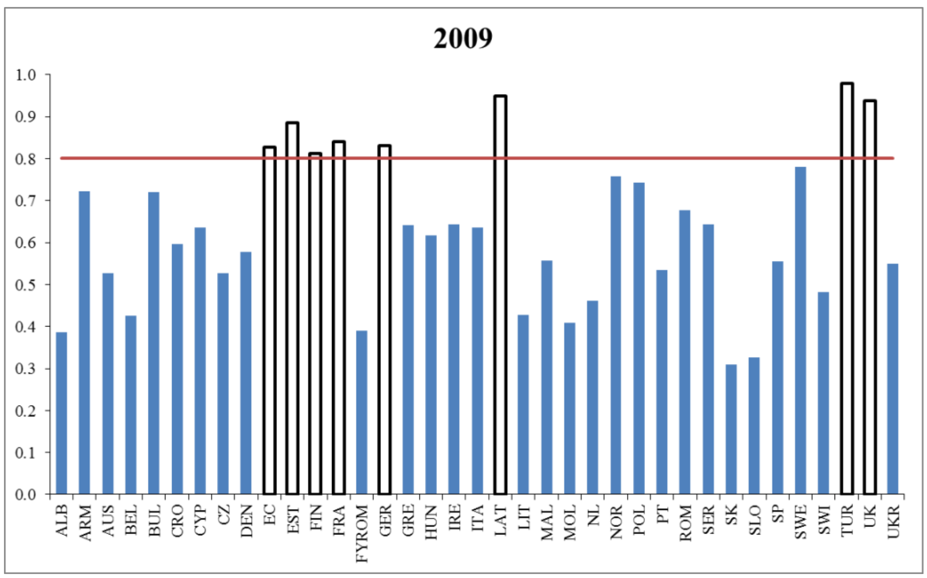

2004
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR PT ROM SK SLO SP SWE SWI TUR UK UKR

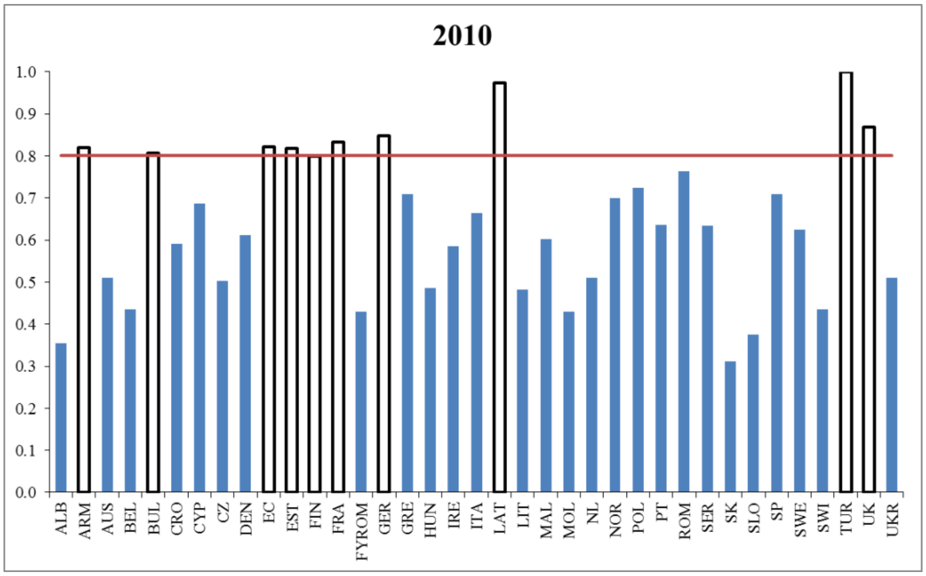

2005
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SK SLO SP SWE SWI TUR UK UKR


2006
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR


2007
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR


2008
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR


2009
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB ARM AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR



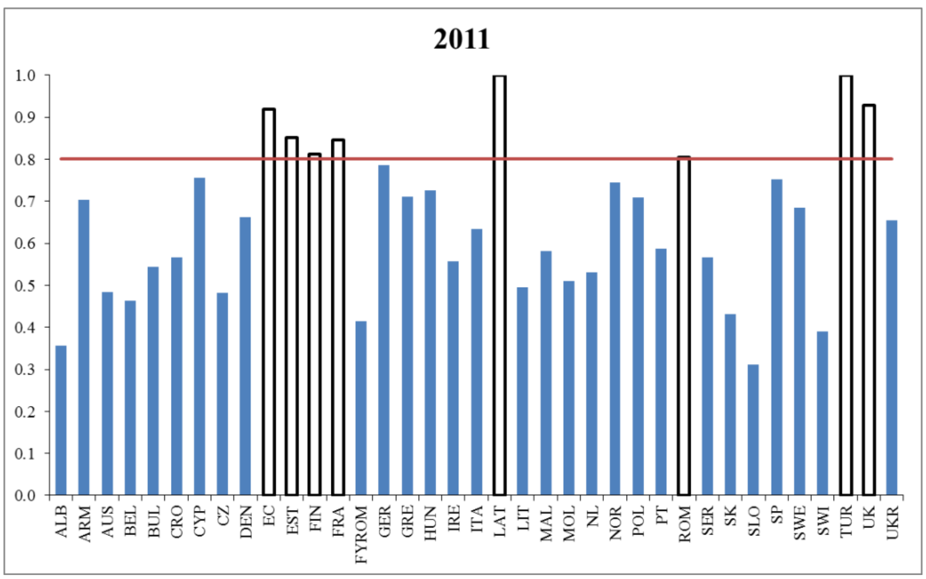


Figure 9 DEA efficiency results for each year

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 10 presents the results for the four basic models for the regression analysis. Table 37 through Table 40 in Appendix IV present some additional models that were tested, which included dummy variables for year and ANSP and traffic complexity variables.

Table 20 DEA bootstrap regression results

Variable	Model 1a	1b	2a	2b
(intercept)	20.27*** (3.953)	20.31*** (3.960)	20.21*** (3.939)	20.24*** (3.942)
YEAR	-9.797e-3*** (-3.836)	-9.796-e3*** (-3.835)	-9.772e-3*** (-3.825)	-9.771e-3*** (-3.822)
AGENCY	4.579e-2** (2.473)	5.507e-3 (0.115)	5.198e-2** (2.905)	2.150e-2 (0.462)
CORP	-	-4.235e-2 (-0.913)	-	-3.259e-2 (-0.710)
AREA	-3.716e-5 (-1.197)	-3.854e-5 (-1.239)	-	-
SECTORS	2.149e-3** (2.954)	1.943e-3** (2.550)	2.977e-3*** (10.476)	2.891e-3*** (9.341)
ATCO	6.006e-5 (1.488)	6.531e-5 (1.601)	-	-
ATCOkm	-5.524e-2*** (-8.040)	-5.463e-2*** (-7.911)	-5.108e-2*** (-9.085)	-5.024e-2*** (-8.898)
STAFF_ATCO	-5.938e-3 (-1.236)	-6.333e-3 (-1.312)	-5.513e-3 (-1.149)	-5.787e-3 (-1.201)
REV_COST	8.030e-2** (2.849)	7.840e-2** (2.774)	7.927e-2** (2.851)	7.747e-2** (2.773)
Adjusted R-squared	0.3858	0.3855	0.3852	0.3844

Variable	Model 3a	3b	4a	4b
(intercept)	15.67** (2.901)	15.64** (2.905)	20.62*** (3.961)	20.63*** (3.976)
YEAR	-7.532e-3** (-2.798)	-7.469e-3** (-2.783)	-9.983e-3*** (-3.851)	-9.946e-3*** (-3.848)
AGENCY	7.817e-2*** (4.040)	-9.319e-3 (-0.182)	3.703e-2** (2.008)	-3.738e-2 (-0.822)
CORP	-	-9.189e-2* (-1.843)	-	-8.017e-2* (-1.789)
AREA	8.428e-5*** (3.765)	8.403e-5*** (3.767)	-	-
SECTORS	1.630e-3*** (4.407)	1.416e-3*** (3.663)	-	-
ATCO	-	-	1.245e-4*** (9.813)	1.172e-4*** (8.819)
ATCOkm	-	-	-4.688-2*** (-8.330)	-4.597e-2*** (-8.160)
STAFF_ATCO	-	-	-8.037e-3* (-1.665)	-8.410e-3* (-1.746)
REV_COST	-	-	9.517e-2*** (3.364)	8.987e-2** (3.169)
Adjusted R-squared	0.2453	0.2504	0.3666	0.3706

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

The results are modest in terms of the overall fit to the data, but the individual coefficients offer some insight as to the influence of the physical and institutional environments in which the ANSPs function.

The negative time variable indicates that efficiency has tended to fall over the period, although given trade-cycle effects on air transportation demand in general, this should be taken at least in part as a reflection of the generic difficulties for ANSPs to adjust their capacity and input mix in line with shifting demand patterns. The analysis with yearly dummy variables shows high levels of significance for the last few years of the dataset, perhaps a result of the financial crisis of the late 2000's and subsequent decline in traffic, leaving ANSPs to have to adjust to falling revenue. This somewhat contrasts to the general finding by EUROCONTROL in their annual reports, which shows increases in financial and economic cost-effectiveness, but their analysis is based on "cost per flight-hour", a somewhat different measure of efficiency.

The positive sign and consistently high level of significance of the variables reflecting the numbers of sectors an ANSP handles suggests that there are economies of some form present although what type of economies are present it is not possible to say. A similar strong link between the geographic areas for which a provider is responsible is found, but again, whether this is the result of less congestion or some scale effect in handling traffic it is impossible to discern[207]. The ratio of overall staff employed by an ANSP to the ATCos employed has a negative coefficient, suggesting that more "front-line" labor relative to support staff increases the technical efficiency of systems.

[207] However, Helios Economics and Policy Services (2006b) suggest that this is due to the presence of economies of scale.

The inclusion of the traffic complexity variables (Table 39 and Table 40 in Appendix IV) seems to indicate that ANSPs that have to deal with these higher levels of complexity have higher levels of relative efficiency. This could be a result of the "incentive" that the presence of this complexity creates, leading ANSPs to become more efficient in order to be able to deal with this increased complexity.

The nature of the ownership effect, embodied in the AGENCY and CORP variables, runs counter to much of the work that has been done in other sectors of air transportation. The findings suggest that ANSPs that are closely linked to the government, basically direct agents of it, are relatively more efficient than those that have been corporatized or are public/private partnerships. This is a robust finding across all of the specifications explored. There may be a number of reasons for this.

While the corporatized entities are more remote from government than those falling into the "agency" grouping, they are subject to what amount to rate-of-return regulation – a *de facto* zero return. This has dangers associated with the "Averch-Johnson effect" (Averch & Johnson, 1962). This comes about because rate-of-return regulation creates a strong incentive for companies to over-invest and have a sub-optimally high capital to labor ratio[208]. While this is a problem normally seen as affecting rate-of-return regulated, profit driven companies, the managerial motivation for efficiency in a non-profit organization should be identical if they are seeking a constrained internal welfare maximization. It may also be that that those that have been corporatized were initially the

[208] This is often embodied in the notion of 'gold-plating' whereby airports' management provides excessively high-quality services within a zero profit framework. It can also be seen in a different context in the form of X-inefficiency whereby the rate-of-return controls allow any cost increases to be passed on to users thus reducing the incentive for management to minimize costs. This problem can be compounded if the ANSP has control over information flows about costs.

least efficient initially and, because of indivisibilities and the retention of legal requirements, are taking time to catch up[209] – in order to test if this is the case or not, a longer time series would be needed, as the one available only starts when most ANSPs had been commercialized already. Put more simply, there remain serious disequilibria in the markets for ANSs with the corporatized entities still adjusting to their new situation[210].

8.3. Spatial Autocorrelation Issues[211]

A possible explanation for the results above is that there may be issues of spatial autocorrelation whereby the efficiency of one ANSP provider is affected by the inefficiencies of those around it. Unlike airlines and airports that involve limited vertical integration with other airlines or airports, one ANSP is often a complementary good with another, and their efficiencies are thus interdependent. This complementarity is the very *raison d'etre* of the Single Sky European initiative.

While the FABs and other SES initiatives do not take place, the system still lives with a great level of fragmentation. To assess the impact of that fragmentation in the efficiency of each individual system and its dependence on the spatial distribution of other systems around it, this section will utilize spatial autocorrelation statistics to study

[209] Shocks to the system can also affect efficiency in the short term. The terrorist attacks on New York and Washington of September 11, 2011, the SARS pandemics, and others, affected air traffic volumes and some ANSPs were probably in a better position to withstand these shocks better than others. NATS for example had only just become a public/private enterprise.

[210] It may also be that there are endogeneity in play that are not captured in the model, and would be difficulty to capture for the short time period covered. In particular, the revenues/costs ratio and staff/ATCos may be endogenous if corporatization or privatization increase the ability to recover costs or improve labor efficiency; in other words they are collinear with whether the organizational structure is a government department or a corporation.

[211] A previous version of the work presented in this section has been published as Button, K., & Neiva, R. (2013), Spatial Autocorrelation in the European Air Navigation System, *Applied Economic Letters*, 20 (15), 1431-1434.

that level of spatial dependence of nearby systems[212]. As the first law of geography states (Tobler, 1970, p. 236), “Everything is related to everything else, but near things are more related than distant things”. The use of spatial autocorrelation is a formal way to measure that degree of interdependence. From a statistical perspective, autocorrelation exists when errors in a statistical model are not independent – a basic premise that models must fulfill in order to be used for hypotheses testing. An ideal model would explain all the variance and leave residuals that are truly independent. In the presence of autocorrelation, the chances of having a Type I error increase, resulting in a “false positive” where the null hypothesis is incorrectly rejected, and a supposed effect is determined to exist where it does not do so. Although this problem of autocorrelation is mostly analyzed in terms of time dependency of observations, spatial dependency of observations can also be an issue when analyzing data where spatial distribution is important (Odland, 1988; Ward & Gleditsch, 2008).

Two different measures of spatial autocorrelation are tested: the distance between each pair of countries and whether each pair of countries are “neighbors” or not, i.e., if their respective airspace share a border. In the context of the SES, the latter assumes a particular importance, as the handing-out of traffic between countries has been identified has a source of inefficiencies and the SES aims to tackle that issue.

In order to test for the existence of spatial autocorrelation, the estimates for the relative levels of efficiency were used to estimate the Moran’s I measure of autocorrelation (Moran, 1950) – Equation 12 .

[212] Spatial autocorrelation was estimated using the R software package with the package “APE: analyses of phylogenetics and evolution in R language”, version 3.0-11 (Paradis, Claude, & Strimme, 2013).

Equation 12

$$I = \frac{n}{S_0} \frac{\sum_{i=1}^{n} \sum_{j=1}^{n} w_{ij}(x_i - \bar{x})(x_j - \bar{x})}{\sum_{i=1}^{n} (x_i - \bar{x})^2}$$

Where w_{ij} is the weight between observations *i* and *j*, in this case either the spatial distance between the two points[213] or a binary variable stipulating whether two points share an airspace border[214], *x* is the measure of interest, in this case the relative levels of efficiency, and S_0 is the sum of all w_{ij}.

Values of *I* range from −1 to 1, indicating perfect dispersion and perfect correlation, respectively.

The expected value, which tends to zero, of *I* under the null hypothesis of no spatial autocorrelation is presented on Equation 13:

Equation 13

$$E(I) = \frac{-1}{N-1}$$

When distances are tested, the values of *I* are great-circle distances[215] between the airports that have the greatest percentage of landings and departures in each respective country pair[216]. Although only crude approximates, and some features of airspace use are omitted, notably flights from A to B that flyover C and domestic flights that never leave a

---

[213] Or the inverse of that distance, to be more precise.

[214] Using different types of weights allows the testing of different hypotheses for spatial organization (Odland, 1988).

[215] Estimated using the tool available at www.gcmap.com.

[216] For example, Lisbon airport (LIS) in Portugal and Schiphol airport (AMS) in the Netherlands are separated by 1848 km.

country's airspace, given that there is no better publicly available data this measure was chosen, as a second-best approach to estimating these distances.[217]

When testing for whether two systems share a border or not, the airspace maps for each system, available in EUROCONTROL Performance Review Commission (2013a) were used[218]. In this case, a weight of one for w_{ij} represents the fact that *i* and *j* share a border and zero if not. One source of potential misestimates in this case is the fact that the dataset only includes 37 systems. As such, there is no information about the interactions with countries outside their combined external borders, so any inefficiencies interacting with these outside countries are not captured. Another problem is that these weights are the same values to pairs of ANSPs with very short airspace boundaries and pairs with very long airspace boundaries.

For this analysis the bias-corrected bootstrapped efficiency results for the last year of the database were used. Figure 10 shows the DEA relative efficiencies for that year.

[217] The ideal scenario would be to have data about all domestic and international flights and do a weighted average of the distances between each country pair.
[218] Note that even if countries do not share a land border they can share an airspace border, e.g., France and the UK.

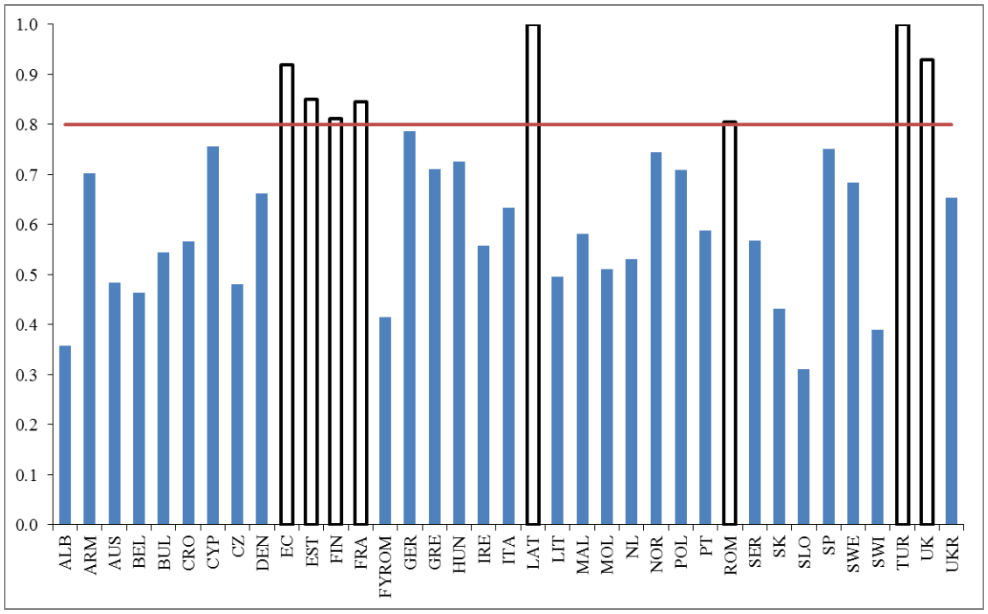


Figure 10 DEA relative efficiencies for 2011

These results are used to compute the two Moran's *I* measures of spatial autocorrelation (Table 21) estimates using distances and shared borders distinctions.

For the first case, the impacts of distance are small, although positive and significant at the 5 percent level. This indicates that there is indeed an issue of spatial autocorrelation in the relative levels of efficiency in the European ANSs system when considered in terms of distances between the biggest airports in each system and that the efficiency of a national system is spatially correlated to the others systems. When using the binary weights for shared airspace borders, the results are still positive and considerably larger, but not significant even at the 10 percent level[219].

[219] Due to the specific nature of the MUAC, which only controls upper airspace, the estimates were also run excluding it, but the exclusion does not significantly affect the results, neither in terms of significance, nor sign or magnitude of the coefficients.

Table 21 Moran's I spatial autocorrelation measures

	Distance	Shared Borders
Observed Moran's I	0.046	0.150
Expected Moran's I	-0.028	-0.028
Standard deviation	0.033	0.112

These results, although not conclusive[220], add to that rationale in support of having a "Single Sky"[221] by suggesting that there is at least some sort of spatial dependency from an economic efficiency perspective, with each ANSP being impacted in its level of efficiency by other systems. In essence, no matter how efficient an air traffic control system is, its interdependency with other systems may lead to drops in its performance if third parties are less efficient.

8.4. Total Factor Productivity

Figure 11 presents the estimation for the average TFP Malmquist indexes for each year of the dataset. Figure 16 and Table 36 in Appendix III and II, respectively, present the individual results for each ANSP. In all these figures TFP values are indexed to the first of the dataset, starting at 100% in that year.

[220] From a technical perspective, when in the presence of spatial autocorrelation, a possible solution to the problem when running regressions is to include dummy variables for each spatial unit in the analysis. This was done (Table 38 in Appendix IV) but the results are not much conclusive, with most of the ownership, operational, and physical variables becoming non-significant, with the majority of significant variables being country dummy variables.

[221] There is, on the other hand, the risk that a merger of airspaces will bring the efficiency down to the lowest common denominator.

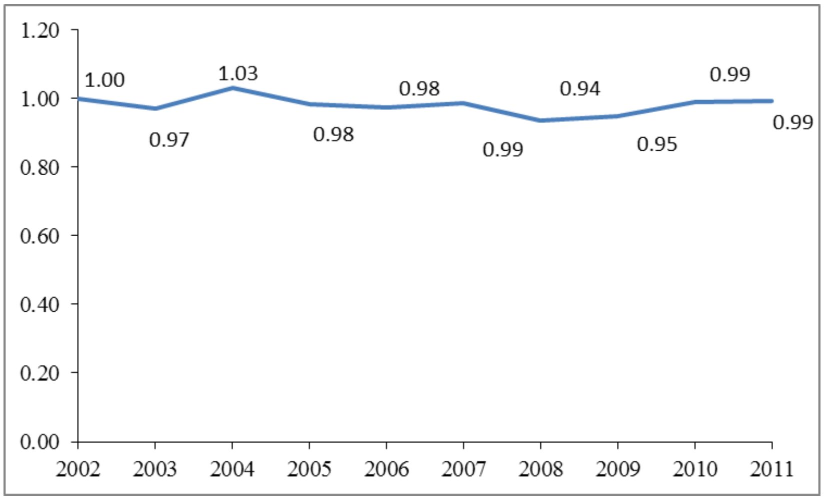


Figure 11 DEA total factor productivity Malmquist indexes – yearly averages

The average yearly figure shows, more or less, constant behavior across the years, with the results hovering around the initial 2002 TFP[222]. The big exception is 2008, where there is a steep decline, perhaps a result of the decline in traffic resulting from the financial crisis, leaving ANSPs with a mostly fixed cost structure while sustaining decline revenues. TFP starts to improve soon after as ANSPs begin to adjust to the new paradigm. A similar thing happened in the beginning of the dataset, with a decline from 2002 to 2003, a period that experienced not only the SARS outbreak but also the decline in traffic that followed the terrorist attacks of September 11th 2001 in the US. It can be the case that ANSPs were still coping with that decline in traffic in 2001-2003 and then managed to adjust their cost structure in 2004 and the following years.

[222] Just as a crude comparison, Eurostat reports that overall productivity in economy of the 27 countries of the European Union – all of the current members except Croatia – increased 10% from 2002 to 2011.

Analyzing the TFPs for the individual ANSPs, it can be seen that ANSPs suffer from a wide range of variation in the TFP values across the years[223], with value of TFP growth in the entire period ranging from -28% to 14%, but with high levels of variation in the middle of the time period, with peaks of -32% and +56%. No ANSP is able, for example, to sustain continued growth in its TFP levels. This can be a result of the volatility of the market in which ANSPs operate, with variations in traffic that are unpredictable and subjected to exogenous conditions in the overall economy, and a cost structure, compounded with full cost recovery requirements, that cannot adjust easily, leaving ANSPs in a difficult position to adapt.

8.5. An Analysis of the Functional Airspace Blocks[224]

This section will do an analysis of the FABS by performing a "simulation" on how would they compare to each if they were operational during the period of the dataset.

This was done by using all the data is reported for individual ANSPs for the period from 2002 through 2011, and then aggregating it[225] at the FAB level to simulate the operation of the European airspace under that paradigm[226]. This is naturally a very crude approximation of what a FAB will eventually constitute, as it is expected, for example, that the number and boundaries of en-route sectors will be adjusted to operate in a more rational manner, thus leading to consolidation of facilities and adjustments on

[223] This behavior was also found in the older EUROCONTROL TFP study (EUROCONTROL Performance Review Commission, 2005b).

[224] A previous version of the work presented in this section has been published as Button, K., & Neiva, R. (2013), Single European Sky and the Functional Airspace Blocks: Will They Improve Economic Efficiency?, *Journal of Air Transport and Management*, 33, 77-80

[225] Except for Luxembourg – which upper space is controlled by the MUAC – and Bosnia and Herzegovina, all the countries that constitute the nine FABs are included in this dataset.

[226] A similar exercise was done by the latest ACE report, where the financial and economic KPIs were estimated at the FAB level, and it was found that the level of dispersion of results was much lower compared to when doing the individual ANSP analysis was conducted.

personnel levels. Given the data that is available at the moment, it allows for a preliminary analysis on how the future FABs stand against each other in terms of economic efficiency.

This exercise was done using the same variable returns to scale DEA specification as in the individual ANSP analysis as well as the same variables as inputs and outputs. Also like in the case of the individual ANSP analysis, the values of relative efficiency for the FABs were bootstrapped to allow for statistical hypothesis testing using ordinary least squares regression. The independent variables used were also the same as before, with the exception of the ownership variables (AGENCY/CORP), which do not make sense to include in this aggregate analysis. The same four basic models were run.

Table 22 presents some basic information about the statistics used in this analysis, and Figure 12 the efficiency results in graphical form for the nine FABs in the ten years of the dataset[227].

[227] Table 41in Appendix V presents the detailed values.

Table 22 Basic statistics for the variables included in the FAB DEA analysis.

	Costs (€)	Provision Costs (€)	Revenues (€)	Revenues/Costs	Flight Hours ('000s)
Mean	835.6	736.2	831.7	1.0	1356.5
Minimum	110.0	92.0	130.0	0.8	286.0
Maximum	3249.0	2796.0	3362.0	1.2	4942.0
Standard Deviation	847.1	724.2	866.9	0.1	1246.1
N	86	86	86	86	86
	Airport Movements ('000s)	Delays ('000s minutes)	ATCO	Staff	
Mean	1593.9	1751.1	1624	5024	
Minimum	120.0	0.0	409	1413	
Maximum	5447.0	15373.0	5811	17873	
Standard Deviation	1477.3	2317.0	1428.6	4695.0	
N	86	86	86	86	
	Airport Movements ('000s)	ATCOkm	AREA ('000s km^2)	SECTORS	
Mean	3.2	1.4	1186.3	68.0	
Minimum	2.1	0.6	400.0	10.0	
Maximum	4.4	3.2	2855.0	262.0	
Standard Deviation	0.7	0.7	786.2	67.8	
N	86	86	86	86	

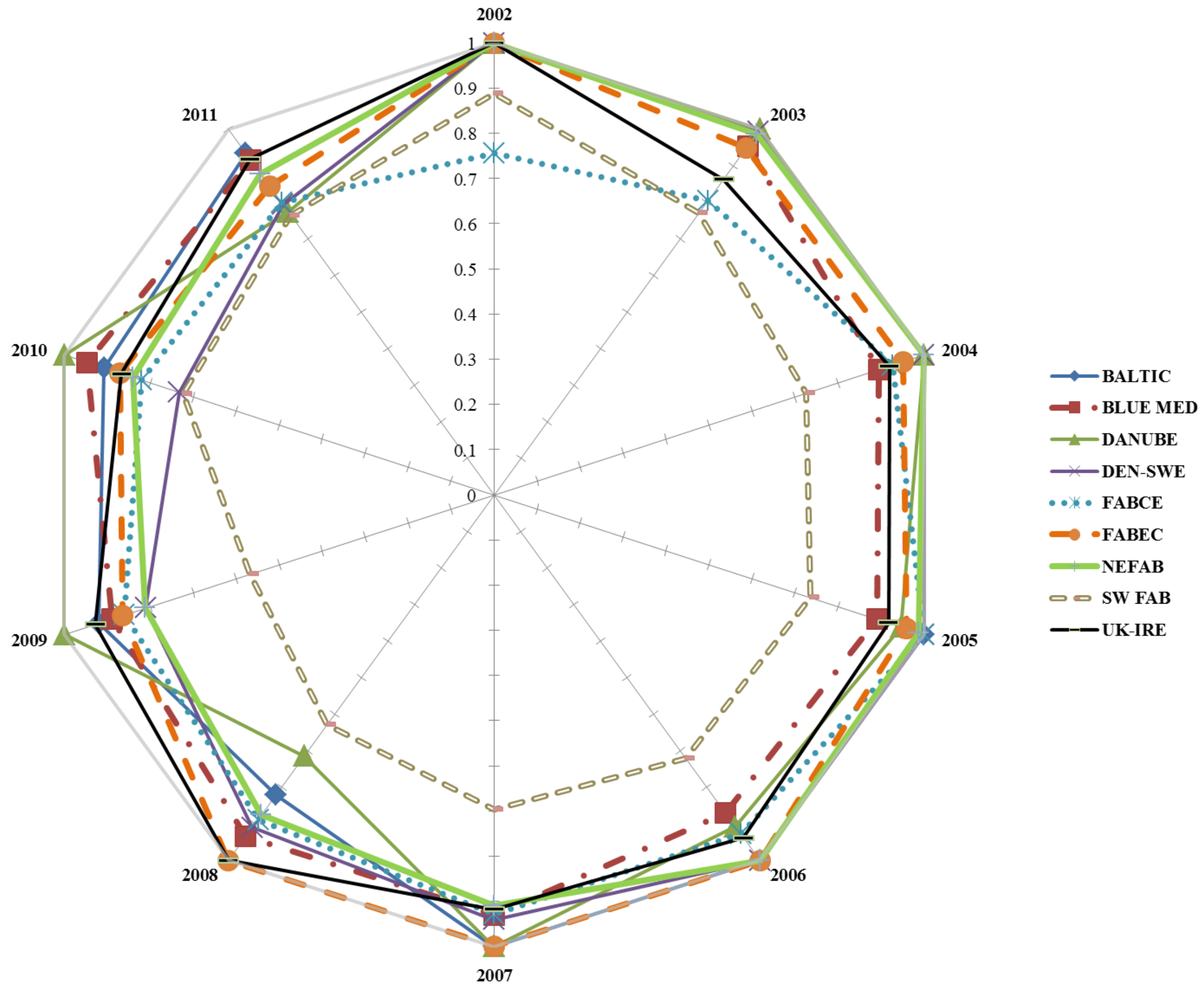


Figure 12 DEA efficiency results for the FAB analysis

Although at first glance it seems that the FAB aggregation would greatly improve efficiency, one must keep in mind that since DEA only estimates relative levels of efficiency, it cannot be concluded that these results are evidence that the creation of the FABs will lead to system-wide increases in efficiency. Indeed, it is quite possible that the system could lead to efficiency being pulled down by the least efficient ANSPs.

What can be determined by the figure is that with the exception of the Southwest FAB (Portugal and Spain), all other blocks tend to consistently stay above the 80% threshold or be very close to it. The Southwest FAB is the one that drops below 70%.

Of the "established blocks", UK-Ireland and Danish-Swedish, the former stayed above the 80% threshold for the entire period, and the latter for all but the last two years (75% in 2010 and 79% in 2011). As expected, since different systems are being combined and all the ANSPs are being average into nine blocks, the levels of efficiency fluctuate much less than in the individual ANSP analysis[228]. In one sense, by combining ANSP's into FABS, there is some evidence that these combinations would at least be consistent. Over time, one would expect some fluctuations in relative efficiency, but in fact the data remains quite stable for most FABs, except for the case of the Danube FAB, which has two big drops in 2008 and 2011 – a result that seems to be a result of a considerable increase in the amount of delays reported by the ANSPs that constitute this FAB for those two years in particular when compared to the other years in the dataset[229]. One explanation for this could be the time it takes for ANSPs to change their structures,

[228] A result consistent with the findings of EUROCONTROL in their estimates of the financial and economic KPIs.
[229] Once again, this result shows the sensitivity of DEA in terms of the variations in the values of outputs.

but this is essentially speculation. If this were so, it could be a cyclical effect, with inflexible equipment needing periodic upgrading[230], or it could be shorter term as a function having to spread fixed costs over fluctuating demand patterns.

Like in the case of individual ANSP analysis, allocative efficiency levels (Table 42 in Appendix V) are also quite high. In fact, they are even higher than in the individual analysis, with an average of more than 98%. Once again, this might be the result of optimal use of resources, or a byproduct of the model specification used. Slack analysis (Table 43 in Appendix V) shows that most of the variables are being used/produced at optimal levels, with the exception of airport movements for which some FABs present some rather large numbers. This suggests that they could improve their performance; however, airport movements control is mostly a localized issue. As such, efficiency gains from the merging of ANSP operations will be less likely at this level. In terms of scale efficiency, out of the 86 DMUs, 15 operate in the optimum scale level, while 38 (44%) operate at levels of 90% or higher of optimum scale, suggesting that the FAB aggregation leads to a more optimal scale, when compared to the individual ANSPs.

To better understand factors that may be affecting the cross-sectional pattern of the programming results and their changes over time, the bias-corrected bootstrapped efficiencies obtained from the DEA efficiencies were regressed on a number of parameters using the same four models as in the individual ANSP analysis.

Table 23 presents the correlation matrix of bilateral relationships for the variables included in the model and Table 24 the regression results.

[230] Given each FAB represents a collection group of ANSPs it is unlikely that all would be upgrading their systems simultaneous.

Table 23 Correlation matrix for FAB DEA regression

	Efficiency	YEAR	ATCOs	SECTORS	AREA
Efficiency	1.000	-0.340	-0.051	0.015	-0.455
YEAR		1.000	-0.003	-0.027	-0.031
ATCOs			1.000	0.979	0.598
SECTORS				1.000	0.503
AREA					1.000

	REV_COST	ATCOkm	STAFF_ATCO
Efficiency	0.341	0.181	0.293
YEAR	0.139	0.000	0.031
ATCOs	0.099	0.650	-0.128
SECTORS	0.179	0.686	-0.062
AREA	-0.229	-0.110	-0.636
REV_COST	1.000	0.259	0.356
ATCOkm		1.000	0.508
STAFF_ATCO			1.000

The correlation matrix show a flagrant case of correlation between the number of ATCos and the number of en-route sectors, with an almost perfect correlation, while other pairs of independent variables have for the most part low levels of correlation.

Table 24 FAB DEA regression results

Variable	Model 1	Model 2	Model 3	Model 4
(intercept)	27.27*** (5.576)	25.04*** (4.291)	22.71*** (4.310)	24.70*** (4.260)
YEAR	-1.321e-2*** (-5.405)	-1.2252e-2*** (-4.204)	-1.086e-2*** (-4.136)	-1.207e-2*** (-4.169)
AREA	-1.301e-4*** (-6.232)	-	-6.947e-5*** (-6.393)	-
SECTORS	-9.127e-4 (-1.522)	-1.959e-4 (-0.871)	4.121e-4** (3.269)	-
ATCO	1.053e-4** (3.035)	-	-	-1.301e-5 (-1.236)
ATCOkm	-7.796e-2** (-3.025)	1.7834e-2 (0.731)	-	2.509e-2 (1.035)
STAFF_ATCO	-4.461e-3 (-0.265)	1.2457e-2 (0.629)	-	6.490e-3 (0.319)
REV_COST	2.742e-1** (2.936)	3.6526e-1** (3.367)	-	3.593e-1** (3.406)
Adjusted R-squared	0.5052	0.2636	0.3883	0.2705

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses.

Regression results show that the variables are mostly non-significant, and the levels of fitness are somewhat low, but a few results stand out, as is the case of the greater number of en-route sectors in Model 3 being associated with higher levels of relative efficiency, while both the area of airspace controlled in Models 1 and 3 and the number of ATCos per unit of area in Model 1 are associated with lower levels of relative efficiency.

These results would suggest that there may be some optimum level of sectors or airspace that would maximize efficiency[231]. The efforts of forming FABs can be considered as a first approximation at achieving this. The difficulty, however, is that this

[231] Analysis with the inclusion of dummy variables for country and year (Table 44and Table 45 in Appendix IV) show some different results, with coefficients for the different variables having more variation in the direction.

information tells little about the parameters of an optimal situation. The FABs are combinations of national airspaces, each of which may well contain areas of efficient ANS provision and some inefficient areas. They are in no way axiomatically optimal spaces; they are just politically determined "market areas". Combining them may increase efficiency over some parts of airspace but equally reduce it over other areas.

From a dynamic, incentive perspective, while the data analysis is insightful in terms of tracking previous patterns of efficiency, it offers little insight into whether the gradualist approach towards a SES via way stations of FABs is either optimal or likely to succeed. While a "big bang" approach limits the opportunities for coalitions to capture-*à la*-Stigler (1971) any reform process during transition, gradualism provides more opening. In the FAB case, the incentives to collaborate are not many, and many national interests can oppose any level of collaboration; particularly, for less efficient blocks there are limited incentives to move forward and that can either limit the full benefits that could come from an ultimately completely integrated European ANS, or *de facto* demand "bribes" in the form of restructuring payments to move forward. By combining in groupings of similar FABs, the bargaining position of any individual ANSPs increases. The outcome of this is much less of a technical economic matter and much more to do with political economy.

The analysis here provides insights into the nature of the FABs by looking at their relative efficiencies over time and some factors that may explain differences. Yet, it describes little more than background to a largely political process, but it does highlight some of the quantitative considerations that need to be considered.

8.6. Difference-in-Differences

From the 37 ANSPs in the dataset only four of them changes ownership status during the 2002-2010 period:

- Macedonia in 2010;
- Poland in 2007;
- Sweden in 2010;
- Slovenia in 2004.

Except for Poland, in which the previously commercialized ANSP that used to be part of the company that also operated the country's airports was spun off into a government agency, the three other ANSPs were commercialized during this period. Considering that the dataset included data from 2002 to 2011[232], it can be seen that the timespan before and after the changes is not extensive, perhaps not leaving enough time for the "treatment" to take effect. Additionally, only four ANSPs remained non-commercialized for the entire 2002-2011 period, leaving a very small number of observations to include in the comparisons with the three ANSPs that were commercialized.

With these caveats in mind, the D-i-D approach was used to test if there were any effects in the relative efficiency due to the chances in ownership[233]. The Polish ANSP was tested against the 29 ANSPs that had been commercialized before the timespan of the dataset, and the other three were compared to the four ANSPs that remain non-commercialized. Table 25 shows the estimate results.

---

[232] Additionally, data for Poland is only available since 2005.

[233] Difference-in-differences was estimated using the R software package with the package "wfe: Weighted Linear Fixed Effects Regression Models for Causal Inference", version 1.2 (Kim & Imai, 2013).

Table 25 Differences-in-differences estimate

	Country			
	Poland	Slovenia	Sweden	FYROM
D-i-D estimate	-0.0382*	0.1704**	-0.1648**	0.0154
t value	-2.055	3.726	-10.215	0.952

Notes **significant at 0.001; * significant at 0.05

Estimates for Macedonia are not significant, not even at the 10% level. For the other three estimates are significant, but rather inconclusive. The "treatment" applied to Poland seems to have resulted in a decrease in efficiency compared to what would have happened if it remained commercialized, but in the case of Slovenia and Sweden, both commercialized during this period, results have different directions. For Slovenia, commercialization seems to have resulted in increased efficiency, and for Sweden, the opposite happened.

The application of the D-i-D approach does not help to address the issue of identification for the impacts of commercialization in the provision of air navigation services. Several reasons can possible explain these results. One is the short period of time considered for the estimate, as all countries change ownership almost at the beginning of the period or at the end, not allowing the D-i-D specification to "capture" the true trends before and/or after the treatment and leading to wrong estimates of the treatment effect. Another possibility is that there might be a number of exogenous variables not captured in the model that are affecting the different ANSPs in different ways. Since the D-i-D approach assumes that trends are the same for both the control and treatment groups, it might be the case that the models used are simply too simplistic to do this analysis.

8.7. Discussion

The structure and governance of ANSPs has been changing over time. They are provided under a number of different regulatory regimes, within a variety of ownership structures, and subject to a number of external conditions. The results of applying programmatic techniques to look at the diversity of systems that exist within Europe indicate a wide dispersion in the relative levels of efficiency that is found and that patterns tends to change over time. Some systems have maintained a high level of relative efficiency; others have improved their relative positions, but a number consistently tend to fall behind. Some of the explanation for this can be found in the operating environment under which ANSPs exist, such as the airspace or number of sectors that they cover, but additional factors within ANSP's control, such as the ratio of ATCos to overall staff are also connected to efficiency. In terms of institutional structure there is no evidence from the data that movement to less government control results in relatively more efficient ANSPs, indeed the opposite finding emerges. However, one should not jump to the conclusion that commercialization efforts are worthless, as there might be other underlying causes in particular characteristics of the systems that could be affecting the results. Some were tested in this analysis, including operational and physical characteristics and the presence of spatial autocorrelation, which estimates indicate that exists at least at some extent, but it might be that some were left out. Causality tests in the form of differences-in-differences estimates do not help to shed a light in this regard, as their results are rather inconclusive.

CHAPTER 9 – STOCHASTIC FRONTIER ANALYSIS

9.1. Model Specification

The SFA model will make use of a production function to model ANSs production in Europe, using both a Cobb-Douglas and a translog specification.[234]

A general specification of a production function can be written as Equation 14,

Equation 14

$$f(x) = f(x, X, \beta, e)$$

Where the output is a result of inputs x, a number of explanatory variables X, unknown parameters β, and an error term e that accounts for unobserved variables and/or inefficiencies.

SFA also can be used with cost functions, but these require prices for the inputs, which are not directly available. As such, it was decided to just use a production function.[235]

This production function will make use of the accounting data presented in the ACE reports for the three inputs, and the single output will be the composite flight-hours reported for each ANSP[236].

---

[234] The models were estimated using the R software package with the package "frontier: Stochastic Frontier Analysis", version 1.1-0 (Coelli & Henningsen, 2013).

[235] For an application of a Cobb-Douglas cost function in a SFA analysis for the European ANSs system and how the issue of lack of input prices was tackled see Competition Economists Group (2011). Estimations with a SFA model similar to the one used in this dissertation found an inefficiency of 57% for the entire system, but the effects of ownership were not tested. For another attempt at modeling a cost function for the industry, this time using a translog parameterization, see Button & Neiva (2013).

The use of a single output, instead of the two outputs used in the DEA specification, is due to the fact the specification and estimation of a production function with multiple outputs involves an additional layer of complexity. Since EUROCONTROL provides this composite output variable for each ANSP, it was decided to go with the simpler case of a single output.

In terms of inputs, the following will be used:

- Staff costs, including both air traffic controllers and other staff;
- Other provision costs, which include capital and depreciation costs, a generic "non-staff operating costs" and "exceptional items";
- Non-provision costs, ranging from aeronautical meteorological costs, EUROCONTROL costs, payments for regulatory and supervisory services, and payments to governmental authorities (e.g. for the use of government-owned assets).

These costs could have been divided in a greater number of categories, as they are reported in 12 different subcategories, but using more categories would have complicated the specification and estimation of the function and possibly lead to some models that would have been undetermined from a computational perspective. It was decided to use a simpler specification that separate operating costs in both staff and non-staff costs (for example in 2011 these represented on average 63% and 37% of operating costs, respectively) as well as another category for non-operating costs, which represent a small percentage of total costs for most of the ANSPs.

---

[236] As a reminder, composite flight-hours, are a composite variable estimated by EUROCONTROL that combines both airport movements and flight-hours controlled.

The use of accounting data in production functions is a contentious subject in the literature; the main drawback being that it is argued that the use of accounting data will lead to parameter estimation that does not represent the underlying technological characteristics of the industry. Thus, post-estimate micro-economic analysis, like for example in terms of the elasticities of inputs, will not be scientifically sound (Bogetoft & Otto, 2011). The traditional neo-classical production function makes use of figures for labor and capital that represent, for example, total man-hours and the value of assets, respectively. However, the data available for this industry does not suit itself well for this. For instance, total man-hours worked are reported only for ATCos, not for other employees of the ANSP[237]. Since the main goal of this analysis is to assess the impact of ownership on efficiency results and not a more detailed micro-economic analysis of the production of air navigation services in Europe, and reported accounting data is mostly consistent throughout the data, it will be used as inputs in the production function.

The Cobb-Douglas and translog specifications are presented, in logarithmic form, in Equation 15 and Equation 16, respectively:

Equation 15

$$\ln(y) = \alpha_0 + \beta_1 \ln(x_1) + \beta_2 \ln(x_2) + \beta_3 \ln(x_3) + v - u$$

Equation 16

$$\begin{aligned}\ln(y) = \alpha_0 &+ \beta_1 \ln(x_1) + \beta_2 \ln(x_2) + \beta_3 \ln(x_3) + \frac{1}{2}\delta_1 \ln(x_1)^2 + \frac{1}{2}\delta_2 \ln(x_2)^2 \\ &+ \frac{1}{2}\delta_3 \ln(x_3)^2 \\ &+ \delta_{12} \ln(x_1)\ln(x_2) + \delta_{13} \ln(x_1)\ln(x_3) + \delta_{23} \ln(x_2)\ln(x_3) + v - u\end{aligned}$$

Where,

[237] See EUROCONTROL Performance Review Commission (2011) for a possible way to address these data issues.

y is the output;

α_0 is the intercept;

x are the inputs with the respective indices $_1$, $_2$, and $_3$ for each of the three different inputs considered;

β and δ are vectors of unknown parameters to be estimated;

v is the random error;

u is the technical inefficiency.

As mentioned before, one of the advantages of SFA is that it allows the inclusion of explanatory variables in the first stage of the analysis. To allow more direct comparisons with what was done in the DEA analysis, the variables included and the models tested will be same four basic models that were used in that DEA analysis.

Table 26 presents the basic statistics for the inputs and outputs included in the production function. Note that the explanatory variables used in the SFA analysis will be the same as the ones used in the second-stage DEA analysis, and their basic statistics have been presented previously (Table 18).

Table 26 Basic statistics for the variables included in the SFA analysis.

	Staff costs (€ million)	Other Provision Costs (€ million)	Non-provision costs (€ million)	Composite Flight Hours (‘000s)
Mean	118.5	36.8	14.3	476.1
Minimum	2.9	1.1	0.0	7.0
Maximum	777.9	221.3	112.0	2800.0
Standard Deviation	161.4	46.6	20.2	616.9
N	354	354	354	354

9.2. Results

Table 27 and Table 28 presents some main results for the four models[238] under the Cobb-Douglas and translog specifications, respectively. In the appendices VIII, IX, and X, the complete results are presented, included the full regressions (Table 50 and Table 51), and the technical inefficiencies in table (Table 46 to Table 49) and figure format (Figure 19 and Figure 20).

[238] A number of different models besides the four basic models were also tested, including the ones that were tested in the DEA analysis. Results follow the same trends reported in these four basic models, so it was decided to just present these.

Table 27 SFA main regression results for Cobb-Douglas specification

	Model			
	1	2	3	4
AGENCY	0.3945*** (4.215)	-0.2933 (-0.304)	-0.2104* (-1.756)	-0.3701*** (-3.387)
Mean inneficiency	77.5%	59.8%	57.0%	54.6%
Mean efficiency	22.5%	40.2%	43.0%	45.5%
σ_u^2	0.0138	0.4429	0.2509	0.2537
σ_v^2	0.0987	0.0297	0.0298	0.0059
λ^2	0.1402	14.9039	8.4313	42.8957
Variance due to inefficiency	12.3%	93.7%	89.4%	97.7%
Variance due to random variation	87.7%	6.3%	10.6%	2.3%
Log likelihood	-104.3407	-173.1192	-163.5451	-151.6983

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; z-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of inefficiency.

Table 28 SFA main regression results for translog specification

	Model			
	1	2	3	4
AGENCY	-0.4476** (-3.136)	-0.4446*** (-3.441)	-0.5875 (-0.738)	-0.4409** (-3.264)
Mean inneficiency	57.2%	56.4%	64.6%	56.3%
Mean efficiency	42.8%	43.6%	35.4%	43.8%
σ_u^2	0.2649	0.2634	0.6099	0.2839
σ_v^2	0.0049	0.0036	0.0230	0.0029
λ^2	54.5020	73.6267	26.5634	97.1366
Variance due to inefficiency	98.2%	98.7%	96.4%	99.0%
Variance due to random variation	1.8%	1.3%	3.6%	1.0%
Log likelihood	-123.7455	-127.6297	-184.4589	-136.9606

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; z-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of inefficiency.

In order to test if using the translog specification instead of the simpler Cobb-Douglas one[239] would increase the significance of the results a simple likelihood ratio test was conducted (Table 29).

Table 29 SFA specifications likelihood ratio tests

	Model			
	1	2	3	4
χ^2	38.81	90.98	41.83	29.48
Probability > χ^2	<0.0001	<0.0001	<0.0001	<0.0001

The assumption in these tests would be that the Cobb-Douglas functions were nested in the associated translog specifications. The results obtained are statistically significantly and indicate that using the translog specifications result in a statistically significant improvement in model fit.

In terms of mean inefficiencies, except for Model 1 of the Cobb-Douglas specification, results are quite consistent, ranging from 55 to 65 percent. The results are also consistent to what Competition Economists Group (2011) estimated (57%) in their SFA analysis using a similar SFA specification – albeit with a cost function instead of a production function. These results suggest that there is a great level of average inefficiency in the European system.

When comparing individual technical efficiencies obtained from this SFA analysis to the ones that were obtained using DEA analysis, as expected, efficiencies obtained using SFA have lower values and more variation between them. On average,

[239] It should be remembered that the Cobb-Douglas is a restricted version of the translog specification, or to put it in another way, the translog function is a generalization of the Cobb-Douglas.

Cobb-Douglas efficiencies were 5.5 percentage points lower than DEA efficiencies, and translog efficiencies 9.1 percentage points.

Table 30 and Figure 13 present some basic comparisons, showing the quartiles of the estimated technical efficiencies and plotting DEA and translog average efficiencies, respectively.

Table 30 DEA vs. SFA efficiencies comparison

		Efficiency	
Percentile	DEA	SFA Cobb-Douglas (average)	SFA translog (average)
25%	0.5435	0.4179	0.3921
50%	0.6690	0.6438	0.5780
75%	0.8339	0.8307	0.8041

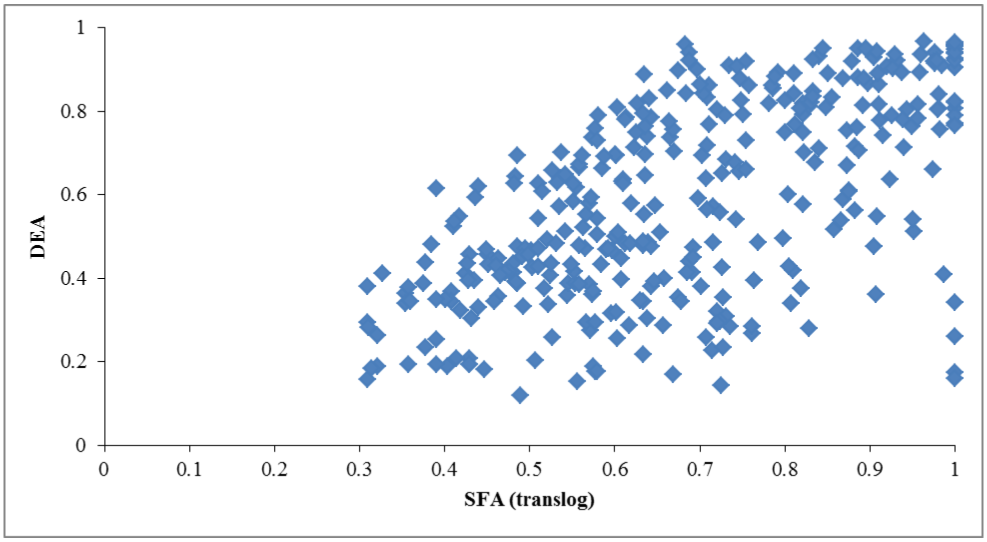


Figure 13 DEA vs. SFA (translog) efficiencies comparison

In terms of the regression results, one must first pay attention to the fact that, opposite to the ordinary least squares regressions used in the second-stage DEA analysis, which measured the impact of explanatory variables on efficiency, these regressions measure the impact on inefficiency. As such, a negative sign in these regressions would be associated with higher levels of efficiency, not lower.

Results are quite similar when compared to the ones obtained in the DEA analysis. For all but one model in which it is statistically significant, the ownership variable AGENCY is associated with higher levels of efficiency, the same result obtained as when using DEA. These similar results also happened in the great majority of other variables with statistically significant coefficients, either operational or physical.

To make it simpler to see those similarities in the results, Table 31 provides a visual comparison between the regressions in the two different specifications. The table presents the number of times that a variable was found to have a positive or negative effect on the efficiency results, with a significance level of at least 10%, or the number of times it was found to be non-significant. [240]

Table 31 DEA vs. SFA explanatory variables comparison

	Model					
	DEA Effect on efficiency			SFA Effect on efficiency		
Variable	Positive	Negative	Non-significant	Positive	Negative	Non-significant
AGENCY	4	0	0	4	1	2
AREA	2	0	0	2	0	2
SECTORS	4	0	0	4	0	2
ATCO	1	0	1	2	2	0
ATCOkm	0	2	0	1	5	0
STAFF_ATCO	0	1	2	0	5	1
REV_COST	3	0	0	2	0	4

9.3. Discussion

The regression results in the SFA analysis have, for the most part, the same direction of what was obtained using a DEA framework, and this happens not only in the "major" variable of interest (ownership) but also in most of the operational and physical variables.

This would suggest that the results are robust across specifications; however, there are some technical reasons in the SFA specifications that can hinder the scientific soundness of these results. In all but one of the specifications, the variance due to inefficiency is the great majority (90% or more) of the variance in the model. This would suggest that there is no noise in the data and that all deviations from the frontier originate

[240] The models compared were the four "main" models of DEA and both SFA specifications.

almost entirely from inefficiency, indicating that a non-stochastic approach (DEA, for example) would work best in this case (Coelli et al., 1998)[241]. However, it is probably unrealistic to assume that the dataset does not have any noise in it, and it is probably the case that the model is biased. A few reasons can potentially be the cause: poor choice and/or misspecification of the functional form, the real noise term is not normally distributed, the real inefficiency term does not follow a truncated normal distribution, or that the noise term and/or the inefficiency term is not independent of the explanatory variables.

A more detailed analysis would be needed to assess what the causes of these results were. Some other variations of the model were tested, including the use of more disaggregated inputs and non-adjusted monetary values; the problem of very high percentages of variance due to inefficiency persists, suggesting that there are other underlying problems in the specifications used.

Nonetheless, these results should not be seen as an indication that it is not possible to model ANSP efficiency using SFA frameworks and that non-stochastic approaches are the only way to do this, but rather that the specifications that were chosen do not seem to be the most suited for this specific problem.

[241] In fact, the only specification in which the explanatory variable AGENCY does not have the same direction as in the DEA models is the one (the first Cobb-Douglas model) where the percentage of variance due to random errors is greater (88% vs. 12%) that the percentage of variance due to inefficiency.

CHAPTER 10 – CONCLUSIONS

10.1. Research Findings

As a reminder, the two research questions/hypotheses that were explicitly tested were:

1. Are "commercialized" ANSPs associated with better economic efficiency than "public agency" ANSPs?

2. Is the impact of non-policy variables, namely operational and physical ones, significant in terms of explaining differences in economic efficiency?

A simple answer to these questions would be "no" to the first one, and "yes" to the second, as results indicate that public agency ANSPs are associated with better economic efficiency than commercialized ones and that operational and physical variables are also associated with differences in economic efficiency.

As for the first research question, although results do indicate that public agencies are indeed associated with better efficiency outcomes, and this is a finding robust across the different specifications used[242], a number of factors might be playing a role here that the model is not capturing. These include the fact that all ANSPs, commercialized or not, are operating in a not-for-profit environment, tantamount to a zero rate-of-return regulation with the problems, X-inefficiency and Averch-Johnson effect, that it brings. It

[242] With the caveat that the SFA specification might have some problems that could potentially undermine the soundness of its results.

might also be the case that the first systems to be commercialized were the ones that were underperforming, because there are more incentives for a government to do so if this is the case. This leads to issues of endogeneity, because systems that were commercialized were not randomly selected to do so. Additionally, although remaining public agencies, most ANSPs already have at least some features that are associated with commercialized ANSPs, namely some sort of independence from the government bureaucracy[243], and the ability to raise their own revenue, be it from charging user fees, or even being able to access capital markets. This leads to a situation where in some cases the distinction between commercialized and non-commercialized ANSPs might be a blurry one, and the *de facto* and *de jure* situation might be different.

For the first issue, it would be interesting to analyze how the industry evolves and its efficiency is affected by Regulation (EC) 1191/2010. This new regulatory scheme will break the full cost recovery requirement in the ANSs system, and will allow ANSPs to keep parts of their profits to create buffers against downturns, instead of having to redistribute them immediately to the airspace users, and then entering the vicious circle of having to increase charges when traffic falls. This will change the rate-of-return requirements for the industry, allowing them to react in different ways to the markets conditions.

For the other point, unfortunately data availability is a problem, and it cannot be used to prove or disprove the point. Another issue also related to data availability is that

[243] On the other hand there are commercialized ANSPs that have great level of dependence from their governments, which nominate their administration and will sack them easily if the government agenda is not being implemented.

the sample of non-commercialized ANSPs is much smaller compared to the sample of commercialized ANSPs, which could bring problems, not only in the modeling of the problem, but also in testing causality links in the commercialization "treatment" – more on data issues will be discussed in Chapter 10.3 – Research Limitations.

As for the second research question, a number of operational and physical variables seem to be significantly associated with efficiency outcomes. An increase in value of the variables related to airspace, numbers of sectors, number of ATCos, and revenue/costs ratio is associated with higher levels of relative efficiency, while an increase in the variables related to the number of ATCos per unit of area and in the total staff/number of ATCos is associated with lower levels of relative efficiency. These results seem to indicate that there are optimized levels of operation for ANSPs; however, it is not possible to determine exactly what that level is, but at least they indicate that systems that operate larger airspaces, more sectors, and are able to recover their costs in a greater extent, are associated with higher levels of efficiency. It was also found that there is at least some level of spatial autocorrelation in the European system that is having impacts at the levels of economic efficiency. All these findings add to previous findings from other sources that the level of fragmentation in the European ANSs system is having impacts on the level of efficiency of the system. Additionally, the results from the total staff/number of ATCos ratio variable seem to indicate that a focus on the "core mission" of providing ANSs. Thus, having more personnel who control traffic as a total of employees is associated with higher level of economic efficiency.

Besides these two main findings, total factor productivity estimates in the DEA framework show that the system did not improve, from this perspective, during the period considered. This is somewhat surprising, as it would be expected that at least some small level of improvement would be achieved. By analyzing the results, it can also be argued that this could be a result of the difficulty of the industry in quickly adapting to changing market conditions, namely declines in traffic resulting from macro-economic factors. The way charges were imposed onto airspace users during this period might also play a role here, since it did not create the conditions for ANSPs for structure their operations in the long-term, making them much more dependent of short-term economic conditions.

10.2. Policy Implications

Commercialization has been promoted as a way to improve the efficiency of ANSPs, and the research in this dissertation aimed to analyze that issue. Results are not conclusive, although the findings suggest that commercialization is not associated with higher levels of efficiency. There are a number of other issues that impact the industry that could be potentially affecting these results. Additionally, results merely indicate that being non-commercialized is associated with higher levels of economic efficiency during this relatively short time period of ten years; it does not provide any indication on how the systems have evolve pre and post-commercialization in order to assess if commercialization was, in fact, associated with improvements in economic efficiency that would have not happened otherwise.

The spatial correlation results and the coefficients of the non-policy variables in the regressions seem to support the rationale behind the efforts of the Single European

Sky to reduce fragmentation in the European ANSs system. The same results have been found before, and in that regard, the dissertation does not greatly contribute to the literature; it merely confirms previous findings using more up-to-date data.

One issue about commercialization is the issue of equity and access to airspace. Traditionally, ANSPs followed principles of network pricing, in which charges were set at the national level. This meant that more remote locations or less used airports, in which the marginal cost to control a single plane is higher, were being subsidized by areas where the marginal costs were smaller due to heavier use of the airspace and terminal facilities. This is still the case in most ANSPs, but some, like the ones in New Zealand and Australia, have adopted location-specific pricing in which the prices charged are more directly linked to the costs of providing the service. For example, in Australia, the price charged in 2013-2014 to a plane that wants to use the control facilities of an airport varies from AUD$1.94 to AUD$14.21 per metric ton of maximum takeoff weight, a factor of more than seven (Australian Competition and Consumer Commission, 2011).

The implementation of location-based charging principles was seen as needed due to issues of equity, and to eliminate, or at least mitigate, cross-subsidies between the different users of the airspace. Network pricing was also seen a protectionist measure to make foreign airlines, which normally travel to more populated areas, subsidize more expensive domestic services within a country. On the other hand, network pricing can also be seen as promoting access to airspace, as it allows users of remote locations to be able to afford services that if charged the full price, they would not be able to do so. It can be also argued that location-based pricing does not take into account the costs of congestion of airspace because even though the marginal cost of controlling an additional plane in a heavily used area might be smaller, the costs that that additional plane imposes on the system can potentially be much larger due to the congestion it imposes on other users of the airspace. This is thus a difficult equilibrium, from wanting to improve equity in terms of charging principles, to not wanting to decrease equity in terms of access to airspace (United States Government Accountability Office, 2005).

Another policy issue with commercialization is how to deal with ANSP profits. Even in the cases where the system is partially (UK) or fully (Canada) privatized, the regulated parts of the ANSPs are subjected to not-for-profit requirements. In Europe, until recently, every profit that was gained in the operation had to be redistributed back to the airspace users. Nevertheless, as it was discussed in Chapter 3.1, this form of rate-of-return regulation has problems in terms of promoting long-term efficiency improvements. Although unlikely, it is not unthinkable that a purely for-profit ANSP would be created at some point, even if it remains to have some sort of pricing regulation. However, this possibility brings another set of questions in itself, as from a policy standpoint it can be argued that the use of profits for the own gain of the ANSP or its shareholders instead of using them to improve social welfare, be it reinvesting in the system or be redistributing the profits to the airspace users, would not be socially optimum.

Experiences in the airport industry can shed some light on this, as there are cases, for example many airports in Europe, where airport operators can use profits to reward shareholders. In contrast, in places like the US federal regulations do not allow revenue diversion and mandates that revenue must be used for capital and operating costs of the airport itself, the local airport system, or other facilities that are directly related to the air transportation of passenger or goods, where profits have to be reinvested back into the system. Seeing how the industry and other stakeholders evolve and behave in Europe with EC Regulation 1191/2010, which will break full cost recovery requirement in the ANSs system, will also provide insights into this question.

10.3. Research Limitations

Perhaps the greatest limitation of this study is the timespan of the data considered in the analysis, which ran from 2002 to 2011. This creates problems for two reasons: due to the amount of sunk costs that it has, and due to the level of specialization that air traffic controllers have, the industry is quite slow at adapting, and it might be the case that ten years, especially ten years that followed a major international event like the terrorist attacks of September 11th, 2001, encompassed several health crisis like SARS or swine flu, and culminated in the greatest economic recession in almost a century[244], is not a timespan long enough to discern long-term trends and study the evolution of such an industry. Nevertheless, the timespan, although not ideal, is large enough to at least get a glimpse of the workings of the industry in terms of economic efficiency.

The other reason is of a more technical nature in what economic analysis is concerned: with such a timespan, it was not possible to encompass the periods before and after commercialization for the majority of ANSPs that are commercialized. Even for the ones in which the timespan studied encompasses changes in ownership – only four out of

[244] On the other hand it can be argued that the existence of major disruptive events like these should be expected, and that these ten years were not atypical in that regard.

37 –, the time elapsed before and after the changes is quite small. This creates a serious issue for identification and causality analysis. This type of analysis is always difficult, because unlike natural sciences, in economics, it is quite difficult to create control and treatment groups to study the effects of a given "treatment". In this particular case, the "treatment" in question was a policy decision of commercializing an ANSP, and it was found that ANSPs did not go through commercialization were associated with higher levels of economic efficiency. These results should be interpreted with care, as other variables might be influencing the results in ways the models are not capturing. There are ways to try to deal with this, and this research tried an approach – the difference-in-differences method – but the results are unclear and do not help much in enlightening the issue. The lack of data undermines the possibility of further study into this question.

Another limitation of the study is the focus on frontier analysis and potential problems within that analysis. Although frontier analysis has been gaining prominence in the literature, other approaches are still useful – namely non-DEA estimations of TFP – and could improve the results of this study. Within the frontier analysis models used, the issue of specification of those models can also be considered a limitation. In both DEA and SFA approaches, it was decided to use an approach that included costs as inputs and physical variables as outputs, but many more possibilities exist, as it cannot be argued that the approach that was followed is the more appropriate to answer the research questions. In the SFA analysis, the choice of a production function over a cost function was done mainly due to the availability of data, but it would also be interesting to try that approach, especially since the results of this SFA analysis seems to indicate the specification used is not the most appropriate for the problem at hand.

The institutional treatment of the ANSPs is also a limitation of the study. Most of the literature, this work included, focuses on the most well-known examples of commercialization in ANSs, but a more complete work would do a more complete analysis from this perspective. A point that deserves some attention, because it can potentially affect the findings in a great extent, is the *level* of commercialization of each system, namely in what ways the national governments still interfere in each system. The case studies showed that commercialization had two major features: independence from governments to operate the system in its best interest, and ability to raise their own revenue. There are shades in the extent to which these features apply in each system. The latter point is more or less settled as existing throughout Europe, as commercialized – and non-commercialized ones as well – at least have the capability of charging user fees, and do not need normally to rely on taxation; the former point is not as clear. Being a government corporation does not guarantee that the operation of the company is independent from the government. The government is normally part of the management appointment process, In an extreme case, it can not only appoint and sack management at will, but can also have great influence in how the ANSP is run[245]; in this more extreme case it could be argued that although being a *de jure* commercialized ANSP, it can be considered a *de facto* government agency, with all the drawbacks that situation implies. On the other hand, a non-commercialized ANSP can be allowed to operate as a *de facto*

[245] Be it directly, or through regulatory agencies, for example.

commercialized one, with little interference from the government. A more detailed analysis of the specificities of each system would greatly improve this work.

Finally, another limitation of the study is the focus on the European ANSs system – a limitation that resulted largely from the availability of data. The inclusion of other systems would increase the interest of this study. A “natural” inclusion would be the US, which has a system that is so often compared to the European one. Other systems like Canada, South Africa, Australia, and New Zealand also represent very interesting case studies that could potentially improve the study. Besides these more “obvious” potential inclusions, there are other systems around the world that also would be an interesting addition to the study, either from an economic perspective or an institutional one. Two good examples of these understudied ANPSs are the multinational endeavors that are present in Africa and Central America, the *L'Agence pour la Sécurité de la Navigation aérienne en Afrique et à Madagascar* (ASECNA)[246], and the *Corporación Centroamericana de Servicios de Navegación Aérea* (COCESNA)[247], respectively, which from a public policy and institutional point-of-view, would provide very interesting cases on how these came to be and how they are performing.

10.4. Other Considerations

10.4.1. Challenges in Commercialization

Although commercialization is a simple concept in theory, the particular circumstances in which ANSPs operate bring a number of challenges that can complicate the implementation of auctions to provide service. ANSPs operate in a highly technical,

[246] More info at www.asecna.aero.
[247] More info at www.cocesna.org.

highly regulated environment, with long-lived equipment that relies on very specialized employees to operate the system. A number of questions can then be asked (Laffont & Tirole, 1993; Williamson, 1976): who will have the ownership of the equipment? The operator? The regulator, government, or other public entity? Who is responsible for capital investments and modernization efforts? If the operator is responsible, how long does the contract need to be to allow the operator to have a reasonable return on investment?

"Reasonable return on investment" also needs definition and is a challenge in itself. Since employees, namely ATCos, are so expensive to train, will they move from one operator to the other? Some of the issues have already been explored in auctions of other types of transportation infrastructure – operation of rail services, for example, which might include rolling stock or train conductors. Those experiences might provide insights into running auctions for the provision of ANSs.

Another issue in this entire process are transaction costs (Laffont & Tirole, 1993). Setting up an auction in a very technical industry like ANSs would probably involve a great number of experts that would be able to correctly assess the technical soundness of the proposals. Also, being an industry that needs to operate seamlessly 24 hours a day, any transfer of responsibility between operators might involve large transition periods, with the corresponding costs associated with that situation. On the other hand, the move to more standardization of procedures and equipment could facilitate transitions between operators if auctions are put in place. Finally, the issue on how to deal with possible disruptions to the aviation industry also needs to be addressed in the contract. The aviation industry is widely affected by exogenous factors like the economic situation of its markets, public health (SARS, swine flu) or environmental (Icelandic volcano) conditions, or terrorist actions (September 11th, 2011 attacks). The price proposed in the auction and its allowed evolution along the years is based on a given number of assumptions that cannot possibly encompass all possible outcomes[248]. Ways to handle these events have to be included in the contract, possibly by allowing for renegotiation of prices, but with the caveat that those renegotiation clauses could be used by an operator to try and renegotiate (and raise) prices just because their traffic forecasts were too optimistic or the price presented in the bid was artificially low in order to win the auction.

The experiences with commercialization already in place provide insights into many of these issues and will help in framing future attempts at it.

10.4.2. Capacity and Innovation

Another issue with commercialization is how the system will be able to react to increasing demand and how commercialized systems will be able to innovate and introduce new technologies. This is a major policy consideration at a time when both in Europe and the US major technological programs aimed at increasing capacity are being introduced. Proponents of privatization and commercialization efforts have long been arguing that taking firms away from government control would allow them to raise more capital to invest and that innovation will be promoted.

[248] An additional issue about pricing is how can it evolve even in "ordinary" circumstances, since if imposing a "inflation adjustments only" rule is a form of price-capping/CPI-X (with a "X" of zero), with the vicissitudes that price-capping is associated with – namely regulatory capture, regulatory taking, and quality concerns (Laffont & Tirole, 1993).

Experiences with commercialization have shown that there is evidence that this might be the case. While in countries like the US, the ANSP struggles to find support to finance their investment programs and modernization efforts; self-funded commercialized systems have been able to go through with theirs with almost or no need for government funds to be involved[249]. A major feature that seems to impact this is the separation from political pressures. As the Mineta Report stated, having "too many cooks" trying to influence an ANSP does not work well. It would be naïve to think that a commercialized ANSP would not be suffer pressures from the different stakeholders, but if it is granted a level of independence that allows it to follow their own agendas[250], not the politicians', it is much more likely that competent management would be able to operate the system to its own, and its customers, good. One should be careful, thus, in asserting that commercialization is the cause for this improved behavior. As discussed in Chapter 10.3, the commercialization literature mainly focuses on a handful of systems, and in these systems, commercialization did indeed bring a great level of independence from political pressures. However, conceivably that level of independence could be achieved without commercialization[251]. Although this occurs in these specific cases of commercialized systems, it can be that there are other commercialized systems in which independence from political agendas has not been achieved – or non-commercialized systems that have achieved it.

---

[249] A major exception is UK's NATS which need government support right after its creation and following the events of September 11th, 2001. Since then, the PPP was de-leveraged and has not needed any governmental support again.

[250] And also if it is able to fund itself; but it can be easily argued that it is more likely that an *independent* ANSP does also have the ability to raise its own revenue than one that remains *dependent* from its government.

[251] Commercialization might still remain the easiest way to achieve that level of independence, though.

APPENDIX I – ANSP FEATURES

Table 32 Air navigation service providers ownership features

ANSP	Commercialized? (year)	ANSP	Commercialized? (year)	ANSP	Commercialized? (year)
Albania	Yes (1999)	Greece	No (-)	Portugal	Yes (1998)
Armenia	Yes (1997)	Hungary	Yes (2002)	Romania	Yes (1991)
Austria	Yes (1994)	Ireland	Yes (1994)	Serbia	Yes (2003)
Belgium	Yes (1998)	Italy	Yes (2000)	Slovakia	Yes (2000)
Bulgaria	Yes (2001)	Latvia	Yes (1997)	Slovenia	Yes (2004)
Croatia	Yes (2000)	Lithuania	Yes (2001)	Spain	Yes (1990)
Cyprus	No (-)	Macedonia	Yes (2010)	Sweden	Yes (2010)
Czech Rep.	Yes (1995)	Malta	Yes (2002)	Switzerland	Yes (1996)
Denmark	Yes (2001)	Moldova	Yes (1994)	Turkey	No (-)
Estonia	Yes (1998)	MUAC	No (-)	UK	Yes (2001)
Finland	Yes (1991)	Netherlands	Yes (1993)	Ukraine	Yes (1992)
France	No (-)	Norway	Yes (?)		
Germany	Yes (1993)	Poland	No (2007)		

Note: from the non-commercialized ANSPs only Poland had been commercialized before. Norway's ANSP was founded in 1947, but the date of commercialization was not found.
Source: EUROCONTROL Performance Review Commission (2013a)

APPENDIX II – ANSP DEA ANALYSIS: TABLES

Table 33 DEA efficiency results

Year	Country	Efficiency	Year	Country	Efficiency	Year	Country	Efficiency
2002	ALB	0.5714	2002	FYROM	0.3095	2005	POL	0.8585
2003	ALB	0.6122	2003	FYROM	0.3214	2006	POL	0.9082
2004	ALB	0.5625	2004	FYROM	0.3766	2007	POL	0.8760
2005	ALB	0.4097	2005	FYROM	0.4026	2008	POL	0.6350
2006	ALB	0.4167	2006	FYROM	0.4286	2009	POL	0.7427
2007	ALB	0.4396	2007	FYROM	0.4286	2010	POL	0.7238
2008	ALB	0.4107	2008	FYROM	0.3571	2011	POL	0.7086
2009	ALB	0.3854	2009	FYROM	0.3896	2002	PT	0.5220
2010	ALB	0.3538	2010	FYROM	0.4286	2003	PT	0.8097
2011	ALB	0.3571	2011	FYROM	0.4143	2004	PT	0.4912
2009	ARM	0.7222	2002	GER	0.9237	2005	PT	0.4980
2010	ARM	0.8194	2003	GER	0.8872	2006	PT	0.5423
2011	ARM	0.7024	2004	GER	0.9118	2007	PT	0.5510
2002	AUS	0.5236	2005	GER	0.9389	2008	PT	0.5154
2003	AUS	0.5209	2006	GER	0.9798	2009	PT	0.5349
2004	AUS	0.5700	2007	GER	1.0000	2010	PT	0.6359
2005	AUS	0.6094	2008	GER	1.0000	2011	PT	0.5876
2006	AUS	0.5723	2009	GER	0.8308	2002	ROM	0.7250
2007	AUS	0.6020	2010	GER	0.8483	2003	ROM	0.6692
2008	AUS	0.5736	2011	GER	0.7863	2004	ROM	0.7282
2009	AUS	0.5272	2003	GRE	0.9823	2005	ROM	0.7202
2010	AUS	0.5101	2004	GRE	1.0000	2006	ROM	0.6569
2011	AUS	0.4831	2005	GRE	0.8208	2007	ROM	0.7279
2002	BEL	0.5673	2006	GRE	0.6100	2008	ROM	0.6465
2003	BEL	0.5439	2007	GRE	0.6884	2009	ROM	0.6779
2004	BEL	0.4852	2008	GRE	0.6257	2010	ROM	0.7638
2005	BEL	0.4626	2009	GRE	0.6410	2011	ROM	0.8050
2006	BEL	0.4583	2010	GRE	0.7088	2006	SER	0.6298
2007	BEL	0.4813	2011	GRE	0.7109	2007	SER	0.9873
2008	BEL	0.4502	2002	HUN	0.6170	2008	SER	0.6395
2009	BEL	0.4254	2003	HUN	0.6748	2009	SER	0.6435
2010	BEL	0.4348	2004	HUN	0.7985	2010	SER	0.6341
2011	BEL	0.4630	2005	HUN	0.8662	2011	SER	0.5673
2002	BUL	0.4895	2006	HUN	0.7688	2002	SK	0.3143
2003	BUL	0.5561	2007	HUN	0.7157	2003	SK	0.3214
2004	BUL	0.5768	2008	HUN	0.6477	2004	SK	0.3542
2005	BUL	0.5750	2009	HUN	0.6176	2005	SK	0.4078
2006	BUL	0.6340	2010	HUN	0.4861	2006	SK	0.4012
2007	BUL	0.7360	2011	HUN	0.7265	2007	SK	0.3900
2008	BUL	0.4928	2002	IRE	0.8734	2008	SK	0.3604
2009	BUL	0.7198	2003	IRE	0.7549	2009	SK	0.3092

2010	BUL	0.8068	2004	IRE	0.6653	2010	SK	0.3110
2011	BUL	0.5447	2005	IRE	0.7851	2011	SK	0.4317
2002	CRO	0.5267	2006	IRE	0.7200	2002	SLO	0.3913
2003	CRO	0.7314	2007	IRE	0.7466	2003	SLO	0.4195
2004	CRO	0.5737	2008	IRE	0.6970	2004	SLO	0.5577
2005	CRO	0.6082	2009	IRE	0.6426	2005	SLO	0.4712
2006	CRO	0.5698	2010	IRE	0.5845	2006	SLO	0.4658
2007	CRO	0.6083	2011	IRE	0.5576	2007	SLO	0.4267
2008	CRO	0.6013	2002	ITA	0.8758	2008	SLO	0.3780
2009	CRO	0.5972	2003	ITA	0.7308	2009	SLO	0.3269
2010	CRO	0.5900	2004	ITA	0.6699	2010	SLO	0.3753
2011	CRO	0.5658	2005	ITA	0.6689	2011	SLO	0.3103
2002	CYP	0.8729	2006	ITA	0.7112	2002	SP	0.9512
2003	CYP	0.8220	2007	ITA	0.7492	2003	SP	0.8041
2004	CYP	0.6361	2008	ITA	0.7041	2004	SP	0.7465
2005	CYP	0.6132	2009	ITA	0.6363	2005	SP	0.7552
2006	CYP	0.6033	2010	ITA	0.6642	2006	SP	0.7259
2007	CYP	0.6382	2011	ITA	0.6340	2007	SP	0.7025
2008	CYP	0.6828	2002	LAT	0.4396	2008	SP	0.6226
2009	CYP	0.6350	2003	LAT	0.4490	2009	SP	0.5554
2010	CYP	0.6871	2004	LAT	0.6883	2010	SP	0.7089
2011	CYP	0.7554	2005	LAT	0.6923	2011	SP	0.7512
2002	CZ	0.5771	2006	LAT	0.7157	2002	SWE	0.9561
2003	CZ	0.6337	2007	LAT	0.7410	2003	SWE	0.9848
2004	CZ	0.6915	2008	LAT	0.9105	2004	SWE	1.0000
2005	CZ	0.6578	2009	LAT	0.9495	2005	SWE	1.0000
2006	CZ	0.5746	2010	LAT	0.9741	2006	SWE	0.9748
2007	CZ	0.5175	2011	LAT	1.0000	2007	SWE	0.9052
2008	CZ	0.5023	2002	LIT	0.4470	2008	SWE	0.9079
2009	CZ	0.5261	2003	LIT	0.5069	2009	SWE	0.7806
2010	CZ	0.5032	2004	LIT	0.6026	2010	SWE	0.6246
2011	CZ	0.4812	2005	LIT	0.7239	2011	SWE	0.6841
2002	DEN	0.8827	2006	LIT	0.5962	2002	SWI	0.6102
2003	DEN	0.8326	2007	LIT	0.6852	2003	SWI	0.5509
2004	DEN	0.8105	2008	LIT	0.6976	2004	SWI	0.4859
2005	DEN	0.7919	2009	LIT	0.4276	2005	SWI	0.5619
2006	DEN	0.8857	2010	LIT	0.4826	2006	SWI	0.5322
2007	DEN	0.7342	2011	LIT	0.4951	2007	SWI	0.5423
2008	DEN	0.6751	2002	MAL	0.6375	2008	SWI	0.5372
2009	DEN	0.5769	2003	MAL	0.4762	2009	SWI	0.4822
2010	DEN	0.6121	2004	MAL	0.6326	2010	SWI	0.4357
2011	DEN	0.6619	2005	MAL	0.6042	2011	SWI	0.3901
2002	EC	0.8680	2006	MAL	0.5799	2002	TUR	1.0000
2003	EC	0.8362	2007	MAL	0.5801	2003	TUR	0.6922
2004	EC	0.8846	2008	MAL	0.5801	2004	TUR	0.7072
2005	EC	0.9556	2009	MAL	0.5577	2005	TUR	0.8231
2006	EC	0.9809	2010	MAL	0.6012	2006	TUR	0.8403
2007	EC	1.0000	2011	MAL	0.5810	2007	TUR	0.8921
2008	EC	0.9772	2002	MOL	1.0000	2008	TUR	0.9319
2009	EC	0.8278	2003	MOL	1.0000	2009	TUR	0.9786
2010	EC	0.8210	2004	MOL	0.7143	2010	TUR	1.0000
2011	EC	0.9197	2005	MOL	0.7619	2011	TUR	1.0000
2002	EST	0.9524	2006	MOL	0.7619	2002	UK	1.0000

2003	EST	0.8214
2004	EST	0.9405
2005	EST	1.0000
2006	EST	1.0000
2007	EST	1.0000
2008	EST	1.0000
2009	EST	0.8857
2010	EST	0.8182
2011	EST	0.8507
2002	FIN	0.8816
2003	FIN	0.9152
2004	FIN	0.9443
2005	FIN	0.9257
2006	FIN	0.9807
2007	FIN	0.9115
2008	FIN	0.8982
2009	FIN	0.8123
2010	FIN	0.7995
2011	FIN	0.8115
2002	FRA	1.0000
2003	FRA	0.9594
2004	FRA	0.9759
2005	FRA	0.9595
2006	FRA	1.0000
2007	FRA	1.0000
2008	FRA	0.9643
2009	FRA	0.8397
2010	FRA	0.8331
2011	FRA	0.8450
2007	MOL	0.6429
2008	MOL	0.4524
2009	MOL	0.4082
2010	MOL	0.4286
2011	MOL	0.5102
2002	NL	0.6023
2003	NL	0.5542
2004	NL	0.5516
2005	NL	0.4837
2006	NL	0.5841
2007	NL	0.5928
2008	NL	0.5582
2009	NL	0.4613
2010	NL	0.5095
2011	NL	0.5305
2002	NOR	0.6198
2003	NOR	0.8005
2004	NOR	1.0000
2005	NOR	0.8788
2006	NOR	0.8546
2007	NOR	0.7304
2008	NOR	0.7889
2009	NOR	0.7585
2010	NOR	0.6999
2011	NOR	0.7436
2003	UK	0.8325
2004	UK	0.9089
2005	UK	0.8932
2006	UK	0.9274
2007	UK	0.8952
2008	UK	1.0000
2009	UK	0.9378
2010	UK	0.8682
2011	UK	0.9289
2003	UKR	0.5795
2004	UKR	0.7074
2005	UKR	1.0000
2006	UKR	0.8292
2007	UKR	0.9069
2008	UKR	0.9054
2009	UKR	0.5493
2010	UKR	0.5095
2011	UKR	0.6545

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 34 DEA allocative efficiency results

Year	Country	Efficiency	Year	Country	Efficiency	Year	Country	Efficiency
2002	ALB	0.9412	2002	FYROM	1.0000	2005	POL	0.9390
2003	ALB	0.7778	2003	FYROM	0.9600	2006	POL	0.9254
2004	ALB	0.7619	2004	FYROM	0.9565	2007	POL	0.9121
2005	ALB	0.9231	2005	FYROM	0.9565	2008	POL	0.9751
2006	ALB	0.9231	2006	FYROM	0.9524	2009	POL	0.9691
2007	ALB	0.8966	2007	FYROM	0.9524	2010	POL	0.9662
2008	ALB	0.9333	2008	FYROM	0.9600	2011	POL	0.9815
2009	ALB	0.9412	2009	FYROM	0.9167	2002	PT	0.9916
2010	ALB	0.9744	2010	FYROM	0.9091	2003	PT	0.9727
2011	ALB	0.9524	2011	FYROM	0.9091	2004	PT	0.9867
2009	ARM	0.9231	2002	GER	0.9070	2005	PT	0.9854
2010	ARM	0.9231	2003	GER	0.8953	2006	PT	0.9850
2011	ARM	1.0000	2004	GER	0.8934	2007	PT	0.9865
2002	AUS	0.9245	2005	GER	0.8994	2008	PT	0.9889
2003	AUS	0.9295	2006	GER	0.9157	2009	PT	0.9863
2004	AUS	0.9268	2007	GER	1.0000	2010	PT	0.9778
2005	AUS	0.9266	2008	GER	1.0000	2011	PT	0.9878
2006	AUS	0.9487	2009	GER	0.9980	2002	ROM	0.9039
2007	AUS	0.9464	2010	GER	0.9941	2003	ROM	0.9361
2008	AUS	0.9540	2011	GER	0.9957	2004	ROM	0.9490
2009	AUS	0.9600	2003	GRE	0.9850	2005	ROM	0.9643
2010	AUS	0.9596	2004	GRE	1.0000	2006	ROM	0.9644
2011	AUS	0.9635	2005	GRE	0.9944	2007	ROM	0.9764
2002	BEL	0.8492	2006	GRE	0.9989	2008	ROM	0.9749
2003	BEL	0.8387	2007	GRE	0.9977	2009	ROM	0.9762
2004	BEL	0.8449	2008	GRE	0.9509	2010	ROM	0.9778
2005	BEL	0.8370	2009	GRE	0.9510	2011	ROM	0.9843
2006	BEL	0.8538	2010	GRE	0.9472	2006	SER	0.9001
2007	BEL	0.8431	2011	GRE	0.9516	2007	SER	0.9417
2008	BEL	0.8564	2002	HUN	0.9636	2008	SER	0.9787
2009	BEL	0.8550	2003	HUN	0.9392	2009	SER	0.9840
2010	BEL	0.8483	2004	HUN	0.9379	2010	SER	0.9685
2011	BEL	0.8646	2005	HUN	0.9423	2011	SER	0.9680
2002	BUL	0.9584	2006	HUN	0.9460	2002	SK	0.9615
2003	BUL	0.9447	2007	HUN	0.9577	2003	SK	0.9492
2004	BUL	0.9423	2008	HUN	0.9686	2004	SK	0.9546
2005	BUL	0.9506	2009	HUN	0.9610	2005	SK	0.9606
2006	BUL	0.9491	2010	HUN	0.9782	2006	SK	0.9516
2007	BUL	0.9492	2011	HUN	0.9857	2007	SK	0.9691
2008	BUL	0.9460	2002	IRE	0.9351	2008	SK	0.9684
2009	BUL	0.9504	2003	IRE	0.9581	2009	SK	0.9546
2010	BUL	0.9467	2004	IRE	0.9638	2010	SK	0.9540
2011	BUL	0.9441	2005	IRE	0.9600	2011	SK	0.9649
2002	CRO	0.9620	2006	IRE	0.9614	2002	SLO	0.9608
2003	CRO	0.9518	2007	IRE	0.9613	2003	SLO	0.9283
2004	CRO	0.9650	2008	IRE	0.9628	2004	SLO	0.9286
2005	CRO	0.9639	2009	IRE	0.9539	2005	SLO	0.9116
2006	CRO	0.9598	2010	IRE	0.9554	2006	SLO	0.9181
2007	CRO	0.9806	2011	IRE	0.9639	2007	SLO	0.9394
2008	CRO	0.9596	2002	ITA	0.9347	2008	SLO	0.9329
2009	CRO	0.9834	2003	ITA	0.9510	2009	SLO	0.9485

2010	CRO	0.9913	2004	ITA	0.9536	2010	SLO	0.9414
2011	CRO	0.9870	2005	ITA	0.9630	2011	SLO	0.9355
2002	CYP	0.9337	2006	ITA	0.9589	2002	SP	0.9608
2003	CYP	0.9376	2007	ITA	0.9575	2003	SP	0.9597
2004	CYP	0.9438	2008	ITA	0.9804	2004	SP	0.9627
2005	CYP	0.9224	2009	ITA	0.9843	2005	SP	0.9584
2006	CYP	0.9150	2010	ITA	0.9948	2006	SP	0.9580
2007	CYP	0.9305	2011	ITA	0.9945	2007	SP	0.9583
2008	CYP	0.9232	2002	LAT	0.9630	2008	SP	0.9636
2009	CYP	0.9066	2003	LAT	0.9655	2009	SP	0.9618
2010	CYP	0.8873	2004	LAT	1.0000	2010	SP	0.9545
2011	CYP	0.8458	2005	LAT	1.0000	2011	SP	0.9460
2002	CZ	0.9928	2006	LAT	0.9735	2002	SWE	0.9747
2003	CZ	0.9894	2007	LAT	0.9341	2003	SWE	0.9684
2004	CZ	0.9855	2008	LAT	0.9756	2004	SWE	0.9468
2005	CZ	0.9862	2009	LAT	0.9870	2005	SWE	1.0000
2006	CZ	0.9880	2010	LAT	0.9803	2006	SWE	0.9982
2007	CZ	0.9937	2011	LAT	1.0000	2007	SWE	0.9989
2008	CZ	0.9930	2002	LIT	1.0000	2008	SWE	0.9937
2009	CZ	0.9908	2003	LIT	1.0000	2009	SWE	0.9988
2010	CZ	0.9890	2004	LIT	1.0000	2010	SWE	0.9958
2011	CZ	0.9917	2005	LIT	0.9848	2011	SWE	0.9944
2002	DEN	0.9833	2006	LIT	0.9909	2002	SWI	0.9776
2003	DEN	0.9402	2007	LIT	0.9828	2003	SWI	0.9820
2004	DEN	0.9480	2008	LIT	0.9967	2004	SWI	0.9898
2005	DEN	0.9319	2009	LIT	0.9500	2005	SWI	0.9998
2006	DEN	0.8913	2010	LIT	0.9736	2006	SWI	0.9976
2007	DEN	0.9349	2011	LIT	0.9862	2007	SWI	0.9947
2008	DEN	0.9482	2002	MAL	0.9091	2008	SWI	0.9944
2009	DEN	0.9843	2003	MAL	0.9655	2009	SWI	0.9936
2010	DEN	0.9990	2004	MAL	0.9167	2010	SWI	0.9922
2011	DEN	0.9689	2005	MAL	0.9600	2011	SWI	0.9997
2002	EC	0.9810	2006	MAL	0.9231	2002	TUR	1.0000
2003	EC	0.9778	2007	MAL	0.9286	2003	TUR	0.9678
2004	EC	0.9782	2008	MAL	0.9630	2004	TUR	0.9790
2005	EC	1.0000	2009	MAL	0.9286	2005	TUR	0.9732
2006	EC	1.0000	2010	MAL	0.9655	2006	TUR	0.9819
2007	EC	1.0000	2011	MAL	0.9375	2007	TUR	0.9946
2008	EC	0.9969	2002	MOL	1.0000	2008	TUR	0.9884
2009	EC	1.0000	2003	MOL	0.8000	2009	TUR	0.9938
2010	EC	1.0000	2004	MOL	1.0000	2010	TUR	1.0000
2011	EC	1.0000	2005	MOL	0.8571	2011	TUR	1.0000
2002	EST	1.0000	2006	MOL	0.8571	2002	UK	1.0000
2003	EST	1.0000	2007	MOL	0.8889	2003	UK	0.9969
2004	EST	1.0000	2008	MOL	0.9231	2004	UK	0.9988
2005	EST	1.0000	2009	MOL	0.9333	2005	UK	0.9981
2006	EST	1.0000	2010	MOL	0.9412	2006	UK	0.9984
2007	EST	1.0000	2011	MOL	0.8750	2007	UK	0.9987
2008	EST	0.9965	2002	NL	0.9212	2008	UK	1.0000
2009	EST	1.0000	2003	NL	0.9048	2009	UK	0.9996
2010	EST	1.0000	2004	NL	0.9061	2010	UK	0.9990
2011	EST	0.9983	2005	NL	0.9003	2011	UK	0.9996
2002	FIN	0.9720	2006	NL	0.8715	2003	UKR	0.9888

2003	FIN	0.9549
2004	FIN	0.9566
2005	FIN	0.9496
2006	FIN	0.9479
2007	FIN	0.9528
2008	FIN	0.9559
2009	FIN	0.9585
2010	FIN	0.9585
2011	FIN	0.9650
2002	FRA	1.0000
2003	FRA	0.9980
2004	FRA	0.9970
2005	FRA	0.9993
2006	FRA	1.0000
2007	FRA	1.0000
2008	FRA	0.9973
2009	FRA	0.9963
2010	FRA	0.9853
2011	FRA	0.9873
2007	NL	0.8697
2008	NL	0.8670
2009	NL	0.8831
2010	NL	0.8796
2011	NL	0.9245
2002	NOR	0.9899
2003	NOR	0.9954
2004	NOR	1.0000
2005	NOR	0.9990
2006	NOR	0.9983
2007	NOR	0.9965
2008	NOR	0.9991
2009	NOR	0.9976
2010	NOR	0.9979
2011	NOR	0.9948
2004	UKR	0.9994
2005	UKR	1.0000
2006	UKR	0.9828
2007	UKR	0.9795
2008	UKR	0.9830
2009	UKR	0.9936
2010	UKR	0.9920
2011	UKR	0.9560

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 35 DEA inputs and outputs slacks

Year	Country	Provision costs	Other costs	Slacks IFR flight hours	Airport movements	1/delays
2002	ALB	0.5714	0.0000	0.0000	7.8163	0.0000
2003	ALB	2.4490	0.0000	0.0000	6.8367	0.0000
2004	ALB	2.8125	0.0000	0.0000	9.0000	0.5833
2005	ALB	0.8194	0.0000	0.0000	8.0000	0.5083
2006	ALB	0.8333	0.0000	0.0000	4.2857	0.0000
2007	ALB	1.3187	0.0000	0.0000	4.7347	0.0000
2008	ALB	0.8214	0.0000	0.0000	9.0000	0.5250
2009	ALB	0.7708	0.0000	0.0000	10.0000	0.5119
2010	ALB	0.3538	0.0000	0.0000	12.6667	0.4861
2011	ALB	0.7143	0.0000	0.0000	11.5714	0.4896
2009	ARM	0.7222	0.0000	10.3333	0.0000	0.0000
2010	ARM	0.8194	0.0000	12.4167	0.0000	0.0000
2011	ARM	0.0000	0.0000	10.4167	0.0000	0.0000
2002	AUS	10.3299	0.0000	0.0000	0.0000	0.4135
2003	AUS	9.9628	0.0000	0.0000	0.0000	0.3963
2004	AUS	11.3762	0.0000	0.0000	0.0000	0.3404
2005	AUS	12.1949	0.0000	0.0000	0.0000	0.2818
2006	AUS	8.0092	0.0000	0.0000	0.0000	0.2552
2007	AUS	9.0206	0.0000	0.0000	0.0000	0.1908
2008	AUS	7.6591	0.0000	0.0000	0.0000	0.1570
2009	AUS	5.6905	0.0000	0.0000	0.0000	0.2486
2010	AUS	5.8408	0.0000	0.0000	0.0000	0.2480
2011	AUS	4.9314	0.0000	0.0000	0.0000	0.2538
2002	BEL	24.3818	0.0000	72.0000	0.0000	0.3488
2003	BEL	26.8520	0.0000	75.0000	0.0000	0.3452
2004	BEL	24.1540	0.0000	62.5000	0.0000	0.3918
2005	BEL	24.8081	0.0000	65.0000	0.0000	0.4111
2006	BEL	23.2523	0.0000	71.0000	0.0000	0.3747
2007	BEL	25.9833	0.0000	69.0000	0.0000	0.3561
2008	BEL	23.4656	0.0000	63.5000	0.0000	0.3571
2009	BEL	22.5662	0.0000	63.5000	0.0000	0.3888
2010	BEL	24.0103	0.0000	66.0000	0.0000	0.3843
2011	BEL	22.6972	0.0000	76.0000	0.0000	0.3295
2002	BUL	3.3209	0.0000	0.0000	22.5503	0.0000
2003	BUL	4.2119	0.0000	0.0000	12.5079	0.0000
2004	BUL	4.7946	0.0000	0.0000	13.7672	0.0000
2005	BUL	4.4871	0.0000	0.0000	12.2434	0.0000
2006	BUL	4.9725	0.0000	0.0000	3.5026	0.0000
2007	BUL	5.6825	0.0000	0.0000	0.0000	0.0000
2008	BUL	3.5219	0.0000	0.0000	0.0000	0.2482
2009	BUL	5.9604	0.0000	0.0000	6.1058	0.0000
2010	BUL	6.8372	0.0000	0.0000	22.9735	0.0000
2011	BUL	4.2426	0.0000	0.0000	0.0000	0.6863
2002	CRO	1.2715	0.0000	0.0000	0.0000	0.5784
2003	CRO	2.9597	0.0000	0.0000	3.3810	0.0000
2004	CRO	1.4407	0.0000	0.0000	0.0000	0.7311
2005	CRO	1.7618	0.0000	0.0000	0.0000	0.8085
2006	CRO	1.9851	0.0000	0.0000	0.0000	0.8094

2007	CRO	0.7377	0.0000	0.0000	0.0000	0.7624
2008	CRO	2.4497	0.0000	0.0000	0.0000	0.7532
2009	CRO	0.6062	0.0000	0.0000	0.0000	0.7363
2010	CRO	0.0286	0.0000	0.0000	0.0000	0.7167
2011	CRO	0.4625	0.0000	0.0000	0.0000	0.6895
2002	CYP	2.3078	0.0000	0.0000	0.0000	0.9084
2003	CYP	2.2552	0.0000	0.0000	0.0000	0.8707
2004	CYP	2.0586	0.0000	0.0000	0.0000	0.8938
2005	CYP	3.1246	0.0000	0.0000	0.0000	0.8941
2006	CYP	3.6478	0.0000	0.0000	0.0000	0.8855
2007	CYP	3.2183	0.0000	0.0000	0.0000	0.8675
2008	CYP	4.0967	0.0000	0.0000	0.0000	0.8422
2009	CYP	5.0709	0.0000	0.0000	0.0000	0.8471
2010	CYP	6.8600	0.0000	0.0000	0.0000	0.8290
2011	CYP	9.9489	0.0000	0.0000	0.0000	0.8298
2002	CZ	0.0000	0.0000	0.0000	0.0000	0.7676
2003	CZ	0.0000	0.0000	0.0000	0.0000	0.7335
2004	CZ	0.0000	0.0000	0.0000	0.0000	0.6653
2005	CZ	0.0000	0.0000	0.0000	0.0000	0.6232
2006	CZ	0.0000	0.0000	0.0000	0.0000	0.5969
2007	CZ	0.0000	0.0000	0.0000	0.0000	0.5517
2008	CZ	0.0000	0.0000	0.0000	0.0000	0.5211
2009	CZ	0.0000	0.0000	0.0000	0.0000	0.5509
2010	CZ	0.0000	0.0000	0.0000	0.0000	0.5492
2011	CZ	0.0000	0.0000	0.0000	0.0000	0.4968
2002	DEN	2.2378	0.0000	0.0000	0.0000	0.3816
2003	DEN	8.6580	0.0000	0.0000	0.0000	0.3887
2004	DEN	7.8842	0.0000	0.0000	0.0000	0.3499
2005	DEN	10.1820	0.0000	0.0000	0.0000	0.3724
2006	DEN	16.9197	0.0000	0.0000	0.0000	0.3871
2007	DEN	9.7120	0.0000	0.0000	0.0000	0.3640
2008	DEN	7.7093	0.0000	0.0000	0.0000	0.3567
2009	DEN	1.7968	0.0000	0.0000	0.0000	0.4016
2010	DEN	0.0000	0.0000	0.0000	0.0000	0.3772
2011	DEN	0.0000	4.6006	0.0000	0.0000	0.1605
2002	EC	3.4718	0.0000	0.0000	9.8752	0.2814
2003	EC	4.1809	0.0000	0.0000	9.0691	0.2581
2004	EC	4.4229	0.0000	0.0000	6.8522	0.1948
2005	EC	0.0000	0.0000	0.0000	4.3666	0.1166
2006	EC	0.0000	0.0000	0.0000	1.9482	0.0536
2007	EC	0.0000	0.0000	0.0000	0.0000	0.0000
2008	EC	0.0000	0.7775	0.0000	7.3431	0.0000
2009	EC	0.0000	0.0000	0.0000	2.8887	0.0654
2010	EC	0.0000	0.0000	0.0000	2.1497	0.0491
2011	EC	0.0000	0.0000	0.0000	0.7390	0.0067
2002	EST	0.0000	0.0000	8.6667	0.0000	0.0000
2003	EST	0.0000	0.0000	0.0000	1.0000	0.1250
2004	EST	0.0000	0.0000	0.0000	4.0000	0.0417
2005	EST	0.0000	0.0000	0.0000	0.0000	0.0000
2006	EST	0.0000	0.0000	0.0000	0.0000	0.0000
2007	EST	0.0000	0.0000	0.0000	0.0000	0.0000
2008	EST	0.0000	0.0000	0.0000	0.0000	0.0000
2009	EST	0.0000	0.0000	0.0000	5.5102	0.0000

2010	EST	0.0000	0.0000	0.0000	4.0000	0.8000
2011	EST	0.0000	0.0000	0.0000	0.0000	0.5012
2002	FIN	2.9104	0.0000	23.5000	0.0000	0.3767
2003	FIN	4.4188	0.0000	13.5000	0.0000	0.4363
2004	FIN	4.4695	0.0000	17.0000	0.0000	0.5374
2005	FIN	5.2286	0.0000	15.0000	0.0000	0.5256
2006	FIN	5.6159	0.0000	22.0000	0.0000	0.4610
2007	FIN	4.9881	0.0000	20.0000	0.0000	0.4826
2008	FIN	4.7581	0.0000	19.0000	0.0000	0.4788
2009	FIN	4.1754	0.0000	18.5000	0.0000	0.4739
2010	FIN	4.1125	0.0000	14.5000	0.0000	0.5335
2011	FIN	3.8098	0.0000	13.5000	0.0000	0.5197
2002	FRA	0.0000	0.0000	0.0000	0.0000	0.0000
2003	FRA	0.0000	0.0000	0.0000	0.0000	0.0001
2004	FRA	0.0000	3.6537	0.0000	0.0000	0.0000
2005	FRA	0.0000	0.0000	0.0000	0.0000	0.0000
2006	FRA	0.0000	0.0000	0.0000	0.0000	0.0000
2007	FRA	0.0000	0.0000	0.0000	0.0000	0.0000
2008	FRA	0.0000	6.4100	0.0000	5.1544	0.0000
2009	FRA	0.0000	7.8888	0.0000	19.1537	0.0000
2010	FRA	31.1216	0.0000	0.0000	0.2152	0.0004
2011	FRA	26.4506	0.0000	0.0000	0.0000	0.0000
2002	FYROM	0.0000	0.0000	0.0000	1.8776	0.0000
2003	FYROM	0.3214	0.0000	0.0000	3.3673	0.0000
2004	FYROM	0.3766	0.0000	0.0000	6.3469	0.0000
2005	FYROM	0.4026	0.0000	0.0000	6.3265	0.0000
2006	FYROM	0.4286	0.0000	0.0000	5.8367	0.0000
2007	FYROM	0.4286	0.0000	0.0000	5.8367	0.0000
2008	FYROM	0.3571	0.0000	0.0000	4.8367	0.0000
2009	FYROM	0.7792	0.0000	0.0000	6.8367	0.0000
2010	FYROM	0.8571	0.0000	0.0000	5.8367	0.0000
2011	FYROM	0.8286	0.0000	0.0000	6.3469	0.0000
2002	GER	141.9356	0.0000	0.0000	0.0000	0.0006
2003	GER	163.5118	0.0000	0.0000	0.0000	0.0008
2004	GER	173.7552	0.0000	0.0000	0.0000	0.0002
2005	GER	168.8701	0.0000	0.0000	0.0000	0.0000
2006	GER	143.2576	0.0000	0.0000	0.0000	0.0000
2007	GER	0.0000	0.0000	0.0000	0.0000	0.0000
2008	GER	0.0000	0.0000	0.0000	0.0000	0.0000
2009	GER	0.0000	2.9142	0.0000	0.0000	0.0003
2010	GER	0.0000	8.7779	0.0000	0.0000	0.0004
2011	GER	0.0000	6.6225	0.0000	0.0000	0.0002
2003	GRE	1.0060	0.0000	0.0000	0.0000	0.0796
2004	GRE	0.0000	0.0000	0.0000	0.0000	0.0000
2005	GRE	0.3552	0.0000	0.0000	0.0000	0.0317
2006	GRE	0.0000	0.0000	0.0000	0.0000	0.0011
2007	GRE	0.0000	0.0000	0.0000	0.0000	0.0015
2008	GRE	10.5716	0.0000	0.0000	0.0000	0.0524
2009	GRE	9.8819	0.0000	0.0000	0.0000	0.0673
2010	GRE	11.7570	0.0000	0.0000	0.0000	0.0476
2011	GRE	9.7609	0.0000	0.0000	0.0000	0.0764
2002	HUN	1.8092	0.0000	0.0000	0.0000	0.3064
2003	HUN	3.7885	0.0000	0.0000	0.0000	0.6380

2004	HUN	4.6541	0.0000	0.0000	0.0000	0.7045
2005	HUN	4.7124	0.0000	0.0000	0.0000	0.6614
2006	HUN	4.3773	0.0000	0.0000	0.0000	0.6222
2007	HUN	3.1533	0.0000	0.0000	0.0000	0.6027
2008	HUN	2.0636	0.0000	0.0000	0.0000	0.5442
2009	HUN	2.7937	0.0000	0.0000	0.0000	0.6405
2010	HUN	1.1114	0.0000	0.0000	0.0000	0.1750
2011	HUN	2.0938	0.0000	0.0000	10.1852	0.0000
2002	IRE	6.7150	0.0000	0.0000	0.0000	0.5338
2003	IRE	3.9700	0.0000	0.0000	0.0000	0.5251
2004	IRE	3.2120	0.0000	0.0000	0.0000	0.5332
2005	IRE	3.8498	0.0000	0.0000	0.0000	0.4277
2006	IRE	3.7695	0.0000	0.0000	0.0000	0.3901
2007	IRE	4.0073	0.0000	0.0000	0.0000	0.3357
2008	IRE	3.6781	0.0000	0.0000	0.0000	0.3693
2009	IRE	4.4653	0.0000	0.0000	0.0000	0.4199
2010	IRE	4.1386	0.0000	0.0000	0.0000	0.4668
2011	IRE	3.0188	0.0000	0.0000	0.0000	0.2286
2002	ITA	67.6169	0.0000	0.0000	0.0000	0.0021
2003	ITA	46.9752	0.0000	0.0000	0.0000	0.0013
2004	ITA	43.4242	0.0000	0.0000	0.0000	0.0014
2005	ITA	33.1360	0.0000	0.0000	0.0000	0.0011
2006	ITA	38.1894	0.0000	0.0000	0.0000	0.0008
2007	ITA	42.9380	0.0000	0.0000	0.0000	0.0003
2008	ITA	17.9525	0.0000	0.0000	0.0000	0.0000
2009	ITA	13.2319	0.0000	0.0000	0.0000	0.0000
2010	ITA	2.8570	0.0000	0.0000	0.0000	0.0000
2011	ITA	3.7996	0.0000	0.0000	0.0000	0.0000
2002	LAT	0.4396	0.0000	0.0000	6.7347	0.0000
2003	LAT	0.4490	0.0000	0.0000	7.6939	0.0000
2004	LAT	0.0000	0.0000	0.0000	4.1020	0.0000
2005	LAT	0.0000	0.0000	1.0000	0.0000	0.0000
2006	LAT	0.5887	0.0000	0.0000	3.4339	0.0000
2007	LAT	1.9056	0.0000	0.0000	0.0847	0.0000
2008	LAT	0.9786	0.0000	0.0000	0.0000	0.0000
2009	LAT	0.0000	0.5300	5.1622	0.0000	0.0000
2010	LAT	0.0000	0.8615	4.6216	0.0000	0.0000
2011	LAT	0.0000	0.0000	0.0000	0.0000	0.0000
2002	LIT	0.0000	0.0000	2.4167	0.0000	0.0000
2003	LIT	0.0000	0.0000	10.5833	0.0000	0.0000
2004	LIT	0.0000	0.0000	17.8333	0.0000	0.0000
2005	LIT	0.3185	0.0000	23.4595	0.0000	0.0000
2006	LIT	0.1908	0.0000	19.4595	0.0000	0.0000
2007	LIT	0.4245	0.0000	15.4054	0.0000	0.0000
2008	LIT	0.0000	0.0914	9.3514	0.0000	0.0000
2009	LIT	0.8553	0.0000	4.8750	0.0000	0.0000
2010	LIT	0.5598	0.0000	7.4595	0.0000	0.0000
2011	LIT	0.3145	0.0000	4.4324	0.0000	0.0000
2002	MAL	1.2750	0.0000	9.6250	0.0000	0.0000
2003	MAL	0.4762	0.0000	5.6667	0.0000	0.0000
2004	MAL	1.2652	0.0000	8.7083	0.0000	0.0000
2005	MAL	0.6042	0.0000	9.7500	0.0000	0.0000
2006	MAL	1.1597	0.0000	6.7083	0.0000	0.0000

2007	MAL	1.1603	0.0000	5.7917	0.0000	0.0000
2008	MAL	0.5801	0.0000	2.7917	0.0000	0.0000
2009	MAL	1.1154	0.0000	0.7500	0.0000	0.0000
2010	MAL	0.6012	0.0000	2.9167	0.0000	0.0000
2011	MAL	1.1619	0.0000	0.0000	1.0204	0.0000
2002	MOL	0.0000	0.0000	0.0000	0.0000	0.0000
2003	MOL	1.0000	0.0000	0.0000	1.0000	0.0000
2004	MOL	0.0000	0.0000	0.0000	0.4898	0.0000
2005	MOL	0.7619	0.0000	0.0000	0.9796	0.0000
2006	MOL	0.7619	0.0000	0.0000	1.9796	0.0000
2007	MOL	0.6429	0.0000	0.0000	0.9592	0.0000
2008	MOL	0.4524	0.0000	0.0000	0.4490	0.0000
2009	MOL	0.4082	0.0000	0.0000	1.9388	0.0000
2010	MOL	0.4286	0.0000	0.0000	1.8980	0.0000
2011	MOL	1.0204	0.0000	0.0000	1.3878	0.0000
2002	NL	16.9944	0.0000	109.5000	0.0000	0.0833
2003	NL	18.2634	0.0000	81.5000	0.0000	0.2000
2004	NL	18.4848	0.0000	89.0000	0.0000	0.1766
2005	NL	19.6800	0.0000	93.0000	0.0000	0.1800
2006	NL	27.3118	0.0000	93.0000	0.0000	0.1411
2007	NL	28.7426	0.0000	99.5000	0.0000	0.1144
2008	NL	28.9590	0.0000	95.5000	0.0000	0.1291
2009	NL	22.8071	0.0000	84.0000	0.0000	0.2000
2010	NL	23.4400	0.0000	80.5000	0.0000	0.2116
2011	NL	15.0959	0.0000	87.5000	0.0000	0.1472
2002	NOR	0.0000	2.0057	15.5000	0.0000	0.0401
2003	NOR	0.9194	0.0000	3.2647	0.0000	0.0000
2004	NOR	0.0000	0.0000	0.0000	0.0000	0.0000
2005	NOR	0.0000	0.2102	0.0000	0.0000	0.0018
2006	NOR	0.0000	0.4169	9.5196	0.0000	0.0000
2007	NOR	0.0000	0.9301	7.9470	0.0000	0.0006
2008	NOR	0.0000	0.2418	2.1003	0.0000	0.0000
2009	NOR	0.0000	0.6002	0.0000	0.0000	0.0000
2010	NOR	0.0000	0.5340	0.0000	0.0000	0.0000
2011	NOR	0.0000	1.5173	0.0000	0.0000	0.0030
2005	POL	6.6746	0.0000	0.0000	0.0000	0.4841
2006	POL	10.3567	0.0000	0.0000	0.0000	0.3822
2007	POL	14.3584	0.0000	0.0000	0.0000	0.3022
2008	POL	1.4731	0.0000	0.0000	0.0000	0.2433
2009	POL	2.5823	0.0000	0.0000	0.0000	0.3044
2010	POL	3.4296	0.0000	0.0000	0.0000	0.2599
2011	POL	0.4973	0.0000	0.0000	0.0000	0.1819
2002	PT	0.0000	0.0000	0.0000	0.0000	0.3795
2003	PT	0.0000	5.4648	9.8108	0.0000	0.0000
2004	PT	0.0000	0.0000	0.0000	0.0000	0.4368
2005	PT	0.0000	0.0000	0.0000	0.0000	0.3269
2006	PT	0.0000	0.0000	0.0000	0.0000	0.3970
2007	PT	0.0000	0.0000	0.0000	0.0000	0.3919
2008	PT	0.0000	0.0000	0.0000	0.0000	0.3623
2009	PT	0.0000	0.0000	0.0000	0.0000	0.4004
2010	PT	1.0682	0.0000	0.0000	0.0000	0.3795
2011	PT	0.0000	0.0000	0.0000	0.0000	0.3452
2002	ROM	14.6288	0.0000	0.0000	47.9259	0.0000

2003	ROM	10.5655	0.0000	0.0000	46.4868	0.0000
2004	ROM	9.6106	0.0000	0.0000	41.9153	0.0000
2005	ROM	7.4764	0.0000	0.0000	42.9477	0.0000
2006	ROM	7.4618	0.0000	0.0000	30.9477	0.0000
2007	ROM	4.9853	0.0000	0.0000	11.6471	0.0000
2008	ROM	5.5760	0.0000	0.0000	29.8954	0.0000
2009	ROM	5.0880	0.0000	0.0000	11.9216	0.0000
2010	ROM	5.2161	0.0000	0.0000	35.4183	0.0000
2011	ROM	3.7648	0.0000	0.0000	56.9673	0.0000
2006	SER	7.5430	0.0000	0.0000	0.0000	0.2666
2007	SER	8.5812	0.0000	0.0000	52.5344	0.0000
2008	SER	1.4492	0.0000	0.0000	0.0000	0.3489
2009	SER	1.0200	0.0000	0.0000	0.0000	0.1797
2010	SER	2.5769	0.0000	0.0000	0.0000	0.4574
2011	SER	2.6682	0.0000	0.0000	0.0000	0.6158
2002	SK	0.6286	0.0000	0.0000	7.0816	0.0000
2003	SK	0.9643	0.0000	0.0000	7.0000	0.9804
2004	SK	1.0382	0.0000	0.0000	0.0000	0.9627
2005	SK	1.0149	0.0000	0.0000	0.0000	0.9529
2006	SK	1.3101	0.0000	0.0000	0.0000	0.9203
2007	SK	0.7564	0.0000	0.0000	0.0000	0.9496
2008	SK	0.8469	0.0000	0.0000	0.0000	0.9154
2009	SK	1.2838	0.0000	0.0000	0.0000	0.8767
2010	SK	1.4383	0.0000	0.0000	0.0000	0.9167
2011	SK	1.6377	0.0000	0.0000	19.2540	0.0000
2002	SLO	0.3832	0.0000	0.0000	0.0000	0.7002
2003	SLO	0.7821	0.0000	0.0000	0.0000	0.5875
2004	SLO	1.1154	0.0000	13.7500	0.0000	0.0000
2005	SLO	1.2917	0.0000	0.0000	0.0000	0.6398
2006	SLO	1.2593	0.0000	0.0000	0.0000	0.4744
2007	SLO	1.0607	0.0000	0.0000	0.0000	0.5916
2008	SLO	1.2681	0.0000	0.0000	0.0000	0.4344
2009	SLO	0.8590	0.0000	0.0000	0.0000	0.2887
2010	SLO	1.2308	0.0000	11.9730	0.0000	0.0000
2011	SLO	1.2414	0.0000	7.0000	0.0000	0.0000
2002	SP	47.2991	0.0000	0.0000	0.0000	0.0014
2003	SP	49.8314	0.0000	0.0000	0.0000	0.0002
2004	SP	49.3899	0.0000	0.0000	0.0000	0.0008
2005	SP	59.9431	0.0000	0.0000	0.0000	0.0006
2006	SP	63.8353	0.0000	0.0000	0.0000	0.0003
2007	SP	65.5814	0.0000	0.0000	0.0000	0.0000
2008	SP	57.1774	0.0000	0.0000	0.0000	0.0000
2009	SP	52.7774	0.0000	0.0000	0.0000	0.0007
2010	SP	63.3464	0.0000	0.0000	0.0000	0.0011
2011	SP	77.9457	0.0000	0.0000	0.0000	0.0005
2002	SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2003	SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2004	SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2005	SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2006	SWE	0.0000	0.3535	0.0000	0.0000	0.0000
2007	SWE	0.0000	0.2014	0.0000	0.0000	0.0002
2008	SWE	0.0000	1.6386	0.0000	0.0000	0.0000
2009	SWE	0.0000	0.1853	0.0000	0.0000	0.0000

2010	SWE	0.0000	0.8654	0.0000	0.0000	0.0000
2011	SWE	0.0000	1.4734	0.0000	0.0000	0.0000
2002	SWI	3.4181	0.0000	0.0000	0.0000	0.1036
2003	SWI	2.0126	0.0000	0.0000	0.0000	0.1500
2004	SWI	0.2336	0.0000	0.0000	0.0000	0.1443
2005	SWI	0.0000	0.0265	0.0000	0.0000	0.0418
2006	SWI	0.0000	0.4936	0.0000	0.0000	0.0307
2007	SWI	0.0000	1.0612	0.0000	0.0000	0.0058
2008	SWI	0.0000	1.0586	0.0000	0.0000	0.0054
2009	SWI	0.0000	1.3798	0.0000	0.0000	0.0182
2010	SWI	0.0000	1.6770	0.0000	0.0000	0.0192
2011	SWI	0.0000	0.0000	0.0000	0.0000	0.0051
2002	TUR	0.0000	0.0000	0.0000	0.0000	0.0000
2003	TUR	7.6248	0.0000	0.0000	0.0000	0.0000
2004	TUR	5.1629	0.0000	0.0000	0.0000	0.0000
2005	TUR	8.6106	0.0000	0.0000	0.0000	0.0012
2006	TUR	6.4041	0.0000	0.0000	0.0000	0.0000
2007	TUR	1.8191	0.0000	0.0000	0.0000	0.0000
2008	TUR	5.2787	0.0000	0.0000	0.0000	0.0002
2009	TUR	2.9890	0.0000	0.0000	0.0000	0.0003
2010	TUR	0.0000	0.0000	0.0000	0.0000	0.0000
2011	TUR	0.0000	0.0000	0.0000	0.0000	0.0000
2002	UK	0.0000	0.0000	0.0000	0.0000	0.0000
2003	UK	0.0000	3.9244	0.0000	0.0000	0.0013
2004	UK	0.0000	1.6288	0.0000	0.0000	0.0008
2005	UK	0.0000	2.6311	0.0000	0.0000	0.0004
2006	UK	0.0000	2.3513	0.0000	0.0000	0.0001
2007	UK	0.0000	1.9647	0.0000	0.0000	0.0000
2008	UK	0.0000	0.0000	0.0000	0.0000	0.0000
2009	UK	0.0000	0.5531	0.0000	0.0000	0.0004
2010	UK	0.0000	0.8242	0.0000	0.0000	0.0007
2011	UK	0.0000	0.0000	0.0000	0.0000	0.0002
2003	UKR	0.0000	0.9831	0.0000	0.0000	0.1338
2004	UKR	0.0000	0.0000	0.0000	0.0000	0.3496
2005	UKR	0.0000	0.0000	0.0000	0.0000	0.0000
2006	UKR	0.0000	3.8429	0.0000	29.1699	0.0000
2007	UKR	0.0000	5.2494	0.0000	58.7647	0.0000
2008	UKR	0.0000	4.8174	0.0000	86.2353	0.0000
2009	UKR	0.0000	0.0000	0.0000	0.0000	0.3098
2010	UKR	0.0000	0.0000	0.0000	0.0000	0.2662
2011	UKR	0.0000	14.6317	0.0000	130.8039	0.0000

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 36 DEA total factor productivity Malmquist indexes

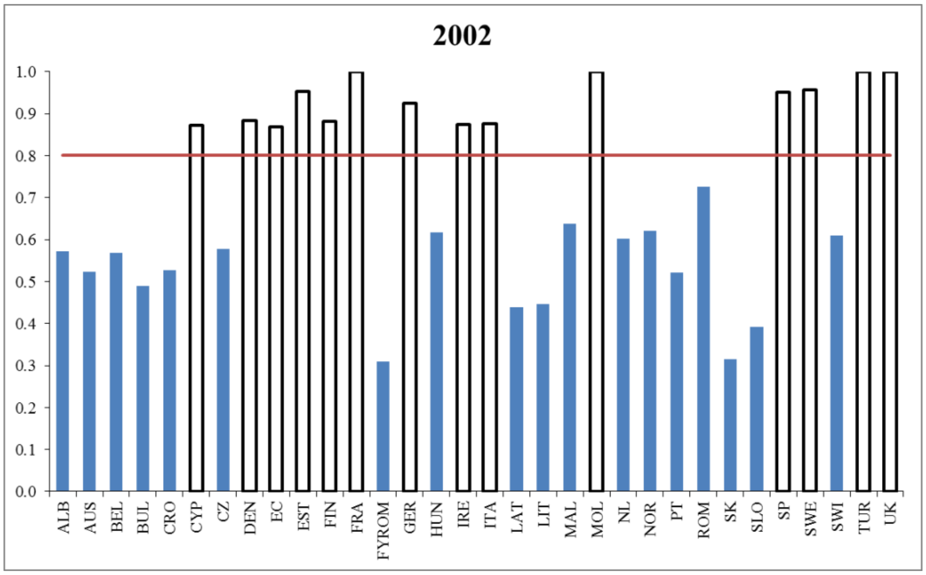
Year	Country	TFP	Year	Country	TFP	Year	Country	TFP
2002	ALB	1.0000	2002	FYROM	1.0000	2005	POL	1.0000
2003	ALB	1.0604	2003	FYROM	1.0001	2006	POL	1.1075
2004	ALB	0.7615	2004	FYROM	1.1594	2007	POL	0.9504
2005	ALB	0.7536	2005	FYROM	1.0535	2008	POL	0.7062
2006	ALB	1.3181	2006	FYROM	1.0666	2009	POL	1.1661
2007	ALB	1.0249	2007	FYROM	1.0000	2010	POL	0.9538
2008	ALB	0.6800	2008	FYROM	0.8462	2011	POL	0.9506
2009	ALB	0.9459	2009	FYROM	1.0609	2002	PT	1.0000
2010	ALB	0.9040	2010	FYROM	1.1000	2003	PT	0.9813
2011	ALB	1.0231	2011	FYROM	0.9755	2004	PT	0.9796
2009	ARM	1.0000	2002	GER	1.0000	2005	PT	0.9920
2010	ARM	1.0409	2003	GER	0.9543	2006	PT	1.0808
2011	ARM	0.9502	2004	GER	1.0239	2007	PT	1.0114
2002	AUS	1.0000	2005	GER	1.0240	2008	PT	0.9279
2003	AUS	0.9967	2006	GER	1.0396	2009	PT	1.0489
2004	AUS	1.0929	2007	GER	1.1407	2010	PT	1.1796
2005	AUS	1.0353	2008	GER	0.9851	2011	PT	0.9058
2006	AUS	0.9165	2009	GER	0.8621	2002	ROM	1.0000
2007	AUS	1.0331	2010	GER	1.0232	2003	ROM	0.9049
2008	AUS	0.9514	2011	GER	0.9220	2004	ROM	1.0645
2009	AUS	0.9165	2003	GRE	1.0000	2005	ROM	0.9723
2010	AUS	0.9756	2004	GRE	1.0151	2006	ROM	0.9122
2011	AUS	0.9375	2005	GRE	0.8126	2007	ROM	1.1052
2002	BEL	1.0000	2006	GRE	0.7434	2008	ROM	0.8826
2003	BEL	0.9588	2007	GRE	1.1147	2009	ROM	1.0760
2004	BEL	0.8920	2008	GRE	0.8648	2010	ROM	1.0860
2005	BEL	0.9535	2009	GRE	1.0136	2011	ROM	1.0342
2006	BEL	0.9906	2010	GRE	1.1222	2006	SER	1.0000
2007	BEL	1.0502	2011	GRE	1.0145	2007	SER	0.9383
2008	BEL	0.9354	2002	HUN	1.0000	2008	SER	1.0593
2009	BEL	0.9447	2003	HUN	1.0720	2009	SER	1.0146
2010	BEL	1.0222	2004	HUN	1.1358	2010	SER	0.9737
2011	BEL	1.0649	2005	HUN	1.0669	2011	SER	0.8946
2002	BUL	1.0000	2006	HUN	0.8844	2002	SK	1.0000
2003	BUL	1.1558	2007	HUN	0.9347	2003	SK	1.0339
2004	BUL	1.0132	2008	HUN	0.9145	2004	SK	1.0538
2005	BUL	0.9714	2009	HUN	0.9536	2005	SK	1.0918
2006	BUL	1.0835	2010	HUN	0.7867	2006	SK	0.9677
2007	BUL	1.1253	2011	HUN	0.9914	2007	SK	0.9581
2008	BUL	0.9756	2002	IRE	1.0000	2008	SK	0.8931
2009	BUL	0.9726	2003	IRE	0.8611	2009	SK	0.8734
2010	BUL	1.0849	2004	IRE	0.8695	2010	SK	1.0129
2011	BUL	1.0112	2005	IRE	1.0902	2011	SK	1.1260
2002	CRO	1.0000	2006	IRE	0.9090	2002	SLO	1.0000
2003	CRO	0.9827	2007	IRE	1.0221	2003	SLO	1.0487
2004	CRO	1.0475	2008	IRE	0.9240	2004	SLO	1.1003
2005	CRO	1.0304	2009	IRE	0.9037	2005	SLO	0.9807
2006	CRO	0.9296	2010	IRE	0.8746	2006	SLO	0.9887
2007	CRO	1.0559	2011	IRE	0.9393	2007	SLO	0.9120
2008	CRO	0.9874	2002	ITA	1.0000	2008	SLO	0.8864

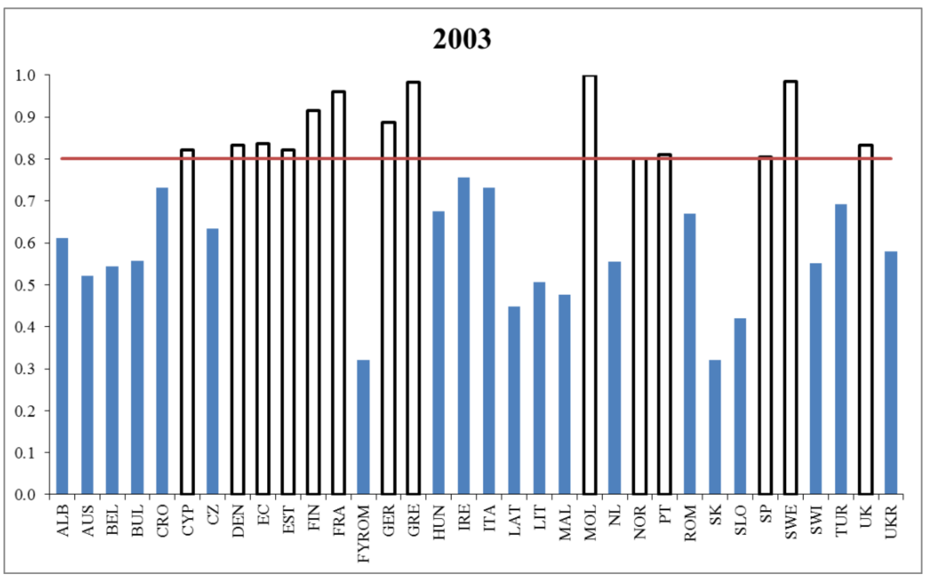
2009	CRO	0.9943	2003	ITA	0.8422	2009	SLO	0.8798
2010	CRO	0.9934	2004	ITA	0.9226	2010	SLO	0.9394
2011	CRO	0.9605	2005	ITA	0.9929	2011	SLO	0.9449
2002	CYP	1.0000	2006	ITA	1.0555	2002	SP	1.0000
2003	CYP	0.9549	2007	ITA	1.0333	2003	SP	0.8454
2004	CYP	0.7664	2008	ITA	0.9269	2004	SP	0.9190
2005	CYP	0.9594	2009	ITA	0.9254	2005	SP	0.9963
2006	CYP	0.9821	2010	ITA	1.0160	2006	SP	0.9525
2007	CYP	1.0500	2011	ITA	0.9634	2007	SP	0.9490
2008	CYP	1.0598	2002	LAT	1.0000	2008	SP	0.9076
2009	CYP	0.9359	2003	LAT	1.0401	2009	SP	0.9087
2010	CYP	1.0738	2004	LAT	1.5614	2010	SP	1.2639
2011	CYP	1.0996	2005	LAT	0.9696	2011	SP	1.0524
2002	CZ	1.0000	2006	LAT	0.8920	2002	SWE	1.0000
2003	CZ	1.0929	2007	LAT	0.9113	2003	SWE	1.0128
2004	CZ	1.0693	2008	LAT	1.1001	2004	SWE	1.0222
2005	CZ	0.9495	2009	LAT	1.0032	2005	SWE	0.9593
2006	CZ	0.8826	2010	LAT	0.9925	2006	SWE	0.9203
2007	CZ	0.8934	2011	LAT	1.0343	2007	SWE	0.9153
2008	CZ	0.9551	2002	LIT	1.0000	2008	SWE	0.9895
2009	CZ	1.0270	2003	LIT	0.9528	2009	SWE	0.9050
2010	CZ	0.9209	2004	LIT	1.1177	2010	SWE	0.7906
2011	CZ	0.9352	2005	LIT	1.0424	2011	SWE	1.0725
2002	DEN	1.0000	2006	LIT	0.8318	2002	SWI	1.0000
2003	DEN	0.9358	2007	LIT	1.0529	2003	SWI	0.8808
2004	DEN	0.9724	2008	LIT	0.9671	2004	SWI	0.8698
2005	DEN	0.9771	2009	LIT	0.7890	2005	SWI	1.1347
2006	DEN	1.0698	2010	LIT	1.0061	2006	SWI	0.9377
2007	DEN	0.8207	2011	LIT	1.0107	2007	SWI	1.0096
2008	DEN	0.9279	2002	MAL	1.0000	2008	SWI	0.9934
2009	DEN	0.8802	2003	MAL	0.8513	2009	SWI	0.9164
2010	DEN	1.0914	2004	MAL	1.2438	2010	SWI	0.9214
2011	DEN	1.0697	2005	MAL	0.9479	2011	SWI	0.8998
2002	EC	1.0000	2006	MAL	0.9751	2002	TUR	1.0000
2003	EC	0.9626	2007	MAL	0.9869	2003	TUR	0.9338
2004	EC	1.0558	2008	MAL	1.0237	2004	TUR	1.0676
2005	EC	1.0782	2009	MAL	0.9894	2005	TUR	1.1411
2006	EC	1.0248	2010	MAL	1.0293	2006	TUR	0.9899
2007	EC	1.0183	2011	MAL	1.0008	2007	TUR	1.0465
2008	EC	0.9552	2002	MOL	1.0000	2008	TUR	1.0468
2009	EC	0.8682	2003	MOL	0.7862	2009	TUR	1.0296
2010	EC	0.9913	2004	MOL	0.8482	2010	TUR	1.0097
2011	EC	1.1192	2005	MOL	0.8884	2011	TUR	0.9693
2002	EST	1.0000	2006	MOL	0.9704	2002	UK	1.0000
2003	EST	1.0166	2007	MOL	0.8165	2003	UK	0.9268
2004	EST	1.1220	2008	MOL	0.7020	2004	UK	1.0827
2005	EST	1.1139	2009	MOL	0.8835	2005	UK	0.9733
2006	EST	0.9096	2010	MOL	0.9307	2006	UK	1.0281
2007	EST	1.0583	2011	MOL	1.1444	2007	UK	0.9618
2008	EST	0.8213	2002	NL	1.0000	2008	UK	1.1242
2009	EST	1.0233	2003	NL	0.9202	2009	UK	0.9548
2010	EST	0.8136	2004	NL	0.9953	2010	UK	0.9305
2011	EST	0.9944	2005	NL	0.8769	2011	UK	1.0615

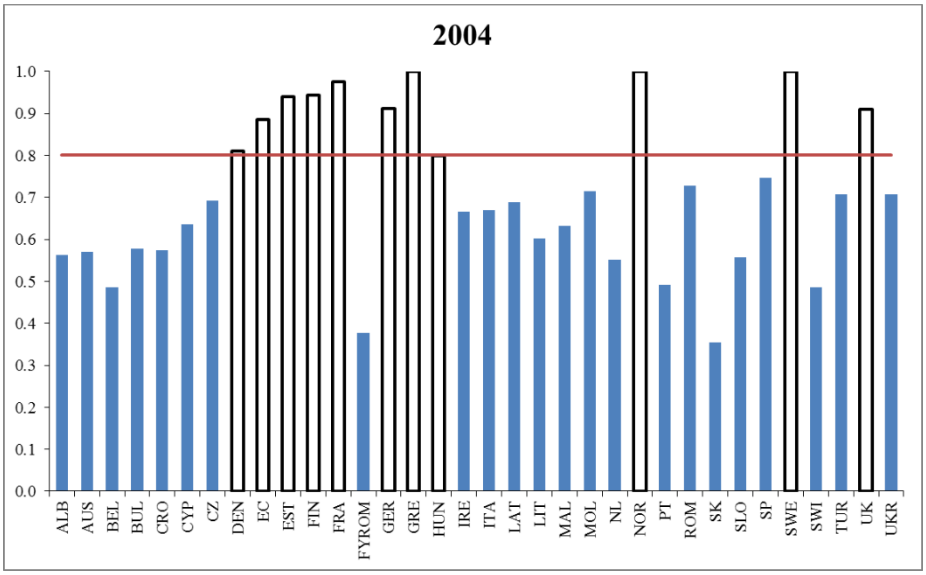
2002	FIN	1.0000	2006	NL	1.2075	2003	UKR	1.0000
2003	FIN	1.0211	2007	NL	1.0149	2004	UKR	1.2418
2004	FIN	1.0320	2008	NL	0.9416	2005	UKR	0.9334
2005	FIN	0.9799	2009	NL	0.8266	2006	UKR	0.7833
2006	FIN	1.0555	2010	NL	1.1044	2007	UKR	1.0679
2007	FIN	0.9339	2011	NL	1.0412	2008	UKR	0.9939
2008	FIN	0.9883	2002	NOR	1.0000	2009	UKR	0.9982
2009	FIN	0.9069	2003	NOR	1.2547	2010	UKR	0.9214
2010	FIN	0.9865	2004	NOR	1.3134	2011	UKR	0.7212
2011	FIN	1.0216	2005	NOR	0.8643			
2002	FRA	1.0000	2006	NOR	0.9073			
2003	FRA	0.9392	2007	NOR	0.8279			
2004	FRA	0.9838	2008	NOR	1.0640			
2005	FRA	0.9926	2009	NOR	1.0149			
2006	FRA	1.0215	2010	NOR	0.9186			
2007	FRA	0.9430	2011	NOR	0.9874			
2008	FRA	0.9609						
2009	FRA	0.9103						
2010	FRA	1.0063						
2011	FRA	1.0217						

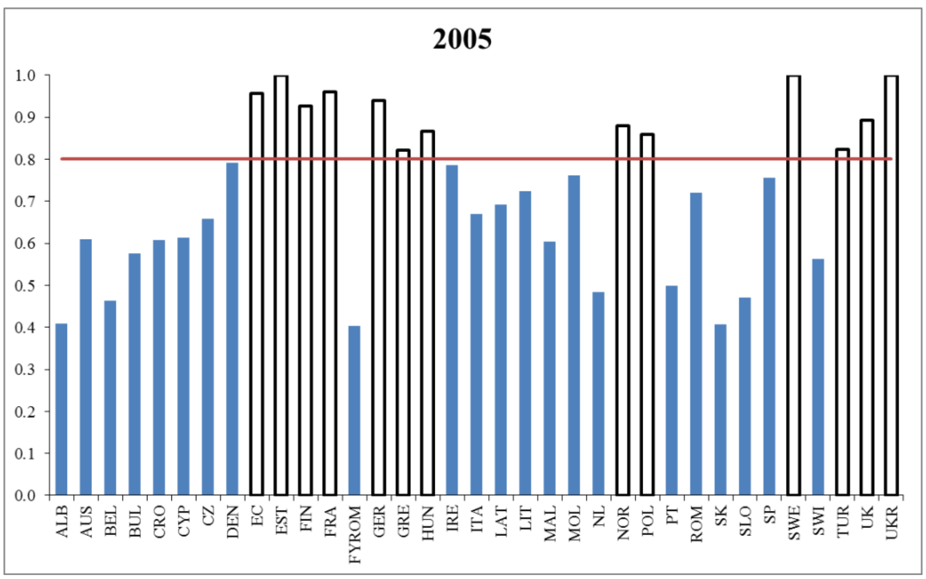
Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).
Total Factor Productivity values equal 1 in the first year of the time series for each ANSP – 2002 for most.

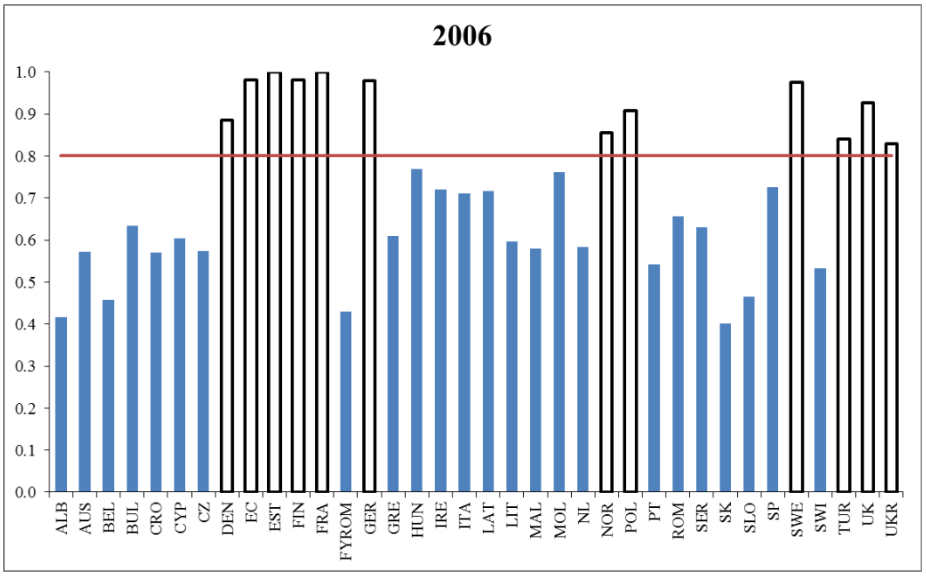
APPENDIX III – ANSP DEA ANALYSIS: FIGURES

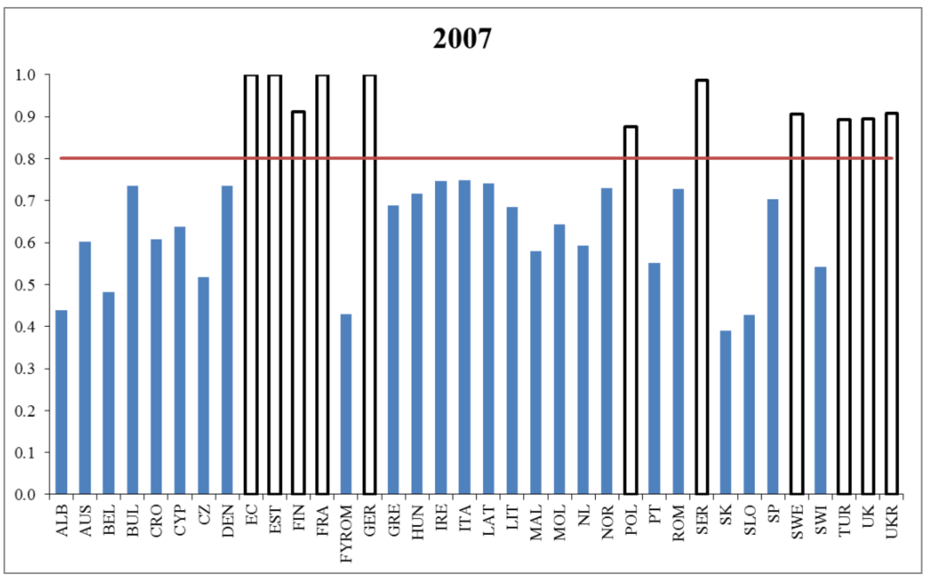


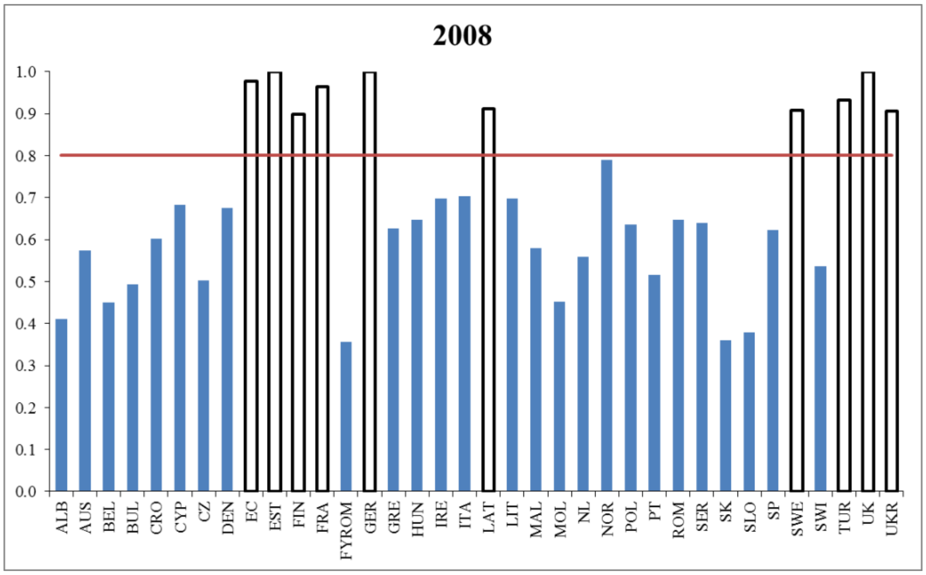


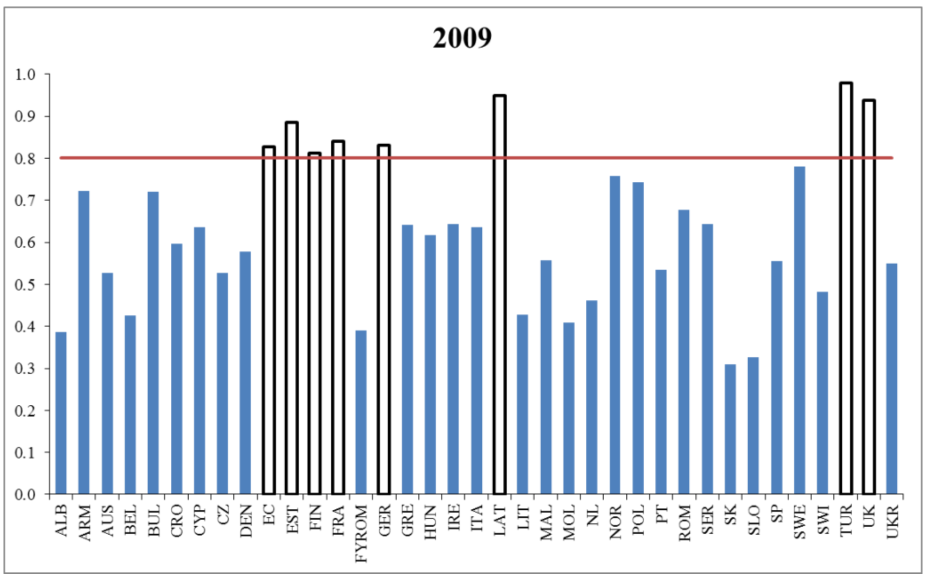

2004
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB
AUS
BEL
BUL
CRO
CYP
CZ
DEN
EC
EST
FIN
FRA
FYROM
GER
GRE
HUN
IRE
ITA
LAT
LIT
MAL
MOL
NL
NOR
PT
ROM
SK
SLO
SP
SWE
SWI
TUR
UK
UKR


2005
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB
AUS
BEL
BUL
CRO
CYP
CZ
DEN
EC
EST
FIN
FRA
FYROM
GER
GRE
HUN
IRE
ITA
LAT
LIT
MAL
MOL
NL
NOR
POL
PT
ROM
SK
SLO
SP
SWE
SWI
TUR
UK
UKR


2006
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB
AUS
BEL
BUL
CRO
CYP
CZ
DEN
EC
EST
FIN
FRA
FYROM
GER
GRE
HUN
IRE
ITA
LAT
LIT
MAL
MOL
NL
NOR
POL
PT
ROM
SER
SK
SLO
SP
SWE
SWI
TUR
UK
UKR


2007
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB
AUS
BEL
BUL
CRO
CYP
CZ
DEN
EC
EST
FIN
FRA
FYROM
GER
GRE
HUN
IRE
ITA
LAT
LIT
MAL
MOL
NL
NOR
POL
PT
ROM
SER
SK
SLO
SP
SWE
SWI
TUR
UK
UKR


2008
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR


2009
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
ALB ARM AUS BEL BUL CRO CYP CZ DEN EC EST FIN FRA FYROM GER GRE HUN IRE ITA LAT LIT MAL MOL NL NOR POL PT ROM SER SK SLO SP SWE SWI TUR UK UKR

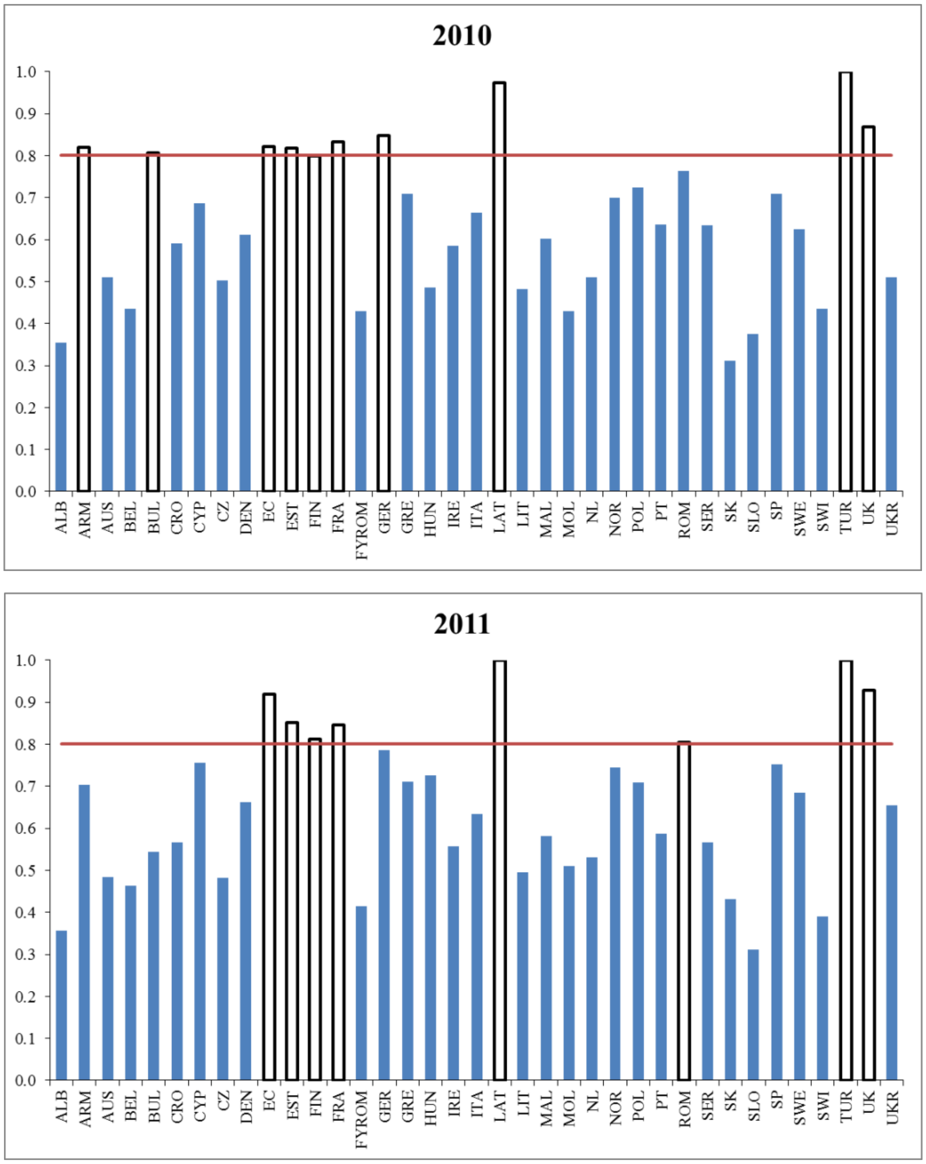
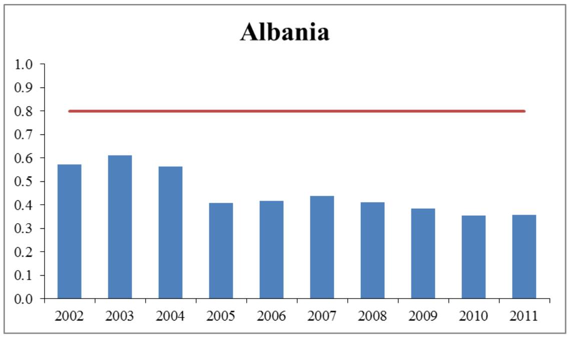
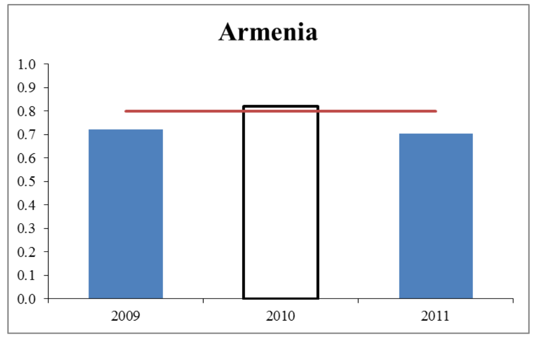
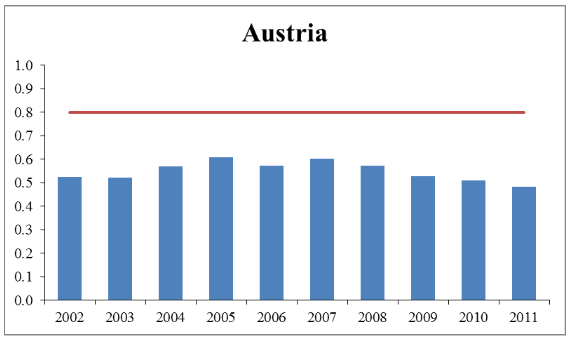


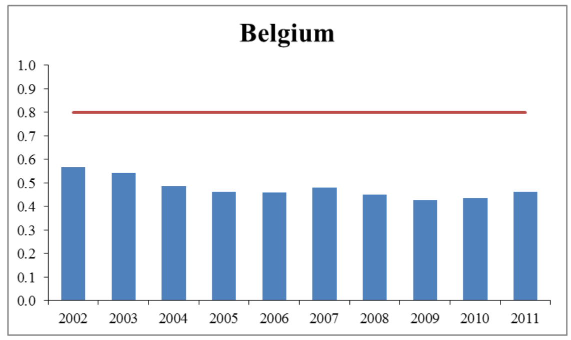
Figure 14 DEA efficiency results for each year

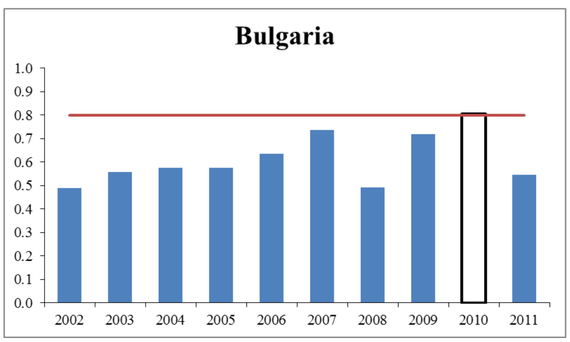
Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

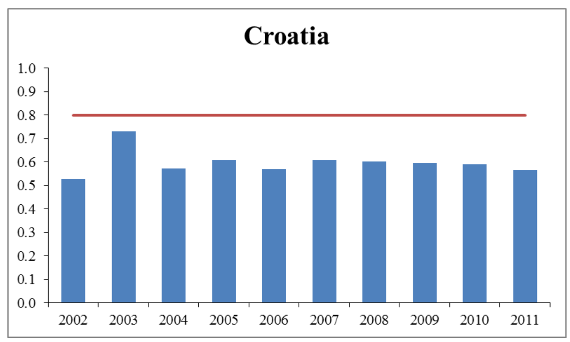

Albania
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

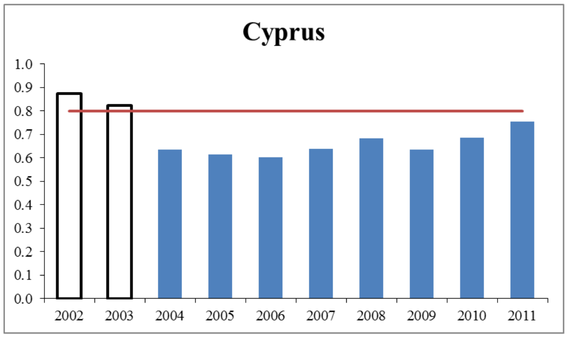

Armenia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2009
2010
2011

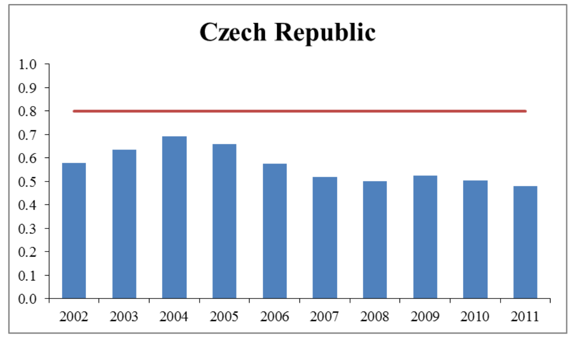

Austria
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

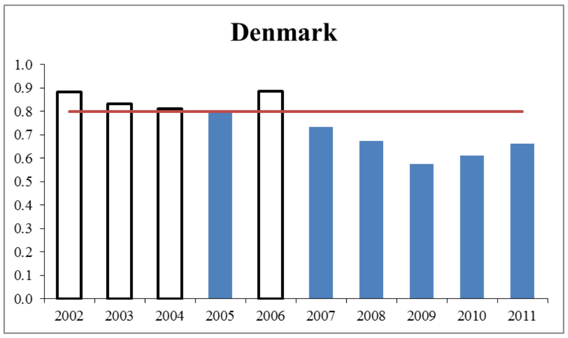

Belgium
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

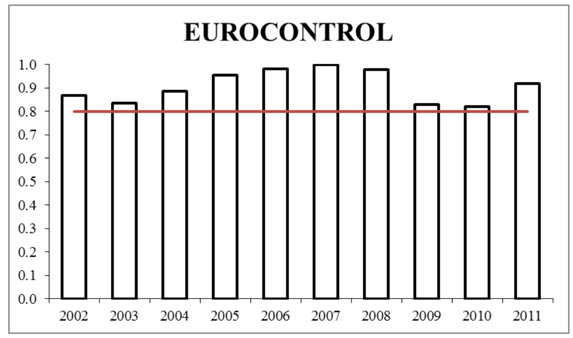

Bulgaria
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

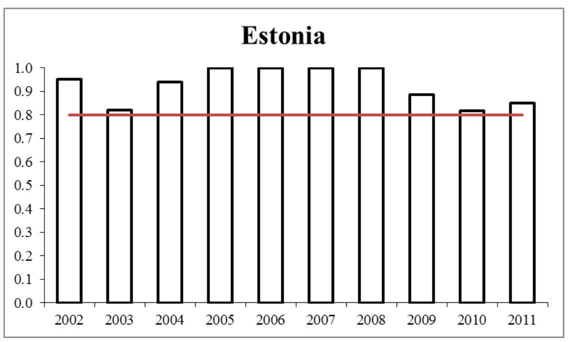

Croatia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

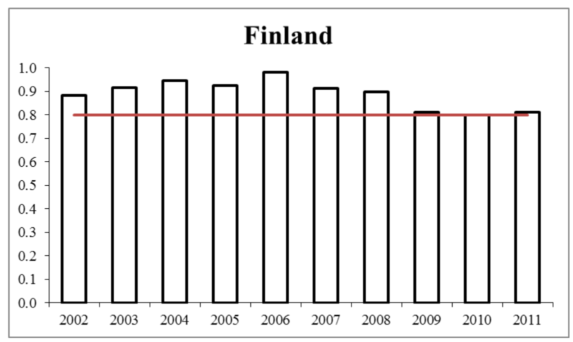

Cyprus
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

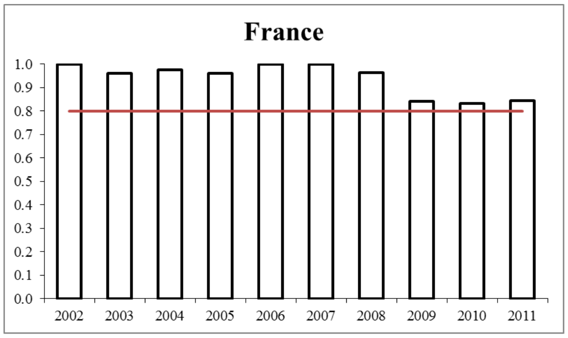

Czech Republic
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

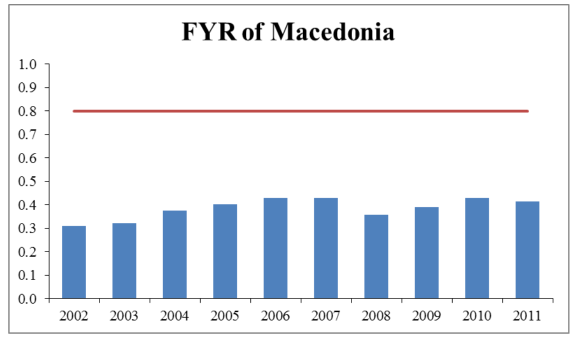

Denmark
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

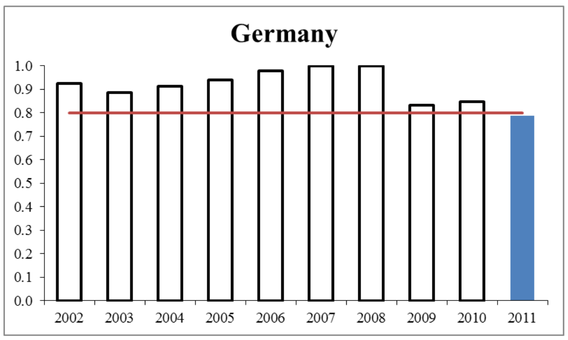

EUROCONTROL
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

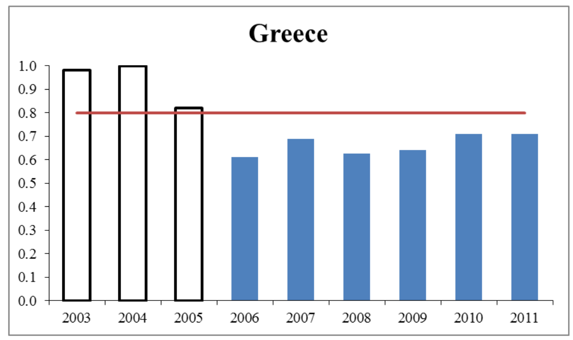

Estonia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

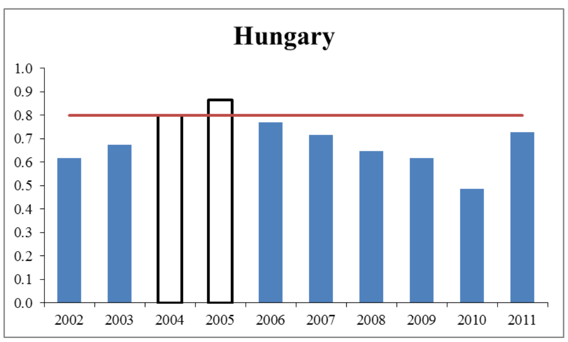

Finland
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

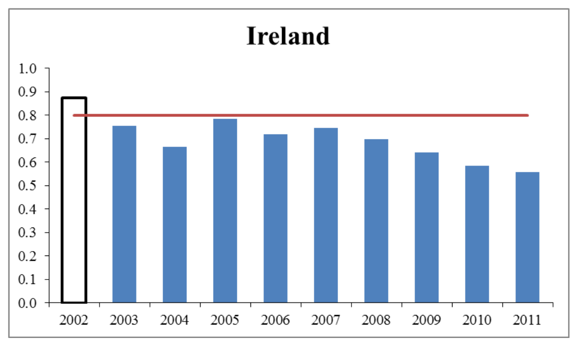

France
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

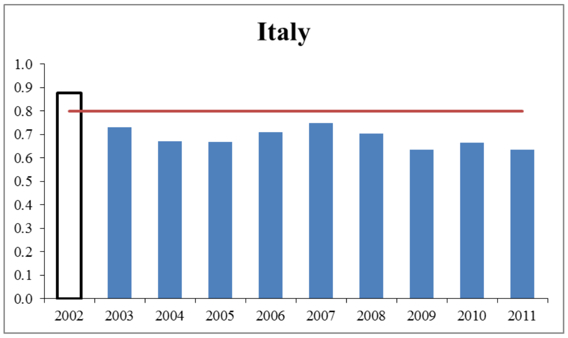

FYR of Macedonia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

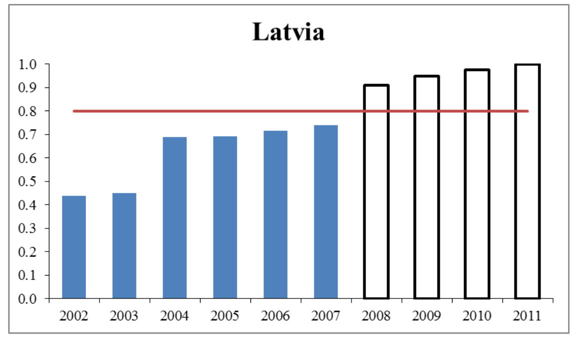

Germany
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

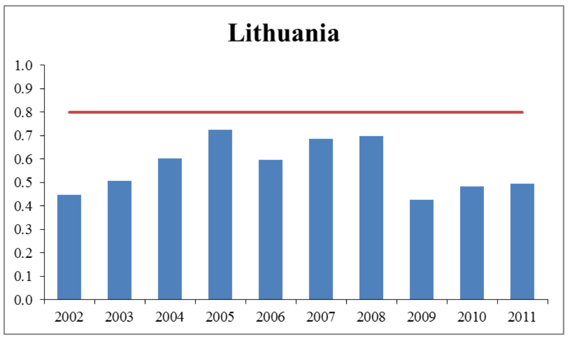

Greece
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2003 2004 2005 2006 2007 2008 2009 2010 2011

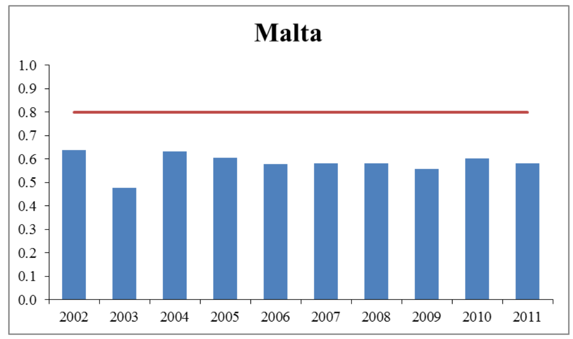

Hungary
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

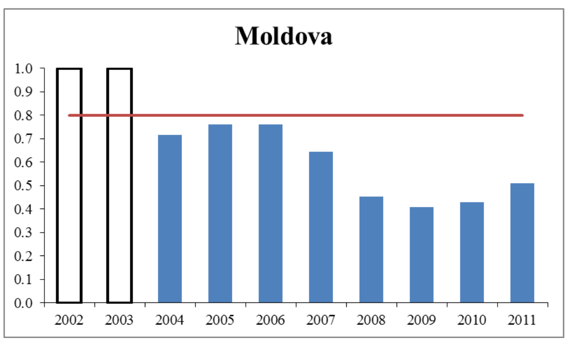

Ireland
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

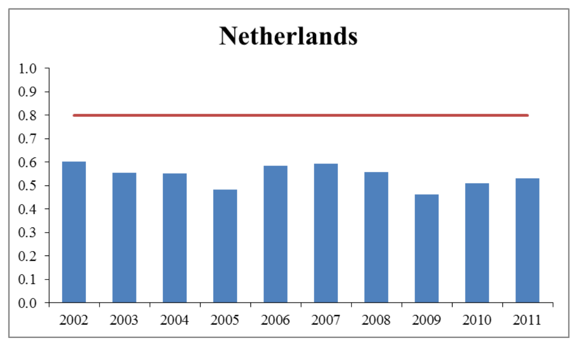

Italy
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

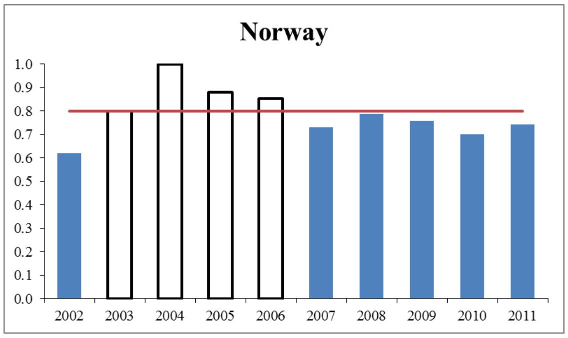

Latvia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

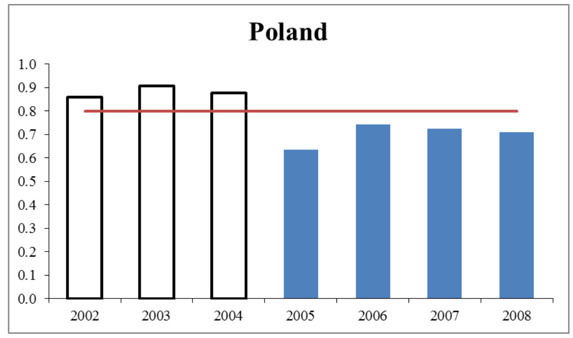

Lithuania
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

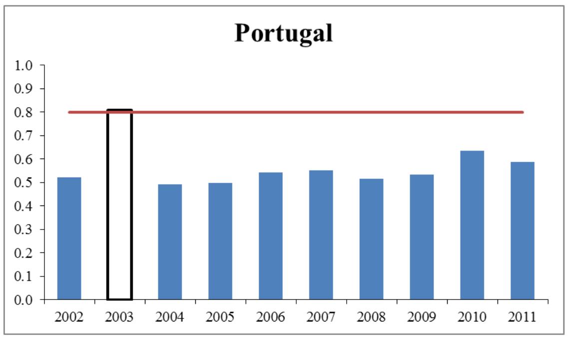

Malta
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

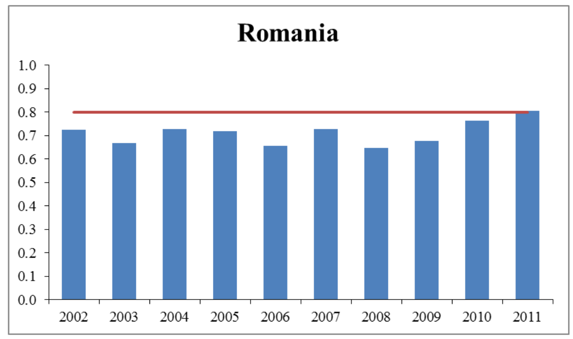

Moldova
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

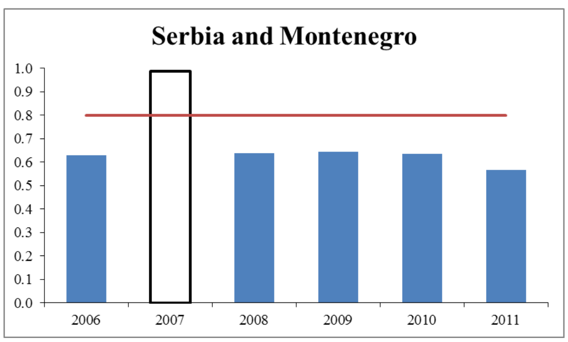

Netherlands
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

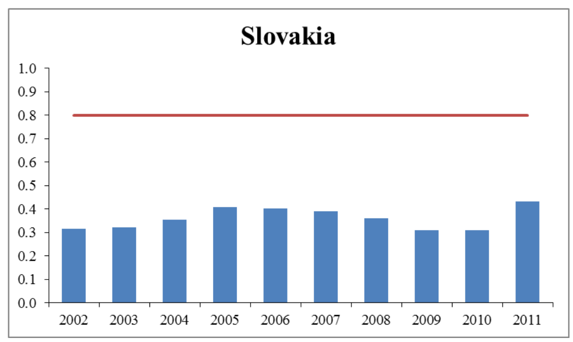

Norway
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Poland
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008


Portugal
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Romania
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Serbia and Montenegro
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2006 2007 2008 2009 2010 2011


Slovakia
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

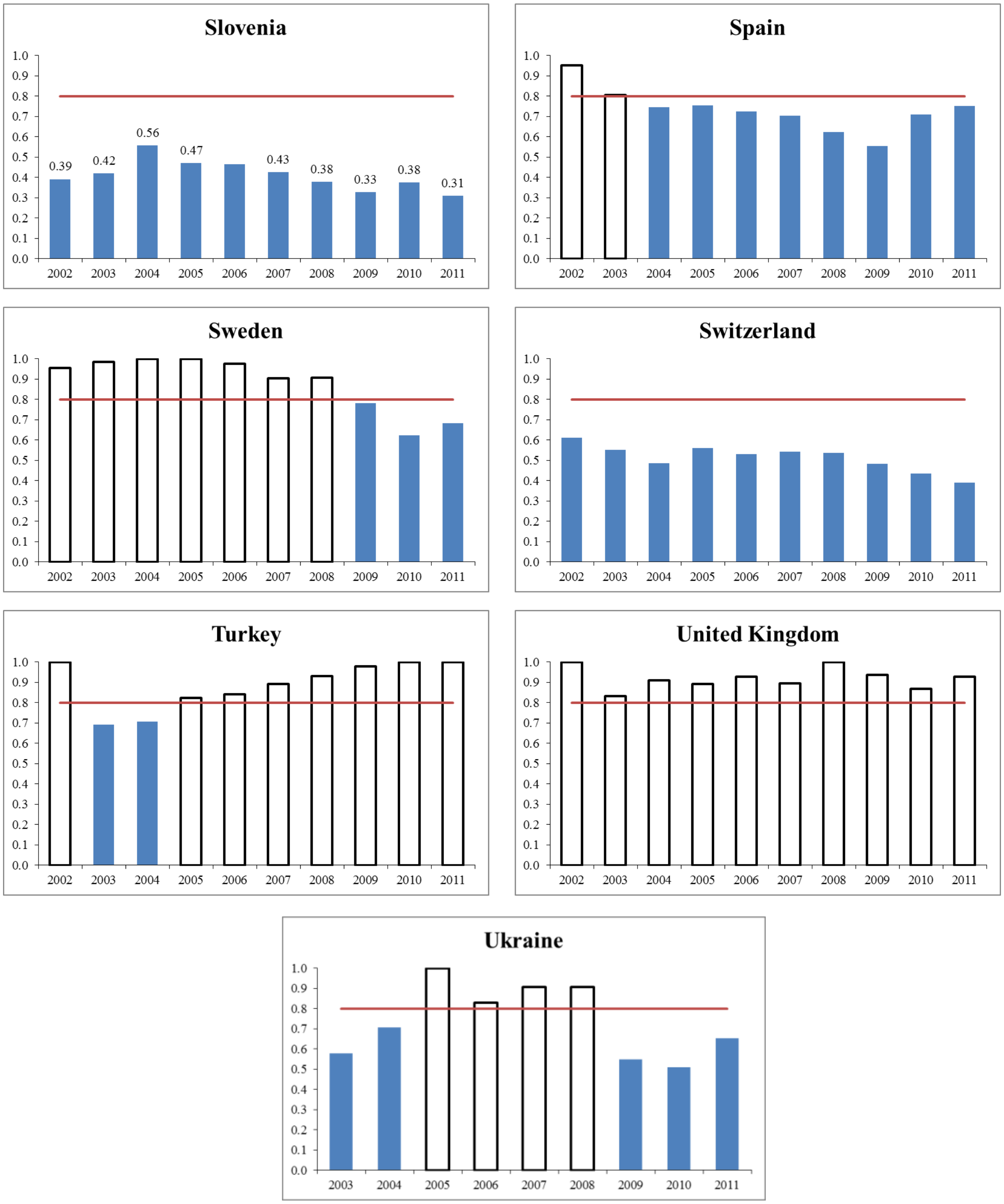
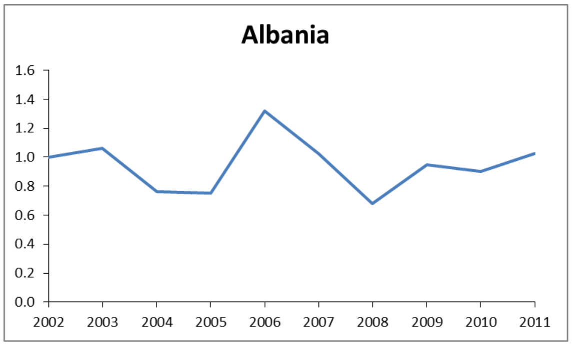
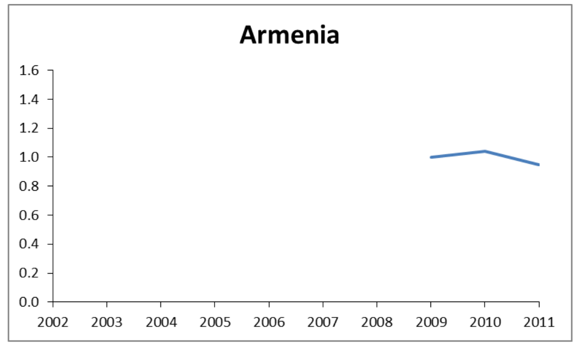
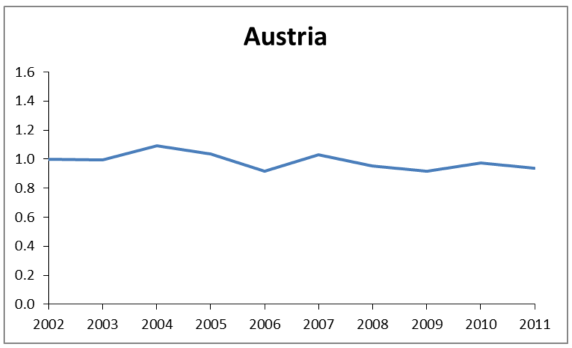
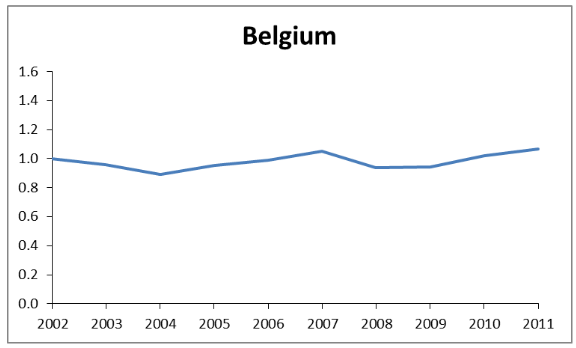


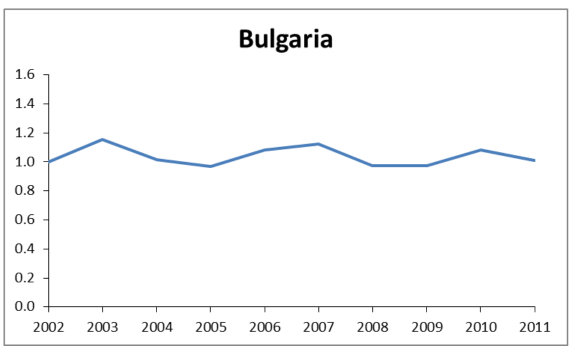
Figure 15 DEA results for each ANSP

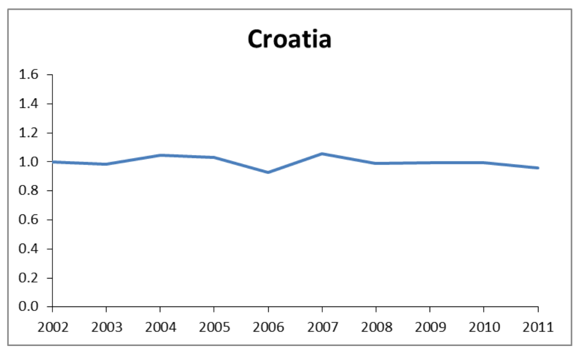

Albania
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

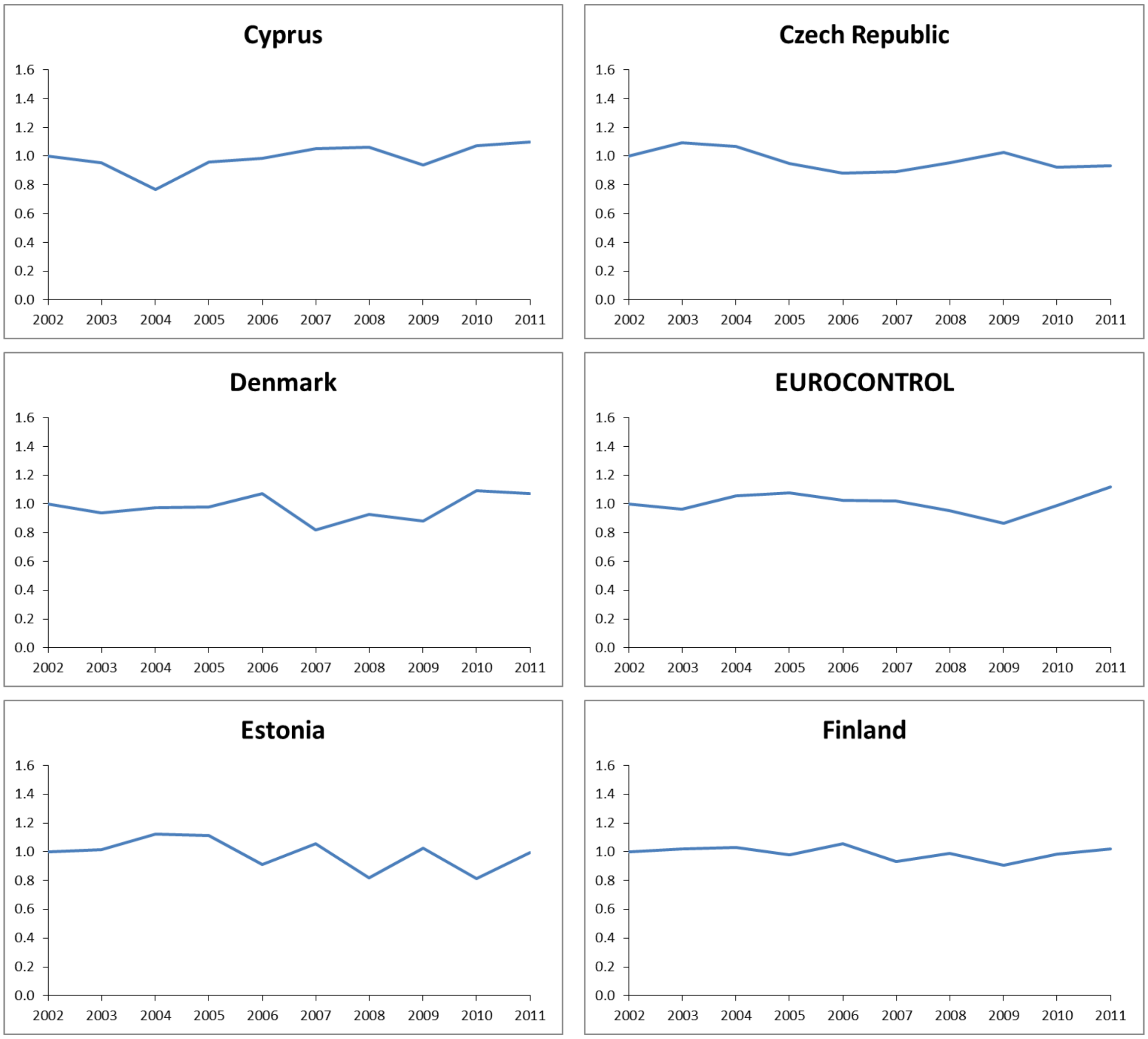

Armenia
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

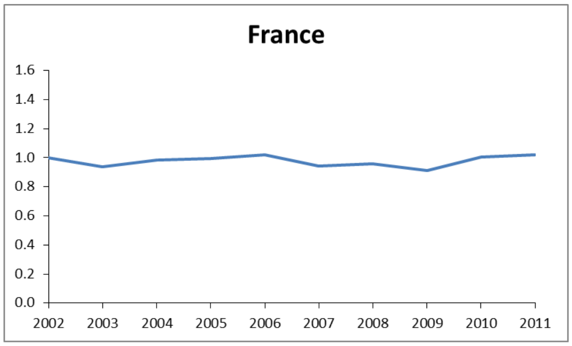

Austria
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

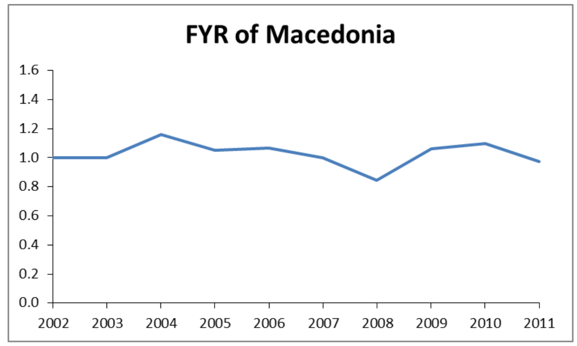

Belgium
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

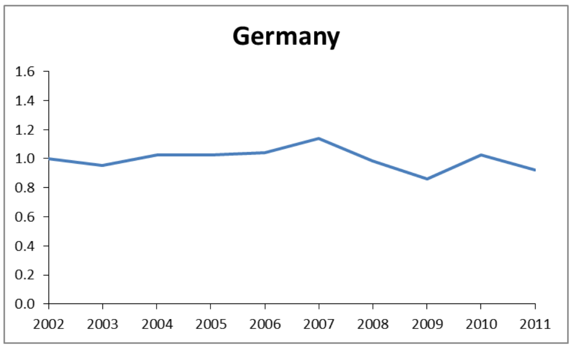

Bulgaria
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

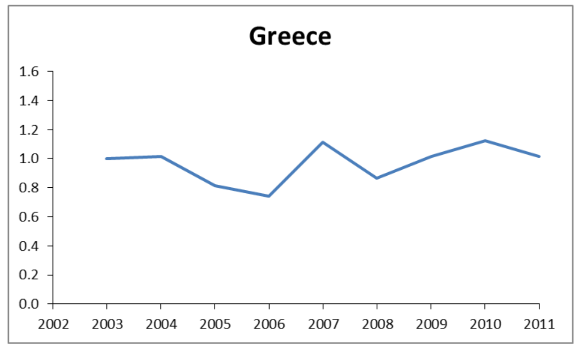

Croatia
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

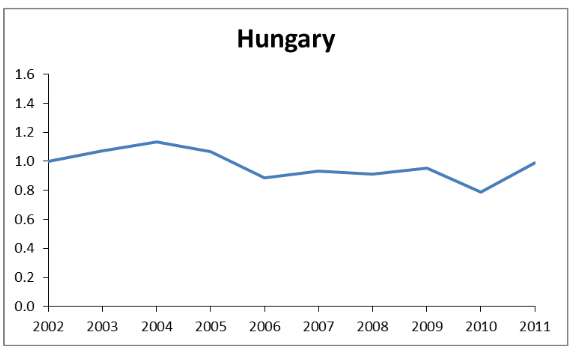

Cyprus
Czech Republic
Denmark
EUROCONTROL
Estonia
Finland
0.0 0.2 0.4 0.6 0.8 1.0 1.2 1.4 1.6
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

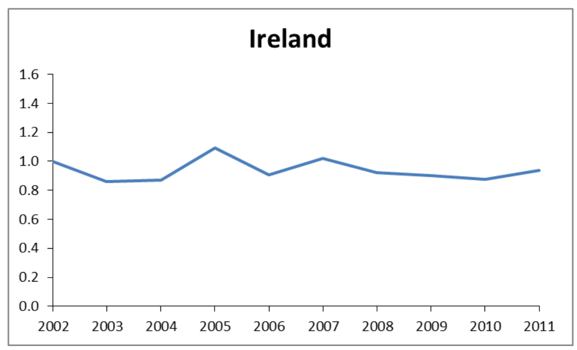

France
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

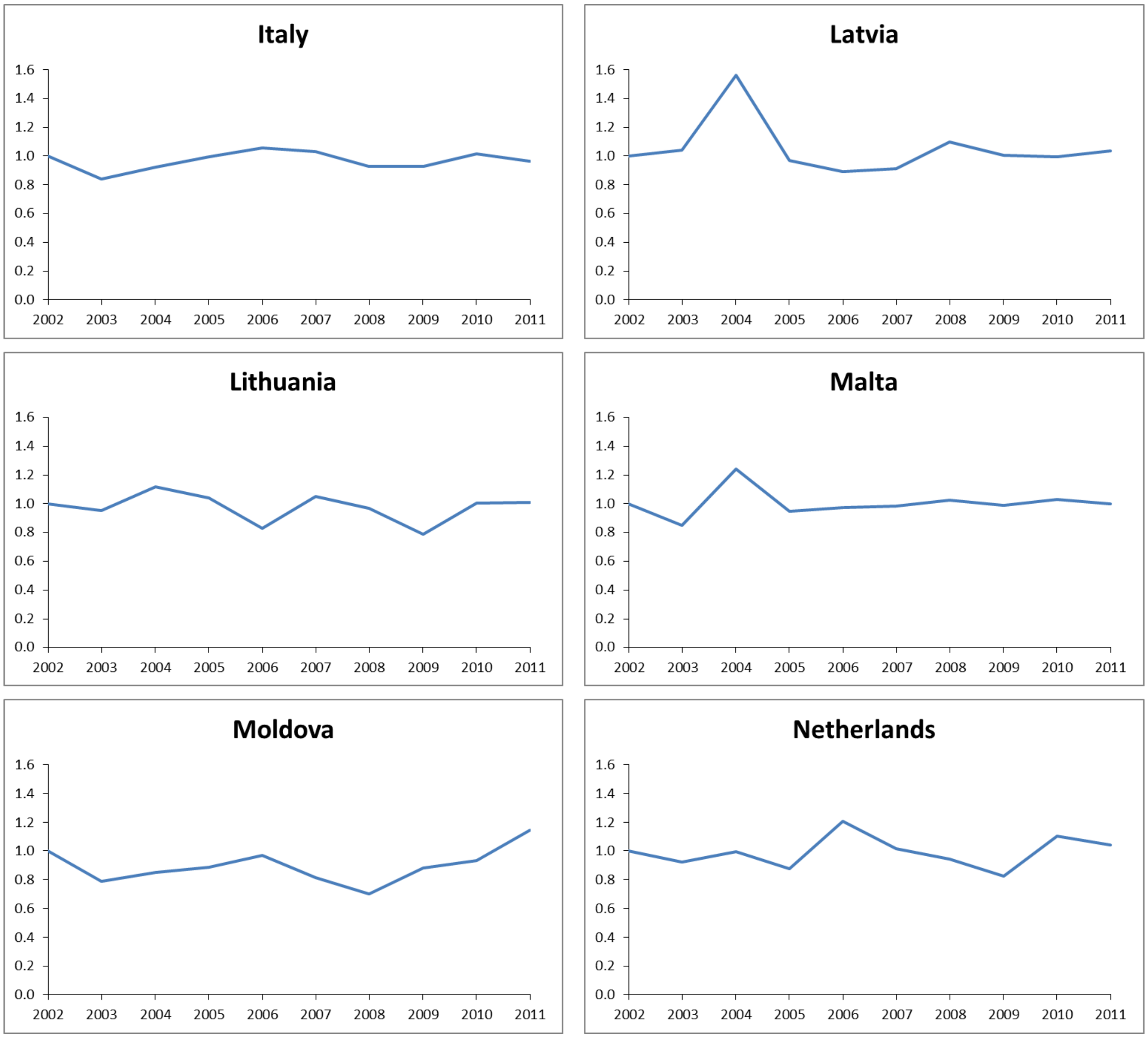

FYR of Macedonia
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

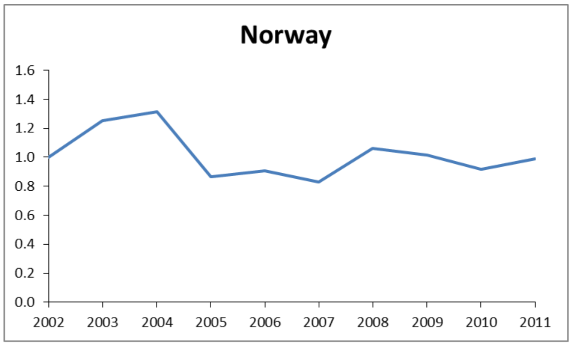

Germany
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

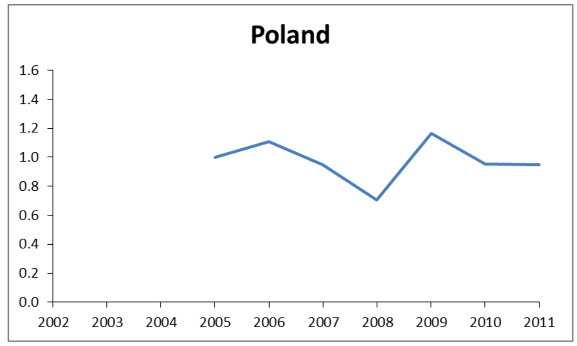

Greece
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

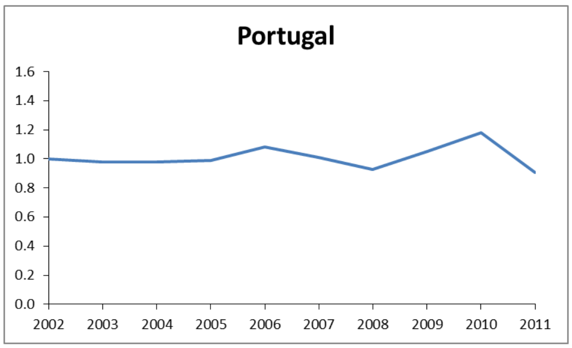

Hungary
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

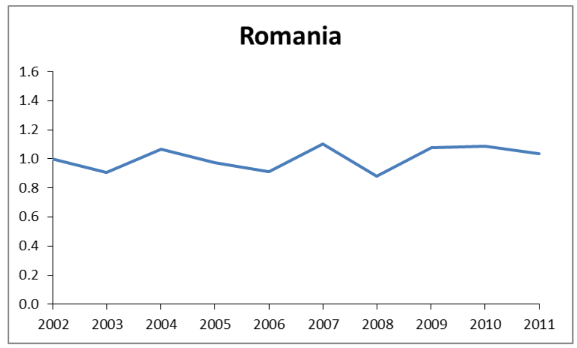

Ireland
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

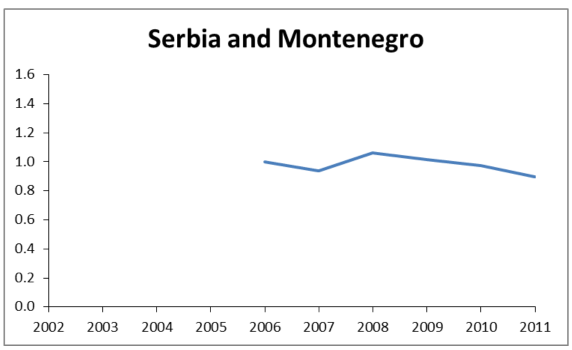

Italy
Latvia
Lithuania
Malta
Moldova
Netherlands
0.0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

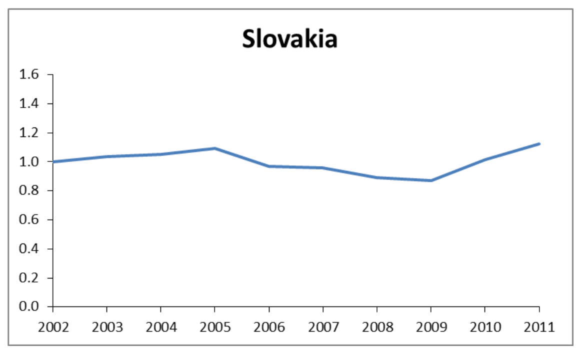

Norway
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Poland
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Portugal
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Romania
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Serbia and Montenegro
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011


Slovakia
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2002 2003 2004 2005 2006 2007 2008 2009 2010 2011

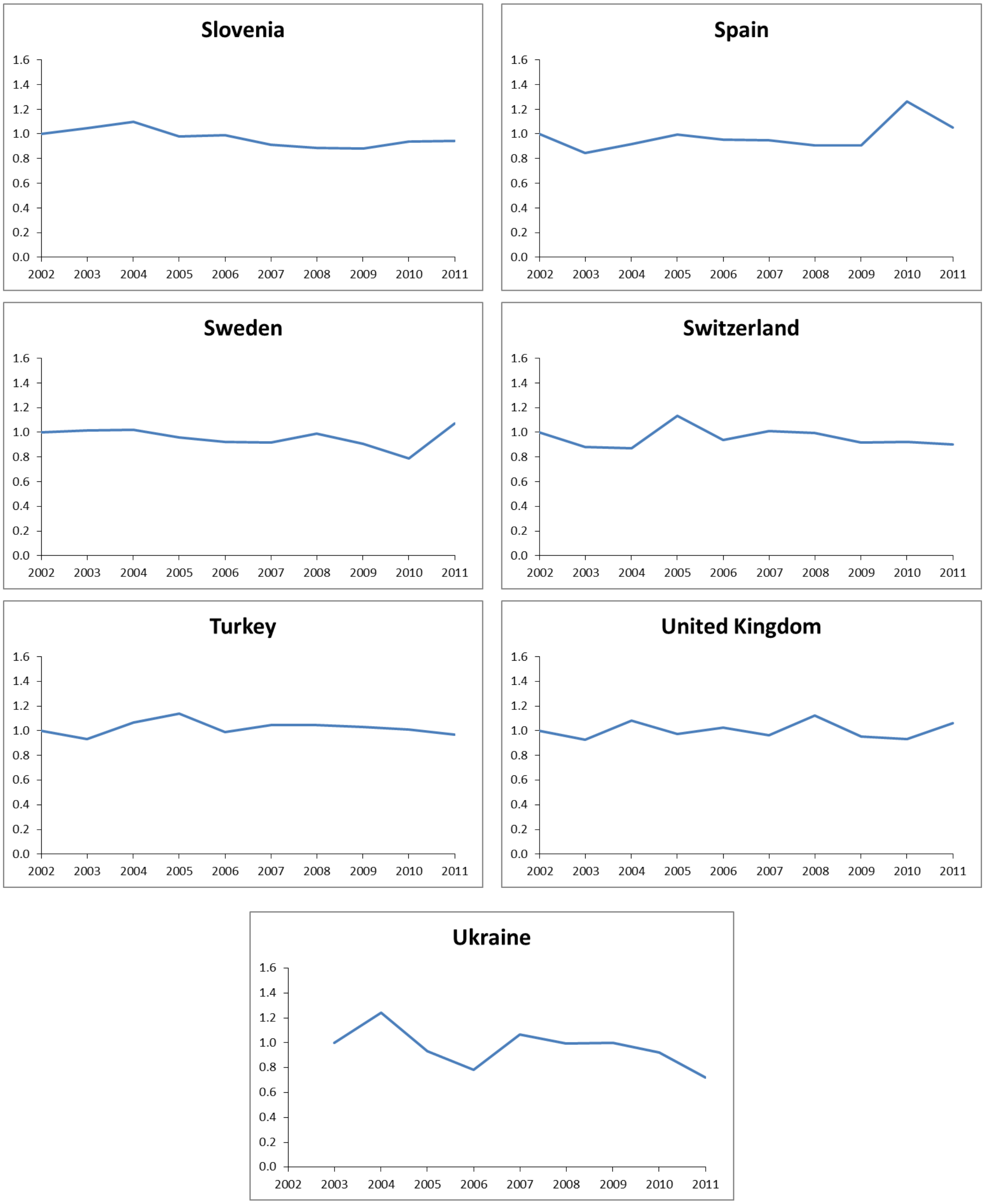


Figure 16 DEA total factor productivity Malmquist indexes for each ANSP

APPENDIX IV – ANSP DEA ANALYSIS: REGRESSIONS

Table 37 DEA regression with temporal dummy variables

Variable	Model 1	Model 2	Model 3	Model 4
(intercept)	6.338e-1*** (14.189)	6.215e-1*** (14.698)	5.681e-1*** (21.263)	6.166e-1*** (14.266)
AGENCY	4.723e-2** (2.550)	5.231e-2** (2.927)	7.868e-2*** (4.050)	3.780e-2** (2.047)
AREA	-3.449e-5 (-1.111)	-	8.357e-5*** (3.721)	-
SECTORS	2.261e-3** (3.093)	2.931e-3*** (10.278)	1.638e-3*** (4.412)	-
ATCO	5.107e-5 (1.257)	-	-	1.218e-4*** (9.522)
ATCOkm	-5.474e-2*** (-7.972)	-5.079e-2*** (-9.049)	-	-4.661e-2*** (-8.277)
STAFF_ATCO	-9.854e-3* (-1.796)	-9.693e-3* (-1.768)	-	-1.174e-2** (-2.116)
REV_COST	8.251e-2** (2.922)	8.229e-2** (2.955)	-	9.756e-2*** (3.437)
Y2003	4.250e-3 (0.132)	7.289e-3 (0.227)	4.177e-3 (0.117)	-2.873e-3 (-0.088)
Y2004	1.268e-2 (0.394)	1.585e-2 (0.494)	1.783e-2 (0.499)	5.092e-3 (0.156)
Y2005	2.400e-2 (0.750)	2.735e-2 (0.859)	3.004e-2 (0.847)	1.613e-2 (0.498)
Y2006	1.431e-2 (0.451)	1.705e-2 (0.539)	1.864e-2 (0.529)	8.981e-3 (0.279)
Y2007	1.211e-2 (0.382)	1.444e-2 (0.457)	1.424e-2 (0.405)	7.220e-3 (0.224)
Y2008	-2.866e-2 (-0.903)	-2.640e-2 (-0.834)	-2.201e-2 (-0.625)	-3.435e-2 (-1.066)
Y2009	-5.470e-2* (-1.735)	-5.211e-2* (-1.658)	-5.283e-2 (-1.510)	-6.125e-2* (-1.916)
Y2010	-4.572e-2 (-1.447)	-4.275e-2 (-1.359)	-4.136e-2 (-1.182)	-5.332e-2* (-1.666)
Y2011	-9.248e-2** (-2.643)	-9.163e-2** (-2.620)	-4.175e-2 (-1.193)	-9.651e-2** (-2.715)
Adjusted R-squared	0.3873	0.3878	0.2408	0.3665

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses.
Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

Table 38 DEA regression with geographical dummy variables

Variable	Model 1	Model 2	Model 3	Model 4
(intercept)	20.26*** (5.496)	20.71*** (5.498)	18.71*** (5.653)	20.39*** (5.448)
YEAR	-9.902e-3*** (-5.399)	-1.007e-2*** (-5.376)	-9.136e-3*** (-5.537)	-9.914e-3*** (-5.325)
AGENCY	-1.266e-2 (-0.361)	-1.621e-2 (-0.452)	-1.357e-2 (-0.389)	-1.509e-2 (-0.423)
AREA	1.347e-3*** (3.607)	-	1.436e-3*** (4.045)	-
SECTORS	-9.655e-4 (-0.929)	-6.110e-4 (-0.577)	-9.566e-4 (-0.923)	-
ATCO	8.197e-5 (1.216)	-	-	1.333e-4** (1.987)
ATCOkm	-1.070e-2 (-0.601)	1.390e-2 (0.893)	-	-4.957e-3 (-0.275)
STAFF_ATCO	-3.769e-3 (-0.792)	-4.909e-3 (-1.014)	-	-3.739e-3 (-0.772)
REV_COST	2.113e-2 (0.868)	1.882e-2 (0.757)	-	1.597e-2 (0.645)
ARM	3.131e-1*** (5.092)	2.051e-1*** (3.600)	3.054e-1*** (5.286)	2.340e-1*** (4.042)
AUS	4.761e-2 (0.984)	-7.958e-3 (-0.168)	4.489e-2 (1.304)	9.538e-3 (0.199)
BEL	6.083e-2 (0.721)	-1.061e-1 (-1.430)	2.972e-2 (0.780)	-3.817e-2 (-0.470)
CRO	-2.414e-2 (-0.564)	6.785e-2* (1.853)	-1.834e-2 (-0.440)	5.390e-2 (1.531)
CYP	5.626e-2 (0.904)	1.888e-1*** (3.572)	6.021e-2 (1.060)	1.816e-1*** (3.449)
CZ	6.597e-2* (1.756)	3.153e-1 (0.780)	6.178e-2* (1.830)	3.996e-2 (1.064)
DEN	9.383e-2** (2.221)	1.876e-1*** (5.284)	1.007e-1** (2.457)	1.779e-1*** (5.026)
EC	6.947e-2 (0.823)	3.153e-1*** (5.563)	9.480e-2 (1.231)	2.906e-1*** (5.182)
EST	3.146e-1*** (8.183)	3.096e-1*** (7.869)	3.325e-1*** (9.857)	3.112e-1*** (7.965)
FIN	-1.166e-1 (-0.914)	3.433e-1*** (8.904)	-1.281e-1 (-1.068)	3.210e-1*** (8.045)
FRA	-1.007** (-2.914)	3.577e-1*** (3.466)	-8.954e-1** (-2.721)	7.754e-3 (0.049)
FYROM	-3.057e-2 (-0.567)	-1.477e-1** (-3.143)	-3.887e-2 (-0.789)	-1.172e-1** (-2.401)
GER	-8.027e-2 (-0.516)	3.359e-1** (2.832)	-8.196e-3 (-0.057)	1.330e-1 (1.450)
GRE	-4.209e-1** (-2.445)	2.215e-1*** (4.201)	-4.163e-1** (-2.511)	1.581e-1** (2.637)
HUN	1.586e-1*** (4.425)	1.479e-1*** (4.052)	1.614e-1*** (4.831)	1.544e-1*** (4.236)
IRE	-3.365e-1**	1.795e-1***	-3.411e-1**	1.502e-1***

	(-2.368)	(4.524)	(-2.551)	(3.704)
ITA	-7.620e-1**	1.672e-1**	-7.206e-1**	-4.949e-3
	(-3.202)	(2.569)	(-3.114)	(-0.062)
LAT	1.515e-1***	1.658e-1***	1.571e-1***	1.656e-1***
	(4.272)	(4.591)	(4.699)	(4.617)
LIT	2.281e-2	6.330e-3	2.852e-2	1.102e-2
	(0.660)	(0.180)	(0.843)	(0.316)
MAL	-1.667e-1**	4.039e-2	-1.677e-1**	3.452e-2
	(-2.474)	(1.035)	(-2.794)	(0.887)
MOL	1.652e-1***	7.978e-2**	1.604e-1***	9.518e-2**
	(4.166)	(2.317)	(4.121)	(2.736)
NL	7.844e-2	-2.379e-2	6.038e-2**	1.025e-2
	(1.478)	(-0.498)	(1.669)	(0.203)
NOR	-6.630e-1**	2.165e-1***	-6.821e-1**	1.651e-1***
	(-2.811)	(5.428)	(-3.037)	(3.778)
POL	-8.295e-2	2.701e-1***	-7.594e-2	2.337e-1***
	(-0.820)	(5.687)	(-0.779)	(4.645)
PT	-7.621e-1***	4.038e-2	-7.904e-1***	1.205e-2
	(-3.484)	(1.055)	(-3.829)	(0.299)
ROM	-8.665e-2	1.441e-1***	-7.241e-2	1.040e-1**
	(-1.275)	(3.808)	(-1.079)	(2.581)
SER	8.599e-2*	1.573e-1***	8.981e-2**	1.493e-1***
	(1.901)	(3.712)	(2.016)	(3.540)
SK	-1.036e-1**	-1.857e-1***	-1.080e-1**	-1.637e-1***
	(-2.485)	(-4.946)	(-2.959)	(-4.213)
SLO	-1.105e-2	-1.703e-1**	-2.423e-2	-1.141e-1*
	(-0.171)	(-3.252)	(-0.573)	(-1.949)
SP	-2.744***	2.125e-1**	-2.777***	-5.216e-2
	(-3.577)	(3.071)	(-3.742)	(-0.427)
SWE	-4.306e-1**	3.253e-1***	-4.314e-1**	2.592e-1***
	(-2.128)	(6.341)	(-2.228)	(4.682)
SWI	2.425e-2	-6.070e-2	1.316e-2	-3.578e-2
	(0.402)	(-1.050)	(0.361)	(-0.610)
TUR	-9.227e-1**	3.391e-1***	-9.584e-1**	2.468e-1***
	(-2.767)	(6.194)	(-3.004)	(3.652)
UK	-7.791e-1**	3.503e-1***	-7.422e-1**	1.509e-1*
	(-2.677)	(4.383)	(-2.625)	(1.736)
UKR	-7.950e-1**	1.800e-1***	-7.787e-1**	4.227e-2
	(-3.202)	(3.932)	(-3.229)	(0.601)
Adjusted R-squared	0.7312	0.7182	0.7318	0.7214

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses.
Key: Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR). Albania was excluded for identification purposes.
Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

Table 39 DEA regression results with COMPLEX variable

Variable	Model			
	1	2	3	4
(intercept)	38.81*** (3.511)	38.58*** (3.483)	27.92** (2.528)	39.17*** (3.494)
YEAR	-1.901e-2*** (-3.457)	-1.891e-2*** (-3.432)	-1.361e-2** (-2.474)	-1.921e-2*** (-3.443)
AGENCY	5.127e-2** (2.114)	5.803e-2** (2.603)	9.476e-2*** (3.944)	4.202e-2* (1.819)
AREA	-6.790e-5* (-1.719)	-	3.503e-5 (1.119)	-
SECTORS	1.809e-3 (1.611)	2.381e-3*** (6.271)	2.331e-3*** (4.104)	-
ATCO	6.208e-5 (1.050)	-	-	9.506e-5*** (5.764)
ATCOkm	-8.037e-2*** (-6.251)	-6.864e-2*** (-6.334)	-	-7.256e-2*** (-6.664)
STAFF_ATCO	-2.806e-3 (-0.443)	-2.435e-3 (-0.384)	-	-4.070e-3 (-0.638)
REV_COST	4.330e-2 (1.404)	4.973e-2 (1.629)	-	5.192e-2* (1.672)
COMPLEX	1.157e-2** (2.404)	9.813e-3** (2.151)	-8.304e-3** (-2.377)	1.382e-2** (3.136)
Adjusted R-squared	0.4096	0.4070	0.2562	0.3921

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

Table 40 DEA regression results with DENS and STRUCT variables

Variable	Model			
	1	2	3	4
(intercept)	36.17** (3.277)	36.51** (3.290)	26.17** (2.359)	36.87** (3.279)
YEAR	-1.775e-2** (-3.233)	-1.793e-2** (-3.248)	-1.273e-2** (-2.305)	-1.812e-2** (-3.240)
AGENCY	5.054e-2** (2.102)	5.921e-2** (2.656)	1.006e-1*** (4.149)	4.248e-2* (1.843)
AREA	-8.494e-5** (-2.126)	-	3.518e-5 (1.135)	-
SECTORS	1.651e-3 (1.516)	2.429e-3*** (6.427)	2.336e-3*** (4.136)	-
ATCO	8.177e-5 (1.386)	-	-	9.855e-5*** (5.902)
ATCOkm	-8.182e-2*** (-6.651)	-6.788e-2*** (-6.485)	-	-6.996e-2*** (-6.618)
STAFF_ATCO	-5.923e-4 (-0.093)	-5.088e-4 (-0.080)	-	-2.022e-3 (-0.314)
REV_COST	5.274e-2* (1.734)	5.749e-2* (1.909)	-	6.368e-2** (2.067)
DENS	4.719e-3 (1.006)	4.284e-3 (0.910)	-1.083e-2** (-2.572)	6.503e-3 (1.390)
STRUCT	1.531e-1** (3.161)	1.230e1** (2.694)	1.288e-2 (0.276)	1.506e-1** (3.294)
Adjusted R-squared	0.4203	0.4133	0.2569	0.3978

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

APPENDIX V – FAB DEA ANALYSIS: TABLES

Table 41 DEA efficiency results – FAB analysis

Year	FAB	Efficiency	Year	FAB	Efficiency
2005	BALTIC FAB	1.0000	2002	FABEC	1.0000
2006	BALTIC FAB	1.0000	2003	FABEC	0.9496
2007	BALTIC FAB	1.0000	2004	FABEC	0.9506
2008	BALTIC FAB	0.8211	2005	FABEC	0.9589
2009	BALTIC FAB	0.9190	2006	FABEC	1.0000
2010	BALTIC FAB	0.9074	2007	FABEC	1.0000
2011	BALTIC FAB	0.9341	2008	FABEC	1.0000
2003	BLUE MED	0.9539	2009	FABEC	0.8634
2004	BLUE MED	0.8943	2010	FABEC	0.8697
2005	BLUE MED	0.8908	2011	FABEC	0.8447
2006	BLUE MED	0.8709	2002	NEFAB	1.0000
2007	BLUE MED	0.9313	2003	NEFAB	0.9869
2008	BLUE MED	0.9346	2004	NEFAB	1.0000
2009	BLUE MED	0.8887	2005	NEFAB	0.9883
2010	BLUE MED	0.9462	2006	NEFAB	1.0000
2011	BLUE MED	0.9149	2007	NEFAB	0.9085
2002	DANUBE	1.0000	2008	NEFAB	0.8754
2003	DANUBE	1.0000	2009	NEFAB	0.8118
2004	DANUBE	1.0000	2010	NEFAB	0.8401
2005	DANUBE	0.9463	2011	NEFAB	0.8786
2006	DANUBE	0.9074	2002	SW FAB	0.8882
2007	DANUBE	1.0000	2003	SW FAB	0.7710
2008	DANUBE	0.7141	2004	SW FAB	0.7263
2009	DANUBE	1.0000	2005	SW FAB	0.7359
2010	DANUBE	1.0000	2006	SW FAB	0.7204
2011	DANUBE	0.7742	2007	SW FAB	0.6968
2002	DEN-SWE	1.0000	2008	SW FAB	0.6288
2003	DEN-SWE	0.9930	2009	SW FAB	0.5678
2004	DEN-SWE	1.0000	2010	SW FAB	0.7238
2005	DEN-SWE	1.0000	2011	SW FAB	0.7652
2006	DEN-SWE	1.0000	2002	UK-IRE	1.0000
2007	DEN-SWE	0.9400	2003	UK-IRE	0.8630
2008	DEN-SWE	0.9105	2004	UK-IRE	0.9196
2009	DEN-SWE	0.8101	2005	UK-IRE	0.9171
2010	DEN-SWE	0.7324	2006	UK-IRE	0.9386
2011	DEN-SWE	0.7946	2007	UK-IRE	0.9175
2002	FABCE	0.7552	2008	UK-IRE	1.0000
2003	FABCE	0.8039	2009	UK-IRE	0.9278
2004	FABCE	0.9267	2010	UK-IRE	0.8672
2005	FABCE	1.0000	2011	UK-IRE	0.9189
2006	FABCE	0.9283			

2007	FABCE	0.9292
2008	FABCE	0.8882
2009	FABCE	0.8613
2010	FABCE	0.8209
2011	FABCE	0.7990

Table 42 DEA allocative efficiency results – FAB analysis

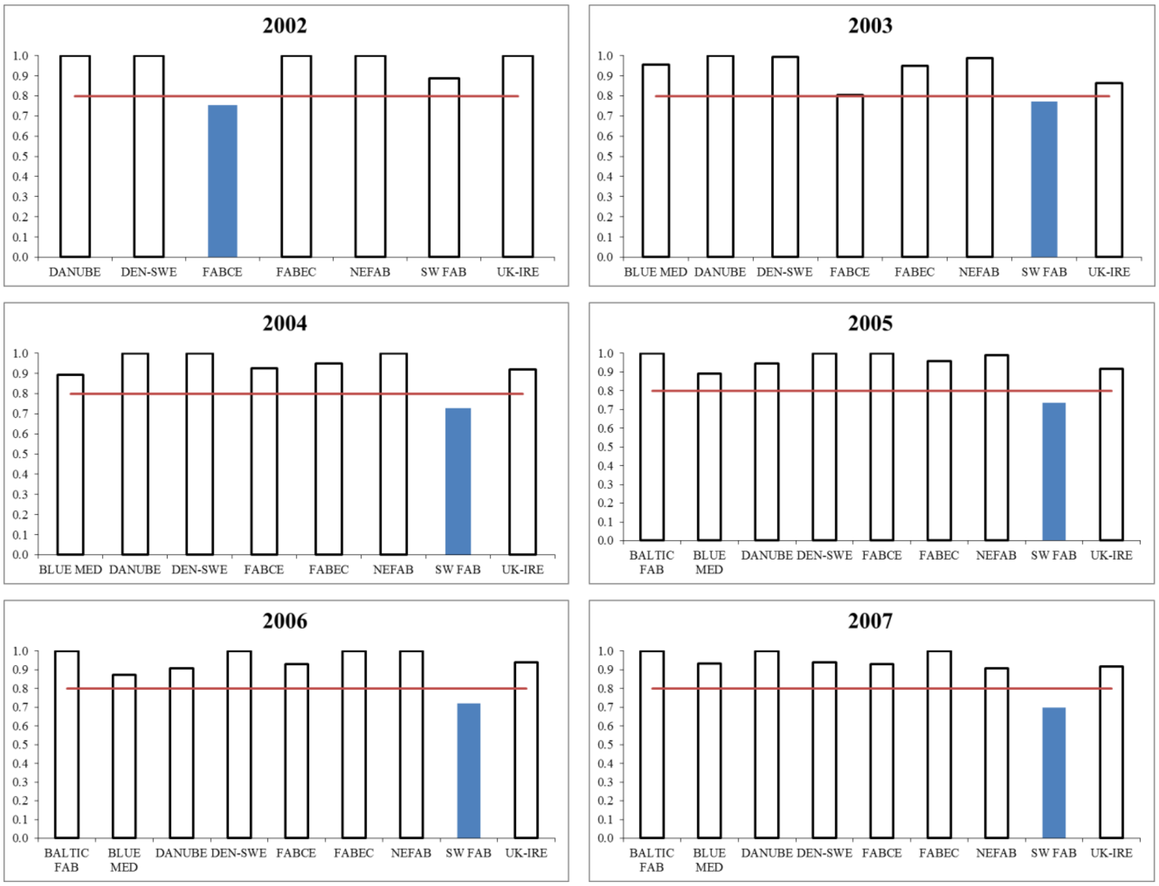
Year	FAB	Efficiency	Year	FAB	Efficiency
2005	BALTIC FAB	1.0000	2002	FABEC	1.0000
2006	BALTIC FAB	1.0000	2003	FABEC	0.9951
2007	BALTIC FAB	0.9930	2004	FABEC	0.9767
2008	BALTIC FAB	1.0000	2005	FABEC	0.9953
2009	BALTIC FAB	1.0000	2006	FABEC	0.9824
2010	BALTIC FAB	0.9798	2007	FABEC	0.9628
2011	BALTIC FAB	1.0000	2008	FABEC	0.9942
2003	BLUE MED	0.9581	2009	FABEC	0.9857
2004	BLUE MED	0.9972	2010	FABEC	0.9787
2005	BLUE MED	0.9843	2011	FABEC	1.0000
2006	BLUE MED	0.9807	2002	NEFAB	0.9937
2007	BLUE MED	0.9857	2003	NEFAB	0.9775
2008	BLUE MED	0.9855	2004	NEFAB	1.0000
2009	BLUE MED	0.9782	2005	NEFAB	0.9833
2010	BLUE MED	0.9913	2006	NEFAB	0.9640
2011	BLUE MED	0.9606	2007	NEFAB	1.0000
2002	DANUBE	1.0000	2008	NEFAB	0.9682
2003	DANUBE	0.9797	2009	NEFAB	0.9828
2004	DANUBE	0.9746	2010	NEFAB	0.9992
2005	DANUBE	0.9785	2011	NEFAB	0.9778
2006	DANUBE	0.9995	2002	SW FAB	0.9766
2007	DANUBE	0.9780	2003	SW FAB	0.9987
2008	DANUBE	0.9945	2004	SW FAB	0.9864
2009	DANUBE	1.0000	2005	SW FAB	0.9627
2010	DANUBE	0.9622	2006	SW FAB	1.0000
2011	DANUBE	0.9980	2007	SW FAB	0.9586
2002	DEN-SWE	1.0000	2008	SW FAB	0.9845
2003	DEN-SWE	0.9706	2009	SW FAB	0.9952
2004	DEN-SWE	0.9792	2010	SW FAB	0.9695
2005	DEN-SWE	0.9962	2011	SW FAB	0.9681
2006	DEN-SWE	0.9734	2002	UK-IRE	0.9973
2007	DEN-SWE	0.9951	2003	UK-IRE	0.9764
2008	DEN-SWE	1.0000	2004	UK-IRE	0.9663
2009	DEN-SWE	0.9630	2005	UK-IRE	0.9916
2010	DEN-SWE	1.0000	2006	UK-IRE	0.9500
2011	DEN-SWE	1.0000	2007	UK-IRE	0.9852
2002	FABCE	0.9755	2008	UK-IRE	0.9931
2003	FABCE	0.9823	2009	UK-IRE	0.9616
2004	FABCE	1.0000	2010	UK-IRE	0.9597
2005	FABCE	0.9721	2011	UK-IRE	0.9985
2006	FABCE	0.9972			
2007	FABCE	0.9845			
2008	FABCE	0.9586			
2009	FABCE	1.0000			
2010	FABCE	0.9886			
2011	FABCE	0.9793			

Table 43 DEA inputs and outputs slacks – FAB analysis

Year	FAB	Slacks				
		Provision costs	Other costs	IFR flight hours	Airport movements	1/delays
2005	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2006	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2007	BALTIC FAB	1.7425	0.0000	0.0000	281.0310	0.0000
2008	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2009	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2010	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0029
2011	BALTIC FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2003	BLUE MED	0.0000	0.0000	0.0000	0.0000	0.0012
2004	BLUE MED	0.0000	0.0000	0.0000	0.0000	0.0000
2005	BLUE MED	0.0000	0.0000	0.0000	0.0000	0.0000
2006	BLUE MED	4.6902	0.0000	0.0000	222.9706	0.0000
2007	BLUE MED	35.7290	0.0000	0.0000	0.0000	0.0000
2008	BLUE MED	0.0000	0.0000	18.7615	0.0000	0.0000
2009	BLUE MED	0.0000	0.0000	0.0000	0.0000	0.0018
2010	BLUE MED	0.0000	12.5064	0.0000	0.0000	0.0016
2011	BLUE MED	0.0000	0.0000	0.0000	0.0000	0.0012
2002	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0000
2003	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0000
2004	DANUBE	2.0485	0.0000	0.0000	93.2697	0.0009
2005	DANUBE	39.1011	0.0000	0.0000	0.0000	0.0000
2006	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0000
2007	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0023
2008	DANUBE	0.0000	8.2255	0.0000	0.0000	0.0011
2009	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0000
2010	DANUBE	0.0000	0.0000	0.0000	0.0000	0.0003
2011	DANUBE	0.0000	0.0928	0.0000	21.1356	0.0000
2002	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2003	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2004	DEN-SWE	32.0780	0.0000	0.0000	0.0000	0.0000
2005	DEN-SWE	0.0000	0.0000	4.5507	0.0000	0.0000
2006	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0025
2007	DEN-SWE	0.0000	7.8400	0.0000	0.0000	0.0005
2008	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2009	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0002
2010	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2011	DEN-SWE	0.0000	0.0000	0.0000	0.0000	0.0000
2002	FABCE	0.0000	0.0000	0.0000	61.7062	0.0001
2003	FABCE	0.0000	0.0000	0.0000	0.0000	0.0000
2004	FABCE	0.0000	0.0000	0.0000	0.0000	0.0000
2005	FABCE	0.0000	0.0000	0.0000	0.0000	0.0023
2006	FABCE	0.0000	4.6986	0.0000	0.0000	0.0001
2007	FABCE	0.0000	0.0000	0.0000	0.0000	0.0000
2008	FABCE	0.0000	0.0000	0.0000	0.0000	0.0003
2009	FABCE	0.0000	0.0000	0.0000	0.0000	0.0000
2010	FABCE	0.0000	5.6653	0.0000	24.6622	0.0011
2011	FABCE	0.0000	0.0000	0.0000	121.1473	0.0002
2002	FABEC	0.0000	0.0000	0.0000	0.0000	0.0000
2003	FABEC	0.0000	0.0000	0.0000	0.0000	0.0000
2004	FABEC	0.0000	0.0000	0.0000	0.0000	0.0017

2005	FABEC	0.0000	8.2982	0.0000	0.0000	0.0000
2006	FABEC	0.0000	4.0269	0.0000	106.6608	0.0032
2007	FABEC	0.0000	0.0000	0.0000	355.8995	0.0001
2008	FABEC	0.0000	1.5627	0.0000	162.7372	0.0000
2009	FABEC	0.0000	7.3642	0.0000	8.8936	0.0032
2010	FABEC	0.0000	0.0000	0.0000	122.1182	0.0001
2011	FABEC	0.0000	0.0000	0.0000	0.0000	0.0000
2002	NEFAB	0.0000	0.0000	0.0000	0.0000	0.0043
2003	NEFAB	0.0000	0.0000	0.0000	0.0000	0.0014
2004	NEFAB	0.0000	0.0000	0.0000	0.0000	0.0000
2005	NEFAB	0.0000	3.2160	0.0000	90.5731	0.0028
2006	NEFAB	0.0000	0.0000	0.0000	348.3823	0.0000
2007	NEFAB	0.0000	0.0000	0.0000	0.0000	0.0000
2008	NEFAB	0.0000	14.4454	0.0000	0.0000	0.0000
2009	NEFAB	0.0000	0.0000	0.0000	236.3380	0.0003
2010	NEFAB	0.0000	4.0028	0.0000	34.6421	0.0000
2011	NEFAB	0.0000	0.0000	0.0000	0.0000	0.0000
2002	SW FAB	0.0000	0.0000	0.0000	0.0000	0.0023
2003	SW FAB	0.0000	1.9360	0.0000	0.0622	0.0000
2004	SW FAB	0.0000	2.7750	0.0000	127.3158	0.0027
2005	SW FAB	0.0000	0.0000	0.0000	433.5980	0.0000
2006	SW FAB	0.0000	0.0000	0.0000	0.0000	0.0000
2007	SW FAB	0.0000	19.5944	0.0000	6.2657	0.0000
2008	SW FAB	0.0000	0.0000	0.0000	305.8911	0.0007
2009	SW FAB	0.0000	0.0000	0.0000	15.5337	0.0001
2010	SW FAB	0.0000	2.0968	0.0000	0.0000	0.0000
2011	SW FAB	2.5684	0.0000	0.0000	0.0000	0.0032
2002	UK-IRE	0.0000	3.9376	0.0000	45.2207	0.0004
2003	UK-IRE	0.0000	6.7424	0.0000	188.7661	0.0019
2004	UK-IRE	0.0000	0.0000	0.0000	452.5067	0.0001
2005	UK-IRE	0.0000	2.3935	0.0000	345.2111	0.0000
2006	UK-IRE	0.0000	25.7826	0.0000	18.0513	0.0000
2007	UK-IRE	0.0000	0.0000	0.0000	353.5449	0.0000
2008	UK-IRE	0.0000	35.0437	286.4737	0.0000	0.0000
2009	UK-IRE	0.0000	7.7741	0.0000	0.0000	0.0017
2010	UK-IRE	45.5730	0.0000	0.0000	0.0000	0.0009
2011	UK-IRE	0.0000	2.1951	0.0000	69.0675	0.0000

APPENDIX VI – FAB DEA ANALYSIS: FIGURES



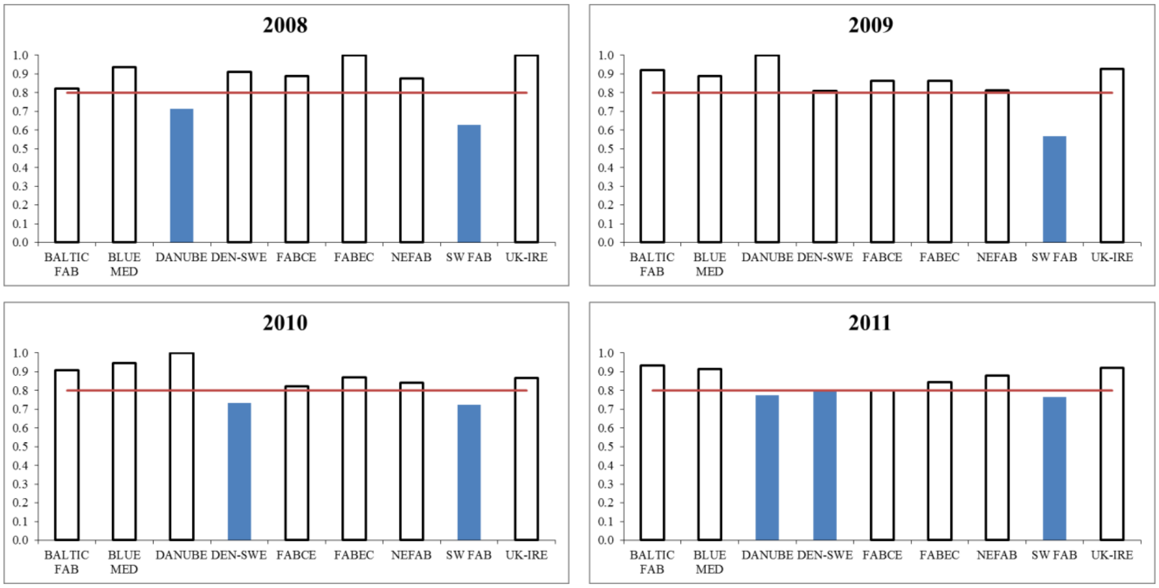
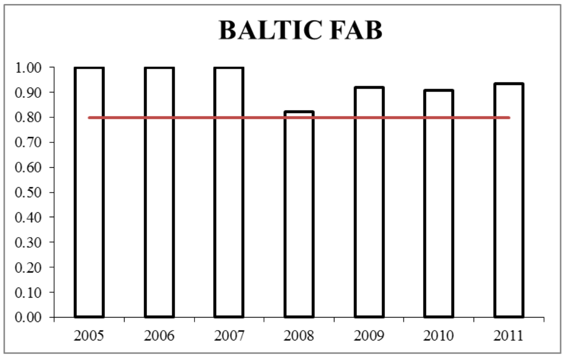
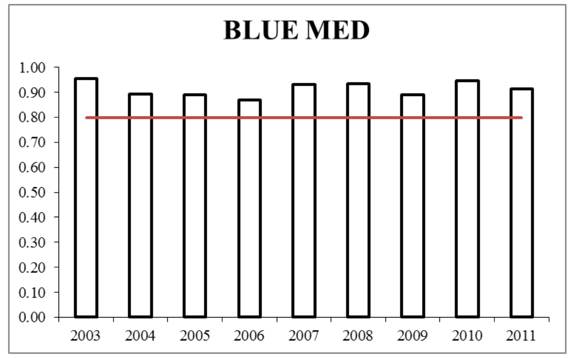
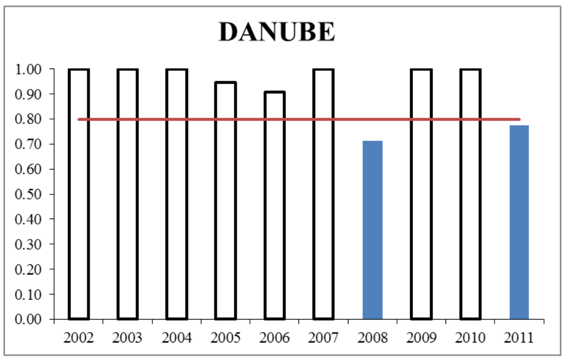
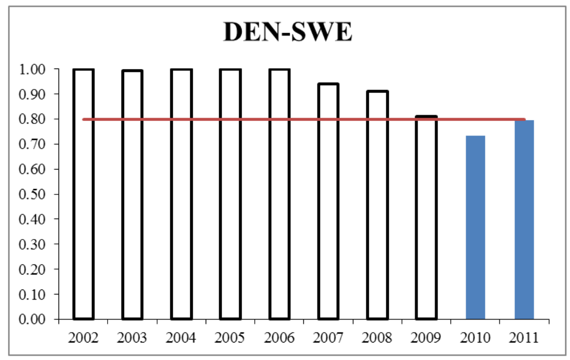


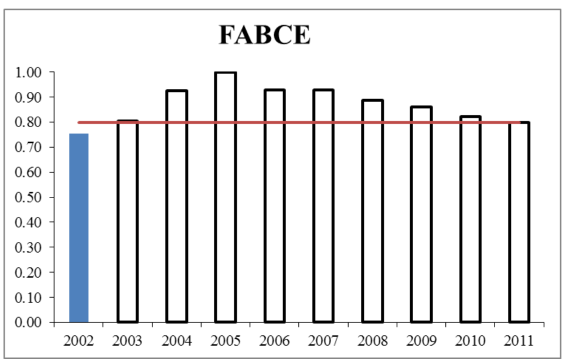
Figure 17 DEA FAB results for each year

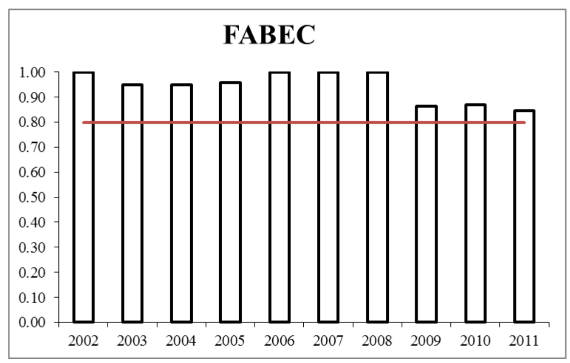

BALTIC FAB
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2005
2006
2007
2008
2009
2010
2011


BLUE MED
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2003
2004
2005
2006
2007
2008
2009
2010
2011


DANUBE
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


DEN-SWE
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


FABCE
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011


FABEC
1.00
0.90
0.80
0.70
0.60
0.50
0.40
0.30
0.20
0.10
0.00
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011

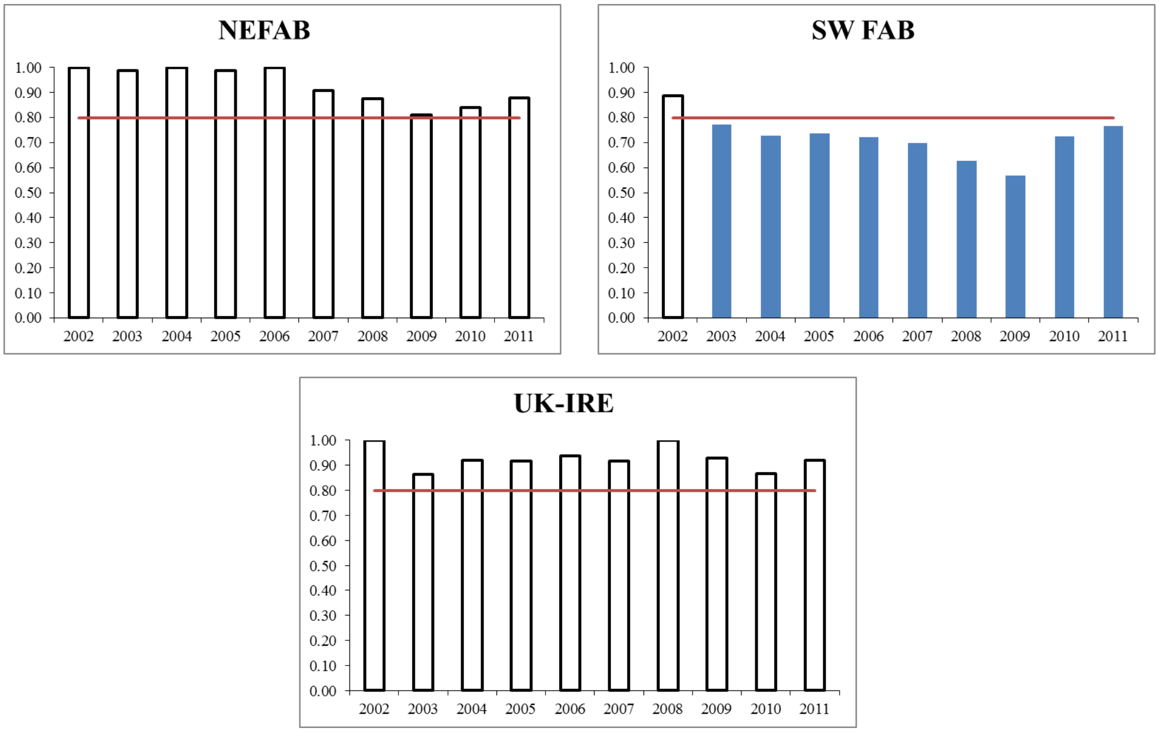


Figure 18 DEA results for each FAB

APPENDIX VII – FAB DEA ANALYSIS: REGRESSIONS

Table 44 FAB regression results with temporal dummy variables

Variable	Model 1	Model 2	Model 3	Model 4
(intercept)	8.253e-1*** (7.687)	4.921e-1*** (4.557)	9.484e-1*** (32.77)	5.109e-1*** (4.696)
AREA	-1.289e-4*** (-5.917)	-	-6.958-5*** (-6.289)	-
SECTORS	-8.595e-4 (-1.300)	-1.697e-4 (-0.717)	4.186e-4** (3.259)	-
ATCO	1.030e-4** (2.735)	-	-	-1.231e-5 (-1.126)
ATCOkm	-7.893e-2** (-2.956)	1.526e-2 (0.597)	-	2.357e-2 (0.937)
STAFF_ATCO	-2.323e-3 (-0.131)	1.493e-2 (0.706)	-	8.349e-3 (0.389)
REV_COST	2.624e-1** (2.483)	3.608e-1** (2.970)	-	3.572e-1** (3.047)
Y2003	-2.449e-2 (-0.714)	-9.566e-3 (-0.237)	-2.450e-3 (-0.068)	-6.984e-3 (-0.175)
Y2004	-1.441e-2 (-0.419)	-1.129e-3 (-0.028)	1.047e-2 (0.290)	1.220e-3 (0.030)
Y2005	-2.556e-2 (-0.738)	-7.359e-3 (-0.184)	1.110e-2 (0.316)	-5.018e-3 (-0.128)
Y2006	-2.864e-2 (-0.854)	-1.211e-2 (-0.307)	-2.759e-5 (-0.001)	-1.002e-2 (-0.257)
Y2007	-3.616e-2 (-1.086)	-2.038-2 (-0.519)	-1.070e-2 (-0.305)	-1.816e-2 (-0.466)
Y2008	-9.244e-2** (-2.753)	-7.778e-2* (-1.979)	-6.283e-2* (-1.789)	-7.487e-2* (-1.918)
Y2009	-8.900e-2** (-2.670)	-6.636e-2* (-1.688)	-7.462e-2** (-2.124)	-6.380e-2 (-1.631)
Y2010	-9.924-e2** (-2.924)	-8.318e-2** (-2.112)	-6.679e-2* (-1.901)	-8.018e-2** (-2.053)
Y2011	-1.153e-1** (-3.251)	-1.016e-1** (-2.487)	-7.016e-2** (-1.998)	-9.908e-2** (-2.469)
Adjusted R-squared	0.4762	0.2156	0.3676	0.2237

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

Table 45 FAB regression results with geographical dummy variables

Variable	Model 1	Model 2	Model 3	Model 4
(intercept)	24.51*** (5.559)	25.69*** (5.695)	23.85*** (5.262)	25.66*** (5.723)
YEAR	-1.240e-2*** (-5.690)	-1.258e-2*** (-5.564)	-1.147e-2*** (-5.078)	-1.257e-2*** (-5.593)
AREA	5.219e-4** (2.524)	-	7.511e-5* (1.967)	-
SECTORS	-1.728e-3** (-2.331)	5.304e-5 (0.259)	-3.328e-4 (-1.334)	-
ATCO	-1.344e-4 (-1.422)	-	-	8.329e-6 (0.818)
ATCOkm	3.161e-1** (2.328)	1.060e-2 (0.432)	-	-2.172e-3 (-0.081)
STAFF_ATCO	3.670e-2 (1.060)	1.551e-2 (0.436)	-	2.492e-2 (0.688)
REV_COST	3.915e-1** (3.358)	3.361e-1** (2.750)	-	3.250e-1** (2.676)
BALTIC	2.309e-1** (2.227)	2.889e-2 (0.891)	5.760e-2* (1.973)	2.445e-2 (0.746)
BLUEMED	-4.167e-2 (-0.705)	8.171e-2* (1.704)	-2.580e-2 (-0.699)	8.092e-2* (1.703)
DEN_SWE	5.487e-2 (1.322)	1.558e-2 (0.526)	2.650e-2 (1.004)	1.619e-2 (0.561)
FABCE	2.353e-1** (2.642)	5.580e-2 (1.028)	-1.364e-3 (-0.055)	6.164e-2 (1.144)
SWFAB	2.891e-1** (2.818)	8.156e-2* (1.906)	1.339e-2 (0.522)	7.820e-2* (1.826)
UK_IRE	-6.848e-1** (-3.127)	-9.246e-2 (-1.490)	-3.167e-1*** (-4.026)	-9.823e-2 (-1.581)
Adjusted R-squared	0.6211	0.5715	0.5571	0.5749

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; t-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of efficiency.

APPENDIX VIII – ANSP SFA ANALYSIS: TABLES

Table 46 SFA efficiencies for Cobb-Douglas specifications

Year	Country	Model 1	2	3	4	Average
2002	ALB	0.3834	0.3037	0.2151	0.2221	0.2811
2003	ALB	0.3642	0.4351	0.2899	0.3130	0.3506
2004	ALB	0.4624	0.4902	0.3229	0.3536	0.4073
2005	ALB	0.4192	0.4648	0.3104	0.3358	0.3826
2006	ALB	0.4251	0.4774	0.3167	0.3429	0.3905
2007	ALB	0.4231	0.5595	0.3661	0.4031	0.4380
2008	ALB	0.5250	0.5150	0.3442	0.3764	0.4402
2009	ALB	0.4887	0.4644	0.3240	0.3439	0.4052
2010	ALB	0.4285	0.3856	0.2871	0.2954	0.3492
2011	ALB	0.5141	0.4406	0.3023	0.3195	0.3941
2009	ARM	0.3034	0.3203	0.2014	0.2333	0.2646
2010	ARM	0.3132	0.3963	0.2415	0.2881	0.3098
2011	ARM	0.4110	0.4414	0.2470	0.3014	0.3502
2002	AUS	0.6058	0.4166	0.4333	0.3888	0.4611
2003	AUS	0.5846	0.4850	0.4903	0.4532	0.5033
2004	AUS	0.7978	0.5916	0.5830	0.5484	0.6302
2005	AUS	0.8007	0.6302	0.6195	0.5879	0.6596
2006	AUS	0.9296	0.5884	0.5934	0.5521	0.6659
2007	AUS	0.9224	0.6842	0.6750	0.6439	0.7314
2008	AUS	0.8853	0.6950	0.6859	0.6607	0.7317
2009	AUS	0.7508	0.6214	0.6179	0.5869	0.6443
2010	AUS	0.6780	0.5858	0.5879	0.5551	0.6017
2011	AUS	0.6533	0.6148	0.5980	0.5717	0.6094
2002	BEL	0.4279	0.2695	0.2951	0.2623	0.3137
2003	BEL	0.4393	0.3211	0.3409	0.3119	0.3533
2004	BEL	0.5171	0.3437	0.3590	0.3319	0.3879
2005	BEL	0.5263	0.3349	0.3486	0.3201	0.3825
2006	BEL	0.5176	0.3351	0.3516	0.3203	0.3812
2007	BEL	0.5223	0.3843	0.3934	0.3680	0.4170
2008	BEL	0.5316	0.4146	0.4184	0.3969	0.4404
2009	BEL	0.5245	0.3612	0.3716	0.3467	0.4010
2010	BEL	0.5236	0.3558	0.3670	0.3408	0.3968
2011	BEL	0.7062	0.4176	0.4015	0.3825	0.4769
2002	BUL	0.3734	0.1344	0.1598	0.1212	0.1972
2003	BUL	0.3913	0.1762	0.1956	0.1569	0.2300
2004	BUL	0.4036	0.2059	0.2225	0.1832	0.2538
2005	BUL	0.4360	0.2177	0.2362	0.1952	0.2713
2006	BUL	0.4839	0.2509	0.2659	0.2249	0.3064
2007	BUL	0.5452	0.3238	0.3280	0.2897	0.3717
2008	BUL	0.5140	0.3750	0.3705	0.3361	0.3989
2009	BUL	0.5195	0.3627	0.3608	0.3253	0.3921

2010	BUL	0.5977	0.3725	0.3710	0.3372	0.4196
2011	BUL	0.8825	0.4473	0.4051	0.3817	0.5292
2002	CRO	0.9988	0.3176	0.3268	0.2446	0.4720
2003	CRO	0.7830	0.3378	0.2998	0.2870	0.4269
2004	CRO	0.8098	0.4035	0.3541	0.3435	0.4777
2005	CRO	0.7897	0.4440	0.3918	0.3811	0.5016
2006	CRO	0.7983	0.4448	0.3926	0.3797	0.5039
2007	CRO	0.7376	0.5169	0.4503	0.4433	0.5370
2008	CRO	0.7738	0.5709	0.4926	0.4899	0.5818
2009	CRO	0.7487	0.5462	0.4707	0.4668	0.5581
2010	CRO	0.7809	0.5477	0.4776	0.4698	0.5690
2011	CRO	0.9577	0.5639	0.4797	0.4717	0.6182
2002	CYP	0.9629	0.8221	0.6255	0.6719	0.7706
2003	CYP	0.9596	0.8574	0.6737	0.7389	0.8074
2004	CYP	0.9277	0.7884	0.5972	0.6382	0.7379
2005	CYP	0.9394	0.8467	0.6548	0.7059	0.7867
2006	CYP	0.9094	0.8585	0.6767	0.7318	0.7941
2007	CYP	0.9045	0.8227	0.6456	0.6867	0.7649
2008	CYP	0.9328	0.9187	0.8166	0.9160	0.8960
2009	CYP	0.8895	0.8922	0.7522	0.8216	0.8389
2010	CYP	0.8451	0.9102	0.7984	0.8835	0.8593
2011	CYP	0.8218	0.9084	0.7808	0.8727	0.8459
2002	CZ	0.4746	0.3466	0.3274	0.2982	0.3617
2003	CZ	0.5015	0.4042	0.3787	0.3518	0.4091
2004	CZ	0.5814	0.4819	0.4510	0.4238	0.4845
2005	CZ	0.5722	0.4602	0.4408	0.4114	0.4711
2006	CZ	0.5476	0.4184	0.4116	0.3778	0.4389
2007	CZ	0.5978	0.4252	0.4203	0.3847	0.4570
2008	CZ	0.6062	0.5352	0.5080	0.4801	0.5324
2009	CZ	0.5911	0.4967	0.4782	0.4470	0.5032
2010	CZ	0.6907	0.4807	0.4687	0.4352	0.5188
2011	CZ	0.5407	0.5078	0.4702	0.4457	0.4911
2002	DEN	0.9838	0.7687	0.6858	0.6889	0.7818
2003	DEN	0.8944	0.8539	0.7696	0.8199	0.8345
2004	DEN	0.9086	0.8888	0.8187	0.8929	0.8773
2005	DEN	0.8920	0.8790	0.8012	0.8714	0.8609
2006	DEN	0.8971	0.8939	0.8274	0.9112	0.8824
2007	DEN	0.7163	0.8765	0.8010	0.8733	0.8168
2008	DEN	0.8912	0.8774	0.8041	0.8754	0.8620
2009	DEN	0.8372	0.8176	0.7243	0.7532	0.7831
2010	DEN	0.8735	0.8230	0.7324	0.7657	0.7986
2011	DEN	0.8819	0.8678	0.7813	0.8389	0.8425
2002	EC	0.9921	0.7044	0.5554	0.5823	0.7085
2003	EC	0.9920	0.8033	0.6368	0.6847	0.7792
2004	EC	0.9928	0.8606	0.7105	0.7778	0.8354
2005	EC	0.9929	0.8834	0.7508	0.8352	0.8656
2006	EC	0.9928	0.8900	0.7679	0.8563	0.8767
2007	EC	0.9926	0.9106	0.8106	0.9162	0.9075
2008	EC	0.9958	0.9238	0.8218	0.9376	0.9197
2009	EC	0.9960	0.8909	0.7423	0.8421	0.8678
2010	EC	0.9957	0.8741	0.7185	0.8043	0.8481
2011	EC	0.9905	0.9179	0.8020	0.9244	0.9087
2002	EST	0.6031	0.5907	0.3496	0.4145	0.4895

2003	EST	0.7087	0.6686	0.3939	0.4737	0.5612
2004	EST	0.8624	0.8033	0.4750	0.5926	0.6833
2005	EST	0.9463	0.8462	0.5173	0.6528	0.7407
2006	EST	0.9351	0.8676	0.5521	0.6995	0.7636
2007	EST	0.9421	0.9130	0.6416	0.8332	0.8325
2008	EST	0.9033	0.9275	0.6948	0.8998	0.8563
2009	EST	0.8357	0.8925	0.5971	0.7665	0.7730
2010	EST	0.7633	0.8651	0.5602	0.7072	0.7240
2011	EST	0.7485	0.9074	0.6272	0.8080	0.7728
2002	FIN	0.9917	0.6546	0.5560	0.5473	0.6874
2003	FIN	0.9927	0.8080	0.6778	0.7014	0.7950
2004	FIN	0.9930	0.8476	0.7246	0.7643	0.8324
2005	FIN	0.9933	0.8370	0.7125	0.7473	0.8225
2006	FIN	0.9932	0.8447	0.7220	0.7605	0.8301
2007	FIN	0.9935	0.8345	0.7074	0.7465	0.8205
2008	FIN	0.9935	0.8633	0.7425	0.7998	0.8498
2009	FIN	0.9935	0.7963	0.6617	0.6908	0.7856
2010	FIN	0.9934	0.7972	0.6634	0.6894	0.7859
2011	FIN	0.9950	0.8620	0.7431	0.7936	0.8484
2002	FRA	0.9933	0.6916	0.9272	0.6986	0.8277
2003	FRA	0.9937	0.8050	0.9458	0.8369	0.8953
2004	FRA	0.9921	0.8519	0.9526	0.9090	0.9264
2005	FRA	0.9909	0.8470	0.9525	0.9011	0.9229
2006	FRA	0.9877	0.8542	0.9539	0.9145	0.9276
2007	FRA	0.9870	0.8710	0.9570	0.9364	0.9378
2008	FRA	0.9891	0.8782	0.9581	0.9448	0.9426
2009	FRA	0.9588	0.8258	0.9490	0.8761	0.9024
2010	FRA	0.8804	0.8096	0.9463	0.8539	0.8725
2011	FRA	0.9979	0.8657	0.9539	0.9068	0.9311
2002	FYROM	0.2715	0.1805	0.1375	0.1318	0.1804
2003	FYROM	0.2735	0.2163	0.1621	0.1587	0.2027
2004	FYROM	0.2758	0.2571	0.1879	0.1882	0.2272
2005	FYROM	0.2779	0.2236	0.1713	0.1693	0.2105
2006	FYROM	0.2968	0.2288	0.1742	0.1739	0.2184
2007	FYROM	0.3346	0.2420	0.1794	0.1825	0.2346
2008	FYROM	0.3146	0.2218	0.1678	0.1701	0.2186
2009	FYROM	0.2747	0.2039	0.1597	0.1589	0.1993
2010	FYROM	0.4070	0.2050	0.1574	0.1603	0.2325
2011	FYROM	0.4436	0.2358	0.1625	0.1720	0.2535
2002	GER	0.9981	0.5768	0.8638	0.5612	0.7500
2003	GER	0.9981	0.6532	0.8964	0.6359	0.7959
2004	GER	0.9979	0.7296	0.9181	0.7176	0.8408
2005	GER	0.9973	0.7243	0.9165	0.7180	0.8390
2006	GER	0.9980	0.7492	0.9264	0.7366	0.8525
2007	GER	0.9980	0.8140	0.9227	0.7796	0.8786
2008	GER	0.9972	0.8435	0.9396	0.8781	0.9146
2009	GER	0.9975	0.7649	0.9232	0.7531	0.8597
2010	GER	0.9978	0.7311	0.9175	0.7161	0.8406
2011	GER	0.9986	0.7550	0.8985	0.6835	0.8339
2003	GRE	0.9861	0.7192	0.7369	0.6664	0.7771
2004	GRE	0.9868	0.8123	0.8160	0.7785	0.8484
2005	GRE	0.9845	0.7313	0.7516	0.6802	0.7869
2006	GRE	0.9905	0.5548	0.6183	0.5250	0.6721

2007	GRE	0.9911	0.6878	0.7363	0.6636	0.7697
2008	GRE	0.9902	0.7142	0.7523	0.6798	0.7841
2009	GRE	0.9902	0.7003	0.7405	0.6670	0.7745
2010	GRE	0.9907	0.7635	0.7890	0.7309	0.8185
2011	GRE	0.9933	0.8366	0.8232	0.8025	0.8639
2002	HUN	0.4291	0.3425	0.3250	0.2953	0.3480
2003	HUN	0.4852	0.4171	0.3846	0.3614	0.4121
2004	HUN	0.5094	0.5821	0.5132	0.5031	0.5269
2005	HUN	0.5170	0.6111	0.5422	0.5364	0.5517
2006	HUN	0.6042	0.5638	0.5109	0.4942	0.5433
2007	HUN	0.6252	0.6610	0.5797	0.5766	0.6106
2008	HUN	0.6197	0.6667	0.5825	0.5810	0.6125
2009	HUN	0.6153	0.5602	0.5071	0.4907	0.5433
2010	HUN	0.5758	0.5470	0.4970	0.4813	0.5253
2011	HUN	0.6502	0.5129	0.4524	0.4368	0.5131
2002	IRE	0.9966	0.7490	0.6785	0.6454	0.7674
2003	IRE	0.9960	0.7790	0.6969	0.6848	0.7892
2004	IRE	0.9961	0.8292	0.7491	0.7427	0.8293
2005	IRE	0.9962	0.8911	0.8373	0.8787	0.9008
2006	IRE	0.9964	0.8622	0.8071	0.8159	0.8704
2007	IRE	0.9964	0.8912	0.8477	0.8893	0.9061
2008	IRE	0.9964	0.9010	0.8598	0.9118	0.9173
2009	IRE	0.9964	0.8543	0.7975	0.7984	0.8616
2010	IRE	0.9962	0.7602	0.7040	0.6673	0.7819
2011	IRE	0.9958	0.7831	0.7143	0.6821	0.7938
2002	ITA	0.9944	0.5961	0.8199	0.5817	0.7480
2003	ITA	0.9941	0.6862	0.8695	0.6640	0.8035
2004	ITA	0.9959	0.7122	0.8804	0.6868	0.8188
2005	ITA	0.9967	0.7704	0.8996	0.7450	0.8529
2006	ITA	0.9974	0.7842	0.9059	0.7626	0.8625
2007	ITA	0.9975	0.8253	0.9201	0.8270	0.8925
2008	ITA	0.9979	0.8416	0.9272	0.8477	0.9036
2009	ITA	0.9977	0.7814	0.9074	0.7542	0.8602
2010	ITA	0.9973	0.7882	0.9108	0.7679	0.8660
2011	ITA	0.9981	0.8147	0.9147	0.7889	0.8791
2002	LAT	0.6431	0.3565	0.2439	0.2521	0.3739
2003	LAT	0.6696	0.4741	0.3101	0.3328	0.4467
2004	LAT	0.8326	0.5371	0.3521	0.3961	0.5294
2005	LAT	0.7708	0.5670	0.3882	0.4343	0.5401
2006	LAT	0.6544	0.5783	0.4021	0.4472	0.5205
2007	LAT	0.5975	0.7271	0.5125	0.5782	0.6038
2008	LAT	0.5945	0.8565	0.6344	0.7415	0.7067
2009	LAT	0.6131	0.8115	0.5715	0.6589	0.6637
2010	LAT	0.5675	0.7361	0.5172	0.5831	0.6010
2011	LAT	0.6518	0.8523	0.6145	0.7157	0.7086
2002	LIT	0.3968	0.2385	0.1598	0.1711	0.2415
2003	LIT	0.4048	0.2530	0.1842	0.1894	0.2579
2004	LIT	0.4841	0.3153	0.2247	0.2382	0.3156
2005	LIT	0.4762	0.3619	0.2568	0.2744	0.3423
2006	LIT	0.4356	0.3807	0.2754	0.2915	0.3458
2007	LIT	0.4972	0.4834	0.3414	0.3717	0.4234
2008	LIT	0.4990	0.6105	0.4174	0.4803	0.5018
2009	LIT	0.4149	0.4396	0.3130	0.3429	0.3776

2010	LIT	0.4167	0.4559	0.3283	0.3561	0.3892
2011	LIT	0.6656	0.5487	0.3766	0.4156	0.5016
2002	MAL	0.9815	0.3444	0.2457	0.2595	0.4578
2003	MAL	0.9817	0.4737	0.3229	0.3468	0.5313
2004	MAL	0.9816	0.5419	0.3553	0.3959	0.5687
2005	MAL	0.9842	0.5746	0.3732	0.4182	0.5875
2006	MAL	0.9842	0.5708	0.3711	0.4152	0.5853
2007	MAL	0.9858	0.6134	0.4005	0.4517	0.6128
2008	MAL	0.9863	0.7803	0.4996	0.5837	0.7125
2009	MAL	0.9851	0.7407	0.4724	0.5445	0.6857
2010	MAL	0.9852	0.7821	0.4980	0.5827	0.7120
2011	MAL	0.9843	0.8497	0.5600	0.6666	0.7652
2002	MOL	0.3280	0.1747	0.1110	0.1179	0.1829
2003	MOL	0.3130	0.1725	0.1138	0.1214	0.1802
2004	MOL	0.3321	0.2337	0.1456	0.1620	0.2183
2005	MOL	0.3414	0.2660	0.1660	0.1862	0.2399
2006	MOL	0.3431	0.2794	0.1715	0.1955	0.2474
2007	MOL	0.3571	0.3584	0.2163	0.2507	0.2956
2008	MOL	0.4013	0.4081	0.2440	0.2885	0.3355
2009	MOL	0.3602	0.3668	0.2268	0.2619	0.3039
2010	MOL	0.3664	0.4427	0.2727	0.3166	0.3496
2011	MOL	0.4639	0.5499	0.3069	0.3738	0.4236
2002	NL	0.4479	0.3353	0.3675	0.3213	0.3680
2003	NL	0.3932	0.4046	0.4222	0.3854	0.4014
2004	NL	0.3988	0.4269	0.4401	0.4068	0.4182
2005	NL	0.3581	0.3878	0.4026	0.3699	0.3796
2006	NL	0.4295	0.4212	0.4356	0.4033	0.4224
2007	NL	0.4236	0.4562	0.4649	0.4365	0.4453
2008	NL	0.4220	0.4730	0.4780	0.4505	0.4559
2009	NL	0.4185	0.3785	0.3946	0.3646	0.3890
2010	NL	0.3981	0.4104	0.4197	0.3906	0.4047
2011	NL	0.4988	0.4726	0.4602	0.4386	0.4676
2002	NOR	0.9977	0.6891	0.6881	0.5957	0.7427
2003	NOR	0.9977	0.8794	0.8631	0.8658	0.9015
2004	NOR	0.9976	0.9284	0.9108	0.9628	0.9499
2005	NOR	0.9973	0.9146	0.8942	0.9418	0.9370
2006	NOR	0.9975	0.8730	0.8537	0.8613	0.8964
2007	NOR	0.9976	0.8309	0.8212	0.7884	0.8595
2008	NOR	0.9977	0.8848	0.8700	0.8945	0.9117
2009	NOR	0.9977	0.8717	0.8560	0.8658	0.8978
2010	NOR	0.9978	0.8721	0.8601	0.8647	0.8987
2011	NOR	0.9981	0.8886	0.8755	0.8965	0.9147
2005	POL	0.9843	0.6006	0.5830	0.5312	0.6748
2006	POL	0.9818	0.6217	0.6135	0.5586	0.6939
2007	POL	0.9459	0.6380	0.6509	0.5861	0.7052
2008	POL	0.9093	0.5582	0.5871	0.5192	0.6434
2009	POL	0.7950	0.5150	0.5476	0.4823	0.5850
2010	POL	0.7549	0.5401	0.5723	0.5054	0.5932
2011	POL	0.9344	0.5925	0.5864	0.5309	0.6610
2002	PT	0.9974	0.3393	0.3745	0.3095	0.5052
2003	PT	0.9973	0.4087	0.4325	0.3704	0.5522
2004	PT	0.9973	0.4440	0.4642	0.4016	0.5768
2005	PT	0.9974	0.4362	0.4621	0.3975	0.5733

2006	PT	0.9974	0.4662	0.4911	0.4272	0.5955
2007	PT	0.9974	0.5167	0.5359	0.4742	0.6311
2008	PT	0.9973	0.5232	0.5441	0.4825	0.6368
2009	PT	0.9973	0.5037	0.5229	0.4618	0.6214
2010	PT	0.9974	0.5703	0.5797	0.5213	0.6672
2011	PT	0.9970	0.5901	0.5868	0.5323	0.6765
2002	ROM	0.4715	0.1593	0.2028	0.1464	0.2450
2003	ROM	0.7140	0.1872	0.2325	0.1727	0.3266
2004	ROM	0.6331	0.2618	0.3074	0.2384	0.3602
2005	ROM	0.7034	0.3290	0.3730	0.2981	0.4259
2006	ROM	0.7230	0.3256	0.3694	0.2958	0.4284
2007	ROM	0.7440	0.3828	0.4169	0.3514	0.4737
2008	ROM	0.8095	0.3955	0.4288	0.3660	0.4999
2009	ROM	0.8629	0.3790	0.4137	0.3460	0.5004
2010	ROM	0.4308	0.4118	0.4376	0.3828	0.4158
2011	ROM	0.9776	0.4707	0.4653	0.4175	0.5828
2006	SER	0.5932	0.3999	0.3855	0.3500	0.4322
2007	SER	0.6225	0.4808	0.4499	0.4177	0.4927
2008	SER	0.7260	0.5734	0.5109	0.4954	0.5764
2009	SER	0.6869	0.5657	0.5062	0.4884	0.5618
2010	SER	0.6887	0.5771	0.5224	0.4993	0.5719
2011	SER	0.8303	0.6801	0.5756	0.5678	0.6635
2002	SK	0.3820	0.2271	0.1933	0.1826	0.2462
2003	SK	0.4188	0.3163	0.2577	0.2542	0.3117
2004	SK	0.5031	0.4064	0.3202	0.3262	0.3890
2005	SK	0.4962	0.4077	0.3276	0.3332	0.3912
2006	SK	0.5124	0.4167	0.3342	0.3392	0.4006
2007	SK	0.5133	0.4120	0.3308	0.3381	0.3985
2008	SK	0.5260	0.4077	0.3330	0.3368	0.4009
2009	SK	0.5061	0.3519	0.2975	0.2914	0.3617
2010	SK	0.5048	0.3339	0.2894	0.2802	0.3521
2011	SK	0.6136	0.3768	0.3029	0.3012	0.3986
2002	SLO	0.3846	0.2943	0.2144	0.2227	0.2790
2003	SLO	0.3882	0.3578	0.2496	0.2695	0.3163
2004	SLO	0.5358	0.4081	0.2831	0.3141	0.3853
2005	SLO	0.5468	0.4329	0.3042	0.3376	0.4054
2006	SLO	0.5232	0.4071	0.2926	0.3226	0.3864
2007	SLO	0.5846	0.4209	0.3060	0.3393	0.4127
2008	SLO	0.5819	0.4345	0.3190	0.3524	0.4220
2009	SLO	0.6071	0.3873	0.2915	0.3182	0.4010
2010	SLO	0.5882	0.3620	0.2782	0.2993	0.3819
2011	SLO	0.6437	0.4038	0.2931	0.3171	0.4144
2002	SP	0.9992	0.4794	0.8308	0.4716	0.6953
2003	SP	0.9991	0.5195	0.8627	0.5144	0.7240
2004	SP	0.9991	0.5566	0.8844	0.5538	0.7485
2005	SP	0.9991	0.5508	0.8843	0.5523	0.7466
2006	SP	0.9991	0.5303	0.8791	0.5332	0.7354
2007	SP	0.9991	0.5602	0.8989	0.5608	0.7548
2008	SP	0.9991	0.5817	0.9067	0.5785	0.7665
2009	SP	0.9991	0.5084	0.8758	0.5045	0.7220
2010	SP	0.9992	0.6608	0.9263	0.6425	0.8072
2011	SP	0.9994	0.7515	0.9391	0.7263	0.8541
2002	SWE	0.9970	0.8474	0.8587	0.8088	0.8780

2003	SWE	0.9972	0.9026	0.9012	0.9262	0.9318
2004	SWE	0.9971	0.9280	0.9247	0.9648	0.9537
2005	SWE	0.9970	0.9246	0.9136	0.9567	0.9480
2006	SWE	0.9969	0.9164	0.9071	0.9452	0.9414
2007	SWE	0.9968	0.9189	0.9090	0.9501	0.9437
2008	SWE	0.9968	0.9246	0.9157	0.9587	0.9490
2009	SWE	0.9968	0.8729	0.8657	0.8547	0.8975
2010	SWE	0.9967	0.7956	0.7980	0.7389	0.8323
2011	SWE	0.9975	0.8712	0.8594	0.8581	0.8965
2002	SWI	0.9417	0.5966	0.6147	0.5708	0.6809
2003	SWI	0.9569	0.6089	0.6235	0.5804	0.6924
2004	SWI	0.9711	0.6777	0.6826	0.6465	0.7445
2005	SWI	0.9703	0.7198	0.7064	0.6809	0.7693
2006	SWI	0.9712	0.6751	0.6723	0.6335	0.7380
2007	SWI	0.9551	0.6946	0.6965	0.6566	0.7507
2008	SWI	0.8918	0.7363	0.7317	0.7056	0.7664
2009	SWI	0.9150	0.6607	0.6642	0.6257	0.7164
2010	SWI	0.9742	0.6176	0.6336	0.5845	0.7025
2011	SWI	0.9797	0.6413	0.6441	0.5973	0.7156
2002	TUR	0.9980	0.3215	0.4715	0.3136	0.5262
2003	TUR	0.9980	0.4484	0.6061	0.4298	0.6206
2004	TUR	0.9980	0.6350	0.7862	0.5954	0.7537
2005	TUR	0.9979	0.7233	0.8459	0.6895	0.8141
2006	TUR	0.9978	0.7321	0.8545	0.7039	0.8221
2007	TUR	0.9976	0.8295	0.8984	0.8344	0.8900
2008	TUR	0.9978	0.8908	0.9290	0.9352	0.9382
2009	TUR	0.9976	0.8890	0.9291	0.9327	0.9371
2010	TUR	0.9974	0.9121	0.9408	0.9620	0.9531
2011	TUR	0.9972	0.9118	0.9364	0.9545	0.9499
2002	UK	0.9982	0.6841	0.8813	0.6425	0.8016
2003	UK	0.9983	0.7867	0.9128	0.7556	0.8633
2004	UK	0.9984	0.8342	0.9280	0.8285	0.8973
2005	UK	0.9983	0.8196	0.9243	0.8076	0.8875
2006	UK	0.9984	0.8332	0.9294	0.8280	0.8973
2007	UK	0.9985	0.8833	0.9436	0.9151	0.9351
2008	UK	0.9985	0.9099	0.9514	0.9566	0.9541
2009	UK	0.9982	0.8399	0.9292	0.8474	0.9037
2010	UK	0.9982	0.8340	0.9264	0.8292	0.8969
2011	UK	0.9985	0.8921	0.9427	0.9249	0.9396
2003	UKR	0.2041	0.1845	0.2305	0.1627	0.1954
2004	UKR	0.2804	0.2846	0.3504	0.2573	0.2932
2005	UKR	0.9921	0.2973	0.3741	0.2668	0.4826
2006	UKR	0.9953	0.3123	0.3966	0.2798	0.4960
2007	UKR	0.9963	0.4034	0.4959	0.3665	0.5655
2008	UKR	0.9970	0.5351	0.6264	0.4850	0.6609
2009	UKR	0.9971	0.4953	0.5803	0.4444	0.6293
2010	UKR	0.9964	0.5234	0.6158	0.4789	0.6536
2011	UKR	0.9985	0.6072	0.6493	0.5053	0.6901

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia

(SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 47 SFA efficiencies for translog specifications

Year	Country	Model 1	2	3	4	Average
2002	ALB	0.2557	0.2517	0.3398	0.2486	0.2740
2003	ALB	0.4409	0.4332	0.6322	0.4260	0.4831
2004	ALB	0.4871	0.4785	0.6522	0.4693	0.5218
2005	ALB	0.4486	0.4458	0.7559	0.4442	0.5236
2006	ALB	0.4702	0.4662	0.7877	0.4644	0.5471
2007	ALB	0.5432	0.5396	0.8600	0.5380	0.6202
2008	ALB	0.4701	0.4670	0.7413	0.4649	0.5358
2009	ALB	0.4195	0.4168	0.6760	0.4158	0.4820
2010	ALB	0.3252	0.3232	0.4890	0.3223	0.3649
2011	ALB	0.3437	0.3395	0.4874	0.3375	0.3770
2009	ARM	0.2847	0.2805	0.3400	0.2792	0.2961
2010	ARM	0.3653	0.3597	0.4226	0.3579	0.3763
2011	ARM	0.3755	0.3671	0.4123	0.3656	0.3801
2002	AUS	0.3869	0.3811	0.4798	0.3842	0.4080
2003	AUS	0.4672	0.4594	0.5805	0.4653	0.4931
2004	AUS	0.5521	0.5436	0.6741	0.5491	0.5798
2005	AUS	0.6029	0.5933	0.7341	0.6006	0.6327
2006	AUS	0.5658	0.5553	0.6920	0.5611	0.5935
2007	AUS	0.6659	0.6540	0.7943	0.6621	0.6940
2008	AUS	0.7114	0.6975	0.8356	0.7093	0.7385
2009	AUS	0.6273	0.6148	0.7642	0.6245	0.6577
2010	AUS	0.5957	0.5838	0.7350	0.5934	0.6270
2011	AUS	0.6149	0.6013	0.7499	0.6111	0.6443
2002	BEL	0.2780	0.2722	0.3531	0.2765	0.2950
2003	BEL	0.3389	0.3319	0.4300	0.3384	0.3598
2004	BEL	0.3647	0.3569	0.4606	0.3641	0.3866
2005	BEL	0.3363	0.3303	0.4217	0.3356	0.3560
2006	BEL	0.3256	0.3200	0.4051	0.3239	0.3436
2007	BEL	0.3920	0.3848	0.4894	0.3916	0.4145
2008	BEL	0.4324	0.4240	0.5389	0.4324	0.4569
2009	BEL	0.3874	0.3792	0.4899	0.3875	0.4110
2010	BEL	0.3723	0.3645	0.4681	0.3715	0.3941
2011	BEL	0.4250	0.4147	0.5264	0.4223	0.4471
2002	BUL	0.1141	0.1125	0.1392	0.1113	0.1193
2003	BUL	0.1446	0.1427	0.1787	0.1417	0.1519
2004	BUL	0.1687	0.1664	0.2085	0.1655	0.1773
2005	BUL	0.1801	0.1778	0.2224	0.1768	0.1893
2006	BUL	0.2080	0.2052	0.2566	0.2044	0.2185
2007	BUL	0.2703	0.2667	0.3321	0.2665	0.2839
2008	BUL	0.3165	0.3124	0.3876	0.3127	0.3323
2009	BUL	0.3059	0.3018	0.3748	0.3020	0.3211
2010	BUL	0.3234	0.3187	0.3958	0.3197	0.3394
2011	BUL	0.3738	0.3658	0.4476	0.3671	0.3886
2002	CRO	0.2554	0.2419	0.3019	0.2388	0.2595
2003	CRO	0.2989	0.2904	0.3529	0.2930	0.3088
2004	CRO	0.3484	0.3397	0.4114	0.3420	0.3604
2005	CRO	0.3843	0.3751	0.4546	0.3776	0.3979
2006	CRO	0.3710	0.3631	0.4425	0.3644	0.3852
2007	CRO	0.4304	0.4220	0.5129	0.4234	0.4472
2008	CRO	0.4827	0.4734	0.5724	0.4756	0.5010

2009	CRO	0.4508	0.4413	0.5348	0.4425	0.4673
2010	CRO	0.4517	0.4421	0.5364	0.4430	0.4683
2011	CRO	0.4569	0.4452	0.5359	0.4457	0.4709
2002	CYP	0.7247	0.7156	0.8710	0.7104	0.7554
2003	CYP	0.8008	0.7912	0.8949	0.7858	0.8182
2004	CYP	0.6676	0.6580	0.8052	0.6542	0.6963
2005	CYP	0.7595	0.7497	0.8891	0.7445	0.7857
2006	CYP	0.7892	0.7789	0.8966	0.7731	0.8095
2007	CYP	0.7098	0.7008	0.8520	0.6970	0.7399
2008	CYP	0.9590	0.9637	0.9496	0.9663	0.9596
2009	CYP	0.8841	0.8770	0.9248	0.8720	0.8895
2010	CYP	0.9395	0.9409	0.9387	0.9410	0.9400
2011	CYP	0.9230	0.9209	0.9190	0.9194	0.9206
2002	CZ	0.2765	0.2738	0.3590	0.2725	0.2954
2003	CZ	0.3246	0.3209	0.4110	0.3196	0.3440
2004	CZ	0.3915	0.3870	0.4907	0.3856	0.4137
2005	CZ	0.3811	0.3757	0.4678	0.3746	0.3998
2006	CZ	0.3516	0.3460	0.4279	0.3448	0.3676
2007	CZ	0.3588	0.3529	0.4354	0.3515	0.3746
2008	CZ	0.4449	0.4389	0.5455	0.4379	0.4668
2009	CZ	0.4155	0.4095	0.5066	0.4086	0.4350
2010	CZ	0.4083	0.4015	0.4938	0.4009	0.4261
2011	CZ	0.4188	0.4104	0.4995	0.4097	0.4346
2002	DEN	0.6960	0.6819	0.7983	0.6869	0.7158
2003	DEN	0.8408	0.8288	0.8834	0.8365	0.8474
2004	DEN	0.8906	0.8835	0.9041	0.8891	0.8918
2005	DEN	0.8927	0.8850	0.9029	0.8933	0.8935
2006	DEN	0.9528	0.9561	0.9294	0.9647	0.9507
2007	DEN	0.9102	0.9043	0.9096	0.9154	0.9099
2008	DEN	0.8980	0.8898	0.9049	0.8991	0.8979
2009	DEN	0.7408	0.7286	0.8328	0.7323	0.7586
2010	DEN	0.7656	0.7520	0.8462	0.7576	0.7804
2011	DEN	0.8441	0.8319	0.8844	0.8383	0.8497
2002	EC	0.5901	0.5885	0.5991	0.5799	0.5894
2003	EC	0.6690	0.6717	0.7055	0.6652	0.6779
2004	EC	0.7564	0.7580	0.7812	0.7522	0.7619
2005	EC	0.8203	0.8192	0.8157	0.8133	0.8171
2006	EC	0.8458	0.8463	0.8322	0.8394	0.8409
2007	EC	0.9196	0.9203	0.8632	0.9192	0.9056
2008	EC	0.9236	0.9289	0.8771	0.9297	0.9148
2009	EC	0.8210	0.8169	0.8003	0.8112	0.8123
2010	EC	0.8099	0.7990	0.7664	0.7920	0.7919
2011	EC	0.9316	0.9271	0.8430	0.9302	0.9080
2002	EST	0.4594	0.4595	0.6745	0.4592	0.5131
2003	EST	0.5286	0.5269	0.7299	0.5260	0.5779
2004	EST	0.6666	0.6657	0.8534	0.6655	0.7128
2005	EST	0.7351	0.7330	0.8796	0.7331	0.7702
2006	EST	0.7843	0.7800	0.8869	0.7805	0.8079
2007	EST	0.9247	0.9271	0.9253	0.9314	0.9271
2008	EST	0.9591	0.9643	0.9373	0.9690	0.9574
2009	EST	0.8758	0.8703	0.9028	0.8720	0.8802
2010	EST	0.7939	0.7846	0.8642	0.7865	0.8073
2011	EST	0.8878	0.8817	0.9042	0.8852	0.8897

2002	FIN	0.5408	0.5314	0.6433	0.5326	0.5620
2003	FIN	0.7251	0.7127	0.8151	0.7153	0.7421
2004	FIN	0.7937	0.7805	0.8575	0.7835	0.8038
2005	FIN	0.7776	0.7645	0.8482	0.7677	0.7895
2006	FIN	0.7972	0.7844	0.8582	0.7878	0.8069
2007	FIN	0.8105	0.7953	0.8595	0.8020	0.8168
2008	FIN	0.8691	0.8550	0.8850	0.8628	0.8680
2009	FIN	0.7575	0.7413	0.8269	0.7490	0.7687
2010	FIN	0.7358	0.7209	0.8149	0.7265	0.7495
2011	FIN	0.8399	0.8235	0.8747	0.8287	0.8417
2002	FRA	0.7848	0.7735	0.8460	0.7530	0.7893
2003	FRA	0.8992	0.8934	0.9034	0.8758	0.8929
2004	FRA	0.9451	0.9476	0.9273	0.9426	0.9406
2005	FRA	0.9408	0.9428	0.9258	0.9368	0.9365
2006	FRA	0.9522	0.9558	0.9336	0.9536	0.9488
2007	FRA	0.9644	0.9689	0.9412	0.9693	0.9610
2008	FRA	0.9711	0.9753	0.9485	0.9769	0.9679
2009	FRA	0.9356	0.9368	0.9273	0.9309	0.9326
2010	FRA	0.9265	0.9262	0.9260	0.9192	0.9245
2011	FRA	0.9563	0.9561	0.9341	0.9517	0.9495
2002	FYROM	0.1401	0.1383	0.2131	0.1374	0.1572
2003	FYROM	0.1710	0.1687	0.2517	0.1674	0.1897
2004	FYROM	0.2108	0.2079	0.3118	0.2062	0.2342
2005	FYROM	0.1774	0.1743	0.2317	0.1729	0.1891
2006	FYROM	0.1851	0.1814	0.2314	0.1801	0.1945
2007	FYROM	0.1982	0.1941	0.2432	0.1928	0.2071
2008	FYROM	0.1881	0.1832	0.2195	0.1830	0.1934
2009	FYROM	0.1903	0.1854	0.2167	0.1859	0.1946
2010	FYROM	0.1895	0.1847	0.2123	0.1854	0.1930
2011	FYROM	0.2080	0.2015	0.2251	0.2019	0.2091
2002	GER	0.6287	0.6103	0.7201	0.5928	0.6380
2003	GER	0.6965	0.6777	0.7932	0.6608	0.7070
2004	GER	0.7752	0.7552	0.8486	0.7373	0.7791
2005	GER	0.7742	0.7564	0.8480	0.7392	0.7795
2006	GER	0.8074	0.7842	0.8647	0.7635	0.8050
2007	GER	0.9323	0.9232	0.8871	0.8823	0.9062
2008	GER	0.9348	0.9252	0.9144	0.9098	0.9211
2009	GER	0.8344	0.8082	0.8623	0.7818	0.8217
2010	GER	0.8212	0.7910	0.8601	0.7652	0.8094
2011	GER	0.9007	0.8716	0.8371	0.8136	0.8558
2003	GRE	0.7297	0.7113	0.8581	0.7230	0.7555
2004	GRE	0.8075	0.7897	0.8875	0.7991	0.8209
2005	GRE	0.7261	0.7081	0.8508	0.7174	0.7506
2006	GRE	0.6049	0.5849	0.7638	0.5931	0.6367
2007	GRE	0.9174	0.9000	0.9439	0.9299	0.9228
2008	GRE	0.7993	0.7788	0.9019	0.7976	0.8194
2009	GRE	0.8127	0.7913	0.9103	0.8133	0.8319
2010	GRE	0.8176	0.7989	0.9022	0.8148	0.8334
2011	GRE	0.8574	0.8368	0.9050	0.8486	0.8619
2002	HUN	0.2723	0.2690	0.3429	0.2679	0.2880
2003	HUN	0.3371	0.3322	0.4128	0.3318	0.3535
2004	HUN	0.4726	0.4667	0.5784	0.4666	0.4961
2005	HUN	0.5158	0.5083	0.6187	0.5100	0.5382

2006	HUN	0.4652	0.4587	0.5633	0.4591	0.4866
2007	HUN	0.5470	0.5400	0.6604	0.5407	0.5720
2008	HUN	0.5493	0.5421	0.6649	0.5426	0.5747
2009	HUN	0.4620	0.4555	0.5608	0.4556	0.4835
2010	HUN	0.4566	0.4495	0.5511	0.4501	0.4768
2011	HUN	0.4103	0.4023	0.4907	0.4020	0.4263
2002	IRE	0.6489	0.6361	0.7600	0.6388	0.6710
2003	IRE	0.7136	0.6972	0.8110	0.7039	0.7314
2004	IRE	0.7173	0.7047	0.8226	0.7052	0.7375
2005	IRE	0.8577	0.8455	0.8955	0.8465	0.8613
2006	IRE	0.7938	0.7793	0.8667	0.7809	0.8052
2007	IRE	0.8788	0.8665	0.9010	0.8698	0.8791
2008	IRE	0.9017	0.8927	0.9096	0.8964	0.9001
2009	IRE	0.7714	0.7578	0.8564	0.7587	0.7861
2010	IRE	0.6403	0.6285	0.7563	0.6294	0.6637
2011	IRE	0.6435	0.6317	0.7602	0.6314	0.6667
2002	ITA	0.5972	0.5902	0.6711	0.5797	0.6096
2003	ITA	0.6705	0.6636	0.7484	0.6525	0.6837
2004	ITA	0.6908	0.6821	0.7709	0.6705	0.7036
2005	ITA	0.7455	0.7363	0.8170	0.7243	0.7558
2006	ITA	0.7615	0.7503	0.8285	0.7377	0.7695
2007	ITA	0.8244	0.8122	0.8656	0.7988	0.8252
2008	ITA	0.8450	0.8319	0.8762	0.8178	0.8427
2009	ITA	0.7550	0.7422	0.8247	0.7288	0.7627
2010	ITA	0.7678	0.7559	0.8335	0.7426	0.7749
2011	ITA	0.7949	0.7784	0.8463	0.7628	0.7956
2002	LAT	0.2842	0.2829	0.4713	0.2829	0.3303
2003	LAT	0.3951	0.3947	0.6903	0.3957	0.4690
2004	LAT	0.4060	0.4033	0.5504	0.4031	0.4407
2005	LAT	0.4518	0.4454	0.5525	0.4451	0.4737
2006	LAT	0.4632	0.4567	0.5676	0.4564	0.4860
2007	LAT	0.6600	0.6506	0.7493	0.6480	0.6770
2008	LAT	0.8658	0.8566	0.8851	0.8530	0.8651
2009	LAT	0.7443	0.7352	0.8432	0.7310	0.7634
2010	LAT	0.6384	0.6295	0.7478	0.6274	0.6608
2011	LAT	0.8231	0.8096	0.8568	0.8066	0.8240
2002	LIT	0.1557	0.1588	0.2499	0.1604	0.1812
2003	LIT	0.1903	0.1876	0.2476	0.1870	0.2031
2004	LIT	0.2453	0.2411	0.3009	0.2406	0.2570
2005	LIT	0.2808	0.2765	0.3499	0.2759	0.2957
2006	LIT	0.3002	0.2958	0.3760	0.2948	0.3167
2007	LIT	0.3965	0.3907	0.4815	0.3892	0.4145
2008	LIT	0.5880	0.5744	0.6271	0.5786	0.5920
2009	LIT	0.3886	0.3798	0.4335	0.3811	0.3958
2010	LIT	0.3821	0.3746	0.4414	0.3749	0.3932
2011	LIT	0.4628	0.4531	0.5203	0.4525	0.4722
2002	MAL	0.2976	0.2908	0.3368	0.2901	0.3038
2003	MAL	0.3874	0.3825	0.5168	0.3795	0.4166
2004	MAL	0.4588	0.4511	0.5544	0.4473	0.4779
2005	MAL	0.4881	0.4803	0.5955	0.4758	0.5099
2006	MAL	0.4833	0.4756	0.5917	0.4712	0.5054
2007	MAL	0.5213	0.5130	0.6275	0.5091	0.5427
2008	MAL	0.7081	0.6976	0.8235	0.6903	0.7299

2009	MAL	0.6437	0.6347	0.7885	0.6286	0.6739
2010	MAL	0.6586	0.6520	0.8259	0.6487	0.6963
2011	MAL	0.7722	0.7608	0.8684	0.7555	0.7892
2002	MOL	0.1562	0.1543	0.2344	0.1519	0.1742
2003	MOL	0.1523	0.1499	0.1948	0.1479	0.1612
2004	MOL	0.2143	0.2113	0.2780	0.2080	0.2279
2005	MOL	0.2593	0.2547	0.3114	0.2497	0.2688
2006	MOL	0.2768	0.2717	0.3198	0.2666	0.2838
2007	MOL	0.3696	0.3631	0.4366	0.3548	0.3810
2008	MOL	0.4284	0.4206	0.4726	0.4119	0.4334
2009	MOL	0.3609	0.3546	0.4146	0.3486	0.3697
2010	MOL	0.4369	0.4306	0.5402	0.4227	0.4576
2011	MOL	0.5425	0.5306	0.5779	0.5200	0.5427
2002	NL	0.3048	0.3003	0.3716	0.3000	0.3192
2003	NL	0.3696	0.3644	0.4521	0.3658	0.3880
2004	NL	0.3973	0.3913	0.4859	0.3937	0.4170
2005	NL	0.3713	0.3647	0.4569	0.3680	0.3902
2006	NL	0.4115	0.4042	0.5080	0.4086	0.4331
2007	NL	0.4481	0.4401	0.5517	0.4455	0.4713
2008	NL	0.4560	0.4483	0.5587	0.4532	0.4790
2009	NL	0.4078	0.3979	0.5153	0.4056	0.4317
2010	NL	0.4057	0.3981	0.5034	0.4035	0.4277
2011	NL	0.4600	0.4502	0.5643	0.4563	0.4827
2002	NOR	0.5527	0.5424	0.6782	0.5393	0.5782
2003	NOR	0.8155	0.8020	0.8869	0.8006	0.8262
2004	NOR	0.9577	0.9600	0.9362	0.9647	0.9546
2005	NOR	0.9219	0.9171	0.9209	0.9205	0.9201
2006	NOR	0.8291	0.8113	0.8832	0.8127	0.8341
2007	NOR	0.7806	0.7592	0.8566	0.7616	0.7895
2008	NOR	0.8874	0.8699	0.9030	0.8740	0.8836
2009	NOR	0.8632	0.8428	0.8941	0.8474	0.8619
2010	NOR	0.8682	0.8464	0.8955	0.8506	0.8652
2011	NOR	0.9153	0.8972	0.9106	0.9028	0.9065
2005	POL	0.4925	0.4871	0.5979	0.4872	0.5162
2006	POL	0.5232	0.5175	0.6334	0.5188	0.5482
2007	POL	0.5756	0.5683	0.7154	0.5728	0.6080
2008	POL	0.5255	0.5145	0.6525	0.5179	0.5526
2009	POL	0.5120	0.5003	0.6480	0.5061	0.5416
2010	POL	0.5281	0.5168	0.6658	0.5224	0.5583
2011	POL	0.5449	0.5280	0.6530	0.5294	0.5638
2002	PT	0.3241	0.3137	0.3978	0.3153	0.3377
2003	PT	0.4014	0.3882	0.4945	0.3925	0.4191
2004	PT	0.4320	0.4185	0.5314	0.4234	0.4513
2005	PT	0.4356	0.4221	0.5424	0.4278	0.4570
2006	PT	0.4864	0.4707	0.6117	0.4792	0.5120
2007	PT	0.5546	0.5359	0.6953	0.5473	0.5833
2008	PT	0.5787	0.5581	0.7260	0.5711	0.6085
2009	PT	0.5429	0.5244	0.6825	0.5358	0.5714
2010	PT	0.6150	0.5953	0.7643	0.6094	0.6460
2011	PT	0.6587	0.6368	0.8161	0.6552	0.6917
2002	ROM	0.1386	0.1370	0.1650	0.1355	0.1440
2003	ROM	0.1637	0.1614	0.1960	0.1597	0.1702
2004	ROM	0.2242	0.2217	0.2699	0.2196	0.2339

2005	ROM	0.2782	0.2750	0.3370	0.2729	0.2908
2006	ROM	0.2757	0.2724	0.3333	0.2702	0.2879
2007	ROM	0.3393	0.3332	0.4138	0.3332	0.3549
2008	ROM	0.3730	0.3655	0.4642	0.3681	0.3927
2009	ROM	0.3290	0.3235	0.3995	0.3227	0.3437
2010	ROM	0.3750	0.3690	0.4604	0.3708	0.3938
2011	ROM	0.4125	0.4032	0.4977	0.4045	0.4295
2006	SER	0.3301	0.3260	0.4027	0.3262	0.3462
2007	SER	0.3897	0.3849	0.4767	0.3844	0.4089
2008	SER	0.4631	0.4562	0.5648	0.4558	0.4850
2009	SER	0.4545	0.4480	0.5579	0.4472	0.4769
2010	SER	0.4630	0.4574	0.5729	0.4564	0.4874
2011	SER	0.5290	0.5213	0.6467	0.5199	0.5542
2002	SK	0.1729	0.1704	0.2254	0.1698	0.1847
2003	SK	0.2467	0.2435	0.3190	0.2427	0.2630
2004	SK	0.3190	0.3148	0.4074	0.3141	0.3388
2005	SK	0.3287	0.3233	0.4003	0.3232	0.3439
2006	SK	0.3310	0.3260	0.4106	0.3256	0.3483
2007	SK	0.3366	0.3305	0.4039	0.3308	0.3504
2008	SK	0.3290	0.3232	0.3988	0.3234	0.3436
2009	SK	0.2795	0.2751	0.3467	0.2747	0.2940
2010	SK	0.2699	0.2653	0.3296	0.2652	0.2825
2011	SK	0.2927	0.2863	0.3495	0.2860	0.3036
2002	SLO	0.2462	0.2405	0.2910	0.2392	0.2542
2003	SLO	0.3162	0.3084	0.3583	0.3072	0.3225
2004	SLO	0.3813	0.3730	0.4171	0.3726	0.3860
2005	SLO	0.4095	0.4007	0.4470	0.4010	0.4145
2006	SLO	0.4039	0.3940	0.4346	0.3969	0.4074
2007	SLO	0.4323	0.4205	0.4622	0.4260	0.4352
2008	SLO	0.4348	0.4234	0.4699	0.4283	0.4391
2009	SLO	0.4084	0.3965	0.4414	0.4035	0.4125
2010	SLO	0.3814	0.3703	0.4174	0.3771	0.3866
2011	SLO	0.3764	0.3654	0.4122	0.3692	0.3808
2002	SP	0.5335	0.5173	0.6122	0.5047	0.5419
2003	SP	0.5876	0.5698	0.6910	0.5582	0.6017
2004	SP	0.6408	0.6211	0.7568	0.6097	0.6571
2005	SP	0.6447	0.6258	0.7626	0.6146	0.6620
2006	SP	0.6350	0.6158	0.7531	0.6039	0.6520
2007	SP	0.6797	0.6570	0.7961	0.6431	0.6940
2008	SP	0.7015	0.6766	0.8145	0.6623	0.7137
2009	SP	0.6029	0.5832	0.7175	0.5700	0.6184
2010	SP	0.7072	0.6867	0.8032	0.6719	0.7172
2011	SP	0.7974	0.7683	0.8564	0.7498	0.7930
2002	SWE	0.7662	0.7514	0.8627	0.7501	0.7826
2003	SWE	0.9116	0.9035	0.9191	0.9065	0.9102
2004	SWE	0.9621	0.9651	0.9403	0.9694	0.9592
2005	SWE	0.9434	0.9413	0.9308	0.9436	0.9398
2006	SWE	0.9243	0.9173	0.9235	0.9172	0.9206
2007	SWE	0.9338	0.9289	0.9262	0.9302	0.9298
2008	SWE	0.9470	0.9458	0.9320	0.9485	0.9433
2009	SWE	0.8123	0.7922	0.8800	0.7884	0.8183
2010	SWE	0.7388	0.7163	0.8261	0.7166	0.7495
2011	SWE	0.8447	0.8203	0.8823	0.8194	0.8417

2002	SWI	0.5984	0.5851	0.7289	0.5922	0.6261
2003	SWI	0.6009	0.5874	0.7266	0.5933	0.6271
2004	SWI	0.6696	0.6549	0.7926	0.6620	0.6948
2005	SWI	0.6733	0.6580	0.7826	0.6610	0.6938
2006	SWI	0.6090	0.5964	0.7203	0.5964	0.6305
2007	SWI	0.6272	0.6148	0.7394	0.6140	0.6489
2008	SWI	0.6807	0.6670	0.7892	0.6678	0.7012
2009	SWI	0.6063	0.5934	0.7159	0.5939	0.6274
2010	SWI	0.5733	0.5595	0.6781	0.5596	0.5926
2011	SWI	0.5948	0.5795	0.7029	0.5810	0.6145
2002	TUR	0.3274	0.3240	0.3972	0.3208	0.3424
2003	TUR	0.4256	0.4217	0.5331	0.4195	0.4500
2004	TUR	0.6039	0.5983	0.7623	0.5965	0.6402
2005	TUR	0.6693	0.6635	0.8132	0.6610	0.7018
2006	TUR	0.6797	0.6739	0.8162	0.6707	0.7101
2007	TUR	0.7958	0.7898	0.8874	0.7866	0.8149
2008	TUR	0.9184	0.9193	0.9279	0.9199	0.9214
2009	TUR	0.9197	0.9214	0.9279	0.9222	0.9228
2010	TUR	0.9558	0.9612	0.9401	0.9643	0.9553
2011	TUR	0.9438	0.9464	0.9294	0.9472	0.9417
2002	UK	0.7699	0.7572	0.8115	0.7263	0.7662
2003	UK	0.8480	0.8313	0.8647	0.8001	0.8360
2004	UK	0.9058	0.8947	0.8942	0.8663	0.8903
2005	UK	0.8963	0.8827	0.8854	0.8515	0.8790
2006	UK	0.9197	0.9118	0.8974	0.8831	0.9030
2007	UK	0.9605	0.9621	0.9255	0.9537	0.9505
2008	UK	0.9729	0.9756	0.9382	0.9743	0.9652
2009	UK	0.9100	0.8964	0.8936	0.8702	0.8925
2010	UK	0.8944	0.8793	0.8879	0.8511	0.8782
2011	UK	0.9492	0.9459	0.9185	0.9350	0.9371
2003	UKR	0.1649	0.1652	0.2119	0.1623	0.1761
2004	UKR	0.2444	0.2433	0.3033	0.2407	0.2579
2005	UKR	0.2499	0.2462	0.3061	0.2434	0.2614
2006	UKR	0.2666	0.2628	0.3269	0.2591	0.2789
2007	UKR	0.3465	0.3400	0.4230	0.3373	0.3617
2008	UKR	0.4556	0.4472	0.5585	0.4444	0.4764
2009	UKR	0.4136	0.4068	0.5123	0.4035	0.4341
2010	UKR	0.4509	0.4430	0.5514	0.4408	0.4715
2011	UKR	0.4869	0.4761	0.6057	0.4689	0.5094

Key: Albania (ALB), Armenia (ARM), Austria (AUS), Belgium (BEL), Bulgaria (BUL), Croatia (CRO) Cyprus (CYP), Czech Republic (CZ), Denmark (DEN), EUROCONTROL (EC), Estonia (EST), Finland (FIN), France (FRA), Republic of Macedonia (FYROM), Germany (GER), Greece (GRE), Hungary (HUN), Ireland (IRE), Italy (ITA), Latvia (LAT), Lithuania (LIT), Malta (MAL), Moldova (MOL), Netherlands (NL), Norway (NOR), Poland (POL), Portugal (PT), Romania (ROM), Serbia (SEB), Slovakia (SK), Slovenia (SLO), Spain (SP), Sweden (SWE), Switzerland (SWI), Turkey (TUR), United Kingdom (UK), and Ukraine (UKR).

Table 48 SFA mean efficiencies by year for Cobb-Douglas specification

Year	Model				
	1	2	3	4	Average
2002	0.7327	0.4548	0.4606	0.3982	0.5116
2003	0.7285	0.5237	0.5107	0.4699	0.5582
2004	0.7633	0.5828	0.5587	0.5313	0.6090
2005	0.7908	0.5986	0.5724	0.5471	0.6272
2006	0.7899	0.5891	0.5669	0.5392	0.6213
2007	0.7899	0.6348	0.6020	0.5864	0.6533
2008	0.7997	0.6713	0.6337	0.6331	0.6845
2009	0.7691	0.3144	0.5823	0.5610	0.5567
2010	0.7564	0.6172	0.5841	0.5613	0.6298
2011	0.8219	0.6663	0.6090	0.6034	0.6752

Table 49 SFA mean efficiencies by year for translog specification

Year	Model				
	1	2	3	4	Average
2002	0.4149	0.4079	0.4983	0.4047	0.4315
2003	0.4933	0.4858	0.5793	0.4837	0.5105
2004	0.5520	0.5452	0.6302	0.5435	0.5677
2005	0.5672	0.5596	0.6449	0.5580	0.5824
2006	0.5606	0.5527	0.6382	0.5509	0.5756
2007	0.6207	0.6126	0.6901	0.6125	0.6340
2008	0.6658	0.6579	0.7255	0.6591	0.6771
2009	0.5927	0.5827	0.6688	0.5820	0.6066
2010	0.5905	0.5805	0.6666	0.5798	0.6044
2011	0.6382	0.6267	0.6933	0.6252	0.6459

APPENDIX IX – ANSP SFA ANALYSIS: FIGURES

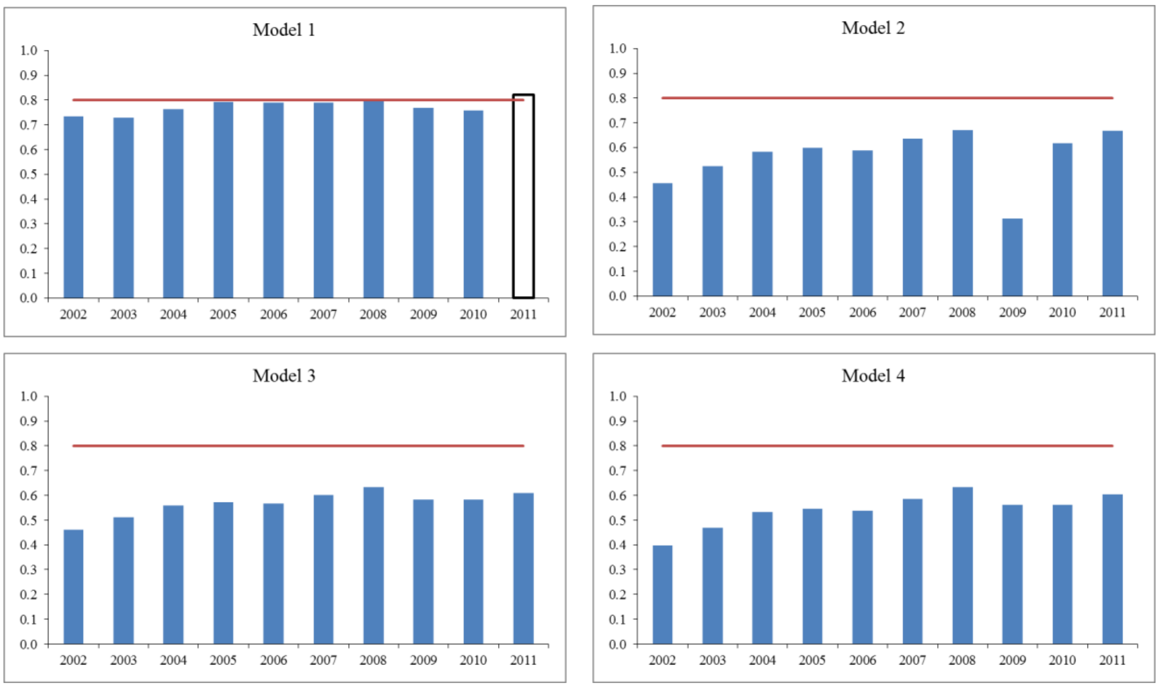


Figure 19 SFA mean efficiencies by year for Cobb-Douglas specification

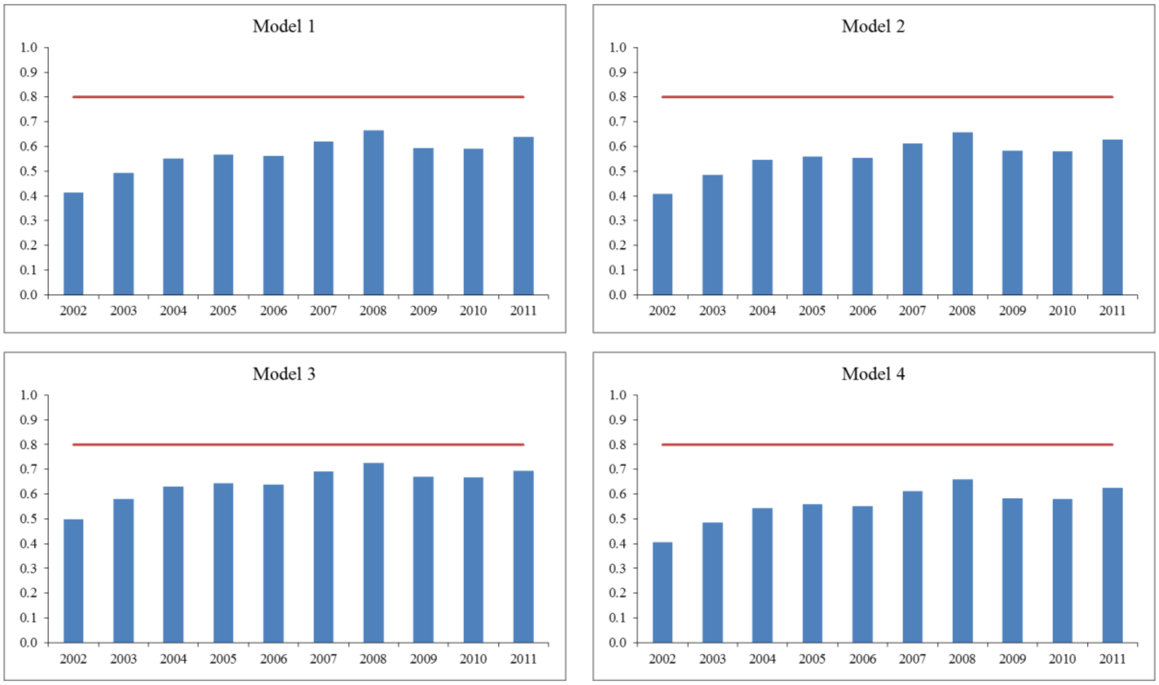


Figure 20 SFA mean efficiencies by year for translog specification

APPENDIX X – ANSP SFA ANALYSIS: REGRESSIONS

Table 50 SFA regression results for Cobb-Douglas specification

	Model			
	1	2	3	4
Production frontier				
Intercept	-3.0662*** (-14.670)	-3.5947* (-1.833)	-1.6287*** (-5.374)	-2.6545*** (-10.739)
β_1	0.6777*** (17.991)	0.7543*** (3.909)	0.6300*** (15.279)	0.6675*** (16.288)
β_2	-0.0337** (-2.938)	-0.0045 (-0.037)	-0.0325** (-2.785)	-0.0157* (-1.757)
β_3	0.1631*** (3.798)	0.1361 (1.545)	0.1096** (2.224)	0.1567** (3.127)
Technical inefficiency				
AGENCY	0.3945*** (4.215)	-0.2933 (-0.304)	-0.2104* (-1.756)	-0.3701*** (-3.387)
AREA	-0.0112*** (-7.409)	-	-0.0013*** (-3.845)	-
SECTORS	-0.1650*** (-8.820)	-0.0196 (-1.442)	-0.0287*** (-3.522)	-
ATCO	0.0090*** (8.426)	-	-	-0.006*** (-3.542)
ATCOkm	-0.2466*** (-4.919)	0.2434** (3.223)	-	0.1054*** (3.702)
STAFF_ATCO	0.0379* (1.845)	0.2224 (1.159)	-	0.1551*** (5.708)
REV_COST	-0.7533** (-2.790)	-0.4156 (-0.541)	-	-0.5824** (-2.207)
Mean inneficiency	77.5%	59.8%	57.0%	54.6%
Mean efficiency	22.5%	40.2%	43.0%	45.5%
σ_u^2	0.0138	0.4429	0.2509	0.2537
σ_v^2	0.0987	0.0297	0.0298	0.0059
λ^2	0.1402	14.9039	8.4313	42.8957
Variance due to inefficiency	12.3%	93.7%	89.4%	97.7%
Variance due to random variation	87.7%	6.3%	10.6%	2.3%
Log likelihood	-104.3407	-173.1192	-163.5451	-151.6983

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; z-values in parentheses. Positive signs in the coefficients indicate that the variable is associated with larger levels of inefficiency.

Table 51 SFA regression results for translog specification

	Model			
	1	2	3	4
<u>Production frontier</u>				
Intercept	-8.9742*** (-5.836)	-8.8519*** (-5.882)	-6.0974*** (-6.175)	-8.5032*** (-5.627)
β_1	1.2224*** (3.690)	1.2175*** (3.872)	1.4273* (1.936)	1.1153*** (3.620)
β_2	-0.2725** (-2.422)	-0.2662** (-2.589)	-0.1326 (-0.304)	-0.2402** (-2.265)
β_3	0.9661* (1.847)	0.9465** (2.012)	0.0679 (0.112)	0.9588** (2.049)
δ_1	-0.2474** (-3.162)	-0.2337** (-2.837)	-0.3630 (-1.601)	-0.2402*** (-3.619)
δ_{12}	0.0025 (0.080)	-0.0034 (-0.100)	-0.0555 (-1.224)	-0.0081 (-0.261)
δ_{13}	0.1948* (2.395)	0.1875** (2.216)	0.3497 (1.306)	0.2073** (2.920)
δ_2	-0.0024 (-0.175)	-0.0056 (-0.394)	-0.0087 (-0.258)	-0.0063 (-0.484)
δ_{21}	0.0223 (0.527)	0.0303 (0.649)	0.0742 (0.858)	0.0330 (0.798)
δ_3	-0.2851** (-2.669)	-0.2839** (-2.616)	-0.4104 (-1.537)	-0.3064** (-3.140)
<u>Technical inefficiency</u>				
AGENCY	-0.4476** (-3.136)	-0.4446*** (-3.441)	-0.5875 (-0.738)	-0.4409** (-3.264)
AREA	-0.0005 (-1.381)	-	-0.0006 (-0.637)	-
SECTORS	-0.0324** (-2.933)	-0.0175*** (-4.440)	-0.0145 (-1.577)	-
ATCO	0.0009** (2.065)	-	-	-0.0006*** (-4.079)
ATCOkm	0.1071** (2.366)	0.1417*** (4.319)	-	0.1300*** (4.247)
STAFF_ATCO	0.1733*** (4.638)	0.1685*** (6.249)	-	0.1885*** (6.154)
REV_COST	-0.0003 (-0.002)	-0.0342 (-0.266)	-	-0.1278 (-0.778)
Mean inneficiency	57.2%	56.4%	64.6%	56.3%
Mean efficiency	42.8%	43.6%	35.4%	43.8%
σ_u^2	0.2649	0.2634	0.6099	0.2839
σ_v^2	0.0049	0.0036	0.0230	0.0029
λ^2	54.5020	73.6267	26.5634	97.1366
Variance due to inefficiency	98.2%	98.7%	96.4%	99.0%
Variance due to random variation	1.8%	1.3%	3.6%	1.0%
Log likelihood	-104.3407	-173.1192	-163.5451	-151.6983

Notes ***significant at 0.001; ** significant at 0.05; *significant at 0.1; z-values in parentheses.

Positive signs in the coefficients indicate that the variable is associated with larger levels of inefficiency.

REFERENCES

Aigner, D., Lovell, C. A. K., & Schmidt, P. (1977). Formulation and Estimation of Stochastic Frontier Production Function Models. *Journal of econometrics*, *6*(1), 21–37.

Airways New Zealand. (2013). *Annual Report 2012-13*. Wellington, New Zealand: Airways New Zealand.

Angrist, J. D., & Krueger, A. B. (1999). Empirical Strategies in Labor Economics. In O. Ashenfelter & D. Card (Eds.), *Handbook of Labor Economics* (Vol. 3A, pp. 1277–1366). Amsterdam: Elsevier.

Assaf, A. (2010). The Cost Efficiency of Australian Airports Post Privatisation: A Bayesian Methodology. *Tourism Management*, *31*(2), 267–273.

Australian Competition and Consumer Commission. (2011). *Airservices Australia Price Notification - Final Decision*. Canberra, Australia: Australian Competition and Consumer Commission.

Averch, H., & Johnson, L. L. (1962). Behavior of the Firm Under Regulatory Constraint. *The American Economic Review*, *52*, 1052–1069.

Banker, R. D., Charnes, A., & Cooper, W. W. (1984). Some Models for Estimating Technical and Scale Inefficiencies in Data Envelopment Analysis. *Management science*, *30*(9), 1078–1092.

Bertrand, M., Duflo, E., & Mullainathan, S. (2004). How Much Should We Trust Differences-in-Differences Estimates? *The Quarterly Journal of Economics*, *119*(1), 249–275.

Black, F. (1982). The Trouble With Econometric Models. *Financial Analysts Journal*, *38*(2), 29–37.

Boardman, A. E., & Vining, A. R. (1989). Ownership and Performance in Competitive Environments: A Comparison of the Performance of Private, Mixed, and State-Owned Enterprises. *Journal of Law and Economics*, *32*, 1.

Bogetoft, P., & Otto, L. (2011). *Benchmarking with DEA, SFA, and R*. New York, N.Y.: Springer.

Borts, G. H. (1981). Report of the Managing Editor: American Economic Review. *American Economic Review, Papers and Proceedings*, *71*(2), 452– 464.

Bös, D. (1991). *Privatization : a Theoretical Treatment*. Oxford: Clarendon.

Button, K. (2004). *Wings Across Europe : Towards an Efficient European Air Transport System*. Aldershot, Hampshire, England; Burlington, VT: Ashgate.

Button, K. (2008). Air Transportation Infrastructure in Developing Countries: Privatization and Deregulation. In C. Winston & G. de Rus (Eds.), *Aviation Infrastructure Performance a Study in Comparative Political Economy*. Washington, D.C.: Brookings Institution Press.

Button, K. (2010). *Transport Economics* (3rd ed.). Northampton, MA: Edward Elgar Publishing.

Button, K. (2013). A Book, the Application and the Outcomes; How Right was Alfred Kahn in The Economics of Regulation about the Impacts of the Deregulation of the US Domestic Airline Market? *Working Paper*.

Button, K. J., & Neiva, R. (2013). Economic Efficiency across National Air Navigation Systems. Presented at the American Economics Association, 125th Annual Meeting, San Diego, CA.

Button, K., & Johnson, K. (1998). Incremental Versus Trend-Break Change in Airline Regulation. *Transportation Journal*, *37*(3), 25–34.

Button, K., & McDougall, G. (2006). Institutional and Structure Changes in Air Navigation Service-Providing Organizations. *Journal of Air Transport Management*, *12*(5), 236–252.

Camp, R. C. (1993). A Bible for Benchmarking, by Xerox. *Financial Executive*, *9*(4), 23–27.

CANSO. (2010). *Global Air Navigation Services Performance Report 2010*. Amsterdam: Civil Air Navigation Services Organisation.

CANSO. (2011). *Global Air Navigation Services Performance Report 2011*. Amsterdam: Civil Air Navigation Services Organisation.

CANSO. (2012). *Global Air Navigation Services Performance Report 2012*. Amsterdam: Civil Air Navigation Services Organisation.

Castelli, L., Labbé, M., & Violin, A. (2012). A Network Pricing Formulation for the Revenue Maximization of European Air Navigation Service Providers. *Transportation Research Part C: Emerging Technologies*. Retrieved from http://www.sciencedirect.com/science/article/pii/S0968090X12000630

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982a). Multilateral Comparisons of Output, Input, and Productivity Using Superlative Index Numbers. *The economic journal*, *92*(365), 73–86.

Caves, D. W., Christensen, L. R., & Diewert, W. E. (1982b). The Economic Theory of Index Numbers and the Measurement of Input, Output, and Productivity. *Econometrica: Journal of the Econometric Society*, 1393–1414.

Caves, R. E. (1962). *Air Transport and Its Regulators: An Industry Study*. Cambridge, MA: Harvard University Press.

Charles, R. A., & Newman, H. K. (1995). Public Policy and Technology Management: Changing the Role of Government in the Operation of Air Traffic Control. *Transportation Journal*, *35*(1), 39–48.

Charnes, A., Cooper, W. W., & Rhodes, E. (1978). Measuring the Efficiency of Decision Making Units. *European Journal of Operational Research*, *2*(6), 429–444.

Chermack, T. J., & Kasshanna, B. K. (2007). The Use and Misuse of SWOT Analysis and Implications for HRD Professionals. *Human Resource Development International*, *10*(4), 383–399.

Civil Aviation Authority. (2011a). *Air Traffic Services Licence for NATS (En Route) plc*. London, UK: Civil Aviation Authority.

Civil Aviation Authority. (2011b). *UK Performance Plan for Air Navigation Services - Reference Period One, 01 January 2012 to 31 December 2014*. London, UK: Civil Aviation Authority.

Coase, R. H. (1974). The Lighthouse in Economics. *Journal of Law and Economics*, *17*, 357–376.

Coelli, T., Prasada Rao, D. S., & Battese, G. E. (1998). *An Introduction to Efficiency and Productivity Analysis*. Boston: Kluwer Academic Publishers.

Competition Economists Group. (2011). *Econometric Cost-Efficiency Benchmarking of Air Navigation Service Providers*. Brussels: EUROCONTROL.

Cook, A. (Ed.). (2007). *European Air Traffic Management: Principles, Practice and Research*. Aldershot: Ashgate.

Cooper, W. W., Seiford, L. M., & Tone, K. (2007). *Data Envelopment Analysis: a Comprehensive Text with Models, Applications, References and DEA-Solver Software*. New York: Springer. Retrieved from http://public.eblib.com/EBLPublic/PublicView.do?ptiID=323342

Coppin, C. A., & High, J. C. (1999). *The Politics of Purity: Harvey Washington Wiley and the Origins of Federal Food Policy*. University of Michigan Press.

Cruz, C. O., & Marques, R. C. (2011). Contribution to the Study of PPP Arrangements in Airport Development, Management and Operation. *Transport Policy*, *18*(2), 392–400.

Czerny, A. I. (2006). Price-Cap Regulation of Airports: Single-Till Versus Dual-Till. *Journal of Regulatory Economics*, *30*(1), 85–97.

Dattakumar, R., & Jagadeesh, R. (2003). A Review of Literature on Benchmarking. *Benchmarking: An International Journal*, *10*(3), 176–209.

Davies, A. J., & Kochhar, A. K. (2002). Manufacturing Best Practice and Performance Studies: a Critique. *International Journal of Operations & Production Management*, *22*(3), 289–305.

De Neufville, R. (1999). Airport Privatization: Issues for the United States. *Transportation Research Record: Journal of the Transportation Research Board*, *1662*, 24–31.

De Neufville, R., & Odoni, A. R. (2002). *Airport Systems : planning, design, and management*. London: McGraw-Hill.

Dempsey, P. S., Janda, R., Nyampong, Y., Saba, J., & Wilson, J. (2005). *The McGill Report on Governance of Commercialized Air Navigation Services*. Montreal: McGill University Center for Research on Air & Space Law.

Demsetz, H. (1968). Why regulate utilities? *Journal of Law and Economics*, *11*(1), 55–65.

Domney, M., Wilson, H. I. M., & Chen, E. (2005). Natural Monopoly Privatisation Under Different Regulatory Regimes: A Comparison of New Zealand and Australian Airports. *International Journal of Public Sector Management*, *18*(3), 274–292.

EUROCONTROL. (2013). *U.S. - Europe Continental Comparison of ANS Cost-Efficiency Trends (2002-2011)*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2001). Cost Effectiveness and Productivity KPIs. *Working Paper*.

EUROCONTROL Performance Review Commission. (2005a). *A Comparison of Performance in Selected US and European En-route Centres*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2005b). *Total Factor Productivity of European Air Navigation Services Providers: Basic Concepts and Empirical Application*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2007). *Evaluation of Civil/Military Airspace Utilisation*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2008). *Evaluation of Functional Airspace Block (FAB) Initiatives and their Contribution to Performance Improvement*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2012). *ATM Cost-Effectiveness (ACE) 2010 Benchmarking Report with 2011-2015 outlook*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2013a). *ATM Cost-Effectiveness (ACE) 2011 Benchmarking Report with 2012-2016 outlook*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission. (2013b). *Performance Review Report - An Assessment of Air Traffic Management in Europe during the Calendar Year 2012*. Brussels: EUROCONTROL.

EUROCONTROL Performance Review Commission, & Federal Aviation Administration. (2009). *U.S./Europe Comparison of ATM-related Operational Performance*. Brussels/Washington DC: EUROCONTROL/FAA.

EUROCONTROL Performance Review Commission, & Federal Aviation Administration. (2012). *2010 US/Europe Comparison of ATM-Related Operational Performance*. Brussels/Washington DC: EUROCONTROL/FAA.

EUROCONTROL Performance Review Commission, & Federal Aviation Administration. (2013). *2012 - Comparison of Air Traffic Management-Related Operational Performance: U.S./Europe*. Brussels/Washington DC: EUROCONTROL/FAA.

European Commission. (2012a). Functional Airspace Blocks (FABs). Retrieved from http://ec.europa.eu/transport/modes/air/single_european_sky/fab/

European Commission. (2012b). Single European Sky. Retrieved from http://ec.europa.eu/transport/modes/air/single_european_sky/

European Economic Community. (1957). *Treaty of Rome*. Rome. Retrieved from http://ec.europa.eu/economy_finance/emu_history/documents/treaties/rometreaty2.pdf

Farrell, M. J. (1957). The Measurement of Productive Efficiency. *Journal of the Royal Statistical Society. Series A (General)*, *120*(3), 253–290.

Federal Aviation Administration. (2008). *Instrument Flying Handbook*. Washington DC.

Federal Aviation Administration. (2013). NextGen. Retrieved from http://www.faa.gov/nextgen/

Forsyth, P. (2001). *Airport Price Regulation: Rationales, Issues and Directions for Reform*. Monash University. Retrieved from http://www.pc.gov.au/__data/assets/pdf_file/0004/19840/sub005.pdf

Fried, H. O., Lovell, C. A. K., & Schmidt, S. S. (2008a). Efficiency and Productivity. In H. O. Fried, C. A. K. Lovell, & S. S. Schmidt (Eds.), *The Measurement of Productive Efficiency and Productivity Change*. New York: Oxford University Press.

Fried, H. O., Lovell, C. A. K., & Schmidt, S. S. (Eds.). (2008b). *The Measurement of Productive Efficiency and Productivity Change*. New York: Oxford University Press.

Glaeser, E. L., & Shleifer, A. (2003). The Rise of the Regulatory State. *Journal of Economic Literature*, *41*(2), 401–425.

Golaszewski, R. (2002). Reforming Air Traffic Control: An Assessment from the American Perspective. *Journal of Air Transport Management*, *8*(1), 3–11.

Goodliffe, M. (2002). The New UK Model for Air Traffic Services - A Public Private Partnership Under Economic Regulation. *Journal of Air Transport Management*, *8*(1), 13–18.

Heckman, J. J., & Vytlacil, E. J. (2007). Econometric Evaluation ofSocial Programs, Part I: Causal Models, Structural Models and Econometric Policy Evaluation. *Handbook of Econometrics*, *6*, 4779–4874.

Helios Economics and Policy Services. (2006a). *Cost Benchmarking of NATS Relative to Selected Air Navigation Service Providers - Phase 2 Report*. Farnborough, UK: UK Civil Aviation Authority - Economic Regulation Group.

Helios Economics and Policy Services. (2006b). *The Impact of Fragmentation in European ATM/CNS*. Farnborough, UK: EUROCONTROL.

Helms, M. M., & Nixon, J. (2010). Exploring SWOT Analysis – Where Are We Now?: A Review of Academic Research from the Last Decade. *Journal of Strategy and Management*, *3*(3), 215–251.

Henry, C., Matheu, M., & Jeunemaître, A. (Eds.). (2001). Regulation of Network Utilities: The European Experience. Oxford University Press.

High, J. (Ed.). (1991). *Regulation: Economic Theory and History*. Ann Arbor: University of Michigan Press.

International Civil Aviation Organization. (2006). *Convention on International Civil Aviation - Doc 7300/9*. Montréal, Canada: International Civil Aviation Organization.

Irish Aviation Authority, & NATS. (2012). *UK-Ireland FAB Annual Report 2011*. Dublin/London: Irish Aviation Authority/NATS.

Jasiński, P., & Yarrow, G. (1996). Privatization: an Overview of the Issues. In G. Yarrow & P. Jasiński (Eds.), *Privatization: Critical Perspectives on the World Economy, Volume I*. London: Routledge.

Kahn, A. E. (1970). *The Economics of Regulation: Principles and Institutions. Volumes I & II*. New York: John Wiley & Sons.

Kahn, A. E. (2004). *Lessons From Deregulation : Telecommunications and Airlines After the Crunch*. Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies : [Distributed by] Brookings Institution Press.

Koch, A. J. (2000). SWOT Does Not Need to be Recalled: It Needs to be Enhanced. *Business Quest*. Retrieved from http://en.scientificcommons.org/48903374

Kolko, G. (1963). *The Triumph of Conservatism: A Reinterpretation of American History, 1900-1916*. New York: Free Press of Glencoe.

Kraus, T. L. (2011). *Celebrating 75 Years of Federal Air Traffic Control*. Washington, D.C.: Federal Aviation Administration.

Laffont, J.-J., & Tirole, J. (1993). *A Theory of Incentives in Procurement and Regulation*. Cambridge, Mass.: MIT Press.

Laffont, J.-J., & Tirole, J. (2000). *Competition in Telecommunications*. Cambridge, Mass.: MIT Press.

Leibenstein, H. (1966). Allocative Efficiency vs.“ X-efficiency.” *The American Economic Review*, *56*(3), 392–415.

Levine, M. E. (1964). Is Regulation Necessary? California Air Transportation and National Regulatory Policy. *Yale Law Journal*, *74*, 1416.

Majumdar, A. (1995). Commercializing and Restructuring Air Traffic Control: A Review of the Experience and Issues Involved. *Journal of Air Transport Management*, *2*(2), 111–122.

mbs ottawa inc. (2006). *Air Traffic Control Commercialization Policy: Has It Been Effective?* Ottawa: mbs ottawa inc.

McCraw, T. K. (1984). *Prophets of Regulation*. Belknap Press.

McDougall, G., & Roberts, A. (2008). Commercializing Air Traffic Control: Have the Reforms Worked? *Canadian Public Administration / Administration Publique du Canada*, *51*(1), 45–69.

McInally, J. (2010). *EUROCONTROL History Book*. Brussels: EUROCONTROL.

Meeusen, W., & van den Broeck, J. (1977). Efficiency Estimation From Cobb-Douglas Production Functions With Composed Error. *International Economic Review*, 435–444.

Merkert, R., Odeck, J., Brathen, S., & Pagliari, R. (2012). A Review of Different Benchmarking Methods in the Context of Regional Airports. *Transport Reviews*, *32*(3), 379–395.

Moran, P. A. P. (1950). Notes on Continuous Stochastic Phenomena. *Biometrika*, *37*(1/2), 17–23.

Morrison, S. A., & Winston, C. (2008). The Effect of FAA Expenditures on Air Travel Delays. *Journal of Urban Economics*, *63*(2), 669–678.

National Civil Aviation Review Commission. (1997). *Avoiding Aviation Gridlock and Reducing the Accident Rate - A Consensus for Change*. Washington DC.

NAV Canada. (2013). *2012 Annual Report*. Ottawa, Canada: NAV Canada.

Nett, L. (1994). Why Private Firms Are More Innovative Than Public Firms. *European Journal of Political Economy*, *10*(4), 639–653.

Nolan, M. S. (1998). *Fundamentals of Air Traffic Control*. Pacific Groove: Brooks/Cole : Wadsworth.

Odland, J. (1988). *Spatial Autocorrelation*. Newbury Park, CA: SAGE Publications.

Office of Inspector General. (1998). *Advance Automation System - Federal Aviation Administration*. Washington, D.C.: Department of Transportation.

Oster, C. V., & Strong, J. S. (2006). *Reforming the Federal Aviation Administration: Lessons from Canada and the United Kingdom*. Washington, D.C.: The IBM Center for The Business of Government.

Oster, C. V., & Strong, J. S. (2007). *Managing the Skies: Public Policy, Organization and Financing of Air Traffic Management*. Aldershot, England; Burlington, VT: Ashgate.

Oum, T. H., Adler, N., & Yu, C. (2006). Privatization, Corporatization, Ownership Forms and their Effects on the Performance of the World's Major Airports. *Journal of Air Transport Management*, *12*(3), 109–121.

Oum, T. H., Yan, J., & Yu, C. (2008). Ownership Forms Matter for Airport Efficiency: A Stochastic Frontier Investigation of Worldwide Airports. *Journal of Urban Economics*, *64*(2), 422–435.

Oum, T. H., & Yu, C. (1995). A Productivity Comparison of the World's Major Airlines. *Journal of Air Transport Management*, *2*(3), 181–195.

Oum, T. H., Zhang, A., & Zhang, Y. (2004). Alternative Forms of Economic Regulation and their Efficiency Implications for Airports. *Journal of Transport Economics and Policy*, *38*(2), 217–246.

Peltzman, S. (1976). *Toward a More General Theory of Regulation*. National Bureau of Economic Research Cambridge, Mass., USA.

Peltzman, S., & Winston, C. (Eds.). (2000). *Deregulation of Network Industries: What's Next?* Washington, D.C.: AEI-Brookings Joint Center for Regulatory Studies.

Posner, R. A. (1971). Taxation by Regulation. *The Bell Journal of Economics and Management Science*, *2*(Spring 1971), 22–50.

Post, T. (2001). Performance Evaluation in Stochastic Environments Using Mean-Variance Data Envelopment Analysis. *Operations Research*, *49*(2), 281–292.

Reinhold, A., Niemeier, H.-M., Kamp, V., & Müller, J. (2010). An Evaluation of Yardstick Regulation for European Airports. *Journal of Air Transport Management*, *16*(2), 74–80.

Robyn, D. (2007). *Reforming the Air Traffic Control System to Promote Efficiency and Reduce Delays*. The Brattle Group, Inc and GRA Inorporated.

Rose, N. L. (2012). After Airline Deregulation and Alfred E. Kahn. *American Economic Review*, *102*(3), 376–380.

Savas, E. (2000). *Privatization and Public-Private Partnerships*. New York: Chatham House.

Schaar, C. (2010). *A Method for Stakeholder-Based Comparative Benchmarking of Airports* (Ph.D. Dissertation). George Mason University, Fairfax, VA.

Schaar, C., & Sherry, L. (2008). Comparison of Data Envelopment Analysis Methods Used in Airport Benchmarking. Presented at the 3rd International Conference on Research in Air Transportation – ICRAT 2008, Fairfax, VA.

Simar, L., & Wilson, P. W. (1998). Sensitivity Analysis of Efficiency Scores: How to Bootstrap in Nonparametric Frontier Models. *Management science*, *44*(1), 49–61.

Simar, L., & Wilson, P. W. (2007). Estimation and Inference in Two-Stage, Semi-Parametric Models of Production Processes. *Journal of econometrics*, *136*(1), 31–64.

Simon, H. A. (1956). Rational Choice and the Structure of the Environment. *Psychological review*, *63*(2), 129–138.

Steuer, M. (2010). The Partially Private UK System for Air Traffic Control. *Journal of air transport management*, *16*(1), 26–35.

Stigler, G. J. (1971). The Theory of Economic Regulation. *The Bell journal of economics and management science*, 3–21.

Syverson, C. (2011). What Determines Productivity? *Journal of Economic Literature*, *49*(2), 326–365.

Thornton, R. L. (1977). Deregulation: the CAB and its Critics. *Journal of Air Law and Commerce*, *43*, 641.

Tobler, W. R. (1970). A Computer Movie Simulating Urban Growth in the Detroit Region. *Economic geography*, *46*, 234–240.

Train, K. (1991). *Optimal Regulation: the Economic Theory of Natural Monopoly*. Cambridge, MA: MIT Press.

Tzu, S. (2005). *The Art of War*. (L. Giles, Trans., J. H. Ford & Shawn Conners, Eds.). El Paso, TX: El Paso Norte Press.

United States Government Accountability Office. (2005). *Air Traffic Control: Characteristics and Performance of Selected International Air Navigation Service Providers and Lessons Learned from their Commercialization*. Washington DC.

United States Government Accountability Office. (2010a). *Next Generation Air Transportation System - Challenges with Partner Agency and FAA Coordination Continue, and Efforts to Integrate Near-, Mid-, and Long-term Activities Are Ongoing*. Washington DC.

United States Government Accountability Office. (2010b). *Next Generation Air Transportation System - FAA's Metrics Can Be Used to Report on Status of Individual Programs, but Not of Overall NextGen Implementation or Outcomes*. Washington DC.

United States Government Accountability Office. (2011a). *Next Generation Air Transportation System - Collaborative Efforts with European Union Generally Mirror Effective Practices, but Near-Term Challenges Could Delay Implementation*. Washington DC.

United States Government Accountability Office. (2011b). *Next Generation Air Transportation System - FAA Has Made Some Progress in Implementation, but Delays Threaten to Impact Costs and Benefits*. Washington DC.

United States Government Accountability Office. (2012a). *Air Traffic Control Modernization - Management Challenges Associated with Program Costs and Schedules Could Hinder NextGen Implementation*. Washington DC.

United States Government Accountability Office. (2012b). *Next Generation Air Transportation System - FAA Faces Implementation Challenges*. Washington DC.

United States Government Accountability Office. (2013). *Next Generation Air Transportation System - FAA Has Made Some Progress in Midterm Implementation, but Ongoing Challenges Limit Expected Benefits*. Washington DC.

Vietor, R. (1991). The Hubris of Regulated Competition: Airlines, 1925-88. In J. High (Ed.), *Regulation: Economic Theory and History*. Ann Arbor: University of Michigan Press.

Vogel, H.-A. (2004, April). *Airport Privatisation and Perfomance* (Ph.D. Dissertation). University of Westminster, London, UK.

Waldman, D. E., & Jensen, E. J. (2007). *Industrial Organization: Theory and Practice*. Boston: Pearson Addison Wesley.

Ward, M. D., & Gleditsch, K. S. (2008). *Spatial Regression Models*. Thousand Oaks, CA: SAGE Publications.

Wei, W., & Hansen, M. (2005). Impact of Aircraft Size and Seat Availability on Airlines' Demand and Market Share in Duopoly Markets. *Transportation Research Part E: Logistics and Transportation Review*, *41*(4), 315–327.

Williamson, O. E. (1976). Franchise Bidding for Natural Monopolies - In General and With Respect to CATV. *The Bell Journal of Economics*, 73–104.

Winston, C. (2012). Government Policy for a Partially Deregulated Industry: Deregulate it Fully. *American Economic Review*, *102*(3), 391–395.

Yarrow, G., & Jasiński, P. (Eds.). (1996). *Privatization: Critical Perspectives on the World Economy, Volumes I, II, III, IV*. London: Routledge.

BIOGRAPHY

Rui Neiva has a background in Civil Engineering. He earned his bachelor’s (2007) and master’s (2009) degree from the Faculty of Engineering of the University of Porto, Portugal.