MICROECONOMIC EFFECTS OF COMPETITION ON PRODUCTIVITY IN THE EU

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Abstract

Differences in the toughness of competition are likely to be one of the major determinants of the large dispersion in productivity, costs and output prices across firms even within narrowly defined sectors and geographical markets. This dissertation examines how increase in the intensity of international competition affects productivity and other performance measures: at the firm, industry, and geographical market levels. The dissertation combines three empirical studies of three distinct types of changes in the competition environment.

The first empirical study investigates the effects of the changes in foreign competition in the form of entry of multinational firms on the total factor productivity growth, innovation and the ways of knowledge-sourcing by incumbent firms. The analysis is based on firm-level panel data from Estonia. I use an instrumental variables approach to identify the effects. Notably, I find no significant short-term effects on productivity growth of incumbents. However, I find that the entry of multinational firms is associated with increase in innovation activities of incumbents and knowledge sourcing from other firms.

The second empirical study investigates the effects of entry and market structure on output price distribution across firms within spatially differentiated markets. Recent heterogeneous-producer models of competition and trade outline new effects how tougher competition affects across-firm price, productivity and cost distributions in the same

sector and market. This chapter tests the implications of these models based on a case study of the European airline sector and a unique airfare dataset. I find some confirmation to the prediction that in more competitive environments, there will be less output price dispersion across firms.

The third essay studies the effects of liberalisation and changes in entry costs on performance of the aviation sector. I use an event study of the enlargement of the European Union (EU) and the Single European Aviation Market in 2004 and employ difference-in-differences and synthetic control methods to study their effects on volume of airline passengers.

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Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 Motivation

It is well known by now that there are large differences in productivity, other performance indicators, and output prices across firms even within narrowly defined sectors and markets. For example, already Griliches and Mairesse (1995) and Bartelsman and Doms (2000) show evidence of large persistent productivity dispersion across firms within detailed single sectors. Roberts and Supina (1997), Sorensen (2000) and Baye *et al*. (2004) show similarly large output price dispersion even for rather homogeneous goods. During recent years, and largely due to better accessibility of detailed micro datasets, there has been an increasing interest to explain these variations.[1]

A number of explanatory factors to these performance differences have been proposed and studied. These include, among others: differences in quality or vintage of inputs, technology, R&D and IT investments, skills, ownership, management practices, organisation of the firms, and barriers to local and international competition. Bartelsman and Doms (2000) and Syverson (2010) provide excellent overviews of related empirical literature.

[1] For example: in Prescott (1997), Syverson (2004a), Schmitz (2005), Syverson (2007).

This dissertation examines how changes and differences in the intensity of international competition affect productivity, other performance measures, and output prices at the firm and geographical market levels. Differences in the toughness of competition are likely to be among major determinants of variation in performance characteristics across production units, industries, markets and countries (e.g. Arrow 1962, Leibenstein 1966, Vickers 1995, Melitz and Ottaviano 2008). There is long-standing interest about the effects of competition, including among others the seminal studies by Hicks (1935), Schumpeter (1943), Arrow (1962), Leibenstein (1966) and Melitz and Ottaviano (2008). Also, economists share a general belief that competition is mostly good for national productivity.

However, empirically identifying the impact of local and foreign competition is difficult. Only a small share of empirical papers can study the causal effects (e.g. Aghion *et al*. 2009, Syverson 2004a). Largely, because it is difficult to find out how the affected units (firms, industries, geographical markets or countries) would have evolved in the absence of changes in the competition environment. The ideal research framework in the form of a true natural experiment, with exogenous changes in competition rarely becomes available.

My dissertation combines three different empirical studies, based on rich panel datasets, that contribute to the empirical literature on industrial organisation and foreign direct investments (FDI). These studies complement each other by investigating different events of changes in the competition environment. Following Vickers (1995), ‘more competition’ can have different commonly used meanings. It can mean: i) increased freedom of rivals to enter an industry (e.g. following a deregulation of entry or removal of barriers to trade); ii) an increase in the number of competitors (or a change towards less concentrated market structure); iii) move away from collusive behaviour to rivalry; and iv) a situation where the potential reward for obtaining the aim that rivals are all striving for is increased. Studies in this PhD dissertation concentrate on the analysis of the first two of these ways of increasing competition.

To be more specific, my three empirical contributions investigate: a) the effects of entry of technologically superior foreign-owned firms on productivity, knowledge sourcing and innovation of incumbent firms (Chapter 2); b) the effect of entry of rival airlines and changes in market structure on across-firm distribution of airfares on different city-pair markets in Europe (Chapter 3); and c) the effect of market liberalisation in the form of the enlargement of the European Union (EU) and the Single European Aviation Market (SEAM) in 2004 on the volume of physical output in passenger aviation sector (Chapter 4). The level of analysis is firm-level in Chapter 2, geographical market (city-pair) level in Chapter 3, and aggregate country-pair level in Chapter 4.

This dissertation adds to the empirical literature about competition by studying the different specific channels of the effects of competition. These channels include the selection effects across firms and the within-firm effects through changes in innovation incentives and knowledge sourcing by incumbent firms. In examining these issues I endeavour to control for the endogeneity of measures of competition by using instrumental variables and an extension to the difference-in-differences, the synthetic control method.

Before outlining the contributions in separate chapters in more detail, it is worth to discuss briefly how competition, through selection and within-firm effects, can affect productive efficiency at firm and aggregate level.

1.2 Effects of competition on productive efficiency

The large and persistent productivity and price differences across production establishments and markets are only possible under one condition: there need to be barriers that enable inefficient and high-price producers to operate without being forced out of the market by other more efficient ones. The productivity differences can persist in different markets, firms, regions or industries if there are differences in strength of resistance to the adoption of new technologies and to the efficient use of existing technologies (Prescott 1997). Economic historians place a significant role to the strength of resistance to the use of better technologies in explaining differences in economic development. For example, Mokyr (1990) argues that this resistance explains why modern economic growth began initially in the West and not in China.[2] Also, following the view of Prescott (1997), the variation in resistance to change is potentially the key driver behind total factor productivity (TFP) differences across regions, industries or individual firms.

Differences in the toughness of competition and in product substitutability between producers in general are likely to be major determinants of the willingness to improve efficiency. That way, competition plays a key role also in the large differences in productivity, costs, and output prices across firms.

The first main way how tougher competition can improve productivity and performance at the firm, the industry and the country levels is by inducing changes within the firms.[3]

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[2] Also, Landes (1969) has claimed that the relative industrial decline of the United Kingdom at the beginning of twentieth century was partly due to the persistent prevalence of generation-after-generation of family management, if compared to the US and German increasing willingness to employ professional managers of firms.

[3] In principle, competition can affect firm's productivity through its effects on a wide host of within-firm determinants of productivity growth. These determinants include: management and work practices at

Competition can improve the incentives of managers and employees at the firm to avoid slack and to 'try harder' (Vickers 1995, Leibenstein 1966). This can be manifested in more efficient use of technologies already existing at the firm and in adoption of new technology and work practices. Competition may also improve incentives to innovate (e.g. Hicks 1935, Leibenstein 1966, Arrow 1962, Aghion *et al*. 2009). In addition, the entry of technologically superior competitors may trigger knowledge spillovers to the incumbent firms in the same sector or in downstream or upstream sectors (e.g. Javorcik 2004).

The within-firm effects may depend on the characteristics of the incumbents, for example as predicted by Glass and Saggi (1998) or the Schumpeterian competition models in Acemoglu *et al*. (2006) and Aghion and Griffith (2005). These models predict that an increase in entry of technologically advanced firms (e.g. multinational enterprises) raises incumbents' performance, innovation incentives and innovation activities if the incumbents are sufficiently close to the productivity frontier. According to Aghion *et al.* (2009) there may be positive effects on innovation of the high-productivity firms because they can escape adverse entry effects by innovating. It could be also expected that if incumbents are far from the productivity frontier then entry of multinational enterprises (MNEs) will reduce their incentives to innovate. Hence, it would have negative effect on their productivity growth. Increasing frontier entry could reduce incumbents' innovation incentives if they are far from the technology frontier, as they have little hope of surviving the entry.

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production units (as studied in Ichniovsky *et al*. 1997, Bloom and van Reenen 2007), information technology (IT) and R&D investments (Bartel *et al*. 2007, van Ark *et al*. 2008), innovation (e.g. Crépon *et al*. 1998, Griffith *et al*. 2006), organization of the firm (incl. decentralisation, as in Bloom *et al*. 2007).

The second main way how competition can improve productivity and performance is through selection effects across firms. The selection effects can affect the productivity distribution of the whole industry, region, and country—even if there are no within-firm productivity changes at all. Competition can force the inefficient producers to lose their market share to the more efficient ones, and finally to exit from the market. This selection process raises the aggregate industry productivity, as predicted in Syverson (2004a) and Melitz and Ottaviano (2008). It can also have effects on output prices, as shown in Syverson (2007) based on the US ready-mixed concrete sector. The Syverson (2004a) and Melitz and Ottaviano (2008) models predict that tougher competition not only results in an effect on average productivity and prices on a market, but also in effects on other moments of the productivity and output price distributions. Tougher competition raises the lower bound (survival cut-off) of the productivity distribution and suppresses the upper-bound prices in a market. Thereby tougher competition will also result in lower dispersion of both productivity and output prices across firms.

1.3 Outline of the thesis

To allow for specific study of different aspects of effects of international competition, this dissertation has been structured into three empirical chapters, each investigating a different type of change in competition environment; each chapter also contains a review of related literature.

Chapter 2 focuses on an issue of considerable policy importance. It studies the effects of entry of MNEs on productivity growth, innovation and knowledge-sourcing by incumbent firms in the host economy. Research in this chapter is motivated by the earlier largely inconclusive empirical evidence about the spillover effects of FDI. Although FDI has a potential to be a catalyst of economic development, the empirical findings about its effects on domestic firms in the host country are mixed, at best. Notably, only a small number of empirical papers are able to account for the endogeneity of MNE entry. Also, vast majority of studies concentrate on the effects on productivity. There is only little research that investigates the various channels how MNE entry can increase productivity of incumbents (e.g. Crespi *et al*. 2008, Aghion *et al*. 2009).

The analysis in Chapter 2, based on firm level data from the manufacturing industry in Estonia, provides new empirical evidence about different channels how MNE entry can affect firms in the host economy. In addition to productivity growth, Chapter 2 investigates whether the MNE entry is associated with an increase in incumbents' innovation and innovation-related co-operation with other firms. It studies whether the MNE entry results in an increase in direct measures of knowledge flows from competitors, suppliers and clients of the incumbent firm. It also tests whether the effects on productivity and innovation are heterogeneous and depend on incumbents' distance to the productivity frontier (as outlined in Section 1.2).

Chapter 2 builds to significant extent upon the empirical approach in a recent study by Aghion *et al*. (2009), which used firm level data from UK. The empirical analysis of data from Estonia starts, first, with estimation of production function and TFP. Next, I regress the TFP growth, the labour productivity growth, or measures of innovation and knowledge flows on the MNE entry rate in the sector, distance to the local technology frontier, and several other controls. In estimating these effects, I endeavour to control for the endogeneity of MNE entry. For that, I use instrumental variables that predict the

MNE entry in Estonia, but are (otherwise) unlikely to affect the outcome variables of incumbent firms.

I check whether the predictions and findings in Aghion *et al.* (2009) about the role of distance to the technology frontier in effects of MNE entry hold also in a transition economy, characteristic to Estonia of 1995-2004. However, my study goes into greater detail with investigation of the various ways how MNE entry affects incumbents than Aghion *et al.* (2009) and other related papers. Estonia is a good case for investigating the impact of FDI as its transitional economy has ranked ahead of most other Central and Eastern European (CEE) countries in terms of per capita FDI inflows. Moreover, I use Estonia's firm-level survey data on knowledge flows and innovation that is linked to firm-level data on productivity growth. Based on Estonia's data I can test directly whether the MNE entry results in knowledge spillovers. That is, whether entry of FDI is associated with an increase in the direct measures of knowledge flows to incumbents.

Chapter 3 shifts the focus to the effects of entry and market structure on the output price distribution across firms within spatially differentiated markets. Recent heterogeneous-producer models from industrial organisation (Syverson 2004a) and new-new trade theory (Melitz and Ottaviano 2008) outline new effects how tougher competition affects across-firm price, productivity and cost distributions in a market. This chapter contributes to the empirical literature of industrial organisation by testing some implications of these models based on a case study of the European airline sector and a unique airfare dataset. I test the predictions that tougher competition (in the form of increased entry, larger number of competitors, or lower value of the Herfindahl index) is associated with a fall in maxima and dispersion of the price distribution across firms in a market. Before, similar effects on output price distribution have been investigated in Syverson (2007) based on

US data of ready-mixed concrete producers. To the best of my knowledge, there are so far no other papers that test these predictions based on data from a services sector.

Focusing on this single sector has significant advantages as the European short-haul passenger aviation sector provides suitable material for a case study of the effects of competition. Passenger aviation sector consists of separate city-pair markets, the technology is relatively similar across firms, the products (economy class flights) are relatively easily substitutable across different airlines on the same short-haul route, and the sector has faced significant entry and exit of airlines on different routes. The primary advantage of such industry case study is that it helps to control, to an extent, for the influence of technology differences and product heterogeneity, helping to focus on the impacts of interest. Many studies use panel data of firms from rather heterogeneous sectors to study the effects of competition (e.g. Nickell 1996, Aghion *et al*. 2009, Chapter 2 of this dissertation). These studies benefit from a broader focus. At the same time, they find it more difficult to isolate the effect of differences in competition from the effects of differences in product and technology that may also drive the dispersion in the outcome variables.

The UK-Ireland, UK-Netherlands and UK-Belgium country-pairs that I investigate have faced changes in competition and entry and exit of airlines during the period studied (2003-2005). A clear advantage of Chapter 3 over most other studies of competition in the aviation sector is the detailed dataset used. I can employ unique primary data of economy class airfares, collected by Claudio Piga from Loughborough University using a 'web spider' computer programme. These data allow me to study the pricing decisions of airlines with greater precision than any other airfare dataset. The empirical analysis of this dataset tries to control for endogeneity of the measures of competition. For that, I employ the system-GMM approach by Blundell and Bond (1998).

Chapter 4 provides an event study of the effects of market liberalisation on output growth of the passenger aviation sector. It focuses on the 2004 enlargement of the EU and the Single European Aviation Market (SEAM), and their impact on physical output (i.e. passenger traffic) of the passenger aviation sector.

The standard problem in studies about the effects of a liberalisation event is—how to construct a suitable proxy for the counterfactual case if no deregulation took place? The simple descriptive statistics show that around the time of enlargement in 2004 there was a large unprecedented increase in international air passenger traffic to the new member countries. However, this need not show the effect of liberalisation. To find out the effects of enlargement on the volume of airline passengers, Chapter 4 uses difference-in-differences and synthetic control methods, combined with variation in the membership coverage of both the Single Aviation Market and the EU.

Chapter 4 provides a more aggregate analysis about the effects of competition than the previous chapters. Unlike Chapter 2 and 3 it does not focus directly on the effects of entry, but on a significant one-time event that increased freedom of rivals to enter the market. This, consequently, resulted in a large-scale entry of low-cost carriers on the routes to the new member countries of the EU.

Finally, Chapter 5 presents the main conclusions from the three empirical studies. It includes a brief discussion of the limitations and potential extensions.

Chapter 2

Does FDI Spur Productivity, Innovation and Knowledge Sourcing of Incumbent Firms? Evidence from Manufacturing Industry in Estonia

2.1 Introduction

The existing empirical evidence base on the effects of foreign direct investments (FDI) on domestic firms is, at best, limited. There are many papers attempting to study the effects of entry of foreign owned firms on local incumbents, i.e. the spillovers of FDI. However, this type of study is difficult. The researcher needs to account for likely econometric problems of reverse causality, endogeneity of FDI, endogeneity of inputs in estimation of the production function, heterogeneity of effects, lack of good instruments or natural experiments for identification of causal relationships. Only very few papers can account for these issues. Reflecting these problems and the resulting likely biases in estimated effects, the findings in different papers and different countries can vary a lot. Insignificant, and sometimes also positive or even negative spillovers have been found.[4]

[4] See, for example, Görg and Strobl (2001), Görg and Greenaway (2004), or Barba Navaretti and Venables (2004) for literature reviews about effects of FDI on incumbent firms.

This study adds to the literature by studying the channels of the effects of entry of foreign owned firms on domestic firms in the host economy of FDI. Using instrumental variable (IV) regression approach to identify the effects, I investigate the association of FDI entry in Estonia with incumbents' total factor productivity (TFP) and labour productivity growth. However, I provide also evidence concerning the association between FDI entry and subsequent domestic firms' innovation activities; and indicators of importance of knowledge flows from suppliers, clients and competitors of the firm. I also check for heterogeneity of these effects, whether they depend on local incumbents' distance to the technology frontier, as suggested by Aghion *et al.* (2009).

Most of the earlier literature investigates the correlation between FDI presence in a host economy and productivity of domestic-owned firms, not the causal effects. Among the exceptions that endeavour to address the effects, by IV regression approach, are studies by Aghion *et al.* (2009) and Haskel *et al*. (2007). Also, for example Barrios *et al*. (2009), Crespo *et al*. (2009) or Halpern and Muraközy (2007) employ the GMM estimator to try to account for the endogeneity of FDI.

Most papers are also firmly rooted in the estimation of the production function of firms or plants. All that FDI entry is expected to do is to shift TFP. The current inconclusive evidence about spillovers, however, suggests that we should look more in detail into the different channels of effects.

The effects of FDI entry on within-firm productivity growth of domestic firms can function through technology transfer and through an increase in toughness of competition. This paper employs detailed firm level data from Estonia, covering all manufacturing firms during 1995-2004. Estonia is a good case study for the effects of FDI, as it is a transition economy that has attracted a lot of FDI per capita. In terms of per capita stock of FDI, it has ranked ahead of most other locations among the Central and Eastern European (CEE) transition countries (UNCTAD 2009). Moreover, the Estonian data include indicators of innovation and knowledge sourcing from other enterprises. This means that, unlike other related studies (except only Crespi *et al*. 2008), I can test whether entry of FDI results indeed in spillovers to domestic firms—whether entry of FDI is positively associated with an increase in direct measures of knowledge flows to incumbents.

By using instrumental variables I can go beyond the standard analysis of correlations. To identify the impact of FDI entry on performance of incumbents, one needs an instrument that predicts changes in the FDI entry, but is unrelated to changes in incumbent productivity in Estonia (after controlling for other relevant factors). I employ the FDI entry rates in 3-digit level NACE sectors of other CEE countries as instruments for FDI entry rates in the corresponding industries in Estonia. These instrumental variables predict the FDI entry in Estonia. At the same time they are not likely to directly affect the performance characteristics of incumbent firms in Estonia. Previously, Haskel *et al*. (2007) have used similar instruments. They instrument FDI share in each sector in UK with FDI share in the same industry in the US.

The estimated main regressions of interest relate the change in TFP (estimated with the Levinsohn-Petrin method to account for endogeneity of inputs in the production function), labour productivity (value added per employee) or different measures of innovativeness, or knowledge sourcing of incumbent firms in a sector to lagged change in the share of foreign owned firms in a sector or a region and other firm and industry level controls. In some specifications these other controls include incumbents' distance to the local productivity frontier and an interaction term between distance to productivity frontier and FDI entry.

Based on Schumpeterian competition models outlined in Acemoglu *et al*. (2006) or Aghion *et al*. (2009) one could expect that an increase in entry of technologically advanced firms (e.g. multinational enterprises) has positive effects on incumbents' performance, innovation incentives and innovation activities if the incumbents are sufficiently close to the productivity frontier.[5] It could be also expected that if incumbents are far from the productivity frontier of the sector then entry of multinational enterprises (MNEs) will reduce innovation incentives of these firms and thereby have negative effect on their productivity growth.[6]

However, I find no support for these predictions. There is no significant effect of lagged entry of foreign owned firms on TFP or labour productivity growth of incumbent firms, regardless of their distance to the productivity frontier or geographical proximity to MNEs.

There are some positive correlations in the case of innovation activities. I find a positive association between the FDI entry rate in an industry and incumbents' probability of engaging in process innovation. A 10 percentage points higher entry rate of foreign owned firms is associated with 4 percentage points increase in incumbents' probability of engaging in process innovation. There is no such significant correlation of FDI entry with product innovation or innovation-related co-operation. Also, these correlations do not appear to depend on the distance of domestic firms from the productivity frontier.

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[5] According to Aghion *et al.* (2009) there may be positive effects on innovation of these high-productivity firms as they can escape adverse entry effects by innovating.

[6] Increasing frontier entry could reduce incumbents' innovation incentives if they are far from the technology frontier, as they have little hope of surviving the entry.

One important question is whether these results can be seen as spillover effects? Analysis of probit and ordered probit models based on Estonian CIS[7] innovation surveys (CIS3 and CIS4) shows that the entry of FDI in 3-digit level sectors is indeed correlated with direct measures of spillovers. This gives support to the interpretation that FDI entry results in spillovers to domestic firms. So far only Crespi *et al*. (2008) have used similar data (from UK) to find out whether the indirect and direct measures of spillovers are correlated.

A notable result is that domestic firms that are further behind the technology frontier tend to grow faster than others. So, there seems to be some firm level productivity convergence taking place within Estonia. This result is similar to a recent study about UK by Bartelsman *et al*. (2008).

This chapter is organized as follows. Section 2.2 provides an overview of theoretical background. Section 2.3 describes shortly related empirical literature. Section 2.4 explains the empirical approach and the identification of the effects. Section 2.5 describes data. Section 2.6 gives the empirical results. Section 2.7 concludes.

2.2 Theoretical background: effects of MNE entry on domestic firms

The spillovers of FDI on domestic owned firms' productivity and other performance characteristics can work through technology transfer and changes in competition. Detailed overviews of the theoretical background of these effects are provided, for example, in Barba Navaretti and Venables (2004) or Görg and Greenaway (2004).

[7] CIS - Community Innovation Survey.

The main prediction from theoretical literature is that the net impact on local firms in a host economy is ambiguous and may depend a lot on the characteristics of the host country and local firms (Barba Navaretti and Venables 2004). There can be negative effects of MNE entry due to changes in market shares of local firms, positive effects due to changes in incentives of incumbents to effort and to innovate, and positive effects due to technology transfer.

The competition related effects of entry of MNEs on productivity in the host economy can work in two general ways. One is by toughening the selection process among heterogeneous firms in a sector. This selection effect could increase the average industry productivity by shrinking the market share of low-productivity firms and forcing some of them to exit (Syverson 2004a, Melitz and Ottaviano 2008). Note, that although this selection effect can improve the average productivity in the host economy, it has a negative effect on some local incumbents, on the ones that have low productivity, are therefore unable to compete with MNEs and lose their market share.

Negative effects on average costs and productivity of these local firms are possible due to the existence of fixed costs (Aitken and Harrison 1999). If imperfectly competitive firms face fixed costs of production, a foreign firm with lower marginal costs will have an incentive to increase production relative to its domestic competitors. In this environment, entering foreign enterprises producing for the local market can draw the sales and the demand away from some domestic firms, thus making them cut production. The productivity of domestic firms could, as shown by Aitken and Harrison (1999), fall as they spread their fixed costs over a smaller market, forcing them back up their (downward sloping) average cost curves.

Stronger competition due to entry of MNEs, can also have significant positive effects on local firms that may outweigh the potential loss of their market shares. Increased competition may improve incentives of employees and managers of the incumbent firm to effort and to innovate (Aghion *et al*. 2009). At the same time, the presence of a MNE in a host country can lead to technology transfer to domestic firms (e.g. Aitken and Harrison 1999, Barba Navaretti and Venables 2004). These effects can result in improvement of performance and productivity of incumbents. If foreign firms introduce new products, production processes and work practices in their affiliates, domestic firms may benefit from accelerated diffusion of this knowledge in the host country.

Spillovers can take place as MNEs cannot reap all the benefits of their activities in a foreign location. This is because of the public good characteristics of their firm-specific assets (incl. knowledge, technology) as these assets are, at least to a certain extent, non-excludable and non–rival goods (Caves 1996).

The spillovers from inward foreign investment can be either horizontal or vertical (i.e. inter-industry). Horizontal (intra-industry) spillovers take place between companies in the same industry, vertical spillovers originate from suppliers and customers of the firm. See Javorcik (2004) for a thorough analysis of vertical spillover effects.

Based on Caves (1974), Blomström and Kokko (1996), Javorcik (2004), Aitken and Harrison (1999), Barba Navaretti and Venables (2004) we can distinguish between the following main channels for spillovers: demonstration (or imitation), worker mobility, supplier upgrading, competition and exporting.

Demonstration effect works by imitation of production technologies and work practices of the MNEs by local firms. Also, diffusion of new technology and know-how may take place through labour turnover, as employees at the MNE plants move to work in domestic owned firms, and take their experience and knowledge with them. Additional source of productivity gain may be through export spillovers (Blomström and Kokko 1996; Görg and Greenaway 2004). Domestic firms often learn from multinationals how to export (Greenaway *et al*. 2004).

The strength of spillover and competition effects may also depend on characteristics of domestic-owned firms. These characteristics may include incumbents' absorptive capacity, export or domestic market orientation, geographical proximity to foreign owned firms and firm's distance to the technology frontier (Barba Navaretti and Venables 2004, Castellani and Zanfei 2006, Findlay 1978, Glass and Saggi 1998, Aghion *et al*. 2009).

This chapter concentrates on the role of distance to technology frontier and geographical proximity. Naturally, spillovers are more likely to materialise in the case of incumbents that are located close to the foreign owned firms. The role of distance to the technology frontier for spillover effects may be similar to the effect of geographical distance, as suggested by some recent papers (Aghion *et al*. 2009). However, the predictions from theoretical literature about the role of distance to technology frontier have been mixed.

Findlay (1978) argues that the relative backwardness of the host economy may in fact mean more scope for spillover effects from FDI. The larger is the difference in development between the home and host country of FDI, the greater is the pressure and need to adopt new technology. The view of Glass and Saggi (1998) is different. They argue that technology gap between domestic firms and foreign owned ones is related to the absorptive capacity of firms—the ability to adopt new technologies. The larger is the technology gap of domestic firms the lower is the possibility of spillovers. Also, more recent Schumpeterian competition models support this conclusion (see e.g. Aghion and Griffith 2005 for a thorough review of such theoretical studies).

I follow the approach similar to Aghion *et al*. (2009) to check whether and how the effects of MNE entry on productivity and innovation of incumbent firms depend on each firm's distance to the technology frontier. Based on Aghion *et al*. (2009) and Acemoglu *et al*. (2006) we would expect that an increase in entry of technologically advanced firms (e.g. MNEs) has positive effects on incumbents' performance, innovation incentives and innovation activities if the incumbents are sufficiently close to the technology frontier. There are positive effects on innovation of these high-productivity firms as they can escape adverse entry effects by innovating.

However, we would also expect, based on the same models, that if incumbents are far from the technology frontier of the sector then the entry of MNEs will reduce innovation incentives of these firms, as they have little hope of surviving the tougher competition. Thereby, it will have negative effect on their productivity growth.

2.3 Review of empirical literature

Evidence about spillovers from MNEs to domestic firms is, despite the large number of studies, still ambiguous. The literature struggles with providing evidence that could be interpreted as causal effects. In the ideal case, one would like to use a natural experiment, a case of exogenous change in FDI inflows that affects some of the domestic firms but not others, to identify the effects of FDI on local firms. However, changes in FDI inflows to a host country are almost never exogenously determined. Therefore empirical study of spillover effects is difficult.

The first empirical research of FDI spillovers is by MacDougall (1960), who investigates the welfare effects of FDI. Other early studies include Caves (1974), Globerman (1979) and Blomström (1986), based on data of Australia, Canada and Mexico. These studies used cross-sectional industry level data and found usually positive spillovers of FDI.

By now, the number of empirical papers in the field has grown larger than 70. The focus of research has shifted since 1990s from industry and country level towards firm or plant level studies, and from cross-section to panel data. The pioneering study, that had the novelty of using panel data, was by Haddad and Harrison (1993) for Morocco. They used enterprise level panel data with 11,700 observations and found negative spillover of FDI. For comparison, the industry level study by Caves (1974) had only 49 observations (sectors). Panel data allow us to account for firm-specific time-invariant characteristics that might otherwise bias the findings if only the cross-section information were used.

There are a several good literature surveys available by now. These include papers by Blomström and Kokko (1996), Görg and Strobl (2001), Görg and Greenaway (2004), Lipsey (2002, 2006), and Barba Navaretti and Venables (2004). In general, the main lesson from the firm-level studies of panel data is that the results are very mixed. There is no strong and conclusive evidence about the existence of positive productivity spillovers. Also, most of the papers study correlation between FDI share in a sector and productivity of domestic firms, not the causal effects. Studies that are based on firm or plant level panel data are less likely to find positive significant spillovers than earlier studies that rely on cross-section and industry-level data. In transition economies often insignificant or even negative horizontal spillovers are found (Damijan *et al*. 2003). Researchers tend to find positive spillovers somewhat more often in the case of developed countries (e.g. Haskel *et al*. 2007 for UK).

The framework of analysis is usually based on estimation of the production function. A few exceptions to this approach include survey based evidence, e.g. by Spatareanu and

Javorcik (2005). A standard approach has been to estimate an augmented production function with proxies for FDI presence in a sector included among other inputs (e.g. Aitken and Harrison study of Venezuela, 1999). Papers that look at vertical spillovers add an additional term to the estimated equation—the FDI share in each sector multiplied by coefficients from the input/output tables of the host country.[8] This way, they endeavour to capture the effects of presence of FDI in the downstream and upstream sectors of the domestic firm.

As an alternative, often the TFP is estimated separately in the 1st stage. Then, in the 2nd stage the TFP is regressed on a number of control variables, including the FDI share in a sector. More recent papers are able to account for endogeneity of capital or labour inputs in the 1st stage, for example by using semiparametric estimation procedures of TFP by Olley and Pakes (1996) or Levinsohn and Petrin (2003). A good and probably the most well known example of such study is by Javorcik (2004). She investigates the horizontal and vertical spillovers of FDI on domestic firms in Lithuania. She finds some evidence that she interprets as positive vertical spillovers to domestic firms, but does not find any horizontal effects. Indeed, based on other later papers, there seems to be some indication that there may be more positive spillovers through vertical linkages than horizontal spillovers (Barba Navaretti and Venables 2004, Damijan *et al*. 2003, Görg and Greenaway 2004).

Neither these 1-step or 2-step estimation approaches are usually able to account for the endogeneity of the spillover variable. FDI is likely to flow to sectors and firms that would have higher productivity and higher productivity growth than others even without FDI inflow. Therefore FDI spillover variable needs to be treated as an endogenous one in the

[8] This approach was first introduced in Schoors and Van der Tol (2002), followed by Javorcik (2004).

estimation of its effects on TFP or other variables. Standard panel fixed effects (FE) model is likely to provide inconsistent estimates.[9]

A solution is to use instrumental variables approach instead. For that the researcher needs to find instrumental variable(s) that help to predict the FDI spillover variable, but are otherwise not affecting the (productivity of) domestic firms in the host economy (after controlling for other relevant factors). This way one can induce exogenous variation in the FDI spillover variable, needed for estimating the effects. This is the approach taken in this paper.

Another problem with most of the empirical literature is treating the link between FDI and productivity of domestic firms as a 'black box'. Usually, researchers do not attempt to address the channels through which these effects take place. In order to understand how the spillovers of FDI work, a detailed analysis about the channels of these effects is needed: like effects on innovation, work practices, and knowledge flows to domestic firms. So far, very few studies have studied the FDI spillovers on innovation activities of domestic firms. These include Bertschek (1995), Blind and Jungmittag (2006) and Girma *et al.* (2009). Bertschek (1995) and Blind and Jungmittag (2006) use German data and find that the market share of foreign-owned firms is positively associated with innovation propensity of domestic firms in the same industry. However, they do not account for the likely endogeneity of the FDI spillover variable. Girma *et al.* (2009) study the FDI spillovers to innovativeness of Chinese state-owned enterprises—on average, they find a negative association with the FDI presence in a sector and state-owned firms' innovation activities.

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[9] The FE approach is based on a very restrictive assumption that the part of the error term that is correlated with endogenous right-hand side regressor(s) can be seen as fixed over the time period studied.

Two main related papers that endeavour to estimate the effects of FDI on domestic firms using IV models with external instruments are by Aghion *et al*. (2009) and Haskel *et al*. (2007), both based on UK data. Both find positive effects of FDI presence and FDI entry in a sector.

Aghion *et al*. (2009) investigate in detail the heterogeneity of the effects of FDI. They find that entry of FDI has positive effects on innovation and growth of TFP or labour productivity only for these incumbent firms within the same sector that are not very far from the productivity frontier. Similarly, Gorodnichenko *et al.* (2007) finds, using a small 2-year panel from different transition economies, that spillovers vary with the firm's 'absorptive capacity', that the firm's distance from the productivity frontier tends to dampen horizontal spillovers. Unlike Aghion *et al*. (2009) paper, they are not able to identify the causal effects.

There is an increase in number of papers that try to use dynamic panel data methods like system-GMM approach to investigate the productivity spillovers of FDI. For example, by Barrios *et al*. (2009), Crespo *et al*. (2009), Suyanto *et al.* (2009), Halpern and Muraközy (2005) and Muraközy (2007). However, Roodman (2009a, 2009b) points out that GMM can easily produce results that are in fact not depleted of endogeneity. Also, the results may vary a lot depending on which lags and differences are used as internal instruments for the explanatory variables. Differently from these papers, I rely here on external instruments—similarly to Aghion *et al*. (2009).

Some previous studies have investigated FDI spillovers in Estonia. These include papers by Sinani and Meyer (2004), Damijan and Knell (2005), Vahter and Masso (2007). All of these look at the correlation between FDI share in a sector and the productivity of local firms. None of them is able to investigate the causality and account for the endogeneity of FDI spillover variable, or look into the channels though which the productivity spillovers work. With the exception of Sinani and Meyer (2004), no significant correlations between FDI share in a sector and TFP of domestic firms has been found in these papers. Sinani and Meyer (2004) and Damijan and Knell (2005) use small sample of Estonian firms, that is significantly biased towards large firms and foreign owned firms. They do not correct their estimated effects for this sample selection bias and calculate the FDI share in each sector (the FDI spillover variable) also based on the biased sample. Sinani and Meyer (2004) paper suffers from serious attrition problem as the number of firms in their sample falls over the studied period falls from 490 to 290. Many of the problems of earlier studies on FDI spillovers in Estonia are avoided in this one by using a dataset that includes all manufacturing firms.

2.4 Empirical modelling of the effects of MNE entry

The estimated empirical model in Equation (2.1) follows closely the regression model from the empirical study of UK data in Aghion *et al*. (2009). The dependent variable (ΔY_{ijt}) in Equation (2.1) is depending on specification, either the change in TFP, labour productivity (value added per employee) or different measures of innovativeness at the incumbent firm level. Subscript i indexes incumbent firms, j indexes industries, t indexes years.

The estimated main regressions relate these different dependent variables to lagged entry of foreign owned firms (E_{jt-1}), distance of incumbents to the local productivity frontier

(D_{ijt-1}), interaction term between these two variables, and some other firm and industry level controls (X_{ijt}), firm fixed effects (μ_i), year effects (τ_t) and an error term (ε_{ijt}):

$$\Delta Y_{ijt} = \alpha + \beta E_{jt-1} + \gamma D_{ijt-1} + \delta E_{jt-1} D_{ijt-1} + X'_{ijt-1}\varphi + \mu_i + \tau_t + \varepsilon_{ijt} . \qquad (2.1)$$

The entry of foreign owned firms is measured as the change in the share of foreign owned firms by their number of employees in each 3-digit NACE sector. The distance to local productivity frontier is defined here as difference between the highest productivity decile (the 90th percentile) of each 3-digit industry and each incumbent firm's productivity level in the sector. Its interaction term with FDI entry enables us to look at how effects of entry depend on distance to the frontier. Other controls include lagged sector-level import penetration and Herfindahl index, and log of size of the firm. We would expect that firms that are more exposed to foreign or local competition have higher productivity growth and engage more in innovation. Therefore we expect the increase in import penetration rate (a very broad proxy for foreign competition) to be positively associated with productivity growth and innovativeness of firms. Also, we would expect that higher Herfindahl index (i.e. less competition) is negatively related to the productivity growth and innovativeness of local firms. Firm size is included as an additional control, as larger firms may be more innovative, increase in firm size may make it easier for the firm to find funds to invest in innovation activities—and consequently, this may also result in higher growth rate of its productivity. The idea that large firms (with market power) innovate more goes back to Joseph Schumpeter (e.g. 1943) and is often named as 'Schumpeterian hypothesis'. The well-documented result from the recent innovation literature has indeed been that larger firms tend to be more innovative: for example a lot of evidence for that has been obtained in applications of the Crépon, Duguet and Mairesse (CDM, 1998) structural model of innovation (e.g. Griffith et al. 2006). Cohen and Klepper (1996) summarise the findings of the earlier literature on the relationship between firm size and R&D. According to them, the likelihood of a firm reporting positive R&D as well as the amount of R&D increases with firm size.

In order to account for the endogeneity of FDI entry[10] I need to instrument this term and its interaction with the distance to the productivity frontier. I need instrumental variables(s) that predict changes in the FDI entry rate, but are (otherwise) unrelated to changes in the dependent variable ΔY_{ijt}. There are few variables that satisfy these conditions.

However, suitable instrumental variables that I can use here are the FDI entry rates (at 3-digit sector level) in other Central and Eastern European (CEE) transition economies.[11] The entry rates in different 3-digit industries are likely to be correlated across different CEE countries as the determinants of FDI inflow for several of the CEE countries are relatively similar. However, it is not likely that the FDI entry rates inside, for example, Slovakia or Lithuania affect directly the productivity growth rate of incumbent firms in Estonia. Here I need to assume that there are few knowledge flows from multinational firms that are geographically far from the incumbent Estonian firms. That is, I assume that entry of FDI in countries like Slovakia or Lithuania does not result in spillover effects in Estonia.

[10] Due to data availability, I define the foreign owned firms as these with at least 50 per cent foreign ownership and define the FDI entry rate also based on these firms only.

[11] I use FDI entry data from Hungary, Czech Republic, Slovakia, Poland, Latvia, Lithuania.

In order to account for potential endogeneity of the *'distance to the productivity frontier'* (D_{ijt-1}) variable I try instrumenting it with the 3-digit industry level capital-labour ratio and intangible assets per employee in Sweden and Finland. Data of Sweden and Finland are chosen because they are the main donors of FDI in Estonia. About 55 per cent of FDI in Estonia comes from these two countries. Also, many industries in both of these countries are on the global technology frontier (Bartelsman *et al*. 2008). Similar variables[12] from the USA are used in the Aghion *et al*. (2009) study as instruments for the UK incumbent firms' distance to the technology frontier. The instruments could be expected to be related to the productivity of Finnish and Swedish firms and their affiliates in Estonia. That way they could affect also the productivity frontier in each 3-digit sector in Estonia, and each domestic firm's distance to the productivity frontier. Also, these variables are not likely to have direct effect on productivity growth of Estonia's domestic-owned firms.

A related question to the effects of FDI entry on productivity and innovation is whether the entry results in knowledge spillovers to the incumbent firms? The standard approach is to use the FDI share or FDI entry rate in a sector as an indirect proxy for the FDI spillovers (e.g. Aitken and Harrison 1999, Javorcik 2004, and many others). Based on data from the EU innovation surveys (CIS3 and CIS4 surveys) we can test whether there is any significant correlation between these indirect measures of spillovers and the importance of 'knowledge flows from other firms' for the domestic firms.

[12] I use the ratio of intangible assets per employee as an instrument instead of the skill intensity measure used in Aghion *et al*. (2009) because the skill-intensity data of Sweden and Finland is not available at 3-digit NACE sector level. Intangible assets per employee is likely to be correlated with the R&D intensity of the firm, which is an important determinant of productivity of firms, and therefore, potentially, an important determinant of the 'distance to the productivity frontier' variable.

The main question asked from each firm about its knowledge flows in the EU CIS innovation survey is: "*Indicate the sources of knowledge and information used in your technological innovation activities, and their importance.*"

The answer choices are: "*importance of the source is* i) *high,* ii) *medium,* iii) *low,* iv) *not used*." Knowledge sources listed in the questionnaire are the following: *from within the enterprise; from suppliers; from customers; from competitors; (a number of other sources have been listed as well, but are seldom indicated as important by Estonian firms).*

Based on the answers of domestic-owned firms, a set of indicator variables has been created, a dummy variable for each knowledge source. These variables are equal to 1, if the corresponding 'source of knowledge' is of high importance for the firm, 0 otherwise. Also, for each of the 4 types of information sources an ordered variable is created, as the 4 possible answer choices have a natural ordering. This ordered variable takes value 0 for answer 'not used', 1 for 'low importance', 2 for 'medium importance' and 3 for 'high importance' of the particular source of knowledge.

Similar question to the one above is also asked about the presence of innovation-related co-operation with firm's competitors, suppliers, and clients. Again, a set of indicator variables has been created, for each type of innovation co-operation: 'co-operation with competitors', 'co-operation with suppliers', 'co-operation with clients'. These dummy variables are equal to 1, if the corresponding type of co-operation is of high or medium importance for the firm, 0 otherwise.

To test the correlation between the indirect measures of FDI spillovers and direct measures of knowledge flows between firms I estimate the following regression:

$$I_{ijt}^{m} = \beta^{m} E_{jt-1} + Z'_{ijt-1}\varphi^{m} + \mu_{i} + \tau_{t} + \omega_{ijt} . \qquad (2.2)$$

The dependent variable in Equation (2.2), I_{ijt}^{m}, is either a dummy variable or an ordered variable (with values 0, 1, 2, 3) indicating the importance of the m_{th} knowledge source. These include importance of knowledge flows from: i) competitors, ii) suppliers, iii) clients, and iv) within the same corporation. In another specification, I_{ijt}^{m} is a dummy variable indicating the importance of innovation related co-operation with either the competitors, suppliers, or clients of the firm.

Explanatory variables are similar to the Equation (2.1). Again, the main regressor of interest is the FDI entry variable. The estimation of Equation (2.2) is performed based on the panel of the CIS3 (years 1998-2000) and the CIS4 innovation survey (years 2002-2004).

2.5 Data

Estonia is a small Central and Eastern European country that has attracted a lot of inward FDI per capita. Until 2008 and the global economic crisis it had also very rapid economic growth. In 2007, the ratio of Estonia's stock of inward FDI to its GDP peaked at 81 per cent (UNCTAD 2009). This figure is much higher than in the world, in the EU, or among the CEE countries on average.

One of the main attractive features for FDI in Estonia has been its relatively close cultural and geographic proximity to Finland and Sweden. These two countries make up about 55 per cent of FDI in Estonia. Although, the rapid growth of wages has outrun the growth of productivity in Estonia and the cost level is higher than in nearby Latvia or Lithuania, the costs of production are still significantly lower than in Western Europe. The costs of production inputs and entry to local market have been the main motivating factors of FDI in Estonia. Since 2000, an attractive feature has been its tax regime with allows postponement of taxation moment of the corporate income tax in the case of reinvested earnings.

By the end of 3rd quarter of 2008 the cumulative stock of FDI in Estonia amounted to 17 billion USD. Most of the FDI has gone to financial services sector (31 per cent of stock of FDI) and real estate and business services (29 per cent). Manufacturing industry accounts for 14 per cent of the FDI stock. The main target sectors of foreign investors inside manufacturing have been electronics, food processing and wood processing.

My econometric analysis is based on firm-level data of the Estonian manufacturing industry (i.e. sectors with NACE two-digit code between 15 and 37). I employ several different sources of data. For productivity analysis, I use yearly balance sheet and income statement information of the whole population of Estonian firms from the Business Register of Estonia. The period covered is 1995–2004. The unit of observation is the firm. The original dataset includes up to 5,400 domestic owned manufacturing firms per year. It includes information indicating whether each firm has foreign (majority) ownership or not and it allows to assess the effects of FDI entry on total factor productivity of domestic (majority) owned firms. The descriptive statistics of this database are given in Annex 2.1 in Table A2.1 and A2.2.

For analysis of effects on innovation and knowledge sourcing I employ a sample of Estonia's firms covered by the CIS3 and CIS4 innovation surveys. CIS is a regular survey in EU countries. CIS3 covers period 1998-2000 and CIS4 2002-2004. In the two surveys there are, respectively, 1,185 and 1,264 Estonia's domestic-owned manufacturing firms. There is a large overlap between the surveys in terms of firms covered. The Estonian surveys have been conducted by the Statistical Office of Estonia and the response rate is rather high. It is 74 per cent in CIS3 and 78 per cent in CIS4, whereas the EU average is 55 per cent (Terk *et al*. 2007). The main descriptive statistics of innovation surveys are given in Table A2.3 in Annex 2.1.

One of the advantages of this study is that it can combine the information from innovation surveys with the firms' financial data from the Estonian Business Register's database. For example, in Western European countries, merging the CIS data with additional firm level databases is more difficult due to the more stringent administrative restrictions by the national Statistical Offices. Also, it has been possible to merge CIS3 and CIS4 data of Estonia's firms into a short two-period panel.

The sector level instrumental variables that are used to identify the effects of FDI on domestic owned firms are calculated based on the Amadeus dataset from the Bureau van Dijk, and datasets of Hungarian and Finnish manufacturing firms of the Hungarian and Finnish Statistical Offices.[13]

I measure capital as the book value of firm's capital stock and labour as average number of employees at the firm in a given year. Output, value added and intermediate inputs are deflated by respective deflators of the system of national accounts provided by the Statistical Office of Estonia. The deflators are available for 16 sectors (that corresponds to the top level in ISIC Rev. 3.1). Capital is deflated using the gross capital formation price index (available only for the total economy). For more information about the

[13] I owe thanks for help with calculation of these sector level variables to Claudia Hochgatterer from Vienna University of Economics, Balazs Muraközy from Hungarian Academy of Sciences, and Markku Pankasalo from Statistics Finland.

deflators, see also the National Accounts of Estonia (2003). The region level FDI entry variable is calculated separately for each of the 15 counties in Estonia.

An important problem in estimating the production function and TFP is the endogeneity bias resulting from the correlation between the unobservable productivity shock and the input choices of each firm. In order to account for this endogeneity bias, I have used the Levinsohn-Petrin (2003) approach to estimate the TFP. It is a semi-parametric estimation procedure for estimating the production function that extends the earlier Olley and Pakes (1996) approach. Both are by now fairly standard methods to estimate TFP at firm level. Therefore, a detailed description of these methods is omitted form here. In order to allow for heterogeneity of the production technology in different sectors, I allow the coefficient of each production input (capital and labour) to be different for each 2-digit NACE industry. The dependent variable in the estimated production functions is deflated value added.

As evident from Table A2.1 in Annex 2.1, the average share of FDI in a 3-digit sector is 18 per cent. This variable varies a lot across sectors and grows over time within sectors. The share of FDI in employment grows from 16 per cent in 1995 to 32 per cent in 2004. The number of domestic owned firms in the panel varies between 2,761 in 1995 and 5,370 in 2003. As shown in Masso *et al*. (2004) there is a lot of entry and exit going on among firms in Estonia, and entry and exit account for about 50 per cent of the productivity growth in Estonia. Vahter and Masso (2007) find that the multinational firms in Estonia have higher TFP, labour productivity, and wages than the domestic firms. In addition, foreign owned firms are much more capital intensive than domestic firms (*Ibid.* 2007, p. 174).

Previous studies have shown that large firms, foreign owned firms, or firms that belong to a larger corporate group have more innovative activities than the rest (for evidence in Estonia, see Terk *et al*. 2007). During 1998-2000, on average 26 per cent of domestic firms in the manufacturing sector engaged in product innovation and 22 per cent in process innovation (see Table A2.3 in Annex 2.1). During 2002-2004, the corresponding figures were 21 and 19 per cent. These figures are smaller than the ones for the whole CIS sample, that included also the foreign owned and services sector firms. During 1998-2004 there was significant growth in knowledge flows to domestic firms and innovation-related co-operation with their suppliers and customers. A more detailed overview of the descriptive statistics, sample and questionnaire of the innovation surveys can be found from Terk *et al*. (2007). A more detailed description of the dataset of the Estonian Business Register can be found from Masso *et al*. (2004).

2.6 Results

This section presents the results of estimating Equation (2.1) and (2.2). The main conclusion is that there are no significant effects of MNE entry on TFP or productivity growth of incumbents, regardless of the distance to productivity frontier or geographical proximity of domestic-owned and foreign-owned firms. However, there are significant positive effects on knowledge sourcing activities and positive correlation with process innovation of incumbent firms.

The effects of MNE entry on TFP and labour productivity growth are summarized in Tables 2.1–2.4. The effects on innovation and knowledge sourcing of incumbent firms in Estonia are shown in Table 2.5–2.7 and in Annex 2.2. The methods used here include

OLS, probit, ordered probit and instrumental variable techniques (2-stage least squares (2SLS) approach and the IV version of ordered probit[14]).

Effects on Productivity Growth

The key identification problem in this study is the endogeneity of FDI entry. The first stage of the 2SLS—with FDI entry rates in Hungary, Czech Republic, Latvia, Lithuania, Poland and Slovakia used as instruments for FDI entry rates in Estonia—is given in Table 2.1. It appears that the FDI entry rates in Hungary (Column 1 and 2) and in other CEE countries (Columns 3 and 4) are significantly and positively correlated, at 1 per cent significance level, with the FDI entry rates in the corresponding 3-digit industries in Estonia.

A standard problem in the IV approach can be weak identification (Murray 2006). It arises when the instruments are correlated with the endogenous regressor(s), but only weakly. Estimators can perform poorly in this case. As pointed out by Bound, Jaeger and Baker (1995)—if the excluded instruments are only weakly correlated with the endogenous variables then the "cure can be worse than the disease". With weak instruments, the IV estimates are biased and may be not consistent, the tests of significance have incorrect size and confidence intervals are wrong.

A commonly used diagnostic of weak instruments is the F-statistic of significance of instruments in the 1st stage of the 2SLS (Angrist and Pischke 2009). Stock, Wright and Yogo (2002) suggest that this statistic should be at least as large as 10. Then we can usually (but not always) reject the H0 that the instruments are weak. Indeed, the F-

[14] A recently developed command *cmp* in Stata (developed by David Roodman) enables to estimate the IV version of the ordered probit model.

statistics in Table 2.1 of the significance of instruments are above 10, and above the critical values calculated in Stock and Yogo (2005).

Next, in Table 2.2 and 2.3 I show the 2nd stage of the 2SLS and describe the effect of FDI entry on TFP and labour productivity growth. Columns 1 and 2 show estimates from the standard FE model. Columns 3-5 endeavour to address the endogeneity of FDI and report the 2SLS results, with firm-level fixed effects included.[15]

Table 2.1. First stage of the 2SLS approach

Dep var:	FE model FDI entry$_{jt}$	FE model FDI entry$_{jt}$	FE model FDI entry$_{jt}$	FE model FDI entry$_{jt}$
FDI entry$_{jt}$ in Hungary (at 3-digit NACE sector level)	0.103*** (0.039)	0.12*** (0.041)	0.091** (0.043)	0.089*** (0.044)
FDI entry$_{jt}$ in Czech Republic			0.066*** (0.017)	0.076*** (0.017)
FDI entry$_{jt}$ in Latvia			0.037*** (0.008)	0.042*** (0.009)
FDI entry$_{jt}$ in Lithuania				0.0361*** (0.009)
FDI entry$_{jt}$ in Poland			0.038** (0.019)	0.0312 (0.019)
FDI entry$_{jt}$ in Slovakia			0.07** (0.027)	0.092*** (0.027)
Year dummies	Yes	Yes	Yes	Yes
Firm fixed effects	Yes	Yes	Yes	Yes
Distance to frontier, import, and competition effects	Yes	No	Yes	Yes
Number of observations	10366	10366	10366	10366
F-test of instrumental variables	26.5 (p=0.00)	27.6 (p=0.00)	28.1 (p=0.00)	33.0 (p=0.00)
Weak identification test critical values (from Stock and Yogo 2005):				
Maximal 5 % allowed IV bias	16.38	16.38	18.37	18.37
Maximal 10 % allowed IV bias	8.96	8.96	10.83	10.83
Maximal 20 % allowed IV bias	6.66	6.66	6.77	6.77

Period: 1995-2004. FE- fixed effects. Heteroscedasticity robust standard errors in parentheses.

[15] I have tested between the fixed effects and random effects specification. The value of the corresponding Hausman test statistic is 405.07 (p=0.000). This indicates that the FE model should be preferred. All regressions in Table 2.2 and 2.3 include year dummies and firm fixed effects. There are no sector or region dummies included, as these are already absorbed by the firm level fixed effects. Standard errors are given in parentheses and are heteroscedasticity robust.

Table 2.2. Effects of FDI entry on TFP growth: FE and the second stage of the IV (2SLS) approach

Domestic firms only:	(1)	(2)	(3)	(4)	(5)
Method:	FE	FE	2-SLS, IV	2-SLS IV	2-SLS IV
Dep. var:	$\Delta lnTFP_{ijt}$	$\Delta lnTFP_{ijt}$	$\Delta lnTFP_{ijt}$	$\Delta lnTFP_{ijt}$	$\Delta lnTFP_{ijt}$
FDI entry$_{jt-1}$(E)	-0.062	0.117	-0.107	-0.03	-0.253
	(0.057)	(0.093)	(0.875)	(0.414)	(0.346)
Firm's distance to the productivity frontier$_{ijt-1}$ (D)	0.738***	0.741***	0.743***	0.745***	0.772***
	(0.019)	(0.019)	(0.02)	(0.02)	(0.02)
FDI entry$_{jt-1}$*Distance$_{ijt-1}$ (E*D)		-0.164**		-0.218	
		(0.082)		(0.324)	
Size$_{ijt-1}$	0.068***	0.068***	0.072***	0.065***	0.065***
	(0.021)	(0.021)	(0.021)	(0.23)	(0.022)
Herfindahl-index$_{jt-1}$	-0.042	-0.036	-0.05	-0.059	-0.059
	(0.046)	(0.065)	(0.068)	(0.075)	(0.076)
Import$_{jt-1}$	-0.194***	-0.197***	-0.158*	-0.143*	-0.145*
	(0.072)	(0.072)	(0.079)	(0.079)	(0.079)
Year dummies	Yes	Yes	Yes	Yes	Yes
Instrumented terms	No	No	E	E, E*D	E
Firm effects	Yes	Yes	Yes	Yes	Yes
Type of instruments	-	-	FDI entry$_{jt-1}$ in Hungary	FDI entry$_{jt-1}$ in 5 CEE countries	FDI entry$_{jt-1}$ in 5 CEE countries
Number of obs.	10975	10975	10366	10366	10366
R^2	0.33	0.33	0.34	0.34	0.34
Hansen χ^2 test of overidentifying restrictions			-	1.249 (p=0.87)	*1.855* *(p=0.76)*

Note: FE- fixed effects. Robust standard errors in parentheses. Methods: FE, 2SLS-IV. TFP is estimated with the Levinsohn-Petrin (2003) method in order to account for the endogeneity of inputs, allowing the coefficients of inputs to differ in each 2-digit sector. Period: 1995-2004. FDI entry and the productivity frontier are calculated at 3-digit NACE sector level. Population of domestic-owned firms, Estonia's manufacturing industry. The test statistic of Hansen J test, a test of overidentifying restrictions, has value 1.249 in Column 4 and 1.855 in Column 5. This means that, we cannot reject the null hypothesis, that the overidentifying restrictions are valid.

Table 2.3. Effects of FDI entry on labour productivity growth: FE and the second stage of the IV (2SLS) approach

Domestic firms only:	(1)	(2)	(3)	(4)	(5)
Method:	FE	FE	2-SLS, IV	2-SLS, IV	2-SLS, IV
FDI entry$_{jt-1}$(E)	-0.077	0.12	-0.579	-0.681	-0.387
	(0.051)	(0.091)	(0.521)	(0.437)	(0.311)
Firm's distance to the productivity frontier$_{ijt-1}$ (D)	0.743***	0.746***	0.752***	0.764***	0.768***
	(0.021)	(0.021)	(0.021)	(0.024)	(0.024)
FDI entry$_{jt-1}$*Distance$_{ijt-1}$ (E*D)		-0.171**		0.278	
		(0.073)		(0.311)	
Size$_{ijt-1}$	0.141***	0.141***	0.138***	0.11***	0.11***
	(0.028)	(0.028)	(0.029)	(0.031)	(0.031)
Herfindahl-index$_{jt-1}$	-0.207***	-0.204***	-0.193***	-0.257***	-0.257***
	(0.054)	(0.054)	(0.057)	(0.062)	(0.062)
Import$_{jt-1}$	-0.107	-0.114*	-0.101	-0.134*	-0.131*
	(0.068)	(0.067)	(0.071)	(0.076)	(0.076)
Year dummies	Yes	Yes	Yes	Yes	Yes
Instrumented terms	No	No	E	E, E*D	E
Firm effects	Yes	Yes	Yes	Yes	Yes
Type of instruments			FDI entry$_{jt-1}$ in Hungary	FDI entry$_{jt-1}$ in 5 CEE countries	FDI entry$_{jt-1}$ in 5 CEE countries
Number of obs.	9080	9080	9080	9080	9080
R^2	0.37	0.37	0.38	0.38	0.38
Hansen χ^2 test of overidentifying restrictions			-	1.66 (p=0.434)	0.314 (p=0.575)

Note: robust standard errors in parentheses. Methods: FE, 2SLS-IV. Period 1995-2004. FDI entry and the productivity frontier are calculated at 3-digit NACE sector level. Population of domestic-owned firms in Estonia's manufacturing industry.

As evident from the FE model (Column 1 in Table 2.2 and 2.3), the average effect of FDI entry on productivity growth is not significantly different from zero. Accounting for endogeneity of FDI entry (see Columns 3 and 5 in Table 2.2 and 2.3) does not change this main conclusion. Also, exclusion of the size of the firm as an explanatory variable did not change the findings. Column 3 in Table 2.2 and 2.3 shows the just-identified case, if only FDI entry rate in Hungary is used as an instrumental variable. Column 4 and 5 report the results if instrumental variables from 5 CEE countries are used.

In Table 2.2, the coefficient of FDI entry variable from the standard FE model is -0.062. In the IV model it is -0.107 or -0.253, depending on the number of instruments used (see Columns 3 and 5). However, these estimates are not statistically significant.[16]

The standard errors of the IV model in Table 2.2 and 2.3 are much larger than in the OLS case. The econometrics literature has shown that the IV estimator has higher variance than the OLS. Therefore, if the explanatory variables were fully exogenous, then the OLS would be preferred because of its efficiency. This is not the case here.[17]

So far I have assumed in the regression models that FDI entry affects all domestic-owned firms similarly. This is a very strong assumption. Next, I check the prediction from Aghion *et al*. (2009) that the effect of FDI entry on incumbents' productivity growth may depend on the incumbents' distance to productivity frontier. For that I add an interaction term between FDI entry and distance to frontier to the set of explanatory variables.

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[16] Despite the significant differences in estimated coefficients, the IV estimates are not more than one standard error from each other.

[17] The endogeneity of the FDI entry variable has been tested here with the Durbin-Wu-Hausman test. This test rejects the H0 that OLS is consistent (value of test statistic is 176.4 (p=0.00). Therefore 2SLS is the preferred approach over OLS.

Based on the augmented FE model (Column 2 in Table 2.2 and 2.3), there appears to be a negative correlation between FDI entry and productivity growth of incumbents that are far from the local productivity frontier. However, this result is not confirmed once we try to account for the endogeneity of FDI entry (in Column 4).

The finding of no short-term effects on productivity growth, regardless of the distance of incumbents to the productivity frontier, does not confirm the theoretical predictions from the FDI spillover literature and from the endogenous growth model by Aghion *et al*. (2009). Theoretical literature underscores the expected role of absorptive capacity and distance to technology frontier in these effects (e.g. based on Glass and Saggi 1998). However, the finding of no horizontal spillovers is consistent with some earlier papers from CEE transition economies. Often, no significant correlation between FDI presence in a sector and productivity of domestic-owned firms is found in these papers. For example, Damijan *et al*. (2003), Lipsey (2006), or Görg and Greenaway (2004) provide overviews of findings in transition economies.

The coefficients of other controls in Equation (1) deserve attention as well. Similarly to Bartelsman *et al*. (2008), we find also in Estonia that the firms that are below the local productivity frontier tend to grow faster than others. This is an important result which deserves more detailed future study. It shows that there is productivity convergence taking place within Estonia towards the local productivity frontier. However, the convergence to a local productivity frontier need not imply convergence to the world productivity frontier.[18]

Another firm level control, size of the firm (as measured by log of number of employees) is positively correlated with the growth rate of productivity. This size effect is stronger on labour productivity growth than on TFP growth. In addition, the

[18] This has been recently demonstrated based on UK establishment level data in Bartelsman *et al*. (2008).

higher Herfindahl index (i.e. higher concentration and weaker competition) and import orientation of the sector are negatively associated with incumbent firms' productivity growth. The finding concerning the effects of local competition is similar to Nickell (1996), who uses UK data and finds positive correlation between competition and productivity growth of firms.

A standard prediction from theory is that FDI spillovers are stronger if the foreign owned firms are geographically close to the domestic enterprises (e.g. Jaffe *et al*. 1993). But, as evident from Table 2.4, there appears to be no significant correlation between the FDI entry within the local geographical region and TFP or labour productivity growth of incumbents of the same region in Estonia. This is similar to Aitken and Harrison (1999) findings based on data from Venezuela. They find no evidence of horizontal spillovers, regardless of the geographical proximity between firms. Because FDI entry rate in Table 2.4 has been calculated separately for different regions within Estonia we cannot use the same instrumental variables as before. Therefore the results concerning the region level effects are likely to be biased. They rely on a restrictive assumption that the part of error term in Equation (1) that is correlated with the FDI entry variable can be seen as fixed over the time period studied. Only then would the FE specification account for the potential endogeneity bias.

Table 2.4. FDI entry in the same region and industry of the incumbent, correlation with incumbents' productivity

Domestic firms only:	(1)	(2)
Method:	FE	FE
Dep. var.:	$\Delta lnTFP_{ijt}$	$\Delta lnLABPROD_{ijt}$
Region level (15 regions) FDI entry in each 3-digit sector $_{jrt-1}$	0.04	0.094
	(0.068)	(0.074)
Distance to the productivity frontier$_{ijt-1}$	0.743***	0.745***
	(0.02)	(0.022)
FDI entry$_{jrt-1}$*Distance$_{ijt-1}$	-0.027	-0.066
	(0.052)	(0.056)
Size$_{ijt-1}$	0.07***	0.141***
	(0.021)	(0.029)
Herfindahl-index$_{jt-1}$	-0.041	-0.203***
	(0.067)	(0.058)
Import$_{jt-1}$	-0.202**	-0.114*
	(0.072)	(0.068)
Year dummies	Yes	Yes
Number of obs.	10380	9080
R^2	0.34	0.38

Note: domestic-owned firms in the manufacturing industry. FE - fixed effects model. LABPROD - labour productivity (value added per employee). Robust standard errors in parentheses. Period: 1995-2004. FDI entry is calculated at 3-digit NACE sector level and within each of the 15 counties.

Table 2.5. Correlation between FDI entry and innovation

Domestic firms only, panel of CIS3 and CIS4:	(1)	(2)	(3)	(4)
Method:	Bivariate probit	Bivariate probit	Bivariate probit	Bivariate probit
Dep. var.:	Pr(product innovation$_{ijt}$=1)	Pr(process innovation$_{ijt}$=1)	Pr(product innovation$_{ijt}$=1)	Pr(process innovation$_{ijt}$=1)
FDI entry$_{jt-1}$	0.169	**0.318*** **	0.211	**0.406** **
	(0.107)	**(0.108)**	(0.172)	**(0.163)**
Distance to the productivity frontier$_{ijt-1}$	-0.05**	-0.06**	-0.048*	-0.056**
	(0.023)	(0.022)	(0.022)	(0.022)
FDI entry$_{jt-1}$*Distance$_{ijt-1}$			-0.038	-0.09
			(0.118)	(0.111)
Size of the firm$_{ijt-1}$	0.079***	0.094***	0.079***	0.094***
	(0.014)	(0.014)	(0.015)	(0.014)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	1000	1000	1000	1000
Log likelihood	-920.5	-920.5	-529.7	-529.7

Note: domestic-owned firms in the manufacturing industry. Estimation by bivariate probit, marginal effects reported (at sample means). All specifications include lagged import intensity of each 3-digit sector and Herfindahl index. Two innovation surveys (CIS3 and CIS4) are included, i.e. panel of two time periods (1998-2000 and 2002-2004) is used in this estimation. Dependent variable in the bivariate probit model is equal to 1 if the firm engages in i) product or ii) process innovation. Stata command *inteff* (developed by Ai and Norton 2003) is used in order to calculate the marginal effect of the interaction term.

Table 2.6. Correlation between FDI entry and organizational innovation

Domestic firms only:	
Method:	Probit (CIS3 only)
Dep. var.:	Pr(Organization innovation=1)
FDI $entry_{jt-1}$	-0.149
	(0.327)
Distance to the productivity $frontier_{ijt-1}$	-0.035
	(0.029)
FDI $entry_{jt-1}$*$Distance_{ijt-1}$	0.278
	(0.29)
Size of the $firm_{ijt-1}$	0.065***
	(0.02)
Sector dummies	Yes
Region dummies	Yes
Number of obs.	519
Log likelihood	-265.2

Note: domestic-owned firms in the manufacturing industry. Estimation by probit, marginal effects reported (at sample means). Lagged import intensity and Herfindahl index of each 3-digit sector are included as controls. Dependent variable in the probit model is equal to 1 if the firm engages in organizational innovation. Stata command *inteff* (developed by Ai and Norton 2003) is used in order to calculate the marginal effect of the interaction term.

Table 2.7. Correlation between FDI entry and direct indicators of knowledge flows to the domestic firms

Domestic firms only, panel of CIS3 and CIS4:	(1)	(2)	(3)	(4)
Method:	Probit	Probit	Probit	Probit
Dep.var.:	Knowledge sourcing from Competitors	Knowledge sourcing from Suppliers	Knowledge sourcing from Clients	Knowledge sourcing from within own corporation
FDI $entry_{jt-1}$	0.017	**0.171*** **	0.07	**0.227*** **
	(0.034)	**(0.06)**	(0.064)	**(0.07)**
Distance to the $frontier_{ijt-1}$	-0.009	-0.06***	-0.032**	-0.043**
	(0.009)	(0.013)	(0.014)	(0.016)
$Size_{ijt-1}$	0.015***	0.022**	0.016**	0.042***
	(0.006)	(0.009)	(0.009)	(0.01)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	907	907	907	907
Log likelihood	-145	-261.5	-258.5	-322.4

Note: domestic-owned firms in the manufacturing industry. Estimation by probit, marginal effects reported (at sample means). Two innovation surveys are included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used in this estimation. The dependent variable is equal to 1, if the corresponding type of knowledge sourcing is of high importance for the firm.

Table 2.8. Correlation between FDI entry and indicators of innovation related co-operation with competitors, suppliers and clients

Domestic firms only, panel of CIS3 and CIS4:	(1)	(2)	(3)
Method:	Probit	Probit	Probit
Dep.var.:	Innovation related co-operation with Competitors	Innovation related co-operation with Suppliers	Innovation related co-operation with Clients
FDI $entry_{jt-1}$	0.073	0.012	0.086
	(0.05)	(0.046)	(0.078)
Distance to the $frontier_{ijt-1}$	-0.01	-0.02*	-0.017
	(0.1)	(0.011)	(0.012)
$Size_{ijt-1}$	0.009*	0.023***	0.021***
	(0.005)	(0.007)	(0.008)
Sector dummies	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes
Number of obs.	907	907	907
Log likelihood	-163.7	-207.2	-216.3

Note: domestic-owned firms in the manufacturing industry. Estimation by probit, marginal effects reported (at sample means). The dependent variable is equal to 1, if the corresponding type of innovation-related co-operation is of medium or high importance for the firm.

As a robustness test I have tried some additional instrumental variables—in order to allow for potential endogeneity of the distance to the productivity frontier. Unfortunately, the instruments tried—the Finnish and Swedish 3-digit NACE level capital-labour ratio and immaterial assets per employee are only weakly correlated with distance to productivity frontier in Estonia. These turn out to be weak instruments, and explain only a very small part of variation of 'distance to productivity frontier'.

One way how FDI can affect local firms is by intensifying the entry-exit and selection process among them. This can have effects of aggregate productivity of sectors, even if there are no within-firm changes in performance. Based on the heterogeneous producer competition model in Syverson (2004a) or the new-new trade theory model in Melitz and Ottaviano (2008) one could expect a more compressed spread of productivity across firms in sectors and markets that are more competitive. For example, in sectors with high FDI entry rates. I do not go into detail here with study of these effects. But if I regress the 3-digit NACE industry level TFP dispersion (e.g. ratio of the 90th productivity percentile to the 10th) on lagged FDI entry rate, year dummies and industry fixed effects, then I find no significant effects. This need not mean that there are no selection effects of FDI. It is likely that these results depend a lot on the level of aggregation of sectors used. The more detailed investigation of selection effects of FDI entry on the productivity distribution of firms is one potential extension of this study.

The fact that effects of FDI do not show up easily in productivity of incumbent firms in transition countries like Estonia, that have attracted a lot of FDI and (until 2008) have had very high output growth rates, is puzzling. It suggests that we should look more into the channels of these effects. The lack of significant association between productivity growth and lagged FDI entry need not mean that there are no spillover effects of FDI at all. The effects on productivity may simply need more time to occur. At first, the FDI may affect other variables like investments in R&D and assets, innovation, capital intensity, and survival of domestic owned firms.

Aghion *et al*. (2009) finds, using a similar empirical specification, that there are positive short term effects of FDI entry on productivity of incumbents in UK. But there appear to be no such effects in Estonia. This difference may have to do with the country-level difference in the absorptive capacity of incumbent firms. In UK the incumbent firms are not as different from the foreign owned firms as the incumbents in Estonia and other transition economies. Based on existing empirical literature we can conclude that gap between productivity and technology of foreign owned firms and domestic owned firms is much larger in transition economies than in Western European economies (see e.g. Bellak 2004, Damijan *et al*. 2003). Therefore, learning from FDIs may be easier and take less time for domestic firms in Western Europe.

However, this does not explain why the (lack of) effects on productivity of incumbents in Estonia do not depend on firm's distance to the local technology frontier. Here the explanation could be that distance to the local productivity frontier may not be the best proxy for absorptive capacity of firms. What might matter more are the actual interactions of domestic firms with foreign owned firms: supplying goods and buying inputs from them; personal contacts through trade organizations, or even through local Rotary clubs, etc. It is difficult to measure these interactions. For that, survey data may be a useful alternative to the standard firm-level datasets.

Often input-output tables are used in examining the spillovers through vertical interactions with suppliers and buyers. Unfortunately, the input-output tables may not be always suitable for study of these buyer-supplier interactions in transition economies. In these countries often the input-output tables are available only at relative aggregate sector levels. Most of vertical interactions between firms take place at less aggregated levels (e.g. between sectors defined at 4-digit NACE level).

Also, only few input-output tables are available for the whole period studied. Hence, one has to assume that input-output relationships do not change over time. This assumption is plausible in Western European countries, but is less plausible in transition countries, where the changes in buyer-supplier relations are more frequent.

Another potential explanation why it is difficult to find evidence of spillovers of FDI is the potential mismeasurement of real outputs and inputs in the standard firm level panel datasets (Griliches and Mairesse 1995, Diewert 2001). For example, Keane (2005) has called it the 'Price*Quantity problem'. The problem is that in standard firm level panel datasets we almost never (except e.g. in Roberts and Supina 1997, Syverson 2004a) observe the firm or plant level price indices for output or the physical output. Therefore the standard approach is to use the value of sales or value added instead as the dependent variable in estimating the production function or in calculating the labour productivity. The sales figure is typically deflated by the industry level price index. This price index, however, could be very different from the unobserved firm level price index. Therefore, the estimated effect of FDI on such sales-based measures of productivity is actually a combination of the effect of FDI on physical productivity and the effect on price(s) of output(s). Still, this is a general problem in the literature and it does not explain why there are often positive spillover effects of FDI found in developed countries and less significant effects in transition countries.

However, this "Price*Quantity" problem might not necessarily be as big problem as it may seem.[19] If the researcher were using the physical quantity instead of the sales or value added, he would, for example, miss the price effect from FDI entry due to increase in quality. Also, in general, production function is better estimated in countries like Estonia compared to the UK, as the importance of intangible assets could be less important in the production process in transition and developing countries than in advanced countries.

FDI Entry and Innovation

It pays to look into the potential channels of productivity spillovers. If we turn our attention to the relationship between FDI entry and innovation, then indeed there are some significant correlations. There is positive significant correlation of lagged FDI entry with process innovation activities of incumbents (see Table 2.5). This result can be both due to the competition effects of FDI on innovation incentives and knowledge transfer to domestic firms.

[19] I owe thanks to Fabrice Defever for pointing this out.

According to Table 2.5, an increase in FDI share in a sector by 10 percentage points increases the propensity of an incumbent firm in the same sector to engage in process innovation by 3-4 per cent. At the same time, there is no evidence of significant effects on product innovation, or organizational innovation (see Table 2.6).

A potential explanation for the difference between the results concerning process and product innovation can be that knowledge that helps a firm to improve its production process can spill over from foreign owned firms to incumbents more easily than product-specific knowledge. Information that helps to improve the production process can be used and combined with local knowledge even in firms that are very different from the foreign owned firms and produce substantially different products.

Also, this difference is consistent with a similar prediction of a theoretical IO paper by Boone (2000). In his model a rise in competitive pressure does not raise both product and process innovation. Under tougher competition, the payoff from process innovation may be greater than from product innovation. One can argue that in a more competitive environment, previous product innovations may still generate some monopoly profits due to product differentiation. However, process innovation is more likely to render the earlier process innovations of competitors obsolete and thereby decrease the earlier monopoly profit of competitor(s). Therefore, increase in competition could more likely spur process innovation than product innovation.

Notably, the effect of FDI entry on incumbent's innovation activities does not depend on incumbent's distance to the technology frontier. This is different from the predictions and findings of Aghion *et al*. (2009) based on the UK data. This is also different from the view of Glass and Saggi (1998) that FDI spillovers depend on the absorptive capacity of local firms, as measured by firm's distance to the productivity frontier.

FDI Entry and Knowledge Sourcing

Next, I show based on the CIS innovation survey data that FDI entry is likely to be resulting in knowledge spillovers to the incumbent firms. I explore the association between FDI entry and knowledge flows to incumbent firms and estimate Equation (2.2) by probit and ordered probit model.

As we can see from probit model in Table 2.7 there is significant and positive association of FDI entry with importance of knowledge sourcing by incumbent firms in the following years after FDI entry. The dependent variable in Table 2.7 is either equal to 1 or 0: it is equal to 1 if the corresponding source of knowledge (e.g. knowledge sourcing from suppliers) is of high importance for the firm, it is 0 otherwise. However, the CIS questionnaire provides significantly more detailed answer choices. There are 4 different ordered answer choices about the importance of each type of knowledge flows. Therefore, in order to use the variation in data in more detail, also an ordered probit model is estimated.

The marginal effects from an IV version of the ordered probit model are reported separately for each of the 4 possible answer choices in Annex 2.2. There the dependent variable in the ordered probit model is equal to 0, if the particular type of knowledge sourcing (from suppliers, clients, or competitors) is ‘not used’, it is 1 if it is of low importance, 2 if it is of medium importance, 3 if it is of high importance for the incumbent firm.

Due to the nature of the CIS data, there is a sample selection problem in estimating the effects of FDI on knowledge flows. The respondents to the questionnaire may say that they do not use a particular knowledge source in their existing innovation process (i.e. their answer choice is “0”), but they may also choose the same answer choice simply because they do not engage in innovation at all. The analysis would need to distinguish between firms that engage in innovation (and thus choose their knowledge sources in innovation process), and firms that do not engage in innovation at all. A way to account for this problem by using a selection model has been outlined by Piga and Vivarelli (2004). Not accounting for this issue may result in biased estimates of the FDI spillovers. The results of a selection model that adjusts the findings for the presence of sample selection bias are presented in Annex 2.3.

In Annex 2.3 the results from the 2-stage sample selection model are presented. The 1st stage of the model estimates the probability that the firm engages in innovation activities. The second stage estimates ordered probit model, using data of only these firms that engage in innovation, and using the inverse of Mill's ratio from the 1st stage as an additional control to account for selection bias. The size and significance of the estimated effects is affected by use of the sample selection model and smaller sample of only innovative firms. The sample selection model yields smaller estimates of the effects of FDI, yet these are broadly similar results to the standard IV model in Annex 2.2.

The marginal effects in Tables in Annex 2.2 and 2.3 show that there is positive association of FDI entry with the intensity of knowledge sourcing in the following periods. We find statistically significant positive association in the case of knowledge flows from suppliers and from within the firm itself.

Notably, the significance of the FDI 'effect' on knowledge flows from clients disappears once the instrumental variables version of the ordered probit is used. The significance of the effects on knowledge sourcing from competitors disappears once the sample selection issue is taken into account. Based on the results of the ordered probit models in Annex 2.2 and 2.3 we can calculate that an increase in FDI share in the employment of a sector by, for example, 50 percentage points results in about 13 -

24 percent subsequent increase in the likelihood that knowledge flows from incumbent's suppliers are 'highly important' for its innovation activities.

I also find that higher FDI entry in a sector lowers the probability that knowledge sourcing from suppliers and from within own corporation is 'not used' in the innovation process of the incumbent firm. The entry of FDI has been instrumented here with entry rates elsewhere in the CEE.[20]

My findings about the importance of knowledge flows are related to a study by Crespi *et al*. (2008) based on UK data. They find that FDI share in a sector is positively correlated with knowledge sourcing of UK local firms from their competitors, but they do not find significant association in the case of learning from other sources.

In addition to innovation and learning from other firms, the FDI entry might also affect innovation related formal co-operation between firms. Still, this is not the case in Estonia (see Table 2.8). FDI entry is not significantly correlated with indicators of incumbents' innovation-related co-operation arrangements with other firms. This is not very surprising. Informal knowledge flows are likely to work faster in spreading the knowledge from foreign owned firms to local incumbents in CEE countries. To be considered for innovation related co-operation by MNEs, the incumbents need high levels of expertise and significant own innovation activities. All these have been of short supply among the domestic-owned firms in transition economies.

2.7 Conclusions

Much has been written about the effects of FDI on incumbent firms in its host economy. However, the literature still struggles to provide empirical evidence that

[20] The estimation is performed in Stata with the command *cmp*. It is developed by David Roodman (2009a) and it enables to estimate also an IV version of the ordered probit model.

could be interpreted as causal effects. This paper estimates the effects of FDI entry on TFP and labour productivity growth of incumbent firms, their innovation activities and knowledge sourcing from other firms. I endeavour to address the problem of the endogeneity of FDI inflows and I check whether the effects are heterogeneous depending on incumbents' distance to the technology frontier or geographical proximity to foreign owned firms.

The main contribution of this paper compared to most of the earlier ones is studying the various channels of spillover effects of FDI—through effects of FDI on innovation and direct measures of knowledge transfer. For that, I can combine rich firm level dataset from the Business Register of Estonia with survey-based information about firms' innovation activities and knowledge flows. Also, this study tries to account for the endogeneity of FDI spillovers.

I find that the FDI entry in the local industry or region has no short-term effect on local incumbents' TFP and labour productivity growth. However, there is a positive spillover on process innovation. A 10 percentage points higher entry rate of foreign owned firms is associated with 4 percentage points increase in incumbents' probability of engaging in process innovation. Also, FDI inflow to a sector intensifies knowledge sourcing activities from other firms and from within the incumbent itself.

The empirical evidence presented here shows that FDI entry is associated with knowledge flows (spillovers) to incumbent firms. But these spillovers are not reflected in short-term in the productivity growth of incumbents. Effects on productivity may take longer to materialise than implicitly assumed in the standard empirical approach of the literature.

A notable additional result is that domestic firms that are further behind the technology frontier tend to grow faster than others. So, there seems to be some firm level productivity convergence taking place within Estonia. This result is similar to a recent study about UK by Bartelsman *et al*. (2008).

In future, survey evidence about spillovers (e.g. like Spatareanu and Javorcik 2005, Javorcik 2008) can shed more light into the longer-term effects. Also, even if there are no productivity enhancing spillovers, the short-term effect of FDI on productivity in the host economy is still likely to be positive. This is, partly, due to the compositional change in the structure of industries, where more productive foreign owned firms increase their share in employment and sales compared to the domestic firms. Also, FDI entry can toughen the selection process among incumbent firms, driving low productivity incumbents out of the market and reallocating market shares and resources towards more productive firms. This selection effect could increase the average productivity of local industries in the host economy, even if there are no positive spillovers on productivity growth within incumbent firms.

Annex 2.1: Descriptive statistics

Table A2.1. Descriptive statistics: domestic firms in Estonia's manufacturing industry

Variable	Mean	Std. Dev.
ΔLn(TFP)	0.049	0.652
ΔLn(Value added per employee)	0.08	0.664
Ln(TFP)	9.108	1.385
Ln(Value added per employee)	10.962	1.019
Ln(Capital)	11.794	2.274
Distance to TFP frontier (in log)	1.107	0.885
Distance to labour productivity frontier (in log)	1.149	0.881
Import orientation (3-digit)	0.409	0.303
Ln (Size)	2.288	1.377
Herfindahl index (3-digit)	0.124	0.152
MNE $entry_{jt-1}$ in Estonia(3-digit)	0.014	0.135
MNE $entry_{jt-1}$ in Hungary (3-digit)	0.002	0.075
MNE $entry_{jt-1}$ in Czech Republic (3-digit)	0.053	0.138
MNE $entry_{jt-1}$ in Latvia (3-digit)	0.021	0.208
MNE $entry_{jt-1}$ in Poland (3-digit)	0.025	0.123
MNE $entry_{jt-1}$ in Slovakia (3-digit)	0.005	0.092
FDI $share_{jt-1}$ in employment in Estonia (3-digit)	0.182	0.165
FDI $share_{jt-1}$ in employment in Hungary (3-digit)	0.296	0.163
FDI $share_{jt-1}$ in employment in Czech Republic (3-digit)	0.278	0.224
FDI $share_{jt-1}$ in employment in Latvia (3-digit)	0.179	0.233
FDI $share_{jt-1}$ in employment in Poland (3-digit)	0.216	0.164
FDI $share_{jt-1}$ in employment in Slovakia (3-digit)	0.04	0.126

Period: 1995-2004. Data sources: Business Register data of all manufacturing firms in Estonia; Amadeus database of Bureau van Dijk.

Table A2.2. Basic facts about manufacturing firms in the Business Register's dataset

Year	Number of domestic-owned firms	Share of foreign-owned firms in employment
1995	2,761	0.16
1996	3,396	0.1
1997	3,883	0.13
1998	4,419	0.19
1999	4,526	0.26
2000	4,768	0.28
2001	5,060	0.31
2002	5,251	0.32
2003	5,370	0.29
2004	4,885	0.32

Note: FDI share is calculated based on firms with majority foreign ownership.

Table A2.3. CIS3 and CIS4 innovation surveys: summary statistics

Variable name	Variable definition	CIS3		CIS4	
		Mean	Std. Dev.	Mean	Std. Dev.
Innovation/knowledge variables					
Product innovation	Dummy, 1 if firm reports having introduced new or significantly improved product	0.26	0.44	0.21	0.41
Process innovation	Dummy, 1 if firm reports having introduced new or significantly improved production process	0.22	0.41	0.19	0.4
ln(Value added/employees)	Value added per employees	11.09	0.81	11.31	0.79
Knowledge flow variables					
Sources of innovation related knowledge within the firm or other firms within the group	Dummy, 1 if information from internal sources within the firm or group was of high importance	0.13	0.33	0.15	0.36
From Competitors	Dummy, 1 if information from competitors and other firms from the same industry was of high importance	0.03	0.18	0.05	0.2
From Customers	Dummy, 1 if information from clients or customers was of high importance	0.08	0.27	0.14	0.35
From Supplier	Dummy, 1 if information from suppliers of equipment, materials, components or software was of high importance	0.08	0.28	0.14	0.34
Innovation cooperation					
Other enterprises within the group	Dummy, 1 if firm had any cooperation arrangements on innovation activities with other enterprises within the corporation	0.04	0.19	0.04	0.2
Suppliers	Dummy, 1 if firm had any cooperation arrangements on innovation activities with suppliers of equipment, materials, components or software was of high importance	0.08	0.28	0.12	0.33
Customers	Dummy, 1 if firm had any cooperation arrangements on innovation activities with clients or customers	0.08	0.28	0.11	0.32
Competitors	Dummy, 1 if firm had any cooperation arrangements on innovation activities with competitors	0.05	0.21	0.07	0.25

Note: domestic-owned firms from manufacturing industry only. The number of domestic-owned manufacturing firms is 1,185 in CIS3 and 1,264 in CIS4 survey.

Annex 2.2: IV version of the ordered probit model

Table A2.4. Knowledge sourcing from competitors: marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	**-0.92*****	**0.151*****	**0.566*****	**0.353****
	(0.395)	**(0.045)**	**(0.182)**	**(0.167)**
Distance to the frontier$_{ijt-1}$	0.069***	-0.008**	-0.032**	-0.02***
(D)	(0.024)	(0.004)	(0.012)	(0.008)
Size$_{ijt-1}$	-0.048***	0.007**	0.025***	0.016***
	(0.016)	(0.003)	(0.008)	(0.005)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	915			
Log likelihood	-374			

Note: Estimation by ordered probit, marginal effects reported. Instrumented terms: E. Instrumental variables used: FDI entry$_{jt-1}$ in 5 CEE countries. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.5. Knowledge sourcing from suppliers: marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	**-0.717****	0.015	**0.309****	**0.392****
	(0.306)	(0.017)	**(0.13)**	**(0.175)**
Distance to the frontier$_{ijt-1}$	0.123***	-0.002	-0.053***	-0.067***
(D)	(0.025)	(0.003)	(0.012)	(0.014)
Size$_{ijt-1}$	-0.056***	0.001	0.024***	0.031***
	(0.016)	(0.001)	(0.007)	(0.008)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	915			
Log likelihood	-336			

Note: Estimation by ordered probit, marginal effects reported. Instrumented terms: E. Instrumental variables used: FDI entry$_{jt-1}$ in 5 CEE countries. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.6. Knowledge sourcing from clients: marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	-0.344	-0.014	0.131	0.2
	(0.284)	(0.015)	(0.109)	(0.165)
Distance to the frontier$_{ijt-1}$ (D)	0.103***	0.004	-0.039***	-0.059***
	(0.024)	(0.003)	(0.01)	(0.014)
Size$_{ijt-1}$	-0.053***	0.002	0.02***	0.009***
	(0.016)	(0.002)	(0.006)	(0.012)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	915			
Log likelihood	-291			

Note: Estimation by ordered probit, marginal effects reported. Instrumented terms: E. Instrumental variables used: FDI entry$_{jt-1}$ in 5 CEE countries. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.7. Knowledge sourcing from within the same corporation: marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	**-0.606****	0.006	**0.227****	**0.373****
	(0.307)	(0.006)	**(0.114)**	**(0.192)**
Distance to the frontier$_{ijt-1}$ (D)	0.101***	-0.001	-0.038***	-0.062***
	(0.024)	(0.001)	(0.01)	(0.015)
Size$_{ijt-1}$	-0.055**	0.001	0.021***	0.034***
	(0.016)	(0.001)	(0.006)	(0.01)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Number of obs.	915			
Log likelihood	-304			

Note: Estimation by ordered probit, marginal effects reported. Instrumented terms: E. Instrumental variables used: FDI entry$_{jt-1}$ in 5 CEE countries. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Annex 2.3: Selection model: FDI and knowledge sourcing

Table A2.8. First stage of the 2-stage selection model

Domestic firms only, panel of CIS3 and CIS4:	
Method:	Probit
Dep. var.:	Pr(Innovator=1)
FDI entry$_{jt-1}$	0.244**
	(0.122)
Distance to the productivity frontier$_{ijt-1}$	-0.078***
	(0.027)
Size of the firm$_{ijt-1}$	0.108***
	(0.018)
Sector dummies	Yes
Region dummies	Yes
Number of obs.	1000
Log likelihood	-553.2

Note: domestic-owned firms in the manufacturing industry. All domestic firms, not only the ones that engage in innovation. Estimation by probit, marginal effects reported (at sample means). Lagged import intensity and Herfindahl index of each 3-digit sector are included as controls. Two innovation surveys (CIS3 and CIS4) are included, i.e. panel of two time periods (1998-2000 and 2002-2004) is used in this estimation. Dependent variable in the probit model is equal to 1 if the firm engages in (product or process) innovation.

Table A2.9. Selection model: knowledge sourcing from competitors, marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	-0.122	0.013	0.078	0.058
	(0.146)	(0.017)	(0.093)	(0.07)
Distance to the frontier$_{ijt-1}$ (D)	0.036	-0.004	-0.023	-0.017
	(0.036)	(0.004)	(0.023)	(0.018)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Inverse of Mill's ratio	0.093	0.01	-0.059	-0.044
	(0.117)	(0.013)	(0.074)	(0.055)
Number of obs.	357			
Log likelihood	-447			

Note: Only these domestic firms that engage in innovation. Estimation by ordered probit, marginal effects reported. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.10. Selection model: knowledge sourcing from suppliers, marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	**-0.222****	-0.051	**0.05**	**0.225***
	(0.13)	(0.031)	**(0.033)**	**(0.131)**
Distance to the frontier$_{ijt-1}$ (D)	0.093***	0.021	-0.021**	-0.093***
	(0.034)	(0.009)	(0.01)	(0.034)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Inverse of Mill's ratio	0.033	0.144	-0.032	-0.145
	(0.024)	(0.101)	(0.025)	(0.102)
Number of obs.	357			
Log likelihood	-447			

Note: Only these domestic firms that engage in innovation. Estimation by ordered probit, marginal effects reported. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.11. Selection model: knowledge sourcing from clients, marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	-0.142	-0.035	0.036	0.142
	(0.128)	(0.033)	(0.034)	(0.128)
Distance to the frontier$_{ijt-1}$ (D)	0.07**	0.018**	-0.018*	-0.07**
	(0.03)	(0.009)	(0.01)	(0.03)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Inverse of Mill's ratio	-0.023	-0.006	-0.006	0.023
	(0.101)	(0.026)	(0.026)	(0.101)
Number of obs.	357			
Log likelihood	-471			

Note: Only these domestic firms that engage in innovation. Estimation by ordered probit, marginal effects reported. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Table A2.12. Selection model: knowledge sourcing from within the same corporation, marginal effects for different answer choices

Domestic firms only, panel of CIS3 and CIS4: Method: IV-ordered probit	(1)	(2)	(3)	(4)
Answer choice:	Not used	Low importance	Medium importance	High importance
FDI entry$_{jt-1}$ (E)	**-0.229***	-0.053	0.002	**0.28***
	(0.121)	(0.029)	(0.018)	**(0.148)**
Distance to the frontier$_{ijt-1}$	0.072**	0.017	-0.001	-0.088***
(D)	(0.028)	(0.007)	(0.004)	(0.034)
Sector dummies	Yes	Yes	Yes	Yes
Region dummies	Yes	Yes	Yes	Yes
Survey wave dummy (CIS3 or CIS4)	Yes	Yes	Yes	Yes
Inverse of Mill's ratio	0.014	0.059	-0.001	-0.073
	(0.019)	(0.084)	(0.005)	(0.102)
Number of obs.	357			
Log likelihood	-438			

Note: Only these domestic firms that engage in innovation. Estimation by ordered probit, marginal effects reported. Two survey waves included (CIS3 and CIS4), i.e. panel of two time periods (1998-2000 and 2002-2004) is used.

Chapter 3

Competition, Productivity Based Selection Effects and Prices: A Case Study of the European Passenger Aviation Sector

3.1 Introduction

The large and persistent output price and productivity dispersion across firms even within narrowly defined sectors of an economy is a stylised finding in the literature. There is large price dispersion across producers even within rather homogeneous product categories like ready mixed concrete (Syverson 2007) or manufactured ice (Roberts and Supina 1997). Also, Griliches and Mairesse (1995), Bartelsman and Doms (2000) show evidence of similar large productivity dispersion across firms within detailed single sectors. During recent years there has been an increasing interest to explain these variations.

This chapter studies the effects of competition on distribution of output prices. It endeavours to explain the persistent across-firm price variation within a single industry, using a case study of the Western-European short-haul passenger aviation sector. The main emphasis of the paper is on the effects of the competition-driven (and cost- and productivity-based) selection process among airlines active on different city-pair markets. This selection process can have reallocation effects across firms within each market, resulting in effects on the productivity, cost and airfare distributions of airlines.

Most of the empirical papers about selection effects tend to concentrate on analysis of large firm-level datasets of productivity related variables from the manufacturing sector. That way they bundle together very different sectors and producers that do not compete with each other (e.g. Foster *et al.* 2001, Baldwin and Gu 2006). Concentrating on a study of a single (transport services) sector with spatially differentiated markets, relatively similar technology and relatively easily substitutable products[21] across different firms within these separate markets enables us to account to some extent for the usual product and technology heterogeneity problem.

I outline the implications of the firm selection process based on recent heterogeneous-producer competition models (Melitz and Ottaviano 2008, Syverson 2004a). Then, in my empirical analysis I test the hypotheses drawn from these models about the effects of competition on price distribution of airlines.

I find some evidence consistent with the implications of these models. Also, the results are of interest from a competition policy aspect. I find that tougher competition (including due to entry of airlines) on a given aviation market leads (through an increase in substitutability between carriers) to lower average and median airfares on a market. However, I also find that tougher competition is associated with lower upper-bound of airfare distribution on the market and less price variation (i.e. smaller across-carrier price spread) across airlines. These latter results are related to somewhat similar previous findings by Syverson (2007), based on data of ready-mixed concrete plants in the US. My results show that these non-trivial effects of competition (product substitutability) on price distribution seem to be more general. These seem to

[21] I.e. a flight on a given city-pair.

exist also in a transport services sector that has a relatively small number of competitors, and are not specific only to the ready-mixed concrete production.

The main contribution of this paper is empirical testing of hypotheses drawn from recent heterogeneous producer competition models, from Melitz and Ottaviano (2008) and Syverson (2004a). The novelty is that I am investigating not only the effects of competition on average prices of airlines[22], but also on the across-airline price distribution on a given aviation market. Arguably, the findings about the effects of competition on price distribution may give also information about the effects on across-firm cost and productivity distribution within the same given spatial market.

Other papers that study the effects of competition on price dispersion in this sector study different type of airfare variation than this study. They look at determinants of within-airline price dispersion, not the across-airline (cost and productivity related part of) price dispersion. I.e., they investigate price discrimination and therefore concentrate on price differences across clients of the same airline. Notable examples from the US are by Borenstein and Rose (1994) and Gerardi and Shapiro (2009). A recent example based on detailed European data that investigates price discrimination by airlines are by Piga and Bachis (2007) and Gaggero and Piga (2009).

Standard well-known competition models, like Salop (1979) assume that producers have homogeneous costs. In these models toughness of competition (extent of product substitutability) affects only the average unique price—it lowers the average optimal price in a given market. Recent extensions to these models in the IO literature (Syverson 2004a)[23] or in the new-new trade theory (Melitz and Ottaviano 2008) that assume heterogeneous firms have significantly richer predictions.

[22] The effects on average airfares have been studied in several papers before (e.g. Schipper *et al*. 2002, 2007).

[23] Also: Alderighi and Piga (2008).

In these models tougher competition is associated not only with lower average prices, but also lower upper-bound and dispersion of prices. These effects work through competition driven cost- or productivity-based selection process among firms. Lack of competition is a barrier to product substitutability between producers. Increased competition (e.g. larger number of competitors on a route, as caused for example by abolition of regulations that deter entry into the market) makes it easier for consumers to substitute between producers. That way it makes it more difficult for low-productivity and high-price firms to survive on a given market.

This selection process drives the least efficient and high-price producers out of the market (city-pair), thus truncating the cost and price distribution of firms from above and truncating the productivity distribution from below. This lowers the average cost levels, raises the average productivity and lowers the average price level in a given market. But in addition to that, this truncation of price distribution from above results in lower maxima (i.e. the upper-bound) of the price distribution and, given some regularity conditions, also lower across-carrier airfare dispersion.

This chapter concentrates on a single sector case study. The European short-haul passenger aviation sector is a suitable case as it has been through significant changes in toughness of competition. The number of competing airlines on the studied city-pairs varies significantly and there is a fair amount of entry and exit on different city-pairs during the studied time period.

At the same time, the ‘hard’ technology (e.g. aircraft used) used in this sector has remained relatively similar over this decade across different airlines. Also, despite the high sunk entry costs, the know-how and innovations to the business model are not something excludable from use by an airline’s competitors. In addition to that, on short haul routes the economy class flights by different airlines on the same city-pair are fairly good substitutes for each other.[24] As pointed out in Doganis (2010), one airline seat is from the passenger's viewpoint very similar to another and a standard large jet aircraft to another. However, a flight on a given short-haul route is of course not even closely as homogeneous as the ready-mixed concrete or some other standardised manufactured product.

Airlines do try hard to differentiate their products. But as they fly on the same short-haul city-pair or route (i.e. on the same market) and almost identical large aircraft (e.g. often the Boeing 737 or Airbus A318-A321), consumers perceive them largely as substitutes for each other. Apart from either providing 'free' food and additional amenities or not, it is difficult and costly to strongly differentiate economy class flights on short-haul routes. This sharpens the focus on how cost differences between airlines, rather than product heterogeneity alone, affect the airfare distribution across carriers on a given route.

This chapter uses two types of data: i) unique primary data of economy class airfares collected by a 'web spider' program during 2003-2005, and ii) secondary data of passenger traffic. Both databases cover flights on routes[25] in three country-pairs: UK-Ireland, UK-Netherlands, and UK-Belgium. This European dataset of airfare postings is much more detailed than any other. The passenger airfare information is available at daily and flight-code level. However, the biggest difference from any other data source is that airfares for the same flights and by the same carrier are available by a number of different booking scenarios. 'Booking scenario' is defined here as the time between booking of the ticket and departure. So, the airfares of different carriers on the same route or city-pair can be compared in the case of the same booking

[24] However, the air journey is only a part of, for example, a business or a holiday trip and not an aim in itself. The overall 'travel product' is of course always a rather heterogeneous product.
[25] A route is hereafter defined as an origin-destination airport-pair.

scenario.[26] The raw airfare database covers over 1.7 million daily price observations, including information of both low-cost carriers (LCC) and full service carriers (FSC). I aggregate this database into monthly city-pair level observations and merge it with traffic database from the UK Civil Aviation Authority (CAA).

The methods that I use to study this information include standard fixed effects (FE) regression, a 3-stage extension of the FE model, and system-GMM. GMM is used in order to endeavour to account for potential endogeneity of the competition variables in estimated equations. The endogeneity of competition variables is a standard problem in studies about the effects of competition. It needs to be accounted for in order to make conclusions about the effects, not only about the correlations.

3.2 Literature review

The relevant empirical literature can be divided broadly into three parts. First, a number of papers that document the effects of competition and deregulation on average prices in the aviation sector. Second, papers from other sectors that study the competition-induced selection processes and how these increase aggregate productivity by driving out the least productive firms. Third, papers that document and study the persistent across-firm price dispersion in a number of different sectors.

Many empirical studies have shown that an increase in competition due to liberalisation has resulted in lower airfares in the aviation sector. For example, Blöndal and Pilat (1997) attribute in their study almost 60 per cent of the fall in average airfares in USA over 1976-1993 to deregulation. Gönenc and Nicoletti (2000) conclude that airfares in OECD countries tend to decline with more

[26] For example, this cannot be done based on the US DOT airfare dataset, which is commonly used in airfare analysis.

deregulation and in the case of more competitive market structure. Dresner and Tretheway (1992) find significant welfare gains from liberalisation in the US. Schipper *et al.* (2002), using a sample of 34 routes with varying liberalisation status over years 1988-1992, investigate the effects of European aviation sector reforms. They find that standard economy airfares are lower on fully liberalised routes than on others. Also, Marin (1995) shows that the 1992 liberalisation of aviation sector in the EU is associated with a fall in airfares. An important implication of his paper is also that the effects of deregulation on prices may take time. Using yearly data on 172 city-pair markets in 8 European countries, Carlsson (2004) studies the association between the market structure and yearly averages of business class airfares. His results about the influence of market power are quite mixed and depend on the specification of price equation estimated.

In general, most of these papers find that liberalisation and more competition (e.g. larger number of firms on a route) is associated with lower average prices in the aviation sector. Also, in the case of the dataset that I use in this paper, Piga and Bachis (2006) show that enjoying a dominant position within routes from UK to Western Europe is conducive to higher airfares of an airline.

An interesting and innovative approach is by Goolsbee and Syverson (2008) and Daraban and Fournier (2008), based on data from the US Department of Transportation (DOT 1A and 1B dataset). These papers study how US airlines respond to the threat of entry of competitors. The main finding is that incumbent airlines cut airfares to a significant extent already before the actual entry—i.e. when threatened by Southwest's or other LCC's entry into their routes.

There is a strand of literature that studies the effects of competition on price discrimination in airline sector. These papers concentrate on the within-airline price dispersion and its changes due to the entry of competitors. However, these do not investigate the determinants of the across-firm (cost and productivity related part of) price dispersion. Notable examples from US studying the price discrimination in airlines sector are the papers by Borenstein and Rose (1994) and Gerardi and Shapiro (2009). Both of them study the effects of competition, as measured by change in Herfindahl index and number of competitors, on within-airline airfare dispersion within each studied route. For example, Gerardi and Shapiro (2009) use a Gini coefficient at route-airline level as a proxy for price dispersion across consumers. A recent related example based on European data documenting significant price discrimination is by Piga and Bachis (2007). A recent example that investigates how competition is related to within airline price dispersion across consumers in Europe is by Gaggero and Piga (2009). They find a negative correlation between market dominance and price dispersion, competition seems to limit the airlines' ability to price discriminate to exploit consumers' heterogeneity in booking time preferences.

There are also some empirical papers related to this one that study the selection effects of competition. Usually these employ data from the manufacturing sector and investigate effects on productivity of firms. These empirical studies—e.g. by Bailey, Hulten, and Campbell (1992), Foster, Haltiwanger, and Krizan (2001), or Syverson (2004b)—have shown that stronger competition tends to drive the less productive producers out of the market. As Syverson (2004a) shows based on data from ready mixed concrete sector, these selection effects increase aggregate sector productivity. At the same time, due to truncation of productivity distribution from below—i.e. due to driving out the 'bad firms', this selection process results in lower productivity dispersion and higher minima ('lower bound') of the productivity distribution of production plants.

A closely related paper to this study is by Syverson (2007). He studies the implications from a heterogeneous producer version of Salop's (1979) model about the price distribution of firms. His research question is: how do competition and product substitutability (more precisely: the market size and demand density) affect across-firm price distribution in separate geographical ready-mixed concrete markets in the US? He finds confirmation to somewhat related hypotheses to these tested in this paper. He shows that higher demand density (a broad proxy for competition) on a market results, due to productivity-based selection process among the producers, in lower average prices, less price dispersion and lower 'upper bound' of the price distribution.

Other studies that document across-firm price dispersion and explain it with differences in search costs, repeat purchases vs one-time purchases, etc, include Sorensen (2000), Chevalier and Goolsbee (2003) and Baye *et al.* (2004). These do not concentrate on selection effects of competition.

3.3 Theoretical motivation

The theoretical framework that I use is based on recent heterogeneous producer models of competition. In this section I derive the hypotheses to be tested in my empirical analysis, using the monopolistic competition model by Melitz and Ottaviano (2008). I use a closed-country version of their new-new trade theory model. This model can be used to analyze the effect of changes in toughness of competition due to deregulation of entry and actual entry of competitors.

The main result from recent heterogeneous producer competition models (incl. Melitz and Ottaviano 2008, Syverson 2004a, Bernard *et al.* 2006) is that tougher competition lowers the zero-profit (i.e. survival) cost cut-off on a market, truncating the (marginal) cost distribution of firms from above. The lower survival cost cut-off makes the survival of high-cost firms more difficult, inducing exit of the highest-cost firms. This cost truncation means also a truncation of the productivity distribution (as productivity is defined as an inverse of the cost here). However, it can also result in the truncation of the price distribution (e.g., as in Syverson 2007) given that carriers' rank ordering on a route is similar for both price and (marginal production) cost distribution, and that prices monotonically increase in costs.

As an alternative to the Melitz and Ottaviano (2008) approach, some related hypotheses can be derived based on somewhat different framework (see Annex 3.1), based on the heterogeneous cost version of Salop's (1979) spatial competition mode (as in Syverson 2004a, or Alderighi and Piga 2008). The homogeneous producer version of Salop's model has been used in earlier papers (e.g., Carlsson 2004) to study the effects of deregulation on average prices on a route. However, the more recent heterogeneous cost version has not been employed so far for the study of this sector. Syverson's (2004a) monopolistic competition model, unlike Melitz and Ottaviano (2008) has a special feature that is especially relevant in the case of aviation sector—spatially differentiated markets.

In the context of Melitz and Ottaviano (2008) model and heterogeneous costs version of Salop's (1979) model, the effect of competition can be seen as an increase in substitutability between airlines. Substitutability increases, for example, due to the entry of new carriers on a market (city-pair). In Syverson (2004a) the substitutability increase is brought about by a specific mechanism, by an increase in market demand (and as the size of market area s fixed in his model, by an increase in demand density). The particular comparative static of interest is different in the Melitz and Ottaviano (2008) and Syverson (2004a) models. The comparative static of interest in the Melitz and Ottaviano (2008) model is $dc^*/d\gamma$, the change in survival cost cut off (c^*) due to change in product substitutability parameter (γ). In Syverson (2004a), the comparative static of interest is dc^*/dD, the change in market demand (D).

In Syverson (2004a), a rise in market demand will raise the expected value of entry into the market, which will increase the number of producers willing to cover the entry cost to the market. Increase in entry and number of competitors will raise the producer substitution possibilities for consumers on the market and, hence, will make the survival of high-cost producers more difficult (i.e. lowers the producers' survival cost cut-off c^* on the market).

Melitz and Ottaviano (2008) model extends the monopolistic competition intra-industry trade model of Melitz (2003) with endogenous markups that depend on the size of the market. Firm heterogeneity occurs here in the form of cost and productivity (defined as 1/marginal cost) differences across firms. Firm heterogeneity is introduced in a similar fashion to Melitz (2003). Firms face some initial uncertainty about their future marginal production cost (and productivity), when making their costly investment decision prior to entry. In this case, prior to entry on a separate city-pair market. Upon entry they learn their cost level.

The demand side of the Melitz and Ottaviano (2008) model is taken from Otttaviano, Tabuchi and Thisse (2002)—an economic geography model, assuming quasi-linear preferences, that yield a linear demand for each variety. Consumers are identical, each has the following utility function:

$$u = q_0 + \alpha \int_0^N q_i di - \frac{\gamma}{2} \int_0^N (q_i)^2 di - \frac{\eta}{2} \left(\int_0^N q_i di \right)^2 , \qquad (3.1)$$

where q_0 is the homogeneous numeraire good;

q_i is consumption level of each variety of the differentiated good[27];

i is index of variety in the differentiated good sector, *N* is the number of varieties consumed.

The demand parameters α, γ and η are all positive. γ is the product substitutability (differentiation) parameter. Its higher values represent higher degree of differentiation between the varieties, as consumers give increasing weight to the distribution of consumption levels across varieties. If $\gamma=0$, consumers care only about their total consumption level of all varieties.

These preferences yield a linear inverse demand for all varieties:

$$q_i = \frac{L}{\gamma}(\alpha - p_i - \eta Q), \qquad (3.2)$$

where *L* is the market size (number of consumers);

Q is aggregate output: $Q = \dfrac{N(\alpha - \bar{p})}{\gamma + \eta N}$; (3.3)

$\bar{p} = \int_0^N p_i di \Big/ N$ is average price (*N* is number of firms). (3.4)

Supply side of the model is summarized in Figure 3.1. The supply side of the model, the introduction of firm heterogeneity into the model and firm entry and exit, follows Melitz (2003). Firms pay sunk entry cost (*s*) to enter the market and after that randomly draw their marginal cost from the c.d.f. *G(c)* with support on [0, c_M].

There is monopolistic competition and firms maximise profits based on their linear residual demand curve, given number of firms *N* and average price $\bar{p}$. In the long run, there is free entry into the industry.

[27] In this case: the flight on a city-pair by different airlines.

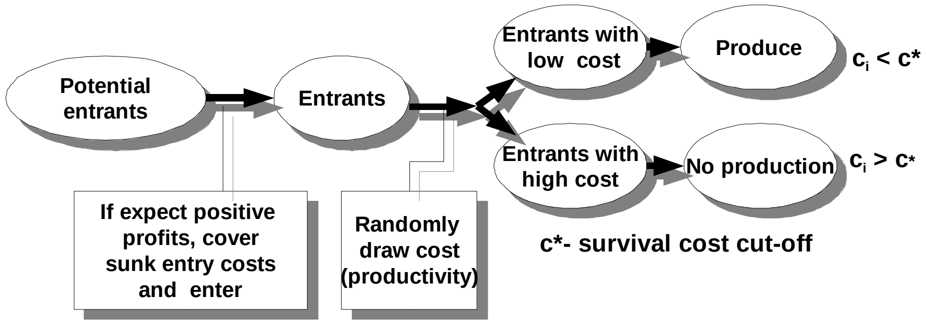

Figure 3.1. Firms' productivity uncertainty and entry/exit in Melitz and Ottaviano (2008) model

After entry, a firm with a cost draw c will maximise its profits,

$$\max_{q(c)\geq 0} \pi = \left[\left(\alpha - \eta Q - \frac{\gamma}{L} q(c) \right) - c \right] q(c). \tag{3.5}$$

The first order condition from this yields:

$$\left[\alpha - \eta Q - \frac{2\gamma}{L} q(c) - c \right] q(c) = 0. \tag{3.6}$$

For all cost draws c for which it holds that $c > c^* \equiv \alpha - \eta Q$, the firm does not produce anything. $q(c) = 0$ as its profit would be negative if it produced under these circumstances. These firms exit market after observing their cost (and productivity) draw.

These firms that draw $c < c^*$ will stay in the market and sell quantity:

$$q(c) = \frac{L}{2\gamma}(c^* - c). \tag{3.7}$$

Similarly to Melitz (2003) there exists thus a (endogenous) survival (zero profit) cost cut-off c^*, such that $\pi(c^*) = 0$. We can write the firm level variables like price, mark-ups, revenue and profit as functions of the survival cost cut-off and firms own cost c.

Prices: $p(c)=\frac{(c*+c)}{2}$. (3.8)

Mark-ups: $\mu(c)=p(c)-c=\frac{(c*-c)}{2}$. (3.9)

Revenue: $r(c)=\frac{L}{4\gamma}\left[(c*)^2-c^2\right]$. (3.10)

Profits: $\pi(c)=\frac{L}{4\gamma}(c*-c)^2$. (3.11)

Hence, more productive firms, that have lower *c*, have lower prices but higher mark-ups, are bigger in terms of output and revenue, and earn higher profit.

The free entry drives expected value of entry to zero. The industry equilibrium of the model is characterised by the zero expected profit condition. There the value of entry for firm is 0, i.e. the expected profit from entry is equal to sunk entry cost *s*.

$$\int_0^{c*}\pi(c)dG(c)=\frac{L}{4\gamma}\int_0^{c*}(c*-c)^2\,dG(c)=s \qquad (3.12)$$

Assuming, for simplicity (in order to get the analytical solution) the Pareto distribution for the productivity draw[28] *G(c),* the model can be solved for the survival cost cut-off $c*$. (Again, only the relatively efficient firms will produce, those that draw cost $c>c*$ will not, they will exit.)

From above, the cost threshold $c*$ will be:

$$c^*=\left[\frac{f_e\gamma\phi}{L}\right]^{\frac{1}{k+2}}, \qquad (3.13)$$

where $\phi=2(k+1)(k+2)c_M^k$.

[28] $G(c)=\left(\frac{c}{c_M}\right)^k$, where $c\in[0,c_M]$, $(k\geq 1)$, k – shape parameter of Pareto distribution of cost draws.

The survival cost cut-off is lower if the substitutability parameter γ is lower (i.e. if varieties are closer substitutes), if c_M is lower (i.e. the distribution of cost draws is better), or sunk cost of entry s is lower (e.g. because of deregulation of entry). The survival cost cut-off is decreasing in market size L. Thus, the implication of the Melitz and Ottaviano (2008) model is the tougher competition (tougher selection and higher exit rate) in the larger market. From (3.13) we can see that the derivative of the cost cut-off with respect to the substitutability parameter $\frac{dc^*}{d\gamma} > 0$; higher product differentiation allows survival of higher cost firms (as also in Syverson 2004b).

Increase in competition can be seen in this model as a fall in this substitutability parameter γ (e.g due to larger number of competitors offering their product). This results in lower c^* and thus truncation of the cost distribution from above[29] (as in Figure 3.2). [The fall in γ can be interpreted here as follows: tougher competition (e.g. due to larger number of competitors or deregulation of entry) increases substitutability between airlines, as e.g. there are more flights on different times on a given route, or there are more possibilities to fly to some given destination].

The result $\frac{dc^*}{d\gamma} > 0$ may show also the effects of competition on the survival price cut-off of the price distribution. Fall in producer substitutability parameter γ will lower the survival-cost and -price cut-off levels (and raise the survival productivity cut-off), resulting in the truncation of cost and price distributions from above (and truncation of productivity distribution from below). This effect on cost distribution of firms on a given market is given in Figure 3.2.

[29] Note that also the effects of deregulation of entry to a market can be studied based on this model. This can be considered as either: a fall in sunk cost of entry s or a fall in substitutability parameter γ. Both these changes result in truncation of the cost distribution from above, as in Figure 3.2.

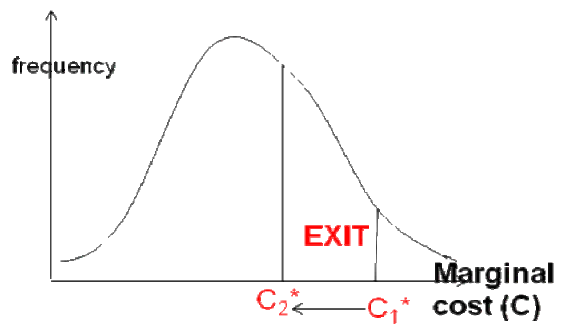

Figure 3.2. Tougher competition leads to truncation of the across-firm cost distribution from above

Notably, there are some assumptions that have to hold in order to have cost distribution's truncation to result in similar truncation of the price distribution. Prices need to monotonically increase in costs, and firms' rank ordering needs to be the same in both price and cost distribution (Syverson 2007).

In summary, the main intuition behind the result $\frac{dc*}{d\gamma} > 0$ is in our case shortly the following. Entry of new carriers into the route increases the substitutability between airlines, i.e. competition gets tougher. This results in a fall in the survival cost cut-off $c*$. Because of easier substitutability between airlines flying on the same city-pair (i.e. offering differentiated varieties of a similar product) the high cost and high-price airlines find it now more difficult to hold their customers. This cost-based selection process eliminates relatively high-cost (inefficient) carriers from the market (city-pair), truncating both the equilibrium production-cost distribution (on this market) and equilibrium price distribution from above. This means lower average price, less price variation across carriers, and lower upper-bound of price distribution on a given market (city-pair), as outlined in Hypotheses 1, 2, and 3 that are to be tested in the empirical analysis.

Hypothesis 1. Tougher competition among airlines on a given city-pair leads (via increase in substitutability between carriers) to lower average airfares on this city-pair market.

Hypothesis 2. Tougher competition among airlines on a given city-pair suppresses the upper-bound of the across-airline price distribution on a given city-pair market.

Hypothesis 3. Tougher competition among airlines on a given city-pair leads to less price variation across carriers on this city-pair market.[30]

3.4 Description of airfare and traffic data

This chapter uses two types of data: primary data of economy class airfares and secondary data of passenger traffic. Both datasets cover flights on routes[31] in 3 country-pairs: UK-Ireland, UK-Netherlands, and UK-Belgium. The airfare data are collected by Claudio Piga from Loughborough University, a detailed description of this dataset can be found from Piga and Bachis (2007). The detailed passenger traffic data are from the UK Civil Aviation Authority (CAA).

The passenger airfare postings database covers over 1.7 million price observations, including both the LCCs and the FSCs. It includes the airfares of the following LCCs: Ryanair, Easyjet, Bmibaby, Buzz and MyTravelLight. For FSCs the coverage is restricted to airlines flying on identical or similar routes with LCCs: BMI, BA, KLM, Lufthansa[32] and Aer Lingus.[33] The time period for which I have both LCC and FSC airfares available extends from April 2003 until June 2005.[34]

[30] Obviously, hypotheses 2 and 3 can be studied only in routes that have initially more than one carrier.
[31] A route is here an origin-destination airport-pair.
[32] Lufthansa flies in codeshare with other airlines, i..e it does not service the studied routes itself. Therefore, Lufthansa is excluded from regression analysis testing the hypotheses 1-3.
[33] Aer Lingus has changed its business model, by now it follows a business model similar to the LCCs.
[34] For LCCs also data from 2002 is also available.

Over this period, each day the internet postings of airfares of LCCs and FSCs have been collected with a special "electronic spider." Each day this program connected directly to the UK website of each LCC and retrieved a number of different price citations (in British pounds) posted there. During the data collection, the return flight of the journey was always scheduled one week after the departure. The retrieved LCC airfares are one-way prices on a return flight, priced separately for the outbound and return flight of the return journey, excluding taxes, fees and other charges. Note that, unlike the FSCs, the LCCs always price the outbound and return leg of the journey separately. Therefore, there are no difficulties in distinguishing between the price of the outbound and returning stage of the journey of a LCC.

Daily airfares of FSCs were collected from the booking website www.opodo.co.uk. The prices cited there include all taxes, fees and surcharges to the airfare. The flight class was always standard economy class. As FSCs priced most of their tickets as return flights, not separating the outbound and return part of the journey, the return ticket prices were collected. Half of the airfare of the return-ticket is assigned to the outbound journey and half to the return journey (as in Piga and Bachis 2007a, 2007b).

The fares were collected for a number of different departure dates from the booking day. That is, I have a number of different fares for the same flight, depending on how many days before the actual flight the ticket was booked. For both the FSCs and LCCs I have these booking scenarios available: the flight to a destination airport taking place 7, 10, 14, 17, 21, 28, 35, 42 49 and 56 days after the query. The distinction between different booking scenarios is very useful for my study. Piga and Bachis (2007) show that the airfares on the same flight of the same airline that are booked at different days can differ a lot. Therefore, when I compare airfares across carriers on a given aviation market (route or region-pair), prices corresponding to the same booking scenario need to be used.

The collection of airfares was conducted every day at the same time. In addition to airfare, also information on the name of company, date and time of query, departure date, scheduled departure and arrival time, origin and destination airport names and identification codes, season of flight, and the flight identification code was collected.

Notably, for LCCs the airfares were collected without taxes, fees and charges, but for FSCs inclusive of these. In order to compare airfares between LCCs and FSCs some assumptions about these additional ingredients of the airfare have to be made, and these added to the LCC fares. For that I use some (crude) country-pair level information about average taxes, fees and surcharges that can be calculated from Yamanaka (2005). Based on Yamanaka (2005) one can find the average approximate country-pair figures also for UK-Netherlands, UK-Belgium, and UK-Ireland country-pairs. Based on her paper the average taxes and fees per one-way ticket amount to 13£ on routes connecting the UK and Ireland, 20£ on UK-Belgium country-pair, and 18£ on UK-Netherlands country pair. I add these average values to the corresponding LCC airfare values on each of these country-pairs.

In order to compare airfares and calculate across-airline airfare dispersion on different aviation markets one has to define these separate geographical markets. One option would be to treat different routes, i.e. airport-pairs, as separate markets. However, flights on different routes often compete significantly with each other. So, this definition would be too narrow. Instead, I define the separate aviation markets as city-pairs, which consist of geographically close routes that are likely to compete with each other. I define the city-pairs based on overlaps of catchment areas of studied airports (see also Annex 3.2).

Table 3.1. City-pairs covered in the airfare dataset

	UK-Ireland city-pairs	UK-Netherlands city-pairs	UK-Belgium city-pairs
1	London to Knock	London to Amsterdam/Rotterdam	London to Brussels area
2	London to Cork	London to Groningen	East Midlands (EMA) to Brussels area
3	London to Dublin	London to Eindhoven	Edinburgh-Glasgow-Dundee to Brussels area
4	London to Kerry County	EMA to Amsterdam/Rotterdam	
5	London to Shannon	Edinburgh-Glasgow-Dundee to Amsterdam/Rotterdam	
6	EMA to Knock	Manchester-Liverpool-Blackpool to Amsterdam/Rotterdam	
7	EMA to Cork		
8	EMA to Dublin		
9	Edinburg-Glasgow-Dundee to Dublin		
10	Leeds-Hull to Dublin		
11	Southampton-Bournemouth to Dublin		
12	Manchester-Liverpool-Blackpool to Cork		
13	Manchester to Dublin		
14	Newcastle to Dublin		
15	Bristol-Cardiff to Cork		
16	Bristol-Cardiff to Dublin		

In its 2002 RASCO survey the UK Department for Transportation (DfT) has conducted analysis about the size and also overlap of catchment areas of UK airports (as of year 2000). Based on their catchment area maps produced by the DfT's National Airport Accessibility Model we can determine which airports and hence which short-haul routes are directly competing with each other. In DfT's approach, the 'catchment area' is calculated as the area within either an average one-hour, or an average two-hour travel time radius.

The largest number of city-pairs with price data available are from the UK-Ireland country-pair, followed by the UK-Netherlands and the UK-Belgium (see Table 3.1).

In both UK-Ireland and UK-Netherlands country-pair I have airfare data available for 7 airlines, in UK-Belgium market for 5 airlines. The detailed CAA traffic dataset for the period includes also other smaller airlines that have served these markets. However, with the exception of SN Brussels, VLM and Aer Arran, the UK airfare database includes the main airlines serving these markets. Airlines for which I have airfare data, account for about three quarters of all passenger flights in UK-Ireland, UK-Netherlands and UK-Belgium markets.

The separate CAA database of traffic on these 3 country-pairs covers monthly data for the same studied period. It includes more than 35,000 observations, covering passenger flights from all UK airports. For each airline, route and month combination it provides the number of monthly aircraft seats, number of passengers and load factors. This data enable us to calculate the number of competitors active on each city-pair, the Herfindahl index and other market structure related variables. All the information in this database has also been aggregated to a city-pair level. For each city-pair and route it enables to identify the entering and exiting companies, as well as the time (month of a year) of this entry or exit.

'Entry' is defined in this context as the first scheduled operation of an airline on an airport-pair (i.e. on a route) within a city-pair. 'Exit' is defined as the last scheduled operation of an airline on an airport-pair within a city-pair. However, some caution is needed in interpreting these entry-exit observations, as it may also result from a merger of two airlines or as it may reflect a coding error of an airline.[35] Corrections for airline merger are however relatively easy to make as there are relatively few of

[35] For example BMI was in some periods coded differently in the dataset, thus creating spurious impression of entry and exit.

these.[36] For a short overview of entry and exit on the largest studied city-pairs see Annex 3.3. A detailed account of entry, exit and their determinants based on data of country-pairs in Western Europe is available in Gil-Molto and Piga (2007).

3.5 Background information and descriptive statistics

A general development since the 1992 (and 1997) deregulation packages of the aviation sector in the EU has been the entry and growth of market share of LCCs. This has resulted in strong price competition, especially on short haul routes, increase in number of airlines and an increase in number of routes served in the EU.

In general, the main characteristic that differentiates the new entrants in the aviation market, the LCCs, is their costs. The European LCCs have copied with remarkable success the first successful LCC in the USA, Southwest, in terms of its cost-related features of the product (Doganis 2006, 2010). They offer high-frequency short-distance point-to-point services. To keep costs and thus also airfares low, they operate a single aircraft type and use high-density seating.[37] Traditionally, LCCs have had much higher daily utilisation of aircraft and their personnel than the full service carriers (FSC) (CAA 2006, Calder 2002). They minimise the time that aircraft or the crew remains idle, for example by reducing the turnaround times between flights. They tend to avoid using main large airports, thus cutting the airport costs and avoiding congestion related problems (that way often reaching high punctuality of departures). They generally (with some exceptions like Virgin Express) have not provided free in-flight catering or pre-assigned seating, hence, lowering the time

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[36] E.g. the Ryanair takeover of Buzz in spring 2003.

[37] For example, according to Doganis (2006) EasyJet has been able to pack 148 seat on its Boeing 737-300 aircraft. British Midland has had only 132 seats on the same type of aircraft.

needed to keep the aircraft grounded at the airport between landing and take-off (e.g. Calder 2002, Jones 2006). The LCCs do not use travel agents for selling their ticket, but service their clients directly from their websites. This lowers their sales costs and amount of ticketing and sales staff needed. Also, the LCCs have usually achieved higher load-factors than the majority of the FSCs.

Higher utilisation of both aircraft and personnel and savings in terms of labour costs have been the main success factors of the LCCs. Labour costs, have traditionally been the largest main single cost item of airlines (CAA 2006). Only very recently has the share of fuel costs (temporarily) surpassed the share of costs of labour in total costs of airlines (Pearce and Smyth 2007). LCCs have achieved low labour costs by employing non-union labour and younger personnel. By the advantage of being new entrants, the LCCs have avoided some of the legacy costs of many old incumbent airlines, such as heavy pension liabilities

An issue, that is relevant to a study of the effects of competition and liberalisation on airfares, is product differentiation. To what extent can the flights on new LCCs be seen as substitutes for the flights on FSCs? Some authors argue that the economy class airline flights on a given route are in fact relatively similar and airline's service standards are more-or-less converging (e.g. Calder 2002). Product differentiation is rather costly in this sector (*Ibid*. 2002, Doganis 2006). Adding seat pitch to please the customers, frequencies, in-flight amenities and airport lounges drives costs up. So does expanding the network scope by using central hubs. Also, congestion due to using large hubs like Heathrow, used more by the FSCs can in fact lower the perceived quality of the traditional airlines' 'full service' product (Doganis 2006, 2010).

One observation is also that on short- and medium-haul routes (which dominate in the EU) product differentiation is more difficult and also less lucrative, since passengers spend relatively little time in the aircraft and thus wider legroom and other amenities are often not that important for them (Doganis 2006). Baily and Zitzewitz (2001) argue that the most important qualities of a flight that matter for consumers are the frequency of flights on a given route and the reliability of service. In that sense the LCCs' product has not been inferior to that of FSCs—as evident also in the punctuality statistics of flights from the UK CAA.

The analysis of our airfare dataset confirms the known fact that on average the LCCs have significantly lower airfares than the FSCs on the studied city-pairs (see Table 3.2 and 3.3). Over the period 2003-2005, Ryanair and MyTravelLite had the lowest average airfares. The average airfare (with added taxes and airport charges) of Ryanair on the 3 country-pairs was 39.8£. The highest average airfares were the ones of the British Airways, which on average were almost 3 times higher than the airfares of Ryanair. Also, the most expensive airfares of separate airlines were higher in the case of the FSCs. Notably, the ranking of airlines in the across-carrier price distribution is relatively similar in different city-pairs. In the case of BA, the variation of airfares across the three country-pairs is larger than in other airlines.

The large differences between LCC and FSCs are also shown in Table 3.4 in the case of labour productivity (RPK[38] per employee), cost and departure/arrival punctuality. LCCs that have lower airfares than the FSC have also significantly higher labour productivity, better punctuality indicators and (with the exception of Easyjet) also lower labour costs than the FSCs (see Table 3.2). These cost, productivity and airfare differences between LCCs and FSCs have to do a lot with the general differences in

[38] Revenue passenger kilometre.

the business models, as described above. A part of the large differences in RPK or number of passengers per employee can be due to different extent of outsourcing of some air service related activities.

The dynamics of punctuality statistics over time is heavily affected by seasonality. However, for the airlines studied here, based on the punctuality statistics form the UK CAA, there is no clear increasing or decreasing trend in average punctuality statistics on the three country-pairs over the period studied. The punctuality of airlines is a major factor of the quality of their service for consumers. Based on the UK CAA punctuality data, there appears no reason to argue that this aspect of quality of service has changed significantly over the 2-year period studied in this chapter.

Piga and Bachis (2007) show that airfares depend a lot on the booking scenario. The earlier before the departure the ticket is booked, the lower is the airfare. I show similar finding in Figure 3.3. This tendency is evident both in the case of the LCCs and, to a bit smaller extent, also in the case of the FSCs.

The results about the FSC airfare premium and the effects of booking time are further confirmed based on a simple pooled OLS regression model, given in Table 3.5 and 3.6. The dependent variable is log of average route-month-airline level airfare and the regression accounts also for city-pair specific fixed effects. It is evident from Table 3.5 that, after accounting for booking day and city-pair specific effects, the FSCs still have on average about 86 per cent higher airfares (calculated as exp(0.63)-1)) than the LCCs. However, note that, if a shorter period April 2003 to December 2004 is used instead, then the similarly calculated FSC premium is lower. Then it is 44 per cent higher (calculated as exp(0.365)-1)) than the LCC level. The gap between the FSCs and LCCs is similar if I consider only the morning flights, departing between 9 am and 12 noon. Then it is 48 per cent. The results in Table 3.5 confirm, again, that there is significant price discrimination across different consumers, based on time of purchase of the ticket.

The airfare premiums of individual airlines over the airfare of BMIbaby, conditional on booking scenario, period and city-pair effects, are shown in Table 3.6. As evident from this table, accounting for the city-pair specific effects (e.g. some airlines concentrating on more 'high premium' city-pairs) does not explain the differences between LCCs and FSCs: the large airfare difference between these two groups is still there.

Table 3.2. Average one-way airfare by main LCCs and FSCs, in £'s

Airlines	Mean	Sd	Median	Max
BMIbaby	45.1	11.8	44.7	91.5
Ryanair	39.8	14.3	36.1	145.5
Easyjet	53.7	12.4	51.6	117.1
MyTravelLite	31.7	8.2	29.8	69.9
Aer Lingus	90.9	74.5	60.2	424.9
BMI	60.6	26.5	50.6	153.3
BA	109.1	77.6	77.4	412.3
KLM	81.9	38.0	73.1	197.9
Lufthansa*	58.6	12.0	56.4	110.1

Note: Period is 2003-2005. *Lufthansa flights are codeshare flights.

Table 3.3. Average one-way airfares by destination country, in £'s

Airlines	Netherlands	Belgium	Ireland
BMIbaby	55.9	54.0	40.8
Ryanar	32.4	35.5	40.3
Easyjet	54.8		
MyTravelLite			31.7
Aer Lingus			90.9
BMI	70.4	53.5	51.2
British Airways	59.7	81.3	129.2
KLM	81.9		
Lufthansa		58.5	57.8

Note: flights to and from UK, period 2003-2005. Due to small number of available price observations airline Buzz is excluded from Tables 3.2 and 3.3.

Table 3.4. Productivity, costs and punctuality of airlines

Airline	Punctuality of flights (%)*, 2003-2005	Passengers per employee** (BA=100), 2005	RPK per employee** (BA=100), 2005	Labour costs per employee*** (BA=100), 2005
Bmibaby	60.5	…	…	72
Ryanair	72.8	1910	600	82
Easyjet	69.9	1049	331	98
Aer Lingus	60.5	312	156	…
BMI	58	317	69	67
BA	54.1	100	100	100
KLM	55.4	116	118	138
Lufthansa	…	72	53	130

These statistics are calculated based on data from: * - UK CAA (short-haul flights to/from UK, 10 main airports, average over the 3 country pairs studied, 2003-2005), ** - IATA WATS, *** ICAO. RPK – revenue passenger kilometres. Punctuality is measured as the share of flights that are on time or max 15 minutes late.

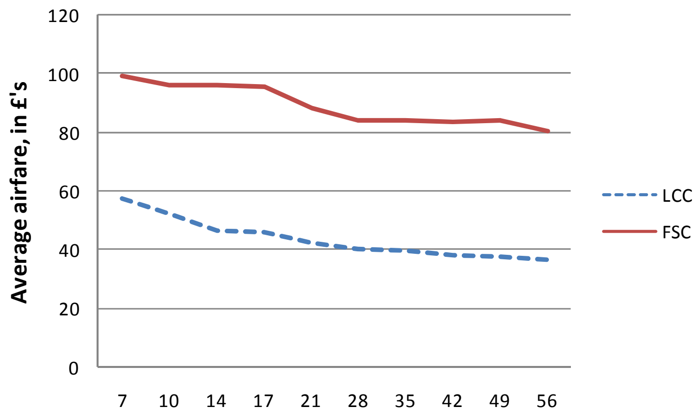

Figure 3.3. Average airfare by booking scenarios
Note: horizontal axis measures days between booking and flight. Period: 2003-2005. UK-Ireland, UK-Netherlands, UK-Belgium country-pairs.

Table 3.5. Full service carrier price premium

Explanatory variables	Dependent variable log(average price) Coeff.	Robust st. err.
Full service carrier dummy	0.632***	(0.009)
Booking scenario dummies:		
D_10 days before departure	-0.076***	(0.013)
D_14 days before departure	-0.165***	(0.013)
D_17 days before departure	-0.206***	(0.016)
D_21 days before departure	-0.267***	(0.013)
D_28 days before departure	-0.324***	(0.013)
D_35 days before departure	-0.34**	(0.013)
D_42 days before departure	-0.36***	(0.013)

D_49 days before departure	-0.375***	(0.013)
D_56 days before departure	-0.405***	(0.013)
Citypair dummies:		
D_London-Amsterdam area	0.065***	(0.016)
D_ London-Groningen	0.001	(0.022)
D_London-Knock	0.524***	(0.024)
D_London-Cork	0.263***	(0.02)
D_London-Dublin	-0.011	(0.016)
D_London-Eindhoven	0.106**	(0.021)
D_London-Kerry county	0.129***	(0.025)
D_London-Shannon	0.17***	(0.027)
D_Midlands-Brussels area	0.429***	(0.021)
D_Midlands-Amsterdam area	0.434***	(0.018)
D_Midlands-Knock	-0.145***	(0.022)
D_Midlands-Cork	0.056**	(0.022)
D_Midlands-Dublin area	0.172***	(0.02)
D_Edingurgh-Glasgow-Dundee to Brussels area	0.107***	(0.022)
D_ Edingurgh-Glasgow-Dundee to Amsterdam area	0.6***	(0.015)
D_ Edingurgh-Glasgow-Dundee to Dublin	0.017	(0.017)
D_Leeds-Hull to Dublin	0.057***	(0.018)
D_Southa-Bournem to Dublin	0.202***	(0.025)
D_Manchester-Liverpool-Blackpool to Amsterdam area	0.358***	(0.015)
D_ Manchester-Liverpool-Blackpool to Cork	0.085***	(0.019)
D_ Manchester-Liverpool-Blackpool to Dublin	-0.027*	(0.016)
D_Newcastle-Teesside to Dublin	-0.018	(0.016)
D_Bristol-Cardiff to Cork	0.291***	(0.017)
D_Bristol-Cardiff to Dublin	0.37***	(0.021)
Period dummies	YES	
No. of Obs.	13699	
F-test	251.13	
Prob > F	0.000	
R-squared	0.51	

Note: *** significant at 1 per cent, ** significant at 5 per cent, * significant at 10 per cent level. Period: 2003-2005. Monthly route-airline-booking scenario level data. Pooled least squares regression.

I also looked briefly into UK airport level differences in airfares. The highest average airfares are in London City airport, Bristol airport and Birmingham airport. E.g. London City airport has about twice higher average airfares than London Gatwick. Therefore, London City airport is excluded from the regression analysis in Section 3.7.

Table 3.6 Airfare premium for different airlines

Explanatory variables	**Dependent variable log(average price)** Coeff.	Robust st. err.
Airline dummies:		
Ryanair	-0.139***	(0.011)
Easyjet	0.221***	(0.013)
MyTravelLite	-0.317***	(0.025)
Aer Lingus	0.538***	(0.014)
BMI	0.274***	(0.016)
BA	0.729***	(0.014)
KLM	0.544***	(0.019)
Lufthansa	0.293***	(0.019)
Booking scenario dummies	YES	
City-pair dummies	YES	
Period dummies	YES	
No. of Obs.	13699	
F-test	294.5	
Prob > F	0.000	
R^2	0.5	

Note: OLS regression. *** significant at 1 per cent, ** significant at 5 per cent, * significant at 10 per cent level. Period: 2003-2005. Monthly route-airline-booking scenario level data. Pooled least squares regression. Comparison group is the airline BMIbaby: the coefficients for different airlines show their (conditional) price premium over the price by BMIbaby.

Table 3.7. Average prices by 4 types of airlines

Type of airline	Log average price	St. error of log average price	Log median price
Continuer	3.686	0.432	3.679
Enter and Exit	3.36*	0.314	3.328
Enter and Stay	3.714	0.466	3.694
Exiting incumbent	3.887	0.401	4.002

*Note: averages over all city-pairs. The low average and median price by these airlines that enter and exit as well on a city-pair is due to dominance of the LCCs among this group. The corresponding average for the 'enter and exit' group FSCs was significantly higher: 3.97.

In Table 3.5, the carriers on the 25 different city-pairs are divided into 4 different types, based on data from April 2003 to June 2005. These are: i) continuing incumbent, ii) entering and also exiting firm, iii) entrant that stays in the city-pair, iv) incumbent that exits the city-pair. A 'continuer' airline exists on a city-pair at the beginning and at the end of the time period studied. An 'enter and exit' type airline enters a city-pair after April 2003 and exits before June 2005. An 'enter and stay' type airline enters a city-pair after April 2003 and exists also at the end of the time period studied. An 'exiting incumbent' is an airline that provides its services on a city-pair at the beginning, but not any more at the end of the studied period.

I find that exiting incumbents have the highest average airfares among these 4 groups. This group has a high share of FSCs. Those entering the city-pairs have on average lower airfares, however, not necessarily lower than the continuing airlines. The low average and median price by these airlines that enter and exit soon is due to dominance of the LCCs among this group. The corresponding average for 'enter and exit' type FSCs was significantly higher.

3.6 Methodology

In order to test the hypotheses about the effects of an increase in competition on moments of across-carrier price distribution (as derived in Section 3) I estimate city-pair level price equations. The studied dependent variable is different in different specifications of the model. The empirical model is the following (*r* denotes city-pair, *b* booking scenario, and *t* month):

$$y_{rbt} = \alpha_r + \lambda_b + \tau_t + E'_{rt}\beta + X'_{rbt}\gamma + \varepsilon_{rbt} . \tag{3.14}$$

In Equation (3.14) the dependent variable y_{rbt} is depending on specification either:

1) city-pair level median or average monthly airfare;
2) city-pair level 'upper-bound' monthly airfare (see below for definition);
3) or city-pair level across-carrier variation in airfare (see below for definition).

Note that all these price variables are calculated separately for each booking scenario *b*. The 'upper-bound airfare' on a city-pair is calculated (for each month) as follows: at first for each route-carrier combination an average (arithmetic mean or median) airfare is calculated. The 'maximal (minimal) airfare' on a city-pair is then simply the largest (smallest) average airfare among the route-carrier combinations within that city-pair. The across-carrier variation in airfare is then simply defined as a difference between this maximal and minimal airfare.[39] Note that this dependent variable is different from the one used in a recent study of price dispersion by Gerardi and Shapiro (2009). Gerardi and Shapiro (2009) study determinants of price discrimination and some of the competition proxies they use are similar to the ones in this chapter. Their dependent variable is a route and airline level Gini coefficient of airfares that measures the dispersion of airfares within each studied airline. My study concentrates on a different topic and therefore on a different dependent variable, on investigation of across-airline airfare differences.

Vector E_{rt} in Equation (3.14) indicates competition-related key control variables on city-pair (market) r at time t. X_{rbt} is a vector of other city-pair specific control variables. τ_t denotes time-specific effects, α_r city-pair specific and λ_b booking scenario specific effects.

The key proxies of competition used in vector E_{rt} include:

a) Herfindahl index of carriers' market shares in the city-pair (based on number of flights) ;
b) Number of competitors active on the city-pair;
c) Entry dummy (route level entry) indicating occasions of entry[40] of airlines on routes within a city-pair.

[39] Or alternatively, it was calculated as a ratio of this difference to the median price on the city-pair.
[40] Note that these entry dummy is defined based on entry on routes within a city-pair. Therefore entry of an airline, already operating on a route within a city-pair, to another route within this city-pair is considered as entry. Entry of airlines on a city-pair means an increase in substitutability between travelling options, thus the expected sign of it should be negative in all the specifications.

These three variables are used separately, in order to avoid the multicollinearity problem, as they are correlated with each other. Hence, for each dependent variable, three different main models were estimated (see Table 3.8). Based on Hypotheses 1 to 3, I would expect the number of competitors and entry dummy to have negative coefficients and Herfindahl index to have positive coefficients in all the specifications with different moments of price distribution as dependent variables. A usual problem with these kinds of competition proxies is their possible endogeneity. I try to deal with the endogeneity issue, to an extent, by using also the GMM approach.

I estimate different versions of Equation (3.14). First version is a standard panel fixed effects (FE) model that includes only the competition proxy, period dummies and citypair-booking day fixed effects. Second specification adds also some other time-invariant controls that may affect the moments of airfare distribution, to the standard FE model:

- Number of all UK airports serving the destination;
- Number of flights on a given month in the city-pair;
- Log of average seat capacity (total available seats divided by total number of flights) on the city-pair.

  The third specification estimates the Plümper and Troeger (2007a, 2007b) 3-stage fixed effects (FE) model, where also some time-invariant controls have been included as additional controls. The Plümper and Troeger (2007a, 2007b) model is a vector decomposition model that extends the standard FE model by allowing the researcher to estimate the effects of time-invariant in one single model together with standard fixed effects estimates for the time-varying variables. For more information on this method see Section 3.7.2.

  The additional time-invariant controls included in this specification are:

- Dummies for main departure regions: South England, North England, Midlands, Scotland;
- Booking scenario dummies;
- Destination country dummies.

Other variables that are not included in the baseline specification, but have been tried during the robustness tests, are:

- Interaction terms of competition proxies with booking scenario dummies;
- Number of routes within the city-pair (this shows within-citypair substitution possibilities).

As an alternative to number of flights, I have also tried the total number of passengers instead of the number of flights as an explanatory variable. However, the number of flights may be a preferable one, as it is less dependent on current airfares. The flight schedules are determined some months before the actual flights. The number of passengers[41] on the city-pair is, however, much more dependent on current airfares, it is simultaneously determined with airfares.

Number of UK airports serving the destination shows either the effects of general product substitutability or the popularity of the destination (e.g. as in Piga and Bachis 2007). It may show the effects of a larger number of (indirectly) competing routes, i.e. larger substitutability between routes and, hence, more competition. Also, this explanatory variable might indicate the importance and popularity of each destination city, which may be related to its population size/market size. If this variable is more an indicator of popularity of the destination (i.e. an indicator of strong demand) than an indicator of larger competition, then its sign could be positive in specifications

[41] Total number of passengers on the city-pair could also be an indicator of the size of the market for flights on a given city-pair. Market size is related to the toughness of competition, it can be also seen as a broad proxy for the extent of competition (e.g. in Melitz and Ottaviano 2008). See also Annex 3.1.

where average or maximal price are used as the dependent variable. If it is more an indicator of extent of indirect competition, then I would expect it to have a negative sign in all specifications, just similarly to the expected sign of the number of competitors. Average seat capacity variable could help to account for possible changes or across-citypair differences in size of the aircraft used.

Apart from these, the 3-stage FE model includes a set of time-invariant dummies and period dummies as explanatory variables.[42] Booking scenario dummies enable to study whether the average and maximal prices decrease monotonically with an increase time difference between date of booking the flight and date of departure. To check whether there are, *ceteris paribus*, destination country (Ireland, Belgium, Netherlands) or UK departure region specific effects, I include the destination and departure region dummies.

Finally, in order to allow for endogeneity of the competition proxies I also use GMM specification (Blundell and Bond 1998) to investigate the relationship between competition and different moments of airfare distribution (see Section 3.7.2).

3.7 Econometric results

3.7.1 Standard fixed effects model

At first I present the results from the fixed effects (FE) models and in the next section also the results based on the system-GMM approach (system GMM, as developed by Blundell and Bond 1998, Bond 2002). Some descriptive statistics of variables used in the regression analysis are given in Annex 3.4.

[42] Unlike the standard FE, the version of FE model (Plümper and Troeger 2007a, 2007b) that is also used here, enables to consistently estimate the effects of time-invariant dummy variables (booking day dummies, etc), while still accounting for other time-invariant cross-section specific control variables by using the cross-section specific fixed effects.

The coefficients of main competition proxies from the standard FE model are given in Table 3.8 and 3.9. Table 3.8 includes the specification with only the competition proxies, period dummies and city-pair fixed effects as controls. Table 3.9 includes also other time-varying controls. By using fixed effects I account for any other city-pair specific time-invariant effects: e.g. distance between airports, existence of travel options with alternative forms of transportation (e.g. Eurostar train), etc.

Table 3.8. Main regression results: standard FE, relationship between competition and different moments of across-carrier price distribution

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(across-carrier variation in median price)$_{rbt}$				
	Herfindahl index$_{rt}$	2.105 (1.357)		
	Number of competitors on the city-pair$_{rt}$		-0.078 (0.063)	
	Entry dummy $_{rt-1}$			-0.195** (0.07)
	R^2	0.06	0.05	0.06
	Prob>F	0.000	0.000	0.000
Ln(across-carrier variation in average price)$_{rbt}$				
	Herfindahl index$_{rt}$	1.817 (1.328)		
	Number of competitors on the city-pair$_{rt}$		-0.036 (0.061)	
	Entry dummy$_{rt-1}$			-0.198*** (0.063)
	R^2	0.04	0.03	0.08
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(upper-bound price on the city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	2.906*** (0.643)		
	Number of competitors on the city-pair$_{rt}$		-0.093** (0.04)	
	Entry dummy$_{rt-1}$			-0.09* (0.047)
	R^2	0.08	0.09	0.08
	Prob>F	0.000	0.000	0.000

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(median price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	2.345*** (0.666)		
	Number of competitors on the city-pair$_{rt}$		-0.072* (0.037)	
	Entry dummy$_{rt}$			-0.019 (0.026)
	R^2	0.07	0.09	0.06
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(average price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	2.604*** (0.526)		
	Number of competitors on the city-pair$_{rt}$		-0.098*** (0.025)	
	Entry dummy$_{rt-1}$			-0.058* (0.032)
	R^2	0.10	0.12	0.09
	Prob>F	0.000	0.000	0.000
	No of obs	2399	2399	2233

Note: robust standard errors clustered at city-pair level are in parentheses. Standard FE model. Only period dummies and citypair-booking day fixed effects are included as additional controls in each model. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3.

I include only these periods and booking scenarios into regression analysis for which I have both the low-cost carriers' and full service carriers' airfare data available. Therefore the period studied here is from April 2003 to June 2005. Only these city-pairs that had at least 3 carriers competing on them were included. However, I did also robustness checks of these results by including city-pairs with just 2 competitors.

Also, data of airfares and flights on routes originating from London City airport or by Lufthansa airline are excluded from estimating all of the regressions below. London City airport is more oriented towards business travellers and has therefore often higher airfare observations in the dataset than other airports. To keep the flights within city-pairs relatively comparable, the flights to and from this airport need to be excluded.

Among other FSCs, Lufthansa is significantly represented in the airfare dataset. However, this airline is excluded because it is flying only under codeshare agreements on the three studied country-pairs (incl. a codeshare agreement with BMI). Codeshare agreement means that it is not flying on a route itself, it is selling tickets to other airlines' flights under the Lufthansa brand name.[43]

One problem with studies on the effects of competition is that the coefficients of competition proxies may show just correlation, and not necessarily the causal effect. However, an opposite argument could be that both entry and exit and thus change in number of competitors takes time in this sector, and these decisions of carriers are not based on only prices from last couple of months. Although I observe quite a number of months, it is still just a 2-year-period that I can include in the regression analysis. Therefore, the causality in the case of this study is more likely to run from entry and number of competitors to prices than the other way.

Herfindahl index, however, is much more likely to be endogenous. Market shares depend on prices and Herfindahl index is based on market shares of firms.

Table 3.9. Regression results: standard FE with additional time-varying control variables, relationship between competition and different moments of across-carrier price distribution

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(across-carrier variation in median price)$_{rbt}$				
	Herfindahl index$_{rt}$	4.859*** (1.588)		
	Number of competitors on the city-pair$_{rt}$		-0.085 (0.064)	
	Entry dummy $_{rt-1}$			-0.186*** (0.063)
	R^2	0.08	0.06	0.07
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(across-carrier variation in average price)$_{rbt}$				
	Herfindahl index$_{rt}$	3.907** (1.688)		
	Number of competitors on the city-pair$_{rt}$		-0.037 (0.066)	
	Entry dummy$_{rt-1}$			-0.195*** (0.057)

[43] However, the main qualitative findings about the competition variables in Table 3.6 and 3.7do not change if Lufthansa and City airport are included.

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
	R^2	0.13	0.14	0.7
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(upper-bound price on the city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	3.739*** (0.764)		
	Number of competitors on the city-pair$_{rt}$		-0.077** (0.034)	
	Entry dummy$_{rt-1}$			-0.081* (0.038)
	R^2	0.09	0.09	0.07
	Prob>F	0.000	0.000	0.000
Ln(median price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	2.705*** (0.965)		
	Number of competitors on the city-pair$_{rt}$		-0.056*** (0.04)	
	Entry dummy$_{rt}$			-0.01 (0.026)
	R^2	0.06	0.07	0.04
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(average price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	3.064*** (0.653)		
	Number of competitors on the city-pair$_{rt}$		-0.081*** (0.021)	
	Entry dummy$_{rt-1}$			-0.05* (0.025)
	R^2	0.11	0.10	0.07
	Prob>F	0.000	0.000	0.000
	No of obs	2399	2399	2233

Note: robust standard errors clustered at city-pair level are in parentheses. Standard FE model. Other control variables are included in all regressions. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3.

The majority of the coefficients of competition proxies in Table 3.8 and Table 3.9 are both statistically and economically significant. For example, an increase in number of competitors on a city-pair is associated with 8-10 per cent fall in upper-bound prices and average prices, and 6-7.5 per cent fall in the median of prices. The result concerning the upper bound of airfares on a city-pair is in accordance with predictions from Melitz and Ottaviano (2008) and Syverson (2004b) concerning the truncation effects of competition on price distribution. The coefficients of competition proxies in the FE specification have expected signs. However, in the case of the simplest standard FE specification, only the route-level entry is the competition proxy that is statistically significantly related to lower across-airline price dispersion.

As can be seen from the comparison of these last two Tables, adding other control variables does change some of the coefficients' magnitudes. In the case of price dispersion measures as dependent variables, inclusion of other controls affects also the statistical significance of the estimates. The estimated 'effect' of change in Herfindahl index on productivity dispersion becomes larger and statistically significant only if other additional controls are included in the regression equation.

Notably, as can be seen from the R^2's of my regression analysis, competition proxies explain only a rather small share of the overall variation of airfare distribution moments. The R^2's in Table 3.8 have values between 0.04 and 0.12. The within-R^2's are in each estimated model, however, significantly larger than the overall R^2's shown in Tables 3.8 and 3.9.

The small values of R^2's may be not too surprising. These indicate that there are many unobserved factors affecting the across-airline differences in airfares. These results are also not too surprising if compared to a related study by Syverson (2007) about the effects of product substitutability on output price distribution. He studied across-producer output price distribution in the ready-mixed concrete sector in the US. In his regression analysis of effects of market demand density on across-producer price dispersion, Syverson (2007, page 211) reports very low R^2's that lie between 0.000 and 0.121.

I conduct several checks of the robustness of my results. My findings that I have presented here are based on city-pairs that had at least 3 active airlines flying on them. However, I checked these results also by including the city-pairs with just 2 competitors. In this case, the effects on price dispersion are significantly smaller than in Tables 3.8 and 3.9 and sometimes not significant. The truncation of price distribution from above due to tougher competition seems to be taking place, for quite obvious reasons, more for these city-pairs that have at least 3 different competitors.

As an additional robustness check I estimate also the Plümper and Troeger (2007a, 2007b) 3-stage FE model. The outline of this method and the results are given in Annex 3.5 and 3.6.

My main finding based on the 3-stage FE model is that the coefficients of main control variables are similar to these in the standard FE specification. More competition is associated with lower price dispersion, lower maximal airfares and lower median or average airfares within a city-pair.

Some further robustness tests tend to confirm these findings (see Annex 3.6). Based on the 3-stage FE specification, I conduct three additional robustness tests by:

i) use of quarterly data instead of monthly data;
ii) using data of morning flights (departing from 9 am to 12 noon) only;
iii) using data from a shorter time period (2003-2004).

These are summarized in Annex 3.6. These results again show that increase in competition within a city-pair market is associated with lower price dispersion, upper-bound prices and average prices within that market.

As an additional robustness check I have also investigated the correlation between market size and airfares. According to Melitz and Ottaviano (2008) we would expect larger market size[44] (i.e. larger number of potential passengers) to be associated with tougher competition and thus lower cost and price dispersion across firms. This implication can be derived from Equation (3.13). Based on Equation (3.13) we can

[44] In Melitz and Ottaviano (2008) the market size is measured by change n number of consumers (L), in Syverson the effects of market demand is measured bases on number of consumers per geographic size of the market.

conclude that, the derivative dc^*/dL has a negative sign. Higher market size (L) results in lower survival cost cut-off (c^*), and therefore also lower cost and price dispersion on a larger market.

A related implication is based on Syverson (2004a) who develops a heterogeneous producer version that extends the standard Salop's circular market model of competition. An implication from his model—see Annex 3.1 for an outline of these effects—is that higher demand density is associated with lower upper bound prices and lower price dispersion across producers on a market.

However, the results in Table A3.8 in Annex 3.7 provide no strong support for these predictions. Larger market size on a city-pair, as measured by number of passengers, is associated with lower average price level on that city-pair. At the same time, it is not associated with lower airfare dispersion. The coefficient of market size (number of passengers) in a model with upper-bound price level as dependent variable is as predicted by Melitz and Ottaviano (2008) or Syverson (2004a) models, but it is not statistically significant at conventional significance levels. Also, one has to stress that the FE specification in Table A3.8 does not account for likely endogeneity of market size. This is very likely to bias the estimated effects of change in market size.

The results concerning the 'effects' of time-invariant variables in the 3-stage FE model are mostly as expected. As indicated earlier by Piga and Bachis (2007), I find also in the 3-stage FE model that the average and median price on a city-pair falls monotonically with an increase in the days between the booking day and departure. This tendency holds also in the case of the 'upper-bound' airfares on a city-pair.

On average, the city-pair upper-bound, median and average airfares are higher in South and Central England than in North England or Scotland. Price dispersion is the highest on city-pairs originating from Southern and Central England. I find also a small positive 'effect' of an increase in number of UK airports serving the destination city on the airfare distribution moments. I.e. increase in popularity of the destination is positively related to average and median price, upper-bound price level and across-airline price dispersion on a city-pair.

3.7.2 Robustness checks: Dynamic (system)-GMM approach

There are several problems in estimating the relationship between competition and airfare distribution with fixed effects specification. Although the FE model allows for fixed city-pair specific effects in Equation (3.14), it does not treat competition related and other control variables as endogenous. FE model is appropriate if one believes that the number of competitors, entry of airlines, etc, are strictly exogenous, and that they do not depend on airfares on the city-pair. Also, FE model is only appropriate if the part of the error term (in Equation 3.14) that is correlated with right-hand side variables can be included as a fixed effect.

If this is not the case, then FE method does not identify the causal effects of an increase in competition on moments of price distribution. It shows simply the correlation between some proxies of competition and moments of price distribution. A solution would be to use external or internal (e.g. lags of endogenous variables) instrumental variables.

Potential solutions (with their own pitfalls) to both the endogeneity problem, omitted variable bias and to a lack of good external instruments, that are often used to conclude a bit more about the causal effects, are either the difference or system GMM (Arellano and Bond 1991, Blundell and Bond 1998, Roodman 2009a, Roodman 2009b). These two estimators allow us to treat some right-hand-side variables as potentially endogenous. They use appropriate lagged levels and/or differences of the dependent variable and of the independent variables as internal instrumental variables.

The GMM methods also allow for cross-section specific fixed effects and enable the researcher at the same time to account for heteroscedasticity and autocorrelation problems and omitted variable bias. Note that when I use (the one step) GMM[45], the Equation (3.14) is now estimated in its dynamic version, with lagged dependent variable included among the explanatory variables:

$$y_{rbt} = \alpha_r + \lambda_b + \tau_t + \lambda y_{rbt-1} + E'_{rt}\beta + X'_{rbt}\gamma + \varepsilon_{rbt} \,. \qquad (3.15)$$

As system GMM uses more instruments than the difference GMM there are some important problems related to using it with a dataset that has a relatively small number of groups (i.e. city-pairs in our case) and relatively large number of periods. In this monthly dataset, the number of periods (T) is 27 in the regression analysis. However, the GMM estimators are designed especially for panels with relatively short time dimensions, and by default they generate instruments sets whose number grows quadratically in T (Roodman 2009a, 2009b[46]). In that case the instruments can overfit endogenous variables, failing to exclude their endogenous components and biasing coefficient estimates. Meanwhile, they can degrade the usability of the Hansen J test for joint validity test of those instruments (Roodman 2009b). Therefore, I keep the overall number of instruments (lagged levels and differences of dependent variable, competition related endogenous variables, number of flights) smaller than the

[45] The system GMM (Blundell and Bond 1998) is an extension of Arellano-Bond difference GMM model. As it is considered to be superior to difference GMM method in terms of efficiency, I use here the system GMM approach. It has been also pointed out that the difference GMM suffers often from weak instrumentation (Blundell and Bond 1998, Roodman 2009a).
I report the one-step system GMM estimators' results (accounting also for heteroscedasticity and autocorrelation) of estimating (3.15), as the standard errors associated with the two-step estimators tend to be significantly downward biased, as noticed by Arellano and Bond (1991).

[46] E.g. if number of periods T = 3, difference GMM may generate only one instrument per instrumented variable, and system GMM only two. But as T grows the number of instrument can grow large relative to the sample size. Too many instruments can overfit endogenous variables and therefore fail to remove their endogenous components (Roodman 2009b).

number of groups.[47] This is the suggested rule-of-the thumb from the literature (Roodman 2009b).[48]

Competition proxies, total number of flights on the city-pair and price variables have been in each specification instrumented with lagged two and/or three periods. Hansen over-identifying test is not rejected, with a p-value at least as large as 0.1 in most specifications. The Arellano-Bond test for second order autocorrelation is accepted with a p-value greater than 0.1 in all but one specification. Based on these statistics, most of the empirical models in Table 3.10 seem to be correctly specified.[49]

Table 3.10. Summary table of the system GMM regression results—effects of competition on different moments of across-carrier price distribution

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(across-carrier variation in median price)$_{rbt}$				
	Herfindahl index	6.539*** (1.53)		
	Number of competitors on the city-pair		-0.169 (0.15)	
	Entry dummy			-0.311 (0.756)
	Period variables	YES	YES	YES
	Other control variables included	YES	YES	YES
	Hansen test of over-identification, p-value	0.161	0.421	0.544
	Arellano-Bond test for AR(1) in 1st differences, p-value	0.000	0.000	0.000
	Arellano-Bond test for AR(1) in 2nd differences, p-value	0.910	0.398	0.783
Ln(across-carrier variation in average price)$_{rbt}$				
	Herfindahl index	6.23*** (1.55)		
	Number of competitors on the city-pair		-0.125 (0.164)	
	Entry dummy			-0.28 (0.492)

[47] I use the *collapse* option in *xtabond2* command in Stata, and also limit the number of lags used, so not all possible lags are used.

[48] When the number of instruments is greater than the number of groups the Sargan/Hansen test may be weak and high p-value on the Hansen test might not in that case show the validity of the GMM results (Roodman 2009b).

[49] However, the results in Table 3.10 are indeed sensitive to how many lags are used. For example, the coefficient of Herfindahl index varies a lot depending on that.

	Period variables	YES	YES	YES
	Other control variables included	YES	YES	YES
	Hansen test of over-identification, p-value	0.185	0.193	0.205
	Arellano-Bond test for AR(1) in 1st differences, p-value	0.001	0.000	0.000
	Arellano-Bond test for AR(1) in 2nd differences, p-value	0.456	0.499	0.614
Dependent variable:	Regression statistic	Model 1	Model 2	Model 3
Ln(upper-bound price on the city-pair)$_{rbt}$				
	Herfindahl index	3.595*** (0.589)		
	Number of competitors on the city-pair		-0.137*** (0.042)	
	Entry dummy			-0.262 (0.17)
	Period variables	YES	YES	YES
	Other control variables included	YES	YES	YES
	Hansen test of over-identification, p-value	0.282	0.125	0.406
	Arellano-Bond test for AR(1) in 1st differences, p-value	0.000	0.000	0.000
	Arellano-Bond test for AR(1) in 2nd differences, p-value	0.763	0.454	0.544
Ln(median price on city-pair)$_{rbt}$				
	Herfindahl index	1.235 (0.87)		
	Number of competitors on the city-pair		-0.048* (0.027)	
	Entry dummy			-0.01 (0.293)
	Period variables	YES	YES	YES
	Other control variables included	YES	YES	YES
	Hansen test of over-identification, p-value	0.237	0.226	0.265
	Arellano-Bond test for AR(1) in 1st differences, p-value	0.000	0.000	0.000
	Arellano-Bond test for AR(1) in 2nd differences, p-value	0.246	0.375	0.777
Dependent variable:	Regression statistic	Model 1	Model 2	Model 3
Ln(average price on city-pair)$_{rbt}$				
	Herfindahl index	2.771*** (0.42)		
	Number of competitors on the city-pair		-0.106*** (0.027)	
	Entry dummy			-0.181 (0.253)
	Period variables	YES	YES	YES
	Other control variables included	YES	YES	YES
	Hansen test of over-identification, p-value	0.1	0.04	0.199
	Arellano-Bond test for AR(1) in 1st differences, p-value	0.000	0.000	0.000
	Arellano-Bond test for AR(1) in 2nd differences, p-value	0.122	0.26	0.791
	No of obs	2233	2233	1671

Notes: Robust standard errors clustered at city-pair level are in parentheses. Other control variables (except time invariant variables) are included in these regressions. All regressions include time dummies. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level.
These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3. The equations are estimated using the dynamic panel data model based on Blundell and Bond (1998). The GMM estimates reported are one-step results. I collapsed the instruments to limit the instrument count (as suggested in Roodman 2009b for samples with relatively large T and relatively limited number of cross sections). This is available in the Stata command *xtabond2* (Roodman, 2009a). In all the reported specifications the count of instruments is smaller than the number of cross-section groups (citypair-booking scenario combinations).

Note, that the GMM results are qualitatively relatively similar to these with the FE models in previous tables. Accounting (to an extent) for endogeneity affects the estimated size of the effects of competition. Now, entry of airlines on routes within a city-pair has a negative, but not significant, effect on both across-carrier price variation measures used. However, the fall in Herfindahl index (i.e. increase in competition) within a city-pair is associated with a fall in price dispersion. The coefficient of Herfindahl index is statistically significant, also if the robust and clustered standard errors are used. Herfindahl index and number of competitors on a city-pair have still the expected and significant effects on the upper-bound airfares on a city-pair market. Both the fall in Herfindahl concentration index and an increase in number of competitors appear to result in lower average and upper-bound of airfares. The magnitude of these effects is different from the FE model (see also Table 3.9). Notably, whereas the entry at route level within a city-pair has the same sign as in the FE model, this ‘effect’ on different moments of airfare distribution is not any more statistically significant at conventional significance levels.

In general, also the results of the GMM model are broadly consistent with implications from heterogenous producer models of competition. Tougher competition tends to be associated with lower upper-bound of airfares. However, the significance of the results depends on the choice of proxy of changes in competition.

3.8 Conclusions

This paper studies the relationship between competition and price distribution, endeavouring to explain the persistent across-firm price variation within separate markets of a single industry. For that I use a case study of the European airline sector – flights between UK and Ireland, Belgium and Ireland. The paper concentrates on the effects of competition-driven selection process among airlines operating on each city-pair (i.e. the reallocation effects across firms within the sector), resulting in effects on price distributions of airlines. These effects are outlined in recent heterogeneous producer competition models (incl. Melitz and Ottaviano 2008, Syverson 2004a).

Based on a unique airfare dataset, I find some evidence that tougher competition on a city-pair is associated with truncation of across-firm price distribution from above. I show that tougher competition tends to be associated with lower 'upper-bound' of prices on a city-pair, and also lower average airfares and less price variation on a city-pair. The results found are broadly consistent with implications of Melitz and Ottaviano (2008) or Syverson (2004a). These results based on price data may give us information about the effects of competition on productivity or cost distribution of firms on different spatial markets (city-pairs). The (average) prices that airlines charge function in this case study to some extent as a proxy for costs or (inverse of) productivity of firms on different spatial markets. The findings about competition lowering the price dispersion and upper-bound prices within-city-pairs can possibly be due to similar effects on cost and productivity distribution. They can appear due to competition-induced selection process lowering the cost and productivity dispersion and lowering the upper-bound cost level (i.e. increasing the lower-bound of productivity distribution) of firms in separate city-pair markets.

Note that our results are related to these of Syverson (2007) who studied the effects of changes in product substitutability and demand density among ready-mixed concrete plants in the US. Our results show that these non-trivial effects of competition (product substitutability) on price distribution can be more general. These are likely to exist also in a service sector that has relatively small number of competitors, and are not specific only to the ready-mixed concrete production.

It should be stressed, though, that the aviation sector has a small number of competitors on each market (city-pair). Hence, the effects of strategic interactions (which are not covered in the models studied here) between airlines cannot be ruled out. Strategic interactions on participants in an oligopolistic market may affect the different moments of across-airline price dispersion on a city-pair. An extension of this study could be testing the implications from recent heterogeneous producer competition models in a cleaner research environment where one can more credibly identify the causal effects and separate fully the different channels of the effects: i.e. a study based on natural experiment framework.

Another caveat in the analysis is that the flights of different airlines on the same city-pair may be not as good substitutes for each other as assumed in this chapter. Then, one would need to use 'quality-adjusted' prices for each airline in similar analysis, in order to account for quality and service differences across airlines. For that, one would need a lot of detailed and accurate route and airline level data about quality of service. As my results showed, differences in competition explain only a small share in variation of airfares across airlines on a city-pair. Heterogeneity of service (incl. unobserved heterogeneity) is still a likely explanatory factor of large share of these differences.

Annex 3.1: Heterogeneous cost version of Salop (1979) competition model: implications about the effects of market size and market demand density on output price distribution

Hypotheses regarding the role of the size of market demand and spatial competition in shaping the across-firm output price distribution can be derived based on Syverson's (2004a) heterogeneous cost version of Salop's (1979) spatial competition model.[50] Notably, the mechanism that brings about entry of additional firms and increase in producer substitutability is different in Syverson (2004a) compared to the Melitz and Ottaviano (2008) framework.

In Syverson (2004a), the producer substitutability increase is brought about by a specific mechanism, by an increase in market demand (and as the size of market area is fixed in his model, by an increase in demand density). The particular comparative static of interest is different in the Melitz and Ottaviano (2008) and Syverson (2004b) models. The comparative static of interest in the Melitz and Ottaviano (2008) model was $dc^*/d\gamma$, the change in survival cost cut off due to change in product substitutability parameter (γ).

In Syverson (2004a) the comparative static of interest is dc^*/dD, the change in market demand. A rise in market demand will raise the expected value of entry into the market, which then will increase the number of producers willing to cover the entry cost to the market. Increase in entry and number of competitors will raise the producer substitution possibilities for consumers on the market and, hence, will make the

[50] Homogeneous producer versions of spatial competition models, or their multi-flight extensions, are often used in IO papers studying the effects of liberalisation in airlines sector. For example, in Schipper et al. (2007), Carlsson (2004).

survival of high-cost (and high-price) producers more difficult (i.e. it lowers the producers' survival cost cut-off c^* on the market).

Hypotheses regarding the role of market demand (per market area) from the heterogeneous costs extension of Salop model by Syverson (2004a):

Hypothesis 1. Larger market demand results (via increase in substitutability between carriers) in lower average airfares on a given route.

Hypothesis 2. Larger market demand results (via increase in substitutability between carriers) in lower upper-bound of price distribution on a given route.

Hypothesis 3. Larger market demand results (via increase in substitutability between carriers) in lower price variation across carriers on a given route.[51]

In the Syverson (2004a) model, entry of carriers depends on the expected value of entry. The expected value of entry will be higher in routes where the demand density is higher.

The Syverson (2004a) model includes two stage entry and production decision of producers that have heterogeneous costs and the consumers choosing among the differentiated products –e.g. a flight on a given time in, for example, 24-hour interval.

Consumers are identical, except (in our case) for their preferences about departure time, and are in terms of their preferred departure times evenly distributed around a circular market, a time interval. This circle time interval has unit circumference with density of D consumers per unit length of the interval (e.g., per one day).

[51] Obviously, Hypotheses 2 and 3 can be studied only in routes where there was initially more than one carrier.

The departure times of flights are located on this circular time interval and spaced in equal time distance from each other. The headway between each flight is equal to the length of the market divided by the total number of flights offered in the market.

Consumer derives gross utility $\bar{v}$ from taking the trip, and faces a price p_i. He suffers disutility tx if he has to choose a departure time (or alternatively: an arrival time) that is different from his ideal time. Here, x is difference between consumer's ideal and the actual departure time. The disutility increases linearly in x. The price that each consumer faces, is thus equal to the airline price p plus disutility from delaying his flight, that is: $p^{'} = p + tx$.

The supply side is modeled here as a two-stage simultaneous entry game, where at first (initially similar) potential entrants consider the entry decision. If they enter the market, a sunk cost s has to be paid. These who choose to enter, receive each an individual marginal cost c_i from a distribution of marginal cost $g(c)$ within the limits of [0, c_M], where c_M is the upper bound of cost distribution. The ones that enter the market observe their own cost, but not that of others. Then in the following stage the airlines that entered decide whether or not to start the 'production' (given the expected number and costs of their competitors). The airlines will face a common fixed cost of production f (also a sunk cost). After paying it they will receive a place, randomly at evenly spaced locations on this circle (the circle has circumference equal to 1, thus distance between producers is $1/n$), and set their 'factory price' p_i. Then the consumers make their buying decisions based on $p^{'}$.

We will examine equilibria where there will be a consumer between any two neighboring airlines that is indifferent between buying from either of the two. The location of that indifferent consumer depends on the prices p_i, p_j and his disutility tx.

For any two neighboring airlines *i* and *j*, the indifferent consumer will be at distance $x_{i,j}$ from plant *i*, where $x_{i,j}$ solves the equality condition (3.16) of prices of these two producers at the 'doorstep' of the consumer.

$$p_i + tx_{i,j} = p_j + t\left(\frac{1}{n} - x_{i,j}\right) \tag{3.16}$$

Equation (3.16) can be solved for $x_{i,j}$ - the 'address' of consumer's indifference between two adjacent airlines in terms of their departure times.

Any consumer on the line between *i* and *j*, who is closer to carrier *i* than $x_{i,j}$ purchases from *i*. If he buys at all, i.e. if his net utility from buying is larger than 0. The consumers that are further away, buy from *j*. If we assume that all customers have net utility from buying the ticket larger than 0, then total quantity sold by airline *i* between competitors *j* and *k* is $(x_{i,j} + x_{i,k})D$, its market share is thus $(x_{i,j} + x_{i,k})$.

Assuming that firms do not know others' costs, $E(x_{i,j}) = E(x_{i,k})$, and this coupled with solving (3.16) for $x_{i,j}$ yields:

$$E(x_{i,j}) = E(x_{i,k}) = E(x_i) = \frac{E(p) - p_i}{2t} + \frac{1}{2}E\left(\frac{1}{n}\right). \tag{3.17}$$

Here *E(p)* is the expected price charged by other firms. The expected profit of an airline *i* is thus given simply as:

$$E(\pi_i) = 2E(x_i)(p_i - c_i)D - f = \left[\frac{E(p) - p_i}{t} + E\left(\frac{1}{n}\right)\right](p_i - c_i)D - f. \tag{3.18}$$

Each carrier chooses its price p_i to maximise its own (expected) profits. Taking the first order condition of (3.18) with respect to price p_i gives us the optimal price for plant i:

$$p_i = \frac{1}{2}c_i + \frac{1}{2}E(p) + \frac{t}{2}E\left(\frac{1}{n}\right). \tag{3.19}$$

Thus an airline's optimal price on a route is increasing in expected price charged by its competitors, customers disutility coefficient t from having to delay their flight, and its own marginal cost.

From equation (3.19) we can then take expectations and compute the competitors expected prices as a function of the expected costs and equilibrium number of competitors:

$$E(p) = E(c) + tE\left(\frac{1}{n}\right). \tag{3.20}$$

Then substituting (3.19) and (3.20) into the expected profit function (3.18) gives us the mark-ups per unit (3.21), and expected profits (3.22) in terms of producers own cost, expected cost of other producers and the expected number of producers in the market:

$$p_i - c_i = \frac{1}{2}E(c) + \frac{t}{2}E\left(\frac{1}{n}\right) - \frac{1}{2}c_i, \tag{3.21}$$

$$E(\pi_i) = \frac{D}{4t}\left[E(c) + 2tE\left(\frac{1}{n}\right) - c_i\right]^2 - f. \tag{3.22}$$

The survival cut-off cost c^* (i.e. firms with $c_i > c^*$ decide not to produce as it is not profitable, and exit) can be found from the zero expected profit condition, setting (3.22) equal with 0:

$$E(\pi_i) = 0 \Rightarrow c^* = E(c) + 2tE\left(\frac{1}{n}\right) - \sqrt{\frac{4tf}{D}}. \qquad (3.23)$$

Cut-off cost is higher the smaller is the expected number of competitors.

As the next step, the maximized operating profits are found as a function of parameters, the cut-off cost c^* and producers own cost (by substituting (3.23) into (3.22)):

$$E(\pi_i \middle| c_i \leq c^*) = \frac{D}{4t}\left(c^* - c_i + \sqrt{\frac{4tf}{D}}\right)^2 - f. \qquad (3.24)$$

Only these producers that get marginal cost level resulting in positive profits (i.e., $c \leq c^*$) choose to service the route in equilibrium. Others do not; they do not earn operating profits and lose their sunk cost. Thus this means that the expected payoff from paying s is the expectation of (3.24) over cost distribution $g(c)$, conditional upon drawing $c \leq c^*$. This expected payoff is affected by the cut-off cost level c^*. Free possible entry of plants results in the following (Syverson 2004a): the equilibrium c^* must set the net expected value of entry into the industry, V^e, equal to zero. Here V^e is equal to expected operating profits before getting to know one's own marginal cost minus the sunk entry cost. Thus c^* solves:

$$V^e = \int_0^{c^*} \left[\frac{D}{4t}\left(c^* - c + \sqrt{\frac{4tf}{D}}\right)^2 - f\right] g(c)dc - s = 0. \qquad (3.25)$$

Note that the expected value of entry depends on demand density D in the market, i.e. the number of potential customers in a given time interval. It also depends on sunk costs of entry s, so if entry gets easier (s gets smaller), then V^e gets larger.

Comparative Statics of Changes in Demand Density

We are interested in the sign of derivative *dc*/dD*. That is, how the change in demand density affects the cut-off cost level *c** (i.e. the upper bound of costs of the producers). This derivative can show also the effects on survival price cut-off of the price distribution.

By applying the implicit function theorem to Equation (3.25) we can write:

$$\frac{dc^*}{dD} = \frac{-(\partial V^e / \partial D)}{\partial V^e / \partial c^*}. \qquad (3.26)$$

The negative of the numerator in (3.26) is, after simplification:

$$\frac{\partial V^e}{\partial D} = \int_0^{c^*} \left[\frac{1}{4t}(c^* - c)^2 + \frac{1}{4t}(c^* - c)\sqrt{\frac{4tf}{D}} \right] g(c)dc > 0 \ , \qquad (3.27)$$

and it is positive.

The denominator in (3.26) is, after simplification:

$$\frac{\partial V^e}{\partial c^*} = \int_0^{c^*} \frac{D}{2t}\left(c^* - c + \sqrt{\frac{4tf}{D}} \right) g(c)dc > 0, \qquad (3.28)$$

which is also positive.

Thus $dc^*/dD < 0$, and *c**, the cut-off level of the producer's cost distribution decreases as demand density increases. This has implications for both cost and output price distribution across producers on the market. High cost, and thus also high prices are not sustainable in the dense market environment.

The truncation of the cost distribution from above means also truncation of the output price distribution from above. Thus in denser markets the average and upper bound output price levels are lower than in markets with less market density. When market density is low, inefficient producers are protected from rivalry from lower-cost and low-price competitors and can operate profitably in equilibrium.

The higher demand density makes it tougher for high-cost firms to survive, because increase in market demand induces additional entry of producers and, thus, consumers on the market can find lower cost substitutes of the product more easily than before. This increase in substitutability between producers will lower the survival cost and price cut-offs, resulting in the truncation of cost and price distributions from above.

The main intuition behind the main result ($dc^*/dD < 0$) is that an increase in demand density (D) raises the expected value of entry V^e, this induces entry of new carriers into the route, increasing substitutability between airlines, i.e. competition gets tougher, and resulting in a fall in the survival cost cut-off c^*. High-cost/high-price airlines find it now more difficult to hold their customers. This cost-based selection process eliminates relatively high-cost (inefficient) carriers from the market, truncating both the equilibrium production-cost distribution and equilibrium price distribution from above. This means lower average price, less price variation across carriers and lower upper bound of the price distribution on a given route.

Annex 3.2: Routes within the 3 largest city-pairs

Table A3.1. Routes within the 3 largest city-pairs

City-pair	London-Amsterdam	London-Brussels	London-Dublin
Routes within the city-pair	London City – Amsterdam London Gatwick – Amsterdam London Heathrow – Amsterdam London Luton – Amsterdam Stansted – Amsterdam London City – Rotterdam Southend – Rotterdam London Gatwick – Rotterdam Heathrow – Rotterdam Stansted – Rotterdam	Gatwick – Brussels Heathrow – Brussels Stansted – Ostend Stansted – Charleroi Stansted – Maastricht London City – Antwerp London City – Brussels Stansted – Brussels Heathrow – Maastricht	London City – Dublin Gatwick- Dublin Heathrow – Dublin Stansted – Dublin Luton – Dublin

Note: routes serviced during 2003-2005.

Defining the overlap of routes

In its 2002 RASCO survey the UK Department for Transportation (DfT) has conducted analysis about the size of catchment areas of UK airports (RASCO 2002). This survey includes, among other issues, also some information about the overlap of catchment areas of airports in UK in year 2000. It provides some catchment area maps, produced using the DfT's National Airport Accessibility Model (NAAM) and published in the annex of 'Catchment Analysis' of the 2002 survey:

These maps of catchment areas show, separately for each UK airport, the geographic location of the modelled demand in the UK– in terms of number of trips to the airport from different CAA planning regions. Also, these maps indicate which regions are one and two-hour trip away from the airport. These maps enable to get a general overview which airports are broad substitutes for each other and which are not.

In DfT's approach, the 'catchment area' is calculated as the area within either:

1) an average one-hour, or
2) an average two-hour travel time radius.

Annex 3.3: Entry and exit on routes in the 3 largest city-pairs

Table A3.2. Entry and exit on routes in the largest 3 city-pairs

	Number and names of entrants			**Number and names of exiters**		
Period:	**London-Amsterdam area**	**London-Brussels area**	**London-Dublin**	**London-Amsterdam area**	**London-Brussels area**	**London-Dublin**
July-Dec 2002	**3 entries**: (**<u>Easyjet</u>, KLM, KLM**)		**1 entry:** (**Aer Lingus**)	**2 exits:** (TTA, **VLM**)	**1 exit:** (Virgin)	
Jan–June 2003	**2 entries:** (**KLM**, <u>Transavia</u>)	**1 entry:** (**<u>Ryanair</u>**)		**1 'exit' due to merger:** (**<u>Buzz</u>**)	**1 exit:** (**KLM**)	
July-Dec 2003	**1 entry:** (**BA**)	**2 entries:** (**BA**, SN Brussels)	**3 entries:** (**Aer Lingus**, Cityjet, Cityjet)	**1 exit:** (<u>City Flyer</u>)	**3 exits:** (<u>City Flyer</u>, United Airlines, **VLM**)	**3 exits:** (<u>City Flyer</u>, **Aer Lingus, Aer Lingus**)
Jan–June 2004	**1 entry:** (<u>Transavia</u>)	(1 entry: Cyprus Airways*)	**2 entries:** (**BMI/** <u>Bmibaby</u>, **BMI/** <u>Bmibaby</u>)	**1 exit:** (<u>Transavia</u>)	**5 exits:** (**<u>Ryanair</u>, VLM, <u>Ryanair</u>, VLM, Cyprus Airways**)	**1 exit:** (<u>Air Luxor</u>)
July-Dec 2004	**1 entry:** (**KLM**)		**1 entry:** (<u>EUJET</u>)		**2 exits:** (**<u>Ryanair</u>, BA**)	
Jan–June 2005	**4 entries:** (**KLM, VLM, VLM, KLM**)	**1 entry:** (<u>Air Exel</u>)		**5 exits:** (<u>EUJET</u>, **KLM, KLM, VLM**, United Airlines)	**1 exit:** (<u>Air Exel</u>)	**3 exits:** (Cityjet, <u>EUJET</u>, **Aer Lingus**)

Note: 'entry' is defined as a first scheduled operation of an airline on an airport-pair (i.e. on a route). The number of entries (exits) during a period on a city-pair, is simply the sum of entries (exits) on different routes belonging to that city-pair.
Entries and exits of relatively large carriers are given in bold script.
Names of low-cost-carriers are underlined.
City Flyer is owned by British Airways, CityJet is subsidiary of Air France. Eujet ceased all its operations in June 2005. *Cyprus Airways is in codeshare with Belgian Airlines (earlier SN Brussels).

Annex 3.4: Descriptive statistics

Table A3.3. Descriptive statistics

Variable	Mean	Std. Dev	Min	Max
Log (average price)	3.996	0.541	2.842	6.052
Log (median price)	3.888	0.577	2.595	6.167
Log (across carrier price variation 1)*	3.588	1.220	0	5.952433
Log (across carrier price variation 2)**	3.583	1.173	0	6.075
Log (maxima of average price on a city-pair)*	4.235	0.584	2.959	6.052
Log (maxima of average price on a city-pair)**	4.145	0.619	2.646	6.170
Number of airports serving the destination	20.720	6.601	1	30
Entry dummy	0.147	0.354	0	1
Exit dummy	0.152	0.359	0	1
Log (number of passengers on a city-pair)	11.07	0.995	8.231	12.967
Number of competitors on a city-pair	3.808	1.362	3	10
H-index (based on number of passengers)	0.427	0.118	0.198	0.732
H-index (based on number of flights)	0.380	0.097	0.186	0.699

Note: *calculated based on average price, **calculated based on median price. Descriptive statistics are given for these observations where the number of competitors on a city-pair is at least three)

Annex 3.5: Robustness checks I: three-stage FE regression results, coefficients of main competition proxies and other controls

As an additional robustness check I estimate the Plümper and Troeger (2007a, 2007b) 3-stage FE model. Unlike the standard FE model, the 3-stage FE model enables to estimate the effects of time-invariant and rarely time-varying control variables (e.g. booking scenario, country and region dummies, etc). For estimating this 3-stage FE model I use a user-written procedure *xtfevd*, developed by Plümper and Troeger (2007a, 2007b).

The main idea of the Plümper and Troeger (2007a, 2007b) 3-stage FE model (*xtfevd*) is similar to an earlier method developed by Oaxaca and Geisler (2003). *xtfevd* command in Stata estimates a three stage panel fixed effects vector decomposition model that allows for the inclusion of time-invariant variables and efficiently estimates almost time-invariant explanatory variables within a panel fixed effects framework. The first stage in this 3-stage FE estimation procedure estimates a pure fixed effects model to obtain an estimate of the unit effects. The second stage decomposes the fixed effects vector into a part that is explained by the time-invariant and almost time-invariant variables and an unexplainable part - the error term of the second stage. The third stage re-estimates the original model by pooled OLS, including the time-invariant variables and the error term of the second stage. This third step assures to control for collinearity between time-varying and invariant right hand side variables, and adjusts the degrees of freedom (Plümper and Troeger 2007a). For more discussion about the method see Plümper and Troeger (2007a) or Breusch *et al.* (2010).

Note that in the case of time-varying variables this estimator produces estimates that tend to be close to the classical fixed-effects estimates, i.e. compare Table A3.4 and Table 3.9. The majority of the results from the 3-stage FE are both statistically and economically significant. For example, an increase in number of competitors on a city-pair is associated with 8 per cent fall in upper-bound prices, 5.7 and 8.5 per cent fall in median price and average price. However, the route level entry indicators are not statistically significant.

Table A3.4. Summary table of the 3-stage FE regression results—effects of competition on different moments of across-carrier price distribution (with time-varying and time-invariant other controls included)

Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(across-carrier variation in median price)$_{rbt}$				
	Herfindahl index$_{rt}$	5.141*** (0.92)		
	Number of competitors on the city-pair$_{rt}$		-0.085** (0.028)	
	Entry dummy $_{rt-1}$			-0.126 (0.184)
	R^2	0.80	0.77	0.78
	Prob>F	0.000	0.000	0.000
Ln(across-carrier variation in average price)$_{rbt}$				
	Herfindahl index$_{rt}$	4.917*** (0.838)		
	Number of competitors on the city-pair$_{rt}$		-0.037 (0.059)	
	Entry dummy$_{rt-1}$			-0.193 (0.125)
	R^2	0.80	0.76	0.77
	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(upper-bound price on the city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	3.742* (2.163)		
	Number of competitors on the city-pair$_{rt}$		-0.077*** (0.011)	
	Entry dummy$_{rt-1}$			-0.05 (0.064)
	R^2	0.62	0.59	0.59

	Prob>F	0.000	0.000	0.000
Dependent variable	Regression statistic	Model 1	Model 2	Model 3
Ln(median price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	2.726** (1.276)		
	Number of competitors on the city-pair$_{rt}$		-0.056*** (0.008)	
	Entry dummy$_{rt-1}$			-0.01 (0.027)
	R^2	0.55	0.52	0.51
	Prob>F	0.000	0.000	0.000
Dependent variable:	Regression statistic	Model 1	Model 2	Model 3
Ln(average price on city-pair)$_{rbt}$				
	Herfindahl index$_{rt}$	3.074*** (0.904)		
	Number of competitors on the city-pair$_{rt}$		-0.082*** (0.005)	
	Entry dummy$_{rt-1}$			-0.052 (0.032)
	R^2	0.62	0.62	0.57
	Prob>F	0.000	0.000	0.000
	No of obs	2399	2399	2233

Note: robust standard errors clustered at city-pair level are in parentheses. 3-stage FE model. Other control variables are included in all regressions. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3.

As expected, also the 3-stage FE model shows that the average price on a city-pair falls monotonically with an increase in the days between the booking day of ticket and the departure. This holds also in the case of the ‘upper-bound’ airfares on a city-pair (see Table A.3.5).

On average, the city-pair upper-bound, median and average airfares are higher in South and Central England than in North England or Scotland. Price dispersion is the highest on city-pairs originating from Southern and Central England. I find also a small positive ‘effect’ of an increase in number of UK airports serving the destination city on some of the airfare distribution moments. I.e. increase in popularity of the destination is positively correlated with average and median price, and across-airline price dispersion on a city-pair.

Table A3.5. Coefficients of control variables in the three-stage FE regression—relationship between competition and different moments of across-carrier price distribution

	Dependent variable				
	(1)	(2)	(3)	(4)	(5)
	Ln(across-carrier variation in median price)	Ln(across-carrier variation in average price)	Ln(max. price)	Ln(median price)	Ln(average price)
Herfindahl index	5.141***	4.917***	3.742*	2.726**	3.074***
	(0.92)	(0.838)	(2.163)	(1.276)	(0.904)
Number of UK airports serving the destination	-0.009	0.043**	0.027	0.027*	0.021**
	(0.024)	(0.022)	(0.025)	(0.014)	(0.01)
Ln(number of flights on a city-pair)	-0.009	-0.029	-0.569	0.522	-0.563
	(0.6)	(0.621)	(0.411)	(0.403)	(0.356)
Ln(average seat capacity)	0.705***	0.746***	0.112	0.018	-0.016
	(0.265)	(0.223)	(0.577)	(0.339)	(0.241)
Dummies for UK departure/arrival regions (Central England is the comparison group):					
Northern England	-0.29	-0.275	-0.288***	-0.227	-0.255***
	(0.752)	(0.711)	(0.049)	(0.029)	(0.02)
Southern England	0.247	0.436	-0.029	0.117***	0.037***
	(0.287)	(0.273)	(0.019)	(0.011)	(0.01)
Scotland	-0.772***	-0.538***	-0.513***	-0.247***	-0.397***
	(0.18)	(0.17)	(0.011)	(0.007)	(0.005)
Booking scenario dummies:					
D_10 days before departure	-0.118***	-0.102**	-0.09***	-0.095***	-0.087***
	(0.045)	(0.042)	(0.002)	(0.002)	(0.01)
D_14 days before departure	-0.023	-0.039	-0.124***	-0.163***	-0.145***
	(0.041)	(0.038)	(0.003)	(0.002)	(0.001)
D_17 days before departure	-0.478***	-0.51***	0.2***	-0.126***	-0.133***
	(0.07)	(0.06)	(0.003)	(0.002)	(0.002)
D_21 days before departure	-0.154***	-0.166***	-0.221***	-0.273***	-0.241***
	(0.067)	(0.064)	(0.004)	(0.002)	(0.002)
D_28 days before departure	-0.253***	-0.369***	-0.31***	-0.334***	-0.312***
	(0.066)	(0.062)	(0.004)	(0.002)	(0.002)
D_35 days before departure	-0.205***	-0.193***	-0.305***	-0.333***	-0.314***
	(0.045)	(0.04)	(0.003)	(0.002)	(0.001)
D_42 days before departure	-0.307***	-0.316***	-0.361***	-0.368***	-0.353***
	(0.045)	(0.042)	(0.003)	(0.002)	(0.001)
D_49 days before departure	-0.263	-0.3***	-0.372***	-0.392***	-0.369***
	(0.055)	(0.052)	(0.003)	(0.002)	(0.001)
D_56 days before departure	-0.431***	-0.46***	-0.465***	-0.452***	-0.442***
	(0.092)	(0.089)	(0.005)	(0.003)	(0.002)
Country dummies (the comparison group is Netherlands):					
Belgium	1.20***	1.969***	0.579***	0.306***	0.284***
	(0.314)	(0.293)	(0.02)	(0.012)	(0.009)
Ireland	2.21***	2.015***	0.231***	-0.081***	-0.01
	(0.04)	(0.038)	(0.002)	(0.001)	(0.001)
R^2	0.80	0.80	0.62	0.55	0.62
Prob>F	0.00	0.00	0.00	0.00	0.00
No of Obs	2399	2399	2399	2399	2399

Note: robust standard errors clustered at city-pair level are in parentheses. 3-stage FE model. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3.

Annex 3.6: Robustness checks II

Some further robustness tests with the 3-stage FE model results tend to confirm our findings from Annex 3.5. I conduct three main types of robustness tests by:

i) use of quarterly data instead of monthly data;

ii) using data of morning flights (departing from 9 am to 12 noon) only;

iii) using data from a shorter time period (2003-2004).

These are summarized in the following Table A3.7. The majority of results confirm the findings from the regression table sin this chapter.

The first robustness test uses quarterly data instead of monthly data. One problem in previous Sections of this chapter might be that the results are based on monthly information. This means that we are considering relatively short-term effects. The effects on equilibrium productivity and prices in the Melitz and Ottaviano (2008), however, may need some time to materialise. Therefore it is crucial to test our findings based on more aggregate time periods.

Note from Table A3.7 that most of the results based on quarterly data are statistically significant and have similar sign as based on the monthly dataset. The magnitude of these effects can, however, vary somewhat from these estimated in Annex 3.5.

Also, it may be reasonable to assume that an early morning flight on the same day and a late evening flight are not always substitutes for each other. Therefore, next I concentrate on only morning flights departing between 9 am and 12 noon and exclude all other flights from analysis. This way I am comparing more comparable products across different airlines. Again, the results are relatively similar to the benchmark in Annex 3.5.

Finally, I test whether the findings are driven by our choice of the particular time period of study—from April 2003 to August 2005. Therefore, I drop all observations from, alternatively, year 2005 or year 2003 and run the same regressions again. If I exclude year 2005 from analysis, then the coefficient of Herfindahl index is significantly smaller than in the case of the whole period. Also, it is not significant if airfare dispersion is the dependent variable. I.e. the effect of change in concentration is, for example, in the case of price dispersion measures about 40-50 per cent lower. The same tendency of smaller effect is evident also in the case of some other moments of price distribution and other competition proxies.

Table A3.7. Robustness checks of results of 3-stage FE model: coefficients of proxies of competition

Dependent variable (in logs)	Competition proxy	Specification (FE) 2003-2005	2003-2004	Quarterly data, 2003-2005	Morning flights (2003-2004)
Price dispersion 1	Herfindahl index	5.141***	3.072	5.323**	5.628
Price dispersion 1	No. of competitors	-0.085	0.022	-0.105	-0.118
Price dispersion 2	Herfindahl index	4.917***	2.624	5.636**	5.114
Price dispersion 2	No. of competitors	-0.037	-0.034	-0.146	-0.079
Upper bound price	Herfindahl index	3.742*	2.935*	3.715**	3.635***
Upper bound price	No. of competitors	-0.077***	-0.039***	-0.111**	-0.071***
Median price	Herfindahl index	2.726**	0.621	2.921	1.474
Median price	No. of competitors	-0.056***	-0.016***	-0.086*	-0.006*
Average price	Herfindahl index	3.074***	1.8***	3.016***	2.121**
Average price	No. of competitors	-0.082***	-0.029***	-0.113***	-0.031***

Note: regression coefficients are from the 3-stage FE model, heteroscedasticity robust standard errors clustered at city-pair level were used. Other time-varying and time-invariant controls, as described in Section 3.7.1, are included in all regressions. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3. Price dispersion 1 is calculated based on median airfares. Price dispersion 2 is calculated based on average airfares.

Annex 3.7: Robustness checks III: correlation between market size and moments of airfare distribution

Table A3.8. Relationship between number of passengers and different moments of across-carrier airfare distribution: standard FE model,

Dependent variable	Regression statistic	Coefficient
Ln(across-carrier variation in median price)$_{rbt}$	Number of passengers$_{rt}$	0.379
		(0.253)
	Overall R^2	0.07
	Within-R^2	0.21
Ln(upper-bound price on the city-pair)$_{rbt}$	Number of passengers$_{rt}$	-0.117
		(0.124)
	Overall R^2	0.05
	Within-R^2	0.20
Ln(median price on city-pair)$_{rbt}$	Number of passengers$_{rt}$	-0.281***
		(0.105)
	Overall R^2	0.03
	Within-R^2	0.17
	No. of obs.	2399

Note: robust standard errors clustered at city-pair level are in parentheses. Standard FE model. Only period dummies and citypair-booking day fixed effects are included as additional controls in each model. * significant at 10 per cent; ** significant at 5 per cent; *** significant at 1 per cent level. These results are calculated for a sub-sample of observations where the number of airlines active on a city-pair is at least 3.

Chapter 4

Effects of Liberalisation on Airline Passenger Traffic: An Event Study of the Enlargement of the EU and the Single European Aviation Market

4.1 Introduction

How large is the increase in industry output, productivity or other performance measures after a liberalisation event in a sector, relative to the counterfactual case if no liberalisation took place? The evidence presented in the literature[52] about the effects of liberalisation in the aviation sector and elsewhere is often limited because it is difficult to find out, how the sector would have developed in the absence of these changes.

This chapter provides an empirical assessment of the economic effects of deregulation of the aviation sector, based on an event study of the enlargement of Single European Aviation Market (SEAM) and European Union (EU) in 2004. To my best knowledge, this is the first study of the effects of the SEAM enlargement in 2004 on economic performance of the airline sector. It employs a recently developed extension to the difference-in-differences method (by Abadie *et al.* 2009).

[52] For example: Borenstein (1989), Dresner and Tretheway (1992), Gonenc and Nicoletti (2000), Marin (1995), Martin *et al*. (2005), Schipper *et al*. (2002), Ng and Seabright (2001).

I use volume of passenger traffic and revenue passenger kilometres (RPK, i.e. number of paying passengers*kilometres flown) on a country-pair or route as outcome variables to measure these economic effects. These two are standard output measures of the airline sector. The main reason why I use traffic as a proxy for economic performance of the sector is the availability of data. In the case of traffic figures one can employ a large dataset that has large number of observations and covers both pre- and post-2004 period.

The main finding is that after the enlargement of the SEAM, already by the end of 2004, passenger flows on affected routes grew 80-106 per cent relative to what these would have been in the absence of the enlargement.[53] This gap widens rapidly further in the following years. There is also some evidence that the effects of liberalisation in 2004 on air traffic, in percentage growth terms, are larger than the immediate effects of the 1992 large-scale deregulation of aviation sector in Western Europe.[54]

The passenger aviation industry in Europe is a particularly suitable sector for studying the effects of the changes in the competitive environment of the firms. It has witnessed large regulatory changes—in Western Europe in 1992 (and 1997) and in Central and Eastern Europe (CEE) in 2004. The liberalised aviation markets in the EU and US are in fact big exceptions in the world. According to Pearce and Smyth (2007), only 17 per cent of international air traffic in the world is conducted in liberalised environment.

[53] Use of RPK as an output measure shows similar large effects. Alternatively, use of number of competitors on a country-pair as a dependent variable shows similar large effects.

[54] The immediate effects of liberalisation in 2004 on percentage growth of number of passengers and flights are much larger than some simple estimates (found using the standard least squares regression approach) from earlier literature about the effect of the 1992 deregulation event in Western Europe on number of flights (e.g. in Schipper *et al*. 2002). However, my results and Schipper *et al*. (2002) coefficients from simple regression analysis are not directly comparable. So, it cannot be determined here exactly by how much the effects in CEE in 2004 were larger than in Western Europe in 1992.

In terms of the size of the population, the eastern enlargement in 2004 has been the largest enlargement of the EU so far. The 8 new members[55] from the CEE that entered in 2004 were Poland, Czech Republic, Hungary, Slovenia, Slovakia, Estonia, Latvia, and Lithuania. For the passenger aviation sector in these countries the enlargement of the SEAM (at the same time with the overall EU enlargement) meant a significant change in the competitive environment. Entry of airlines to routes connecting the affected CEE countries with Western Europe became much easier than before.

However, identification of the effects of the enlargement of the SEAM is a difficult task. One standard approach would be to implement the before-after analysis based on the time series of only the affected country-pairs or routes. Another approach would concentrate on the analysis of cross-section of country-pairs. Both suffer from a number of econometric problems.

Time series analysis of affected routes would ignore the construction of a suitable control group of 'untreated' country-pairs and routes. It is also complicated by a number of other changes taking place at the same time due to the overall enlargement of the EU. The EU enlargement was also a positive demand shock for the airline industry. It meant introduction of visa-free movement of people from the CEE and potential positive effects on GDP growth and growth of trade with the EU countries. In the case of some 'old' EU countries (e.g. UK, Ireland, Sweden) it meant also opening of the labour market for people from new members. All this increased the demand for passenger air transport in 2004 and the following years.

Also, new members of the EU and SEAM differed in 2004 from old members in terms of their determinants of passenger traffic growth. Therefore, a simple comparison of post-2004 dynamics of passenger traffic in the new and an average of the old

[55] In addition to these, also Malta and Cyprus entered the EU in 2004.

members would show not only the impact of enlargement of the EU (demand shock) and SEAM, but also the effect of pre-2004 differences in determinants of passenger traffic.

My identification approach relies, firstly, on building a suitable control group to proxy the counterfactual *"By how much would the volume of air travel to and from the CEE have grown in the absence of the EU and SEAM enlargements?"* For that I use difference-in-differences and its extension—the synthetic control method (as in Abadie *et al.* 2009). Based on the change in regulatory regime in May 2004 we can identify a treatment group and a control group of routes. The treatment group consists of routes or country-pairs connecting the CEE8 with Western Europe, and therefore affected by the change. The potential pool of control units can consist of routes or country-pairs within Western Europe.[56] These were not affected by the 2004 expansion of the SEAM.[57]

The synthetic control method (SCM) by Abadie *et al.* (2009) enables us to include the possibility of non-parallel trends of the treated group and the control group of country-pairs. It accounts for the time-varying unobservable country-pair characteristics which are ignored by the standard estimation methods. The main idea of the synthetic control approach is that a combination of control units can often provide a better comparison for the unit exposed to the intervention than any single unit alone. SCM provides a formal way to select a synthetic control for each treated unit. The synthetic control is a weighted average of control units that is most similar in terms of its pre-treatment trend to the treated unit.

[56] I.e., the EU and SEAM members before the 2004 accession round. The use of the non-EU European destinations as a control group is hindered here by the fact that the dynamics and scale of passenger traffic to the new EU members and to many of the outside-EU Eastern European countries is very different.

[57] There the deregulation of the sector had taken place already in 1992 and 1997.

Secondly, I check whether the results are different between scheduled flights and charter flights. The scheduled flights were affected by both the EU and the SEAM enlargement, charter flights only by the EU enlargement. This difference between the coverage of the effect of enlargement could possibly help us in determining the relative roles of the overall EU enlargement and the SEAM enlargement in growth of scheduled flights after May 2004.[58] It has to be acknowledged though, that this approach relies on a restrictive assumption that scheduled and chartered flights are affected similarly by the EU enlargement, and that in the absence of the enlargement these two types of flights would have followed similar trend over time.

Thirdly, I use differences in the country coverage of the EU and the SEAM to further study whether the effects are because of the EU enlargement or the liberalisation of the aviation sector. For that I study also the effect of Croatia's entering the European Common Aviation Area in 2006 (the SEAM was reorganised and renamed into ECAA in 2006). Croatia became a member of the SEAM in 2006 but not a member of the EU. That way I can in the case of the 2006 enlargement round concentrate more specifically on the effect of the SEAM, not on the combination of the effects of the SEAM and the overall EU enlargement as in the case of the 2004 enlargement round.

4.2 Literature review

The difference-in-differences (DID) approach is very popular in labour economics, starting from the seminal work by Ashenfelter and Card (1985). It has also been employed before to study the effects of regulatory change. One such recent example is by Symeonidis (2008), who examines the impact of competition on wages and

[58] Conditional on the assumption that in the absence of the 'treatment' in May 2004 the quantity of scheduled and charter passengers on routes to new member countries would have followed similar trend over time.

productivity using a 'natural experiment' created by the change in cartel laws in the UK in the 1950s. That change affected some industries but left others unaffected.

The SCM by Abadie *et al.* (2009) and Abadie and Gardeazabal (2003) is a new extension of the DID and has been previously applied to study the effects of: anti-tobacco laws in California on tobacco consumption (Abadie *et al.* 2009); terrorist conflict in Basque Country on GDP per capita (Abadie and Gardeazabal 2003); hurricane Katrina on labour market outcomes of evacuees (Groen and Polivka 2008); financial liberalisation on FDI (Campos and Kinoshita 2009); trade liberalization on GDP per capita (Billmeier and Nannicini 2008).

The majority of earlier academic papers about the effects of liberalisation or market power in the aviation sector study the effects on (yearly) average airfares. The examples include: Morrison and Winston (1986), Dresner and Tretheway (1992), Gönenc and Nicoletti (2000), Marin (1995), Martin *et al.* (2005), Schipper *et al.* (2002). The general finding is that more competition and liberalisation are associated with lower average airfares. Ng and Seabright (2001) look also at the effect of competition on costs of airlines and labour rents. Goolsbee and Syverson (2008) study the effects of entry threat of Southwest (a low-cost carrier in USA) on the airfares of incumbent airlines and provide some information about the effects on their capacity.

The vast majority of studies about the impact of liberalisation events concentrate on the USA in 1970s or Western Europe in 1992. A paper by Schipper *et al.* (2002) tries to explore the size of the welfare effects associated with bilateral airline liberalisation in Western Europe. They investigate a sample of European routes during the period 1988/92, using yearly data. Their estimated fare and frequency (number of flights) equations (estimated with 2-stage least squares) show that standard economy fares on fully liberalised routes were 34 per cent lower and the number of departures 36 per cent higher than on routes without full liberalisation. However, their results about the effect of liberalisation on traffic and its significance vary a lot depending on which type of liberalisation variables are included in the estimated equation. Once a partial liberalisation dummy is included, no significant effect of any type of liberalisation on traffic is found. Also, the number of observations that they use in their regression analysis is small.

To the best of my knowledge there are no academic papers studying the effects of the SEAM enlargement in 2004 on air passenger traffic. The novelty of this chapter, if compared to the majority of earlier literature about deregulation in the airline sector, is the focus on analysis of the effects, using an event study approach. The few earlier studies about liberalisation and air traffic either provide the simple descriptive statistics (INTERVISTAS 2006) about the growth of traffic or rely on standard OLS regression analysis. Recently, the standard gravity model estimation has been used in some papers to examine the impact of liberalisation on bilateral air traffic. These papers (Piermartini and Rousova 2008, Geloso Grosso 2008, InterVISTAS 2006) use cross-section data of a large number of country-pairs to regress the number of passengers travelling on a country-pair on a set of control variables and a proxy for the level of regulation.

The standard approach means ignoring several econometric problems; including the potential endogeneity of control variables, and the question of how to identify the most suitable control group for the units affected by the deregulation. This paper attempts to address some of these issues, to an extent.

4.3 Background information and some descriptive statistics

In 2004 eight Central and Eastern European (CEE) countries[59] and also two Southern European countries Malta and Cyprus became members of the European Union (EU) and also members of the Single European Aviation Market (SEAM). For the passenger aviation sector this meant that entry of airlines with scheduled services on routes connecting these CEE countries with Western Europe became much easier than before. There were no more restrictive bilateral agreements that had tended to favour the national carriers and had helped to keep airfares relatively high. Now, there was a free market and airlines could fly freely anywhere in the enlarged EU (and to Norway, Iceland and Switzerland) where they wanted.[60] The SEAM included by 2004, in addition to the EU countries, also countries like Norway, Switzerland and Iceland. Therefore, routes to Norway were also affected by the enlargement of the SEAM.

The simplification of entry to routes to the CEE resulted in rapid entry[61] of low cost carriers (LCC) and Central and Eastern Europe became a key growth area of air traffic in Europe. For example, at the end of April 2004 Easyjet started flying from Gatwick to Prague, on 1st of May from Stansted to Ljubljana and from Luton to Budapest, in October 2004 from Stansted to Tallinn, Estonia. Other LCCs like Ryanair, BMIbaby and Jet2 started providing their services on routes to the CEE as well. The airfares of these new entrants were substantially below the ones of the old full service carriers that had dominated these routes so far (Jones 2007). This entry of LCCs meant an

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[59] Poland, Czech Republic, Hungary, Slovenia, Slovakia, Estonia, Latvia, and Lithuania.

[60] In SEAM, every airline having licence, issued by any member state, enabling it to offer air passenger transport services can fly any route within SEAM and offer his services for any price that it deems suitable.

[61] Notably, some entry of LCCs took place also 1-2 years before the enlargement of the EU and SEAM.

increase[62] in the number of passengers flown between Western and Eastern Europe, stronger price competition among airlines and an increase in the number of routes served (CAA 2006), i.e. an increase in variety of travelling options.

Figures 4.1-4.3 confirm that there has been a very large significant and permanent increase in scheduled traffic between UK and the new EU and SEAM members. This occurs closely around the time of the enlargement of the EU and SEAM in May 2004. Simple before-after analysis using data series of only the new member states shows that number of flights from 10 main UK airports to new members was, by 2006, more than two times higher than before the enlargement. However, the before-after analysis may overestimate the effect as it does not account for the trend in air traffic, the fact that air traffic could have increased to some extent also without the EU enlargement. As expected, monthly data in figures below demonstrate the seasonal nature of international air traffic.

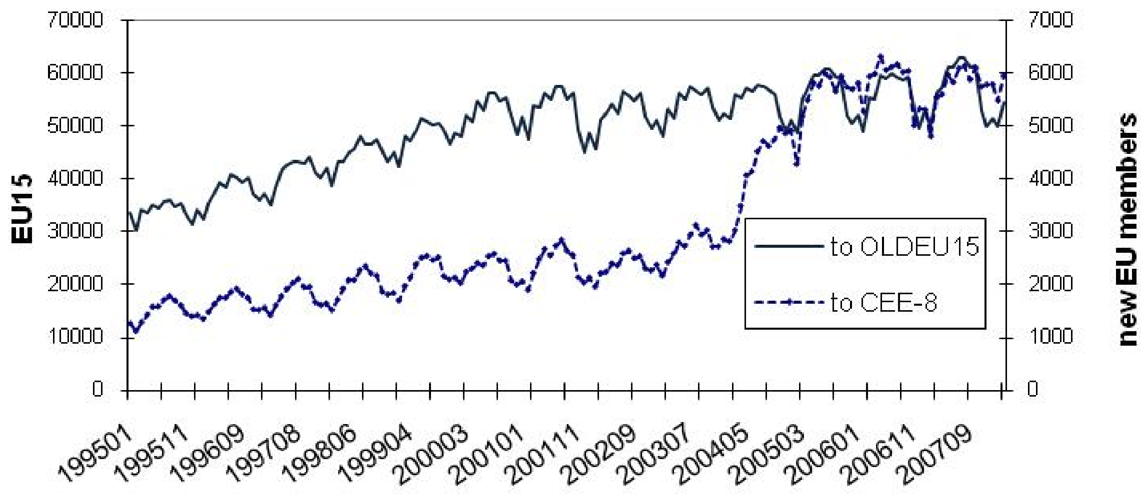

Figure 4.1. Number of scheduled flights from UK to the EU15 and to the new Central and Eastern European EU member countries

Source: UK CAA.

[62] Anecdotal evidence from Western Europe indicates (Calder 2002) that many customers of LCCs were new clients who had not flown before.

Figure 4.1 and 4.2 indicate some similarity in pre-enlargement trends of traffic from the UK to the CEE with the traffic to the EU15. One of the next steps is to perform a formal test whether the pre-treatment trends are similar or not.

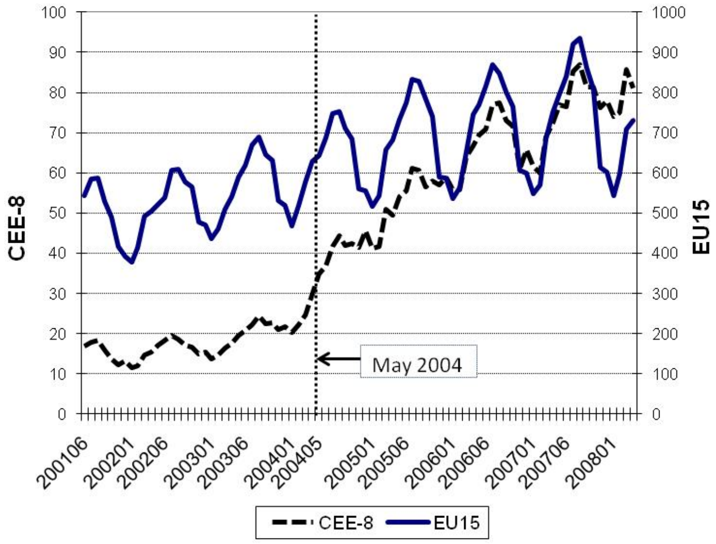

Figure 4.2. Number of passengers (10,000s) of scheduled flights on country-pairs between UK and EU15, and between UK and CEE8

Source: UK CAA.

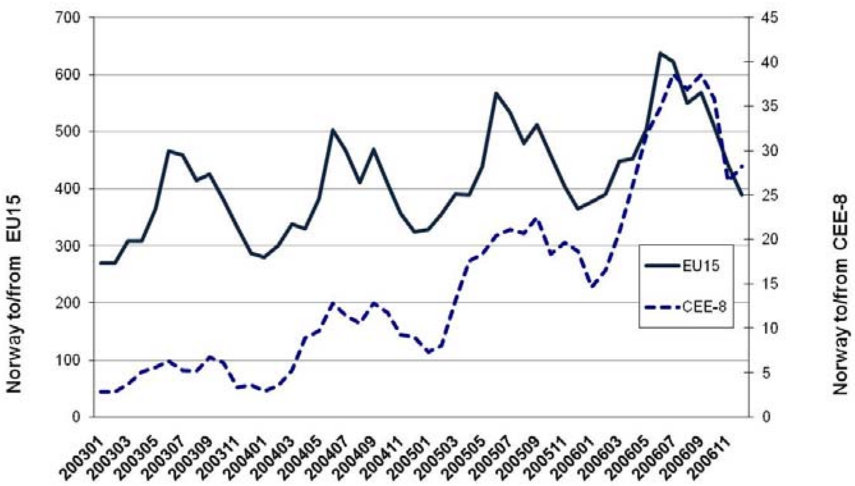

Figure 4.3. Number of passengers (1,000s) on country-pairs between Norway and EU15, and Norway and CEE8

Source: AVINOR.

A good example of the expansion in the number of routes before and after the enlargement of the EU is Poland. According to data from the UK CAA, in 2000 there were only 5 scheduled air routes between the UK and Poland. In 2006 there were already 27 scheduled services that linked 12 UK airports with 12 Polish cities. This can be related to large migration from Poland to the UK after the EU enlargement.

Figure 4.3 reveals that the number of passengers since 2004 has grown more rapidly also on routes from Norway to the new members of the SEAM than on routes to the EU15. Interestingly, although there is already an increase in 2004, the most significant growth of traffic from Norway to the eight studied CEE countries takes place in 2006.

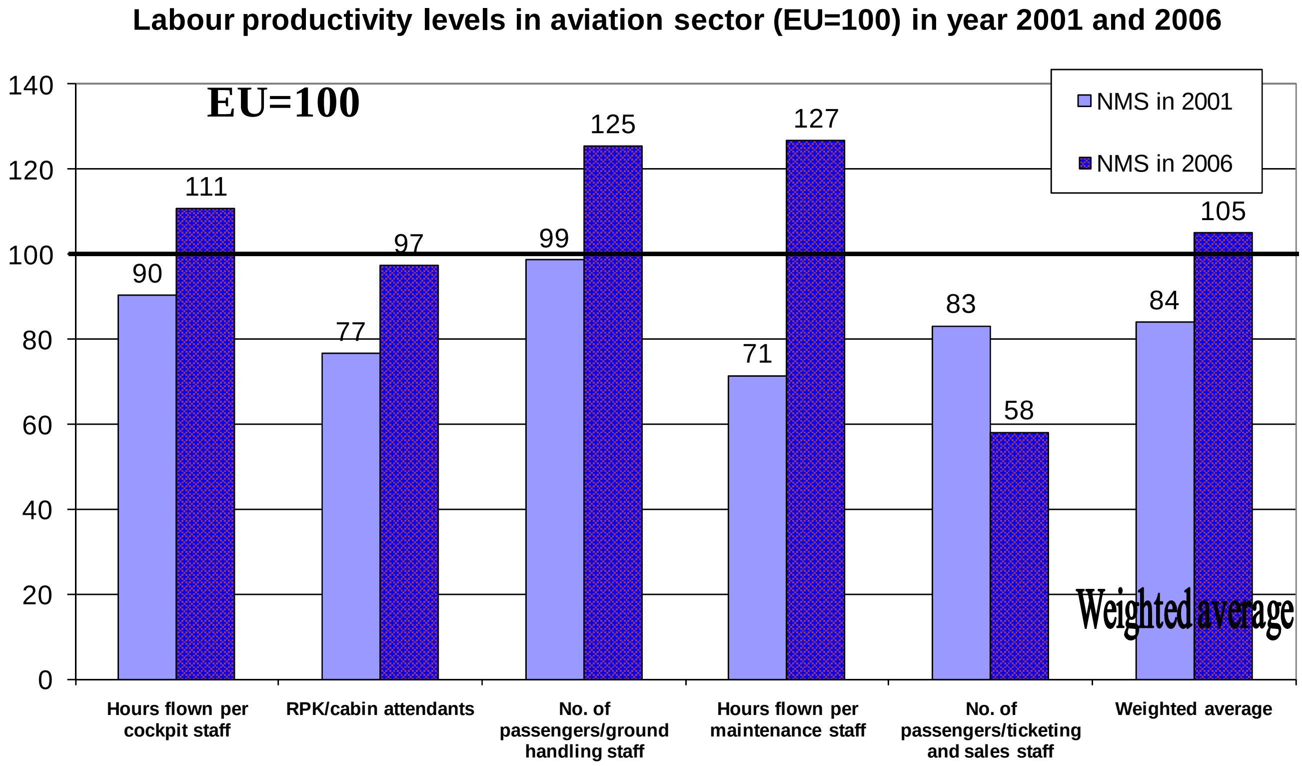

Figure 4.4. Labour productivity levels in the airline industry in Europe

Note: NMS - 7 flag carriers of the new EU member states (from countries that acceded in 2004). EU - 6 of the main full service carriers in Western Europe (BA, Air France, Alitalia, KLM, Lufthansa, SAS). Weighted average is weighed by the employment shares. Source: statistics from IATA WATS 2007 and 2002 publications. (RPK- revenue passenger kilometre).

Figure 4.4 shows how the physical productivity of the CEE flag carriers, which were significantly affected by the EU enlargement, has changed after the enlargement if compared to the full service carriers in Western Europe. Figure 4.4 gives the estimates of labour productivity differences between the Central and Eastern European local carriers and the largest Western European full service carriers in 2001 and 2006. It shows the breakdown of the yearly labour productivity figures into the performance of the different groups of employees. The calculation of these standard productivity indicators of the airline sector follows the approach from Baily and Zitzewitz (2001).

In Figure 4.4, for both year 2001 and 2006, the level of the 6 main Western European full service carriers is set to 100 for each productivity measure. For these airlines the routes to the CEE made up only a small share of all of their routes. Therefore, they were less affected by the EU enlargement than the local flag carriers of the new member states, for whom the majority of their routes were to the EU15 countries.

Notably, aviation enterprises from the new accession countries (Adria Airways, Air Baltic, Czech Airlines, Estonian Air, LOT, Lithuanian Airlines, Malev) have rather high labour productivity levels if compared to the main full service carriers in the EU (British Airways, Air France, Alitalia, KLM, Lufthansa, SAS). The airlines of the new member states (NMS) of the EU have also shown substantial productivity catching-up over the period 2001-2006. Especially high values of labour productivity of these CEE airlines are in 2006 found in the case of maintenance, ground handling and cockpit staff, where they even surpass the level of Western European full service carriers.

This rapid growth in productivity of airlines in new member countries is likely to be due to changes in their business model. Several of these Eastern European flag carriers (e.g. Air Baltic, Czech Airlines) have taken over (some) main ideas of the low-cost airline specific business organisation. This change is likely to be related to the enlargement of the EU and the following entry of many low cost competitors (Ryanair, Easyjet, etc).

Unfortunately, the productivity or cost data of airlines is available for researchers only at yearly and aggregate airline level. Based on these data, we cannot identify the effects of enlargement of the EU on productivity indicators. Therefore, I concentrate in this chapter on the effects of the enlargement on physical output indicators. These are available at route or country-pair level, and separately for the routes affected and the routes not affected by the enlargement of the EU.

This chapter uses route and country-pair level panel datasets of the number of passengers on routes originating from the UK and Norway. UK monthly data of passenger numbers are taken from the website of the UK Civil Aviation Authority (CAA). These cover routes from the UK to the rest of the world for the period June 2001 to April 2008. Norwegian monthly data of passenger numbers on international routes originating from Norway are obtained from a Norwegian company AVINOR. AVINOR owns most airports in Norway and also collects aviation sector data. The Norwegian route level dataset was available for period from January 2003 to December 2006. It has monthly frequency and covers all international routes originating from Norway.

This route level information of UK and Norway is then aggregated into corresponding country-pair level datasets. I use the sub-sample of routes and country-pairs from the UK and Norway to countries of the EU25 (i.e. the members of the EU after the 2004 accession round).

In addition to data on number of passengers, also some additional country-pair (or destination) level control variables are used as control variables. These include distance between origin and destination, real GDP growth rate, trade openness (ratio of export and import to GDP), size of the population of the destination country. Distances between countries are from the CEPII database of geodesic distances. This database is available from the CEPII website. Real GDP and real GDP growth and population are yearly figures taken from Eurostat. Trade openness is taken from the World Bank World Development Indicators Database.

4.4 Methodology

4.4.1 Difference-in-differences approach

The methods employed here to study how the enlargement of the European Single Aviation Market and the EU to the new members in May 2004 affected airline traffic include the difference-in-differences (DID) approach and its recent extension – the synthetic control method. The latter deals with some potential shortcomings of the DID approach.

As a first exercise I use the standard version of the DID approach (see e.g. Meyer 1995, Angrist and Pischke 2009), based on monthly data of number of passengers on route or country-pair as the outcome variable. As I work with data from more than two periods, I employ the regression version of the DID estimator.

The treatment group is here defined as the routes between UK and these new CEE members of the EU that acceded to the EU and European Single Aviation Market in May 2004. The control group is routes from UK to the 'old' 15 EU members countries, as these routes did not experience any such changes in the competitive environment.

'Treatment' is here defined as accession of new member countries to the SEAM in 2004. However, at the same time other aspects of EU enlargement have affected the aviation sector—especially, the free movement of people within the EU and opening of labour markets for people from new members in some EU countries. These meant an increase in demand for aviation services on routes to EU countries and especially to the UK and Ireland, which were the first to open up their labour markets. Therefore, my empirical implementation includes a study of the effect of the SEAM enlargement based on Norwegian international air traffic data, as Norway is a member of the SEAM but not of the EU. Also, I estimate the DID effects separately for scheduled flights and charter flights. The scheduled flights were affected by both the EU and the SEAM enlargement in May 2004, charter flights only by the EU enlargement. This difference between the coverage of the effect of enlargement can help us in determining the relative roles of the overall EU enlargement and the SEAM enlargement in growth of scheduled flights after May 2004.[63]

The first estimated DID equation is the following:

$$y_{igt} = \lambda_t + \alpha_g + \beta x_{gt} + u_{igt}, \qquad (4.1)$$

where i indexes the cross-section unit (country-pair or route[64]), g indexes the group (treatment or control group), t time period (month). Outcome variable y_{igt} is the log of number of passengers.[65] The model has a full set of time effects λ_t, group effects α_g, the policy variable x_{gt} that is defined to be 1 for units and time periods subject to the policy, and cross-section unit specific error term u_{igt}. The coefficient β in Equation (4.1) gives us the standard difference-in-differences estimate of the treatment effect of

[63] Conditional on the assumption that in the absence of the 'treatment' in May 2004 the quantity of scheduled and charter passengers on routes to new member countries would have followed similar trend over time.

[64] Route is an airport-pair.

[65] As a robustness test I also use revenue passenger kilometres (number of passengers*kilometres flown) instead.

liberalisation on the outcome variable y_{igt}. The year effects capture common period-specific shocks, group effects show permanent difference between the outcome of the treatment and control group.

Alternatively, the DID regression is specified with cross-section unit specific fixed effects:

$$y_{igt} = \lambda_t + \alpha_i + \beta x_{gt} + u_{igt}, \qquad (4.2)$$

where α_g is replaced by country-pair or route specific fixed effect α_i. Note that the standard errors in all estimated specifications will be clustered by the cross-section unit (i.e. either country-pair or route) to deal with concerns with serial correlation (Bertrand *et al.* 2004, Besley and Burgess 2004, Imbens and Wooldridge 2007).

The standard DID estimator given in Equation (4.1) or (4.2) is based on strong identifying assumptions. In particular, it requires that, in the absence of the treatment the average outcomes for the treated and control group would have followed parallel trends over time. Only in that case does the simple DID approach take out the selection bias in Equation (4.1). However, in practice, differences in observed or unobserved characteristics can create nonparallel outcome dynamics for the treated and untreated groups (e.g. Meyer 1995).

Based on data from the pre-treatment period one can get some idea whether the trends of these two groups could be also different in the after-treatment period. Using pre-treatment data one can apply a two-period DID estimator:

$$\Delta y_i = \mu + \alpha D_i + \varepsilon_i, \qquad (4.3)$$

where the dependent variable is constructed as the differences in the outcome variable for route *i* between two pre-treatment periods (Abadie 2008). Variable D_i indicates the membership of the treatment group (i.e. routes to the new member countries). The simple t-test of hypothesis $\alpha = 0$ in Equation (4.3) is a test of the common pre-treatment trend assumption.

If there are observable variables that affect treatment and control group differently, one can account for that by including these country-pair/route specific covariates (Z_{igt})[66] into the analysis as control variables:

$$y_{igt} = \lambda_t + \alpha_g + \beta x_{gt} + Z'_{igt}\gamma + u_{igt} \qquad (4.4)$$

Then the identification assumption is that, apart from the control variables Z_{igt}, there are no other forces affecting the treatment and control groups differentially before and after treatment. The variables in vector Z_{igt} have been chosen based on earlier literature on the determinants of passenger traffic (e.g. Piermartini and Rousova 2008). These include the distance between countries in the country-pair, real GDP of the destination country (other than UK and Norway), trade openness (ratio of export and import to GDP), size of the population of the destination country.

Finally, a further robustness check on the DID approach adds also country-pair (or group) specific time trends to the controls. in addition to group-fixed effects α_i and control variables Z_{igt}. This is similar to the approach in Besley and Burgess (2004).The following to DID equations give, correspondingly, the model with group-specific time trends (Eq. 4.5), and the model with group specific trends and additional control variables (Eq. 4.6):

$$y_{igt} = \lambda_t + \alpha_g + c_g t + \beta x_{gt} + u_{igt}, \qquad (4.5)$$

[66] One can also include the interaction terms between the control variables and group identifiers.

$$y_{igt} = \lambda_t + \alpha_g + c_g t + \beta x_{gt} + Z'_{igt}\gamma + u_{igt}, \qquad (4.6)$$

Here c_g is a treatment group specific trend coefficient multiplying the time trend variable, *t*. Equations (4.5) and (4.6) allow the treatment and control units to follow different linear trends. It is important to check if the estimated effects of interest stay similar after inclusion of these trends.[67]

4.4.2 Synthetic control method for comparative case studies

Abadie, Diamond and Heinmueller (2009), building on the original approach of Abadie and Gardeazabal (2003), have recently developed a synthetic control method (SCM) to estimate treatment effects in comparative case studies. It is an extension to the standard DID analysis. It relaxes the strong assumptions of the traditional DID approach by allowing the effects of unobservable confounding factors to vary with time. This means that it addresses the endogeneity problem caused by the existence of unobservable heterogeneity of studied units. It is a useful method especially at aggregate (country) level analysis when the number of observations and number of treated and control units is small, or when there is just one treated unit.

Abadie *et al.* (2009) stress that in comparative case studies performed at the aggregate level (incl. country, region, firm level) there is no sample-based estimation uncertainty. The effect of policy change is measured based on information of the entire population (country, firm) and the aggregate is measured without error. They concentrate instead on another source of uncertainty in comparative case studies—uncertainty related to the choice of the control group.[68]

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[67] For example, in Besley and Burgess (2004) study about the effets of labour regulations on performance of firms, the inclusion of cross-section unit specific trends elimiminates the treatment effect found with standard DID approach.

[68] Often the standard approach is to use time series data in order to study the effects of a policy on some aggregate level variable. Using only data of the unit that was affected by the policy change has its disadvantages, as it does not use a control group. Suitable control groups would account for aggregate

The SCM gives a way to select a synthetic control group based on data of a number of potential controls. Whereas often the choice of the most suitable controls is done informally, Abadie *et al.* (2009) provide a formal way to build a most appropriate control group, in terms of the similarity of its characteristics to the treatment group in the absence of treatment. Synthetic control is found as a weighed combination of potential control units (e.g. country-pairs not affected by the EU and the SEAM expansion) that most closely approximates the relevant pre-treatment characteristics (and trends) of unit(s) affected by the treatment.

This synthetic control can be used after the treatment to approximate the counterfactual situation of the treated unit(s)—if there had been no policy change (treatment). This can be done by comparison of differences in trends of the outcome variable after treatment between the treated unit and the synthetic control unit.

Abadie *et al.* (2009) start with the assumption that there is a panel $J+1$ of units (e.g. countries) over *T* periods. Only unit *i* undergoes the treatment[69] at time T_0 , whereas the remaining J potential control units remain untreated. The treatment effect for this unit *i* at time *t* is:

$$\tau_{it} = Y_{it}(1) - Y_{it}(0) = Y_{it} - Y_{it}(0) \qquad (4.7)$$

where $Y_{it}(l)$ denotes the potential outcome: $Y_{it}(1)$ outcome if the unit *i* is treated at time T_0, $Y_{it}(0)$ if it is not treated. Our aim is to estimate the vector $(\tau_{i,T_{0+1}} ..., \tau_{i,T})$, i.e. during the after-treatment period $t > T_0$. This means that we have to estimate the missing counterfactual $Y_{it}(0)$, as only the Y_{it} is observed for the treated unit. Abadie

level changes in the outcome variable between pre- and after-treatment periods that are due to other factors than the change in policy.

[69] I.e. if there are several units undergoing the treatment, one can estimate the effects separately on all these units. Or, one can aggregate the treated units into one treated unit (e.g. CEE region) and use that in the analysis.

et al. (2009) identify the treatment effects in (4.7) in the case of the following general model for potential outcomes:

$$Y_{it}(0) = \lambda_t + \gamma_t Z_i + \delta_t \mu_i + \varepsilon_{it} \ , \tag{4.8}$$

$$Y_{it}(1) = \lambda_t + \tau_{it} + \gamma_t Z_i + \delta_t \mu_i + \varepsilon_{it} , \tag{4.9}$$

where λ_t is now an unknown time-specific common factor that is constant across units, Z_i is a vector of observed covariates that are not affected by the policy change[70], γ_t is a vector of unknown parameters, δ_t is a vector of unobserved common factors, μ_i is (in our case) a country-pair or route specific unobservable, and ε_{it} are unobserved transitory shocks with zero mean for all *i*. This model in Equation (4.8) and (4.9) generalizes the standard DID model (as given, for example, in Equation (4.2)). Whereas the standard DID model restricts the effect of unobserved factors to be constant over time, this more general model allows them to vary with time.

Next, Abadie *et al.* (2009) define a $J \times 1$ vector of weights $W = (w_1,....,w_J)'$ such that $w_j \geq 0$ and $\sum w_j = 1$. Every value of the vector *W*, i.e. a weighted average of control units, is a potential synthetic control for the treated unit (e.g. country-pair) *i*. Then they define $\overline{Y}_j^k = \sum_{s=1}^{T_0} k_s Y_{js}$ as a generic linear combination of pre-treatment outcomes. They show that, as long as we can choose *W** so that (for every $t < T_0$):

$$\sum_{j=1}^{J} w_j^* \overline{Y_j^k} = \overline{Y}_i^k \text{ and } \sum_{j=1}^{J} w_j^* Z_j = Z_i , \tag{4.10}$$

[70] The fact that Z_i should be chosen so that it is not affected by intervention means that the researcher needs to use pre-treatment values of the variables (then also ruling out anticipation effects) and values of these variables from the after-treatment period that are not affected by intervention.

then $\hat{\tau}_{it} = Y_{it} - \sum_{j=1}^{J} w_j^* Y_{jt}$ is an unbiased estimator of τ_{it}. In practical applications of the SCM, the synthetic control W^* is selected so that the condition (4.10) above holds approximately: the difference between the vector of pre-treatment characteristics of the treated country and the vector of pre-treatment characteristics of the potential synthetic control is minimised with respect to W^*.

Note that the weights W^* identify these units that are used to estimate the counterfactual. So, in our case, SCM identifies which country-pairs make up the synthetic control unit.

In the case of comparative case studies the researcher observes a time series for a particular unit (treatment unit) and often has a limited number of potential control groups. Large sample inferencial techniques are often not suitable in such case. But some information about significance of the results is still needed.

Abadie and Gardeabazal (2003) and Abadie *et al.* (2009) address this inference problem by conducting a number of placebo treatment studies. They apply SCM, similarly to the treated unit, also on every non-treated unit available in the sample. This is similar to permutation tests and it enables us to assess whether the treatment effect estimated by the SCM for the affected unit is large relative to the effect estimated for a randomly chosen unit. It answers the question: *How often would we get results of this magnitude if the researcher had chosen a unit at random for study instead of the treated unit*? If the placebo studies generate estimates of placebo 'treatment' effects of similar magnitude to our estimated actual treatment effect, then we would interpret this as lack of evidence of a significant treatment effect due to the change in policy.

Abadie *et al.* (2009) say that this inferencial exercise is exact, as regardless of the amount of available comparison units, time periods, or whether the data are aggregate or individual, it is possible to calculate the exact distribution of the estimated effect of the placebo interventions.

The stages of the inferencial exercise of finding out the significance of the results are as follows: at first the SCM is implemented based on the true treatment unit. Then a series of placebo studies is conducted iteratively applying the SCM for all the potential comparison units. In each iteration the status of 'treatment unit' is reassigned to one of the control units. It is as if one assumed iteratively that units in the control pool would have had similar policy change as the actually treated unit at a specific period. At each iteration the estimated 'treatment' effect associated with each placebo test is computed. This placebo 'treatment' effect is calculated as the gap between the values of outcome variable of the 'treated' unit and its synthetic counterpart. The iterative process provides us with a distribution of estimated placebo 'treatment' effects for units where no policy change occurred. These placebo results can then be compared to the actual treatment effect.[71]

In addition to the placebo studies, the goodness of results can be assessed based on pre- and post-treatment mean square prediction error (MSPE). The mean-squared-prediction error is the average of sum of squared differences in the outcome variable (and its predictors) between the treated unit and its synthetic counterpart. The pre-treatment MSPE, and its comparison with MSPE from placebo studies, indicates how well the SCM succeeded in finding a synthetic control that is similar to the treated unit in terms of the pre-treatment outcome and its predictor variables.

Sometimes, if the treated unit is very different from all control units in terms of the values of its outcome variable and its predictor variables, the SCM will not succeed in reproducing well a similar synthetic control using the convex combination of potential

[71] An alternative is to use the time dimension of the data to produce placebo studies. In this case the dates of placebo policy changes would be set at random.

control units. This will be then reflected in lack of fit in the synthetic control's dynamics of the outcome variable during the pre-treatment period, and correspondingly in high values of the MSPE. Using information of pre- and post-treatment MSPE from the placebo runs we can additionally evaluate the significance of the (post-treatment) gap between the outcome variable of the treated unit and its synthetic counterpart relative to the placebo cases. For that we can study the distribution of the ratios of post- to pre-treatment MSPE, using MSPEs from placebo runs and the treatment run of the SCM. In the case of significant treatment effect, the placebo studies should have a lower post/pre-treatment MSPE ratio than in the case of the unit actually affected by the policy change.[72]

4.5 Results

4.5.1 Difference-in-differences analysis

Difference-in-differences results based on UK data

This section employs DID analysis to study how the enlargement of the European Union and European Single Aviation Market in May 2004 affected number of passengers travelling on scheduled flights between UK and the CEE8. I also check whether the results are similar if revenue-passenger-kilometres (RPK) is used as an outcome variable instead. RPK is equal to the number of paying passengers times number of kilometres flown. It accounts for differences of flight distances of different passengers.

[72] For example, in Abadie *et al*. (2009) this ratio was 130 in the case of the state of California, where a change in anti-tobacco policy took place. No control state among the other 38 US states studied, where the policy was not implemented, achieved such high ratio. Therefore if one were to assign the intervention at random in their data, the probability of finding a post/pre-treatment MSPE ratio as large as that of California would have been only 1/39, i.e. 2.6 per cent (Abadie *et al*. 2009).

I use monthly panel data of routes between the UK and the rest of the Europe, from June 2001 to April 2008. The number of passengers travelling on a country-pair or route and RPK are output measures of airlines active on that route. One would expect that the liberalisation of the air transport sector (enlargement of the SEAM) would increase the number of passengers (and therefore also RPK) on a route or a country-pair. Liberalisation enables more competition—by making it easier for new airlines to enter the market and by toughening competition among incumbent airlines. This increase in competition should lower airfares, which would lead to increased demand for air travel and an increase in passenger volume. Again, in the case of the scheduled flights to and from UK this enlargement effect of the SEAM cannot be easily differentiated from the overall effect of the EU enlargement (the positive demand shock).

Equations (4.1), (4.4), (4.5) and (4.6) from Section 4.4 are estimated with OLS, with group-specific fixed effects. However, the results are similar if country-pair or route-specific fixed effects are used instead. Table 4.1 uses country-pair level data of 22 country-pairs (14 from the UK to the 'old' EU members, 8 from the UK to the new Central and Eastern European EU members). Table 4.2 uses a much more detailed data at route and airline level. Columns 1 and 6 in Table 4.1 show the results from standard DID regression (Eq. 4.1). Columns 2 and 7 include country-pair specific control variables (i.e. Eq. 4.4).[73]Columns 3 and 8 allow also for different group (treatment or control) specific time trends, as in Eq. (4.5). Note that this last specification estimates in fact a very simplistic gravity model based on bilateral passenger traffic data. Finally, Columns 4 and 9 include both country-pair specific controls and group-specific time trends, as in Eq. (4.6).

[73] These characteristics are the distance between countries (from CEPII database), size of population (yearly data) of the destination country, level of GDP per capita (yearly data) and trade openness (ratio of exports plus imports to GDP) of the destination country (yearly data).

Table 4.1. Difference-in-differences regression results based on monthly UK country-pair level data

	(1)-(4) Scheduled flights				(5) Charter flights	(6)-(9) Scheduled flights			
Column:	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Estimated equation no.:	*4.1*	*4.4*	*4.5*	*4.6*	*4.5*	*4.1*	*4.4*	*4.5*	*4.6*
Dep. var.:	*ln(number of passengers)*	*ln(number of passengers)*	*ln(number of passengers)*	*ln(number of passengers)*	*ln(number of passengers)*	*ln(RPK)*	*ln(RPK)*	*ln(RPK)*	*ln(RPK)*
NewEUmember dummy	-3.005*** (0.596)	-2.065** (0.721)	-3.205*** (0.615)	-2.263*** (0.743)	-3.538*** (0.913)	-2.435*** (0.571)	-2.192*** (0.776)	-2.633*** (0.583)	-2.414*** (0.796)
Policy dummy (i.e. NewEUMember*Post-2004May)[A]	**1.153***** **(0.165)**	**1.132***** **(0.173)**	**0.702***** **(0.101)**	**0.695***** **(0.091)**	-0.275 (0.522)	**1.142***** **(0.161)**	**1.191***** **(0.177)**	**0.697***** **(0.1)**	**0.699***** **(0.087)**
Constant	12.434*** (0.32)	11.24*** (0.484)	12.497*** (0.322)	11.5*** (0.491)	9.24*** (0.898)	19.146*** (0.338)	24.86*** (6.097)	19.208*** (0.339)	24.99*** (6.093)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES	YES
Country-pair specific controls	NO	YES	NO	YES	NO	NO	YES	NO	YES
Group specific trends	NO	NO	YES	YES	YES	NO	NO	YES	YES
R^2	0.485	0.843	0.487	0.845	0.187	0.36	0.794	0.362	0.796
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of Observations	1800	1800	1800	1800	1362	1800	1800	1800	1800

Notes: 22 country-pairs. Method: OLS. *** - significant at 1 per cent level, ** - significant at 5 per cent level, * - significant at 10 per cent level. Robust standard errors, clustered at country-pair level are in parentheses.

A. Policy dummy is equal to 1 for routes to new EU member countries for periods starting from May 2004.

As expected, country-pairs (Table 4.1) and routes (Table 4.2) going from UK to the new EU members have significantly lower number of passengers (see the coefficient of *NewEUmember dummy*) than these from the UK to the Western Europe.

The average treatment effect of the policy change is given by the coefficient of the *Policy dummy*. The coefficient of this variable is positive and statistically significant in the table above, indicating strong positive treatment effect of enlargement of the Single Aviation Market and the EU on passenger numbers and RPK. However, the size of the estimated effect on number of passengers or RPK varies considerably depending on the specification of the DID model. Inclusion of country-pair specific controls changes the estimated treatment effect only by a limited extent (compare Column 1 and 2, or 6 and 7 in Table 4.1). What matters the most is inclusion of separate group-specific time trends. This allows treatment and control units to follow different trends. Notably, now the estimated positive effect of the EU and SEAM enlargement is about 40 per cent lower than otherwise. Evidently, this is due to the fact that air traffic to and from the accession countries was growing somewhat faster than elsewhere anyway. Control for this trend difference therefore drives the estimated effect down.

Based on country-pair level results that include separate group specific trends and country-pair specific controls (the most preferred specification), we can see from Table 4.1 (Column 4 and 9) that on average the enlargement of the EU and European Single Aviation Market resulted in a 100 per cent[74] increase in airline traffic on country-pairs between the UK and Central and Eastern Europe if compared to the counterfactual situation. As evident from Annex 4.1, the country-pair level result is relatively robust to the exclusion of some countries from the treatment and control

[74] I.e. calculated as: exp(0.695) – 1.

group. The effect on RPK is in the case of UK data very similar to the effect on number of passengers (Columns 6-9 in Table 4.1). Also, the effect on number of competitors offering scheduled flights on routes to new member countries is of very similar magnitude (see Table 4.2). Thus, we can argue that the effect is not only due to increase in number of passengers served by existing airlines, but also due to entry of new competitors. At the same time, as evident from Table 4.2 the EU enlargement is not associated with an increase in number of charter airlines serving the routes to the new member countries.

Table 4.2. EU enlargement in 2004 and number of scheduled and charter carriers on a country-pair

	Scheduled flights		Charter flights
Estimated equation no.:	(4.1)	(4.5)	(4.1)
Dep. var.:	*ln(number of airlines)*	*ln(number of airlines)*	*ln(number of airlines)*
NewEUmember dummy	-2.382**	-2.512***	-2.366***
	(0.126)	(0.372)	(0.415)
Policy dummy (i.e. NewEUMember*Post-2004May)[A]	**0.949*** (0.112)**	**0.664*** (0.118)**	0.107 (0.083)
Constant	3.036***	3.073***	3.333***
	(0.256)	(0.255)	(0.416
Time dummies	YES	YES	YES
Group specific trends	NO	YES	NO
R^2	0.494	0.496	0.314
Prob>F	0.000	0.000	0.000
No. of Observations	1800	1800	1362

Notes: Method: OLS. *** - significant at 1 per cent level. Robust standard errors, clustered at country-pair level, are in parentheses. Estimated equation: 4.1. Monthly country-pair level data.

An important result concerns the charter flights (see Column 5 in Table 4.1). There is no significant effect of enlargement of the EU on number of passengers of charter flights. Notably, in the case of charter flights, the 'treatment' in May 2004 includes the EU enlargement (i.e. the demand shock), but not the SEAM enlargement. Unlike the scheduled carriers, the entry barriers for charter flights did not change significantly in May 2004. Their entry was relatively easy already before that. As evident from Table 4.2 the EU enlargement is not associated with an increase in number of charter airlines serving the routes to the new member countries. The fact that the EU entry does not affect charter flights to new member countries at all could potentially say us something about the effect of 'May 2004' on scheduled flights as well. If we were willing to make a fairly restrictive assumption that in the absence of the 'treatment' the quantity of scheduled and charter passengers would have followed similar trend over time, and that the demand effect of EU enlargement of scheduled and charter flights was similar, then the treatment effect on scheduled carriers (as given in Table 4.1) could be due to change in entry barriers because of the enlargement of the SEAM and not due to the effect of overall enlargement of the EU. However, I acknowledge the demand effect of EU enlargement is rather likely to be quite different for the scheduled and charter flights.

Table 4.3. Difference-in-differences regression results based on UK route-airline level data of scheduled flights

Dep. var.: *ln(number of passengers)*	(1) UK-Europe	(2) London-Europe
NewEUmember dummy	-0.353***	-0.462***
	(0.126)	(0.111)
Policy dummy (i.e. NewEUMember*Post-2004May)[A]	**0.239*** (0.12)**	**0.157*** (0.071)**
Constant	8.668***	9.413***
	(0.69)	(0.787)
Full set of time dummies included	YES	YES
Prob>F	0.000	0.000
No. of Observations	48,529	15,723

Notes: Method: OLS. *** - significant at 1 per cent level. Robust standard errors, clustered at route level, are in parentheses. Estimated equation: 4.1. Frequency of data: monthly.
A. Policy dummy is equal to 1 for routes to new EU member countries for periods starting from May 2004.

The impact on number of passengers of scheduled flights at a lower level of aggregation, on route and airline level (Table 4.3) is much smaller than at country level. This is because in the case of route-level data my analysis looks at the effects on already existing routes and airlines, excluding any new ones. The country-pair level analysis includes also expansion in terms of number of routes and entry of new carriers to the Eastern Europe. One of the most visible characteristics of post-2004 development in the aviation sector of the new member states of the EU has indeed been the increase in number of routes served.

As evident from Annex 4.2, the ‘treatment’ effect of May 2004 on the number of flights on a country-pair is also positive. However, the magnitude of the effect on number of flights is to some extent smaller than the effect on number of passengers (compare Column 1 in Table 4.1 with Table A4.3 in Annex 4.2). Hence, we could argue that the enlargement has also increased the average load-factor of airlines. This means that on average each flight carries more passengers than before. The effect of the EU and SEAM enlargement on routes from London is smaller than in UK on average (see Table 4.3). Hence, the effect of enlargement is larger on routes originating from outside London airports.

The main results in this and the next Section are also robust to various modifications of equation (4.1), (4.5) and (4.6):

(i) to inclusion of country-pair or route specific (not treatment/control group specific) fixed effects;

(ii) to allowing the coefficients of control variables (γ) in Equation (4.5) to be different for treatment and control units.

To check whether the results in 2004 might be more due to EU enlargement or air traffic liberalisation (SEAM enlargement) I will utilise the differences in the membership coverage of the EU and the SEAM. For that, I show here the effect of Croatia’s entering the European Common Aviation Area (ECAA) in 2006. The SEAM was reorganised into ECAA in 2006. Croatia became a member of the ECAA but did not become a member of the EU at the same time. For this reason I can in the case of the 2006 enlargement round concentrate more specifically on the effect of the ECAA, not the overall effect of the EU enlargement.

Table 4.4. Robustness test: effect of Croatia's entry to the European Common Aviation Area in 2006

Dep. var.:	*ln(number of passengers)*	*ln(number of passengers)*
Policy dummy (i.e. NewECAAMember*Post-2006January)[A]	**0.592*** (0.035)**	**0.532*** (0.025)**
EU enlargement in 2004 (Croatia dummy* postMay2004 period)		0.126*** (0.054)
Time dummies	YES	YES
Country-pair specific controls	NO	NO
Group specific trends	YES	YES
R^2	0.26	0.26
Prob>F	0.000	0.000
No. of Observations	1245	1245

Notes: Method: OLS. Estimated equation: 4.5. *** - significant at 1 per cent level. Robust standard errors, clustered at country-pair level, are in parentheses. UK country-pair level data. Treatment 'group' is UK-Croatia country-pair, control group is UK-EU15 country-pairs. Frequency of data: monthly.
A. 2006 policy dummy is equal to 1 for routes to Croatia for periods starting from January 2006.

The results in Table 4.4 are based on monthly country-pair level data of flights to and from UK. The 'treatment group' is the UK-Croatia country-pair, the control group consists of the country-pairs between UK and the EU15. As evident from the coefficient of the policy dummy in Table 4.4, there is significant increase after January 2006 in the number of passengers on UK-Croatia country-pair if compared to the routes between the UK and the EU15. There was already some increase after May 2004 (see Column 2 in Table 4.4), but the majority of increase coincided with the SEAM enlargement. The SEAM enlargement in 2006 increases the number of passengers on the affected routes on average by 70-80 per cent, even if we allow for a different linear trend for the Croatia-UK country-pair. This gives more credibility to claim that the effects in Table 4.1 and 4.2 for the 2004 enlargement round are not only due to the overall effect of the EU enlargement. We find effects of similar magnitude if we look at the 2006 enlargement of the ECAA (i.e. Single Aviation Market) alone.

Difference-in-differences results based on Norwegian data

Similar analysis has been implemented in the case of routes between the CEE and Norway (Annex 4.3 shows also the results in case of yearly data of Sweden). The period of study covers monthly data from January 2003 to December 2006, as earlier monthly route level data was not available for Norway. I investigate routes from Norway to the EU25 (i.e. EU after the 2004 accession round). The treatment group consists of routes to countries that became part of the SEAM in 2004. The control group consists of routes to countries that were already SEAM members before 2004.

The results in Table 4.5 and Table 4.6 show that, generally, country-pairs or routes going from Norway to the new SEAM members have lower number of passengers and RPK than country-pairs or routes to the Western Europe (as evident form the coefficient of the *NewSEAMmember dummy*).

The average treatment effect of a change in policy is again given by the coefficient of the *Policy dummy*. This coefficient is positive in Table 4.5 and also in Column 1 of Table 4.6. It indicates a large positive treatment effect of the SEAM enlargement on number of passengers and RPK. However, the coefficient is still positive but not statistically significant in the case of routes originating from Oslo (Column 2 in Table 4.6).

Therefore, the positive effect of SEAM enlargement seems to take place on routes outside Oslo airport. This and similar result based on UK data are consistent with the standard entry strategy of the LCCs. It is well known that the LCCs tend to avoid using main large airports. That way they cut the airport charges and avoid congestion related problems (Doganis 2010).

Table 4.5. Difference-in-differences regression results based on monthly Norwegian country-pair level data

Column:	(1)	(2)	(3)	(4)	(5)	(7)	(6)	(8)
Estimated equation no.:	*4.1*	*4.4*	*4.5*	*4.6*	*4.1*	*4.4*	*4.5*	*4.6*
Dep. var.:	*ln(number of passengers)*	*ln(number of passengers)*	*ln(number of passengers)*	*ln(number of passengers)*	*ln(RPK)*	*ln(RPK)*	*ln(RPK)*	*ln(RPK)*
NewSEAMmember	-3.326***	-2.496*	-3.677***	-2.625*	-2.844***	-1.666	-3.172***	-1.699
dummy	(0.741)	(1.21)	(0.787)	(1.233)	(0.577)	(1.224)	(0.608)	(1.148)
Policy dummy (i.e.	**1.65*** **	**1.71*** **	**0.712***	**0.631***	**1.008*** **	**1.134*** **	**0.597***	**0.577***
NewSEAMmember*Post-2004May)[A]	**(0.497)**	**(0.487)**	**(0.391)**	**(0.322)**	**(0.309)**	**(0.311)**	**(0.32)**	**(0.33)**
Constant	8.231***	13.171***	8.245***	13.422***	15.763***	9.562***	15.788***	9.524***
	(0.612)	(3.854)	(0.613)	(3.991)	(0.474)	(2.417)	(0.476)	(2.63)
Time dummies	YES	YES	YES	YES	YES	YES	YES	YES
Country-pair specific controls	NO	YES	NO	YES	NO	YES	NO	YES
Group specific trends	NO	NO	YES	YES	NO	NO	YES	YES
R^2	0.4	0.673	0.424	0.687	0.406	0.58	0.424	0.607
Prob>F	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
No. of Observations	1010	1010	1010	1010	1010	1010	1010	1010

Notes: Method: OLS. *** - significant at 1 per cent level, ** - significant at 5 per cent level, * - significant at 10 per cent level. Robust standard errors, clustered at country-pair level, are in parentheses. Data of scheduled flights is used.

A. Policy dummy is equal to 1 for routes to new SEAM member countries for periods starting from May 2004.

Table 4.6. Difference-in-differences regression results based on Norwegian route level data

Dep. var.: *ln(number of passengers)*	(1) Norway-Europe	(2) Oslo-Europe
NewSEAMmember dummy	-1.1***	-0.148
	(0.189)	(0.259)
Policy dummy (i.e. NewSEAMMember*Post-2004May)[A]	**0.755*** (0.211)**	**0.336 (0.296)**
Constant	7.078***	6.667***
	(0.197)	(0.353)
Full set of time dummies included	YES	YES
R^2	0.015	0.016
Prob>F	0.000	0.000
No. of Observations	7081	3241

Notes: Method: OLS. *** - significant at 1per cent level. Robust standard errors, clustered at route level, are in parentheses. Data of scheduled flights is used. Estimated equation: 4.1. Frequency of data: monthly. A. Policy dummy is equal to 1 in the case of routes to the new SEAM member countries for periods starting from May 2004.

As in the case of UK, the point estimate of the treatment effect is different depending of the type of DID approach: adding group specific time trends to the list of controls lowers the estimated effect a lot. Based on Column 4 and 8 in Table 4.5 we can see that over the period studied the enlargement of the SEAM resulted in 88 per cent[75] increase in number of passengers on country-pairs between Norway and Central and Eastern European countries if compared to the control group of country-pairs to EU15.[76] The corresponding effect on RPK is 78 per cent. The results vary a bit depending on which countries are included or excluded from the treatment and control group (see Annex 4.1). Notably, the effect on RPK is smaller than the effect on number of passengers. This is because the growth on flights to the CEE has concentrated more on relatively nearby CEE countries. Such concentration on closer destinations after 2004 does not take place in UK.

Tests of common pre-enlargement trends

[75] This is found as: exp(0.631)-1

[76] See Annex 4.3 for similar analysis based on yearly passenger volume data of country-pairs from Sweden to the rest of Europe.

As outlined in the methodology section, one needs to formally test whether the trends of traffic figures of the 'treatment' group and control group differed already before the enlargement of the SEAM. I use pre-treatment data and apply two-period DID estimator to that data. The simple *t*-test of hypothesis that $\alpha = 0$ in Equation (4.3) is a test of the common (pre-treatment) trend assumption. Using UK data on number of passengers or RPK we can reject the hypothesis that the difference in pre-treatment trends is not significant, at 95 per cent level of confidence. Hence the common (pre-treatment) trend assumption of Equation (4.1) or (4.2) does not hold. However, as a number of Figures from Section 2 indicated, these trends are in fact not very different before 2004. Similarly, the common trend assumption does not hold for Norwegian data of number of passengers or RPK.

However, if instead of number of passenger we use the number of flights as a dependent variable in Equation (4.3), then based on the UK data, we cannot reject the hypothesis that $\alpha = 0$. Hence, the common pre-treatment trend assumption holds in this case (see also Annex 4.1). Because of these results I have relied mostly on the point estimates of the treatment effect from Equation (4.5)—the DID model with different group specific linear trends. The corresponding findings are given in Columns 4 and 9 in Table 4.1 and Columns 4 and 8 in Table 4.5.

4.5.2 Results with the synthetic control method

SCM results - based on UK data of passenger numbers

We saw that the strong assumption of the DID approach does not strictly hold here. Therefore one needs to control for the possible non-parallel trends of the treated and untreated group. In order to do that in a more flexible way than in Equation (4.6), I use the synthetic control method (SCM). Using SCM, I demonstrate the effect of expansion of the EU and Single European Aviation Market in May 2004 on passenger traffic between UK and Poland and between UK and the aggregate region of the 8 new Central and Eastern European member states that acceded the EU in 2004 (CEE8). Synthetic control destinations, like synthetic Poland and a synthetic CEE8, are constructed as convex combinations of country-pairs between UK and other 14 before-2004 members of the EU and Single European Aviation Market.

The construction of these synthetic controls is based on country-pair level data of number of passengers and some standard predictors of passenger flows. I use here UK monthly traffic data that cover the same period as in Section 4.1.1. A weighted average of Western European destinations is chosen by the SCM to resemble the values of passenger traffic and its predictors prior to May 2004 for Poland and the CEE8 as a whole region. My sample of potential controls includes the following 'old' EU destinations originating from the UK: Austria, Belgium, Denmark, Finland, France, Greece, Ireland, Italy, Luxembourg, the Netherlands, Portugal, Spain, and Sweden.

The country-pair level outcome variable is the monthly number of passengers of scheduled flights.[77] The predictor variables of passenger traffic in the post-treatment period are chosen based on literature on determinants of bilateral passenger traffic (e.g. Piermartini and Rousova 2008). The predictor variables used for our application, based on flights from the UK, are:

(i) number of passengers during the pre-treatment periods;

[77] I.e.: excluding passengers of charter flight.

(ii) distance between the origin and destination[78];

(iii)size of population of the destination country;

(iv)trade openness (ratio of exports plus imports to GDP) of the destination country;

(v) real GDP growth rate of the destination country.

As the CEE countries have lower GDP per capita than the Western European ones it would be impossible to find a good match based on that variable. Therefore, it has not been included in the set of air traffic predictors and the GDP growth rate of the destination country is used instead. Trade openness is additionally included as a predictor variable because of its potential effect on airline passenger traffic growth, incl. through its possible effect on GDP growth.

Table 4.7 shows the weights of each EU destination country in the synthetic Poland and in the aggregate synthetic CEE8. The synthetic Poland is a weighted average of Finland, Luxembourg and Greece. The synthetic CEE8 is weighted average of Greece, Belgium, Finland, Germany and Luxembourg. Other countries from the pool of potential controls were assigned zero weights by the SCM.

Tables 4.8 and 4.9 compare the pre-enlargement characteristics of the actual Poland and its synthetic counterpart, and actual CEE8 and its aggregate synthetic counterpart. The synthetic CEE8 approximates the actual one accurately in terms of pre-enlargement passenger traffic figures, distance between countries, GDP growth rate and trade openness figures of the destination. Also in the case of Poland, the figures of actual and synthetic Poland are relatively similar, with the notable exception in terms of the size of

[78] Distances between countries are defined similarly to the studies estimating the trade gravity equation. Distances are calculated following the great circle formula, which uses latitudes and longitudes of the most important city (in terms of population).

population (see Table 4.8). The difference between the traffic figures of the Poland and Synthetic Poland is larger than in the case of CEE8 as a whole and synthetic CEE8.

Table 4.7. Country weights in synthetic Poland and synthetic CEE8, estimated using UK origin-destination passenger traffic data

	Synthetic Poland	Synthetic CEE8
Austria	0	0
Belgium	0	0.279
Denmark	0	0
Finland	0.552	0.224
France	0	0
Germany	0	0.122
Greece	0.164	0.296
Ireland	0	0
Italy	0	0
Luxembourg	0.283	0.078
Netherlands	0	0
Portugal	0	0
Spain	0	0
Sweden	0	0
Sum	1	1

Table 4.8. Pre-treatment predictor and outcome means for Poland and its synthetic counterpart

	Treated	Synthetic
Monthly scheduled passengers*	41435	45051
Distance, km	1451.6	1492.9
Real GDP growth rate, %	2.5	2.53
Trade openness, % of GDP	50	66.6
Average population, mill.	38	4.8

*Also, pre-treatment data of each available quarter's passenger numbers, each year's GDP growth and trade openness figure was used in building the synthetic control. The averages over the whole pre-treatment period are presented here.

Table 4.9. Pre-treatment predictor and outcome means for CEE8 and its synthetic counterpart

	Treated	Synthetic
Monthly scheduled passengers	181289	181605
Distance, km	1325.5	1294.1
Real GDP growth rate, %	2.39	2.31
Trade openness, % of GDP	85.7	81

*Also, pre-treatment data of each available quarter's passenger numbers, each year's GDP growth and trade openness figure was used in building the synthetic control. The averages over the whole pre-treatment period are presented here.

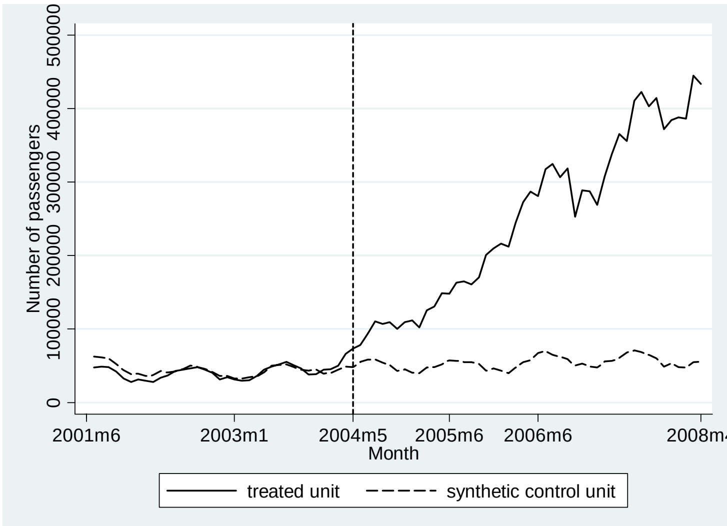

Figure 4.5. Trends in scheduled passenger numbers from UK: Destination Poland (treated unit) vs synthetic Poland

Note: vertical dotted line denotes May 2004.

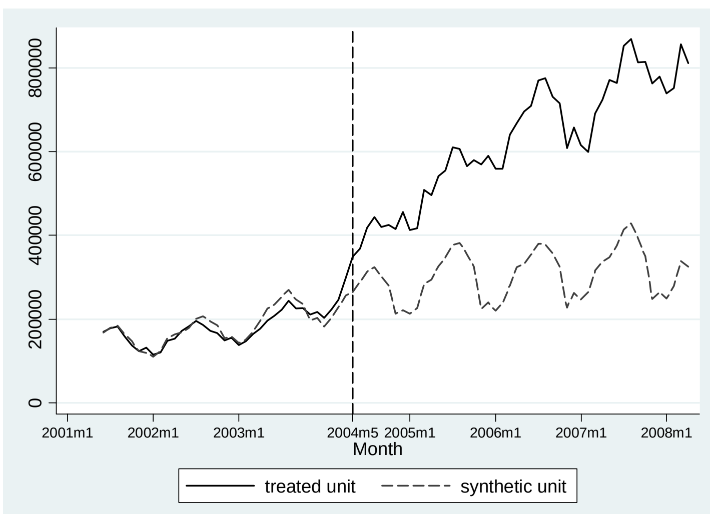

Figure 4.6. Trends in scheduled passenger numbers from UK: Destination CEE8 vs synthetic CEE8

Figure 4.5 plots the passenger traffic trajectory of the UK-Poland country-pair and its synthetic counterpart for the June 2001–April 2008 period. The synthetic Poland reproduces here a trend in pre-treatment passenger traffic that is very similar to the actual

Poland. This fit in Figure 4.5 together with the evidence of covariate balance in Table 4.8 suggests that the weighted average of Finland, Greece and Luxembourg may possibly serve as one relatively sensible estimate of the counterfactual passenger traffic trend that Poland may have experienced in the absence of EU enlargement.

Figure 4.6 shows similar results for the CEE countries as a whole. SCM succeeds here to mimic well the pre-enlargement dynamics of the CEE passenger traffic.

The estimate of the effect of enlargement of the EU and the Single European Aviation Market is given in Figure 4.5 and Figure 4.6 by, respectively, the after-treatment difference between the actual Poland and the synthetic Poland, and the difference between the actual CEE8 and its synthetic counterpart. In both cases the enlargement had a very large effect on the passenger traffic.

Already a couple of months after enlargement the monthly passenger numbers between the UK and the CEE8 countries were up by about 100,000 passengers if compared to the estimate of the counterfactual scenario. One year after the enlargement this gap had already widened to 200,000 people. In percentage terms, by December 2004 this difference between the CEE8 level of outcome variable and that of its synthetic control was already 106 per cent of the level of synthetic CEE8. So, the volume of passengers to and from CEE8 was about 2 times higher than the volume of passengers to and from the synthetic CEE8. By December 2005 this gap had grown to 146 per cent.[79]

This growth is remarkable, especially given that until 2003 the overall number of passengers travelling in a given month between UK and these 8 CEE countries had

[79] Also, analysis of yearly data confirms these findings of a very large effect of the EU and the Single European Aviation Market enlargement.

remained below just 200,000 people. It is also unprecedented: there was no even remotely similar growth occasion during the pre-enlargement period.

I have also implemented similar SCM study based on other CEE8 countries. To save space I have reported here the results for Poland and the CEE8 as a whole. The results for both Hungary and Czech Republic show similar significant effects of the enlargement. These are given in Annex 4.4. The SCM was relatively successful in finding the synthetic controls for Poland and the CEE8 as one aggregate unit. For very small CEE countries like Estonia, Latvia, Lithuania and Slovenia the SCM failed to find a synthetic control with good fit in the pre-treatment period (see Annex 4.4). However, despite the failure of implementing the SCM in these cases, UK traffic to and from these countries grew a lot after enlargement. For example, one year after enlargement monthly passenger traffic between the UK and Estonia was more than 3 times larger than before May 2004.

Statistical significance of the results

To estimate whether the effects found with SCM are statistically significant I conduct a number of placebo studies. In placebo studies the treatment is iteratively assigned to country-pairs among old EU destination countries, as these did not face the change in regulatory framework in May 2004. The results of the placebo studies are given in next three Figures. For example, Figures 4.7 and 4.8 show that the routes from UK to Finland and Greece did not experience any significant increase in terms of traffic around 2004 if compared to their own synthetic counterparts. In our previous section, we showed that both Finland and Greece had important shares in the synthetic controls for Poland and CEE8.

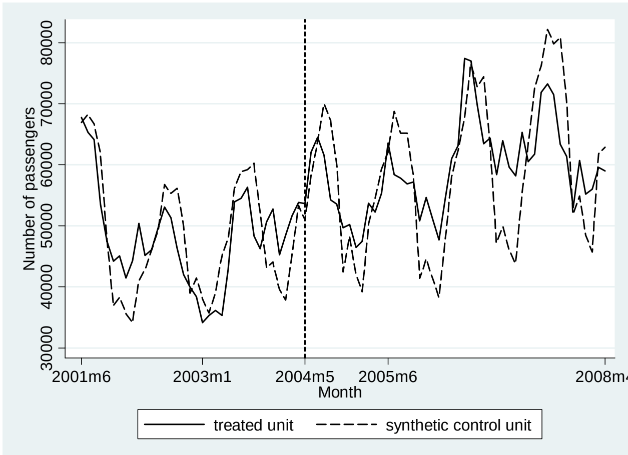

Figure 4.7. Placebo test—passengers travelling on the UK-Finland country-pair (solid line) and the synthetic UK-Finland country-pair

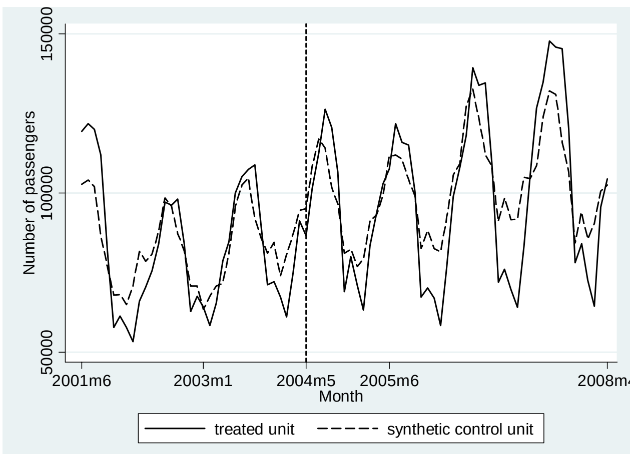

Figure 4.8. Placebo test—passengers travelling on the UK-Greece country-pair (solid line) and the synthetic UK-Greece country-pair

The results of all placebo studies and the actual treatment study are summarised in Figure 4.9. It plots the gap between the outcome variable of the treated unit (CEE8) and its synthetic control group, and shows also the similar placebo gaps[80] for the 14 'old' EU destinations.[81] Note from Figure 4.9, that if one were to re-label the treatment status in this country(region)-pair level data of 14 control units and one treatment unit (CEE8) at

[80] For example: between actual Finland and its synthetic control, between Spain and its synthetic counterpart.
[81] There are 14 'old' EU destination countries as flights from UK to UK itself are excluded from analysis.

random, the probability of obtaining the results of the magnitude of those obtained for CEE8 would be small. It is equal to 1/15, i.e. 6.7 per cent. This is below the 10 per cent level typically used in standard tests of statistical significance. We can see that the gap between the treated CEE8 and its synthetic unit is far larger than the corresponding gap from placebo studies of country-pairs within the EU15. Based on lack of similar placebo gaps it can be argued that this result is statistically significant and that the liberalisation on routes to the CEE8 has resulted in a large increase of volume of passenger traffic.

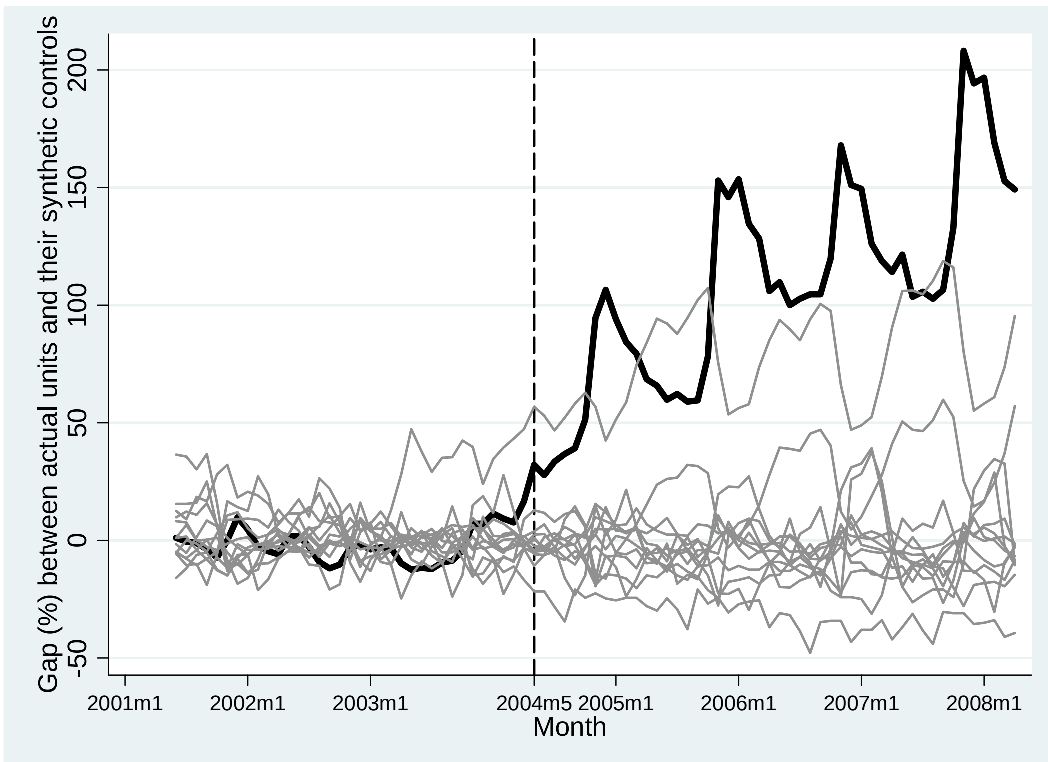

Figure 4.9. Difference between the actual number of passengers travelling on a country-pair and the corresponding synthetic control of the country-pair. UK-CEE8 region-pair vs placebo studies of the 14 control country-pairs.

Note: **Bold line** - outcome difference (as per cent of the synthetic control) between the CEE8 and its synthetic control. **Grey lines** - outcome difference between each of the control units and their synthetic controls in the placebo studies.

Using information of pre- and post-treatment MSPE from the placebo runs we can additionally evaluate the significance of the post-treatment gap between the outcome variable of the treated unit and its synthetic counterpart relative to the placebo cases. For that I study the distribution of the ratios of post- to pre-treatment MSPE, using MSPEs from placebo runs and the treatment run of the SCM. In the case of significant treatment effect, the placebo studies should have a lower ratio of post-treatment MSPE to pre-treatment MSPE than study of the unit actually affected by the policy change (Abadie *et al.* 2009). This is indeed the case here (see Annex 4.5). Based on UK data, the ratio of Post-SEAM enlargement MSPE and Pre-SEAM enlargement MSPE in the treated region pair (CEE-UK) is more than 70 times higher than in the case of placebo studies based on control country-pairs. No country-pair in the control group achieved such high ratio. Again, if one were to assign the intervention at random in the data, the probability of finding a post/pre-treatment MSPE ratio as large as that of UK-CEE region pair would have been only 6.7 per cent.

SCM results - based on Norwegian data of passenger numbers

Next, I show the effects of the expansion of the Single European Aviation Market with SCM based on data of international flights from Norway. In this case the synthetic CEE destinations are constructed based on data of routes between Norway and the EU15 countries. That is, the potential pool of controls is considered to be the 'old' EU destinations. Data used in my analysis is passenger traffic data aggregated to country-pair level, where one end in the country-pair is always Norway. The time-frame studied here is the same as in Section 4.1.2. The predictor variables of passenger traffic are exactly the same as in previous sections.

Table 4.10 shows the weights of each EU destination country in the synthetic CEE8 and synthetic Poland. Now, the synthetic destination of Poland is a weighted average of

Finland, Ireland and Italy. The corresponding weights were 0.035, 0.811, and 0.154. All other destinations have zero weights. The synthetic CEE8 turned out to be a weighted average of Finland (0.1), France (0.234) and Ireland (0.666).

Tables 4.11 and 4.11 compare the pre-enlargement characteristics of the actual Poland (Table 4.11) or the aggregate CEE8 (Table 4.12) with their synthetic counterparts. Note that this time the fit of pre-treatment characteristics is not as good as in the case of UK data. However, the synthetic control group is still more similar to the treated group than the population-weighted average of all EU15 destinations would be.

Table 4.10. Country weights in synthetic Poland and synthetic CEE8, estimated using Norwegian origin-destination passenger traffic data

	Synthetic Poland	Synthetic CEE8
Austria	0	0
Belgium	0	0
Denmark	0	0
Finland	0.035	0.1
France	0	0.234
Germany	0	0
Greece	0	0
Ireland	0.811	0.666
Italy	0.154	0
Luxembourg	0	0
Netherlands	0	0
Portugal	0	0
Spain	0	0
Sweden	0	0
Sum	1	1

Table 4.11. Pre-treatment predictor and outcome means for Poland and its synthetic counterpart, estimated using Norwegian origin-destination passenger traffic data

	Treated	Synthetic
Monthly scheduled passengers*	1455.4	1703.8
Distance to Norway, km	1062.1	1364.9
Real GDP growth rate, %	3.9	3.7
Trade openness, % of GDP	58.3	83.9
Average population, mill.	38.2	12.3

*Also, pre-treatment data of each available quarter's passenger numbers, each year's GDP growth and trade openness figure was used in building the synthetic control. The averages over the whole pre-treatment period are presented here.

Table 4.12. Pre-treatment predictor and outcome means for CEE8 and its synthetic counterpart, estimated using Norwegian origin-destination passenger traffic data

	Treated	Synthetic
Monthly scheduled passengers*	5374.6	5389.4
Distance to Norway, km	1056.9	1237
Real GDP growth rate, %	6.03	4.03
Trade openness, % of GDP	97.1	87.9

*Also, pre-treatment data of each available quarter's passenger numbers, each year's GDP growth and trade openness figure was used in building the synthetic control. The averages over the whole pre-treatment period are presented here.

Figures 4.10 and 4.11 show, respectively, the dynamics of passenger volume to and from the destinations CEE8 and Poland, compared in both cases to their synthetic control group. The synthetic CEE8 and synthetic Poland have relatively similar pre-treatment passenger traffic dynamics if compared with the actual CEE8 or actual destination Poland. In the case of CEE8 as an aggregate region we, find a large effect of the enlargement of the European Single Aviation Market in year 2004. In percentage terms, by December 2004 the difference between CEE8 level of outcome variable and that of its synthetic control was already 80 per cent of the level of the synthetic CEE8.

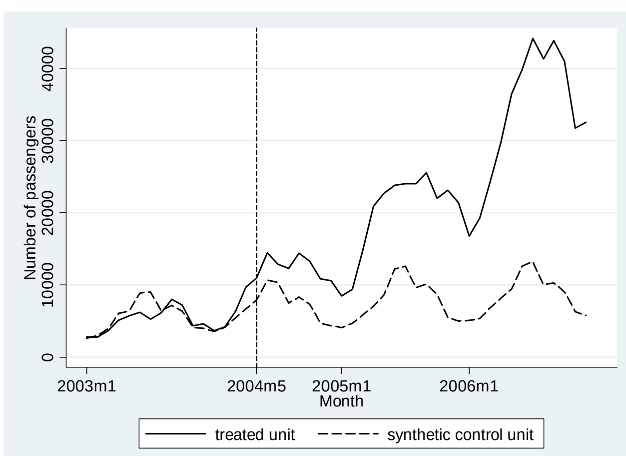

Figure 4.10. Trends in passenger numbers from Norway: Destination CEE8 (treated unit) vs synthetic CEE8

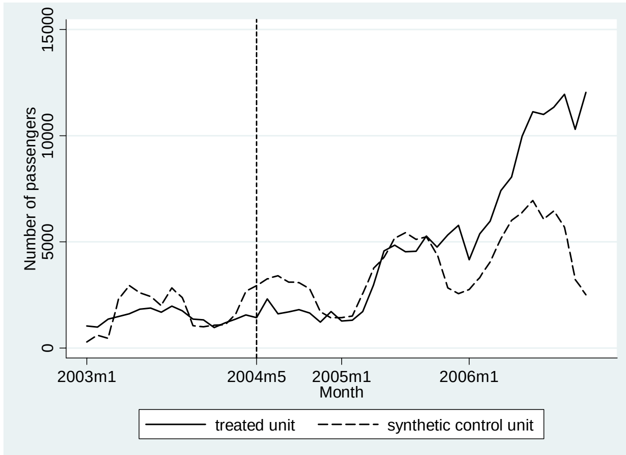

Figure 4.11. Trends in passenger numbers from Norway: Destination Poland (treated unit) vs synthetic Poland

Notably, in the case of the Norway-Poland country-pair (see Figure 4.11), the increase in number of passengers starts one year after the enlargement of the Single Aviation Market. No significant treatment effect of the enlargement was found immediately after the enlargement. The results based on Norway-Poland country-pair are consistent with previous experience from liberalisation of air services in Western Europe (in 1992) where it took at first some years after the liberalisation before the spread of low cost airlines started (Civil Aviation Authority 2006). In 2004 the volume of traffic to the CEE reacted at first more quickly in the case of the UK (see previous section). Similarly, the effects after previous large-scale air traffic liberalisation event in 1992 were at first evident in routes from UK and only gradually appeared elsewhere in Europe (CAA 2006, Pearce and Smyth 2007).

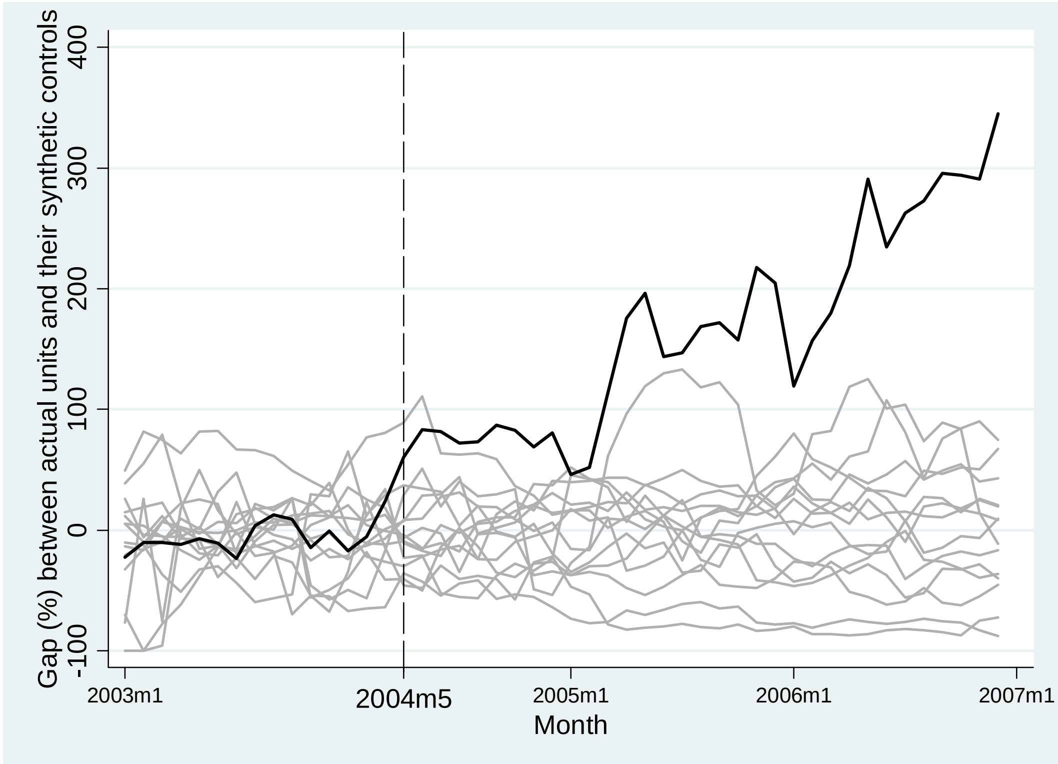

Figure 4.12. Difference between the actual number of passengers travelling on a country-pair and the corresponding synthetic control of the country-pair. Norway-CEE region-pair vs placebo studies of the 14 control country-pairs.

Note: **Bold line** - outcome difference (as per cent of the synthetic control) between the CEE8 and its synthetic control. **Grey lines** - outcome difference between each of the control units and their synthetic controls in the placebo studies.

To evaluate the statistical significance of my results, I conduct a placebo study in a similar way to the last section. Figure 4.12 plots the gap between the outcome variable of the treated unit (CEE8) and its control group, and also the similar placebo gaps for 'old' EU destinations. Again, we can see that the gap between the CEE8 and its synthetic counterpart is far larger than the gap estimated from placebo studies of country-pairs from elsewhere in the EU. Based on lack of any similar placebo gaps it can be argued that this result is statistically significant and that the liberalisation on routes to the CEE8 has resulted in large increase of volume of passenger traffic.

4.6 Conclusions

This chapter employed an event study of the enlargement of the EU and the Single European Aviation Market in 2004 and used difference-in-differences and synthetic control methods to identify its effect on volume of airline passengers. I demonstrate that this liberalisation event in 2004 resulted in substantial increase in number of passengers of scheduled flights travelling between UK and the CEE8, and Norway and the CEE8. I do not find any effect of the enlargement on passenger numbers on charter flights.

Based on implementation of the synthetic control method we can conclude that this sizeable effect is still evident even after construction and analysis of the proxy of the counterfactual—if the liberalisation of air traffic had not taken place in 2004.

I find that after the enlargement of the SEAM, already by the end of 2004, passenger flows on affected routes grew 80-106 per cent relative to what these would have been in the absence of the enlargement. In the case of flights to/from the UK the increase in traffic materialised immediately after the enlargement of the SEAM and EU. In the case of flights to/from Norway (a member of Single European Aviation Market but not a member of the EU) the largest increases in passenger numbers started a year after May 2004.

The majority of the effects take place on routes connecting airports outside London and Oslo with CEE countries. Also, my findings about the immediate effects of the SEAM enlargement in 2004 are much larger, in percentage growth terms, than some estimates about the immediate effects of the deregulation of 1992 (e.g. in Schipper *et al.* 2002).

Based on a number of placebo studies I show that the effect of actual liberalisation (on routes to the CEE8) on passenger numbers is much bigger than the estimated corresponding placebo ‘effects’ in old EU countries. If one were to re-label the treatment status in a country(region)-pair level data of 14 control units and one treatment unit (CEE8) at random, the probability of getting the results of the magnitude of those obtained for the CEE8 would be small—it is 0.067, both if the UK or Norwegian passenger volume data is used.

I have concentrated here on analysis of the effects of the EU and SEAM enlargement in 2004 on number of passengers on scheduled flights. Notably, we do not find similar effects of the 2004 enlargement round on number of charter passengers. Number of charter flights is not expected to be directly affected by the SEAM enlargement in 2004 as the entry barriers to charter entry on routes to the CEE did not change in May 2004. But the demand for charter flights could have been expected to be affected by the EU enlargement (the positive demand shock).

If we were willing to make a fairly restrictive assumption that in the absence of the 2004 enlargement, the quantity of scheduled and charter passengers would have followed similar trend over time, and that the demand effect of EU enlargement of scheduled and charter flights was similar, then the 2004 effect on number of scheduled passengers (as given in Table 4.1) would be fully due to change in entry barriers because of the enlargement of the SEAM and not only due to the demand effect of overall enlargement of the EU. However, it has to be acknowledged that the demand effect of the EU enlargement is likely to be very different for the scheduled and charter flights. Therefore we cannot fully separate these two effects in 2004.

In addition, the study of the 2006 enlargement round of the SEAM shows similarly large effects on scheduled flights. In 2006 the enlargement of SEAM was not accompanied by the overall EU enlargement. Therefore, the effect is likely to be due to the SEAM enlargement. This suggests that the large effects found in the case of the 2004 enlargement round are not only due to the overall EU enlargement, but also due to liberalisation of the aviation market. However, I acknowledge that the present empirical approach does not separate the 2004 EU enlargement effects and the SEAM enlargement effect.

Annex 4.1: Robustness tests of the difference-in-differences results: effects on number of passengers

Here I describe the robustness of the results of my DID analysis, based on passenger volume data from UK and Norway to the European Union. The estimated DID equation is Equation (4.1) from Section 4.4. I check how the exclusion of some countries from the control group affects the results. Table A4.1 gives the results for UK, Table A4.2 for Norway. The coefficient of the policy dummy in Tables below shows the average treatment effect of the enlargement of the European Single Aviation Market and the general effect of the enlargement of the EU.

In the Tables below, Column 1 includes all 'old' EU destination countries as a control group, Column 2 excludes Spain and Greece from the control group, Column 3 excludes also additionally Italy, France and Portugal. In the case of Norway (Table A4.2), Column 4 excludes additionally also UK from the control group.

Table A4.1. Difference-in-differences regression results based on UK country-pair level data

Dep. var.: *ln(number of passengers)*	(1)	(2)	(3)
NewEUmember dummy	-3.005***	-2.978***	-2.762***
	(0.596)	(0.289)	(0.297)
Policy dummy (i.e. NewEUMember*Post-2004May)[A]	**1.153*** **	**1.186*** **	**1.24*** **
	(0.165)	**(0.148)**	**(0.189)**
R^2	0.485	0.465	0.414
Prob>F	0.000	0.000	0.000
No. of Observations	1,800	1,634	1,385

Notes: All regressions include also a constant term and full set of time dummies. Robust standard errors, clustered by country-pair, are in parentheses. Method: OLS. *** - significant at 1 per cent level. Period: June 2001- April 2008. Frequency of data: monthly. Estimated equation: 4.1.
A. Policy dummy is equal to 1 for country-pairs to new Single European Aviation Market member countries for periods starting from May 2004.

The results in Table A4.1 show that the size of estimated treatment effect varies only little depending on which destination countries are included in the analysis. The DID effect is still always positive and significant. Although no additional control variables are included here, the estimated model explains a large share of variation in the dependent variable based on UK data—between 41 and 48 per cent of its variation.

Table A4.2. Difference-in-differences regression results based on Norwegian country-pair level data

Dep. var.: *ln(number of passengers)*	(1)	(2)	(3)	(4)
NewEUmember dummy	-3.326***	-2.647***	-2.893***	-2.718***
	(0.741)	(0.187)	(0.197)	(0.197)
Policy dummy (i.e.	**1.65*** **	**0.978*** **	**1.095*** **	**1.096*** **
NewEUMember*Post-2004May)[A]	**(0.497)**	**(0.322)**	**(0.334)**	**(0.334)**
R^2	0.4	0.352	0.358	0.336
Prob>F	0.000	0.000	0.000	0.000
No. of Observations	1010	899	756	708

Notes: All regressions include also a constant term and a full set of time dummies. Robust standard errors, clustered by country-pair, are in parentheses. Method: OLS. *** - significant at 1 per cent level. ** - significant at 5 per cent level. Period: January 2003 – December 2006. Frequency of data: monthly. Estimated equation: 4.1.

A. Policy dummy is equal to 1 for country-pairs to the new Single European Aviation Market member countries for periods starting from May 2004.

In Norwegian dataset the inclusion or exclusion of destination countries from the control group affects the size of the estimated effect. Still, the coefficient of the policy dummy is statistically significant in all the columns of Table A4.2.

Annex 4.2: Difference-in-differences regression results: effects on number of flights

In addition to the effects on number of passengers I check whether similar effects of SEAM and EU enlargement can be found based on data of number of flights. Monthly data of number of number of flights on a country-pair or route are taken from the UK Civil Aviation Authority (CAA). My dataset of number of flights covers routes between the UK and the rest of the Europe, from June 2001 to March 2008. Time of policy change is again May 2004.

I estimate the Equation (4.1) using data of number of flights. Table A4.3 uses country-pair level data of 24 country pairs (14 from the UK to the 'old' EU members, 8 from UK to the 8 new EU members, excluding Malta and Cyprus) .

Table A4.3. Difference-in-differences regression results based on country-pair level data of number of flights

Dep. var.: *ln(number of flights)*		
	Coeff.	Std. Error
NewEUmember dummy	-2.926***	(0.089)
Policy dummy (i.e. NewEUMember*Post-2004May)[A]	**0.936*** **	**(0.11)**
Constant	7.841***	(0.232)
Full set of time dummies included	Yes	
R^2	0.563	
Prob>F	0.000	
No. of Observations	1778	

Notes: 24 country-pairs. Method: OLS. *** - significant at 1 per cent level. Estimated equation: 4.1.
A. Policy dummy is equal to 1 for routes to the new EU member countries for periods starting from May 2004.

It is clear that country-pairs going from UK to the new EU members have significantly lower level of traffic than these to the Western Europe (see the coefficient of *NewEUmember dummy*).

The average treatment effect of change in policy is given by the coefficient of the *Policy dummy*. The coefficient of this variable is positive, indicating strong positive treatment effect of EU enlargement on number of flights. In quantitative terms, it occurs from Table A.4.3 that the enlargement of the European Single Aviation Market and the EU resulted in 155 per cent[82] increase in number of flights on country-pairs between the UK and Central and Eastern European new member countries.

The analysis in Table A4.3 is based data of scheduled flights. When I used similar approach to look at the effects of EU enlargement on number of charter flights, then no significant effect on traffic was found.

[82] I.e. calculated as: exp(0.936) – 1.

Annex 4.3: Difference-in-differences analysis based on yearly Swedish passenger traffic data

I estimate a standard DID equation as given in Equation (4.1) to find out the effects of the EU enlargement on the passenger traffic to and from Sweden. Table A4.4. below uses Swedish country-pair level data for that.

Data: Swedish data of number of passengers on international flights on country-pairs originating from Sweden.

Level of aggregation: country-pair level.

Period: 1999-2007.

Coverage: European destination countries from Sweden.

Frequency of data: yearly. Source: SIKA-Institute, Sweden.

Table A4.4. Difference-in-differences regression results based on Swedish country-pair level yearly data

Dep. var.: *ln(number of passengers)*	(1) Sweden to the rest of the EU25 (including Malta and Cyprus)	(2) Sweden to the rest of the EU, excluding destinations Malta and Cyprus
NewSEAMmember dummy	-2.285***	-2.266***
	(0.185)	(0.203)
Policy dummy (i.e. NewSEAMmember*Post-2004May)[A]	**0.468** **(0.291)**	**0.551*** **(0.305)**
Constant	12.325***	12.413***
	(0.224)	(0.221)
Full set of time dummies included	Yes	Yes
R^2	0.554	0.547
Prob>F	0.000	0.000
No. of Observations	189	171

Notes: OLS results. *** - significant at 1 per cent level, * - significant at 10 per cent level. Period 1999-2007, yearly data. Estimated equation: 4.1.

A. Policy dummy is equal to 1 in the case of routes to the new member countries of the Single European Aviation Market (SEAM) for periods starting from May 2004.

Similarly to the previous results from UK and Norway, Column 1 and 2 in Table A4.4 show that routes going from Sweden to the new member countries of the European Single Aviation Market have significantly lower number of passengers than routes to the Western Europe.

We find significant treatment effect of enlargement of the Single Aviation Market and the EU on passenger numbers in Column 2, i.e. when both Malta and Cyprus are excluded from the sample. However, unlike the new members from the Central and Eastern Europe (CEE), they Malta and Cyprus had large air traffic numbers from the EU15 already before 2004. These two countries have been important holiday destinations with traditionally large number of (charter) flights from Western Europe.

Annex 4.4: Synthetic control method—effects of enlargement of the EU on number of passengers flying between the CEE countries and the UK

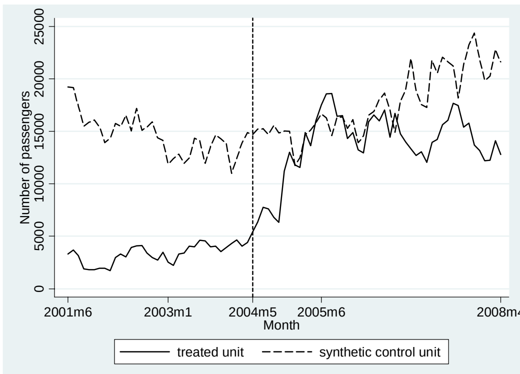

Figure A4.1. Number of passengers: Estonia and its synthetic control

Note that in the case of Estonia the SCM fails to find a suitable synthetic control, due to size difference with control units. The synthetic control found does not follow the pre-treatment trend of number of passengers from Estonia.

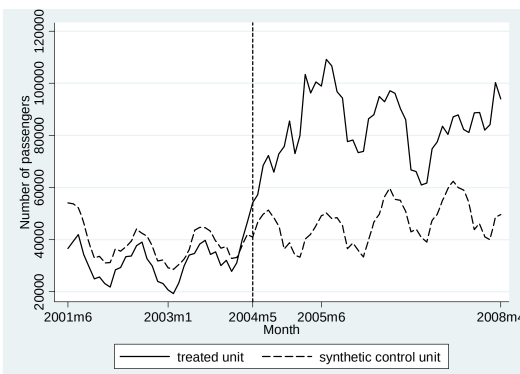

Figure A4.2. Number of passengers: Hungary and its synthetic control

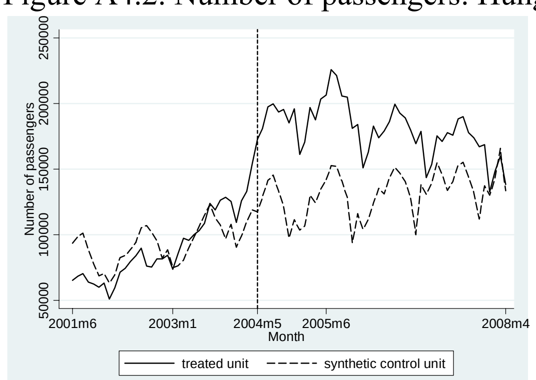

Figure A4.3. Number of passengers: Czech Republic and its synthetic control

Annex 4.5. Ratio of Post-treatment and Pre-treatment MSPE

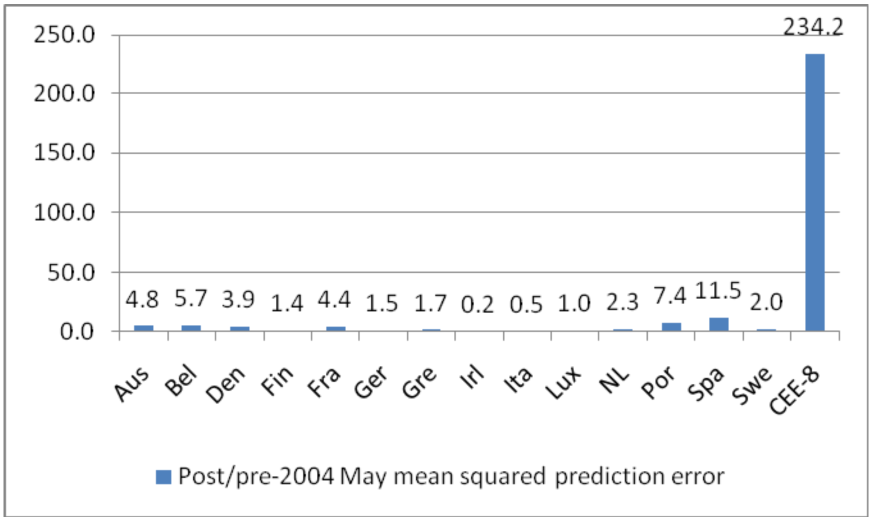

Figure A4.4. Ratio of Post-EU enlargement MSPE and Pre-EU enlargement MSPE. CEE8 to UK region-pair vs. 14 control country-pairs. (MSPE - mean square prediction error).

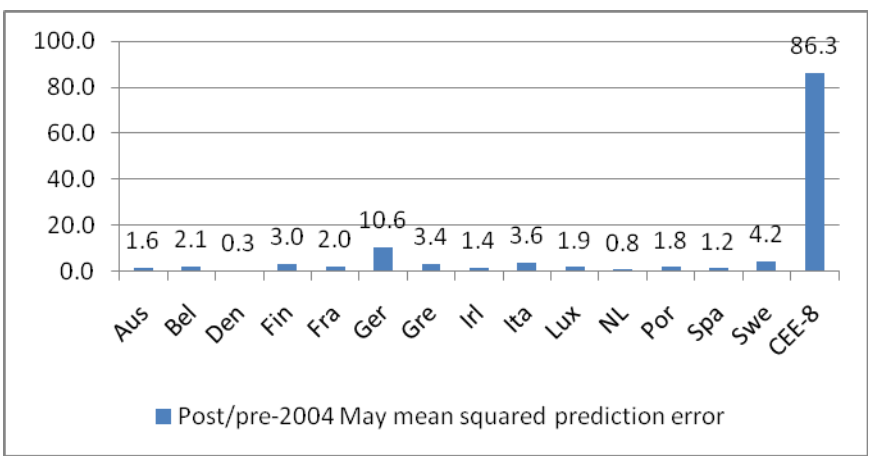

Figure A4.5. Ratio of Post-SEAM enlargement MSPE and Pre-SEAM enlargement MSPE. CEE8 to Norway region-pair vs. 14 control country-pairs.

5. Conclusions

5.1 Summary and discussion of findings

This thesis contributes to the growing literature of microeconometric analyses of the effects of competition. My study has been motivated by the empirical evidence of persistent large productivity and output price dispersion across production units and spatial markets. The increased availability of rich micro level datasets enables to study the role of competition in these variations. Also, the new models in industrial organisation and trade theory outline how international competition affects heterogeneous firms, and how these firm level effects result in changes in productivity and output price distributions at more aggregate levels.

This dissertation provides empirical evidence about different ways how changes in the intensity of international competition affect productivity, other performance measures, and output prices. My study contributes to the literature on empirical industrial organisation and FDI. It studies the within-firm and selection effects of market entry and changes in market structure, and aggregate level effects of entry liberalisation. Also, it endeavours to control for the endogeneity of measures of competition. Each chapter of this thesis has dealt with a particular aspect of change in the competitive environment of firms. Overall, my results underline the importance of building upon micro level evidence in order to find out the effects of international competition on national economies.

Chapter 2 provides, based on rich firm-level data from the manufacturing industry in Estonia, comprehensive empirical evidence how entry of multinational firms (MNE) affects incumbent firms in the host economy. The study concentrates on the effects on productivity growth, innovation and direct measures of knowledge-flows to incumbents. This chapter adds to the literature about the effects of MNE entry, firstly, by investigating the channels of productivity spillovers of FDI that have been either little studied (effects on innovation, effects on direct measures of knowledge flows) or have not been studied before (effects on innovation related co-operation). Secondly, Chapter 2 adds to the literature by trying to account for the endogeneity of MNE entry in the host economy. Identification of the effects is based on instrumental variables that predict the MNE entry in Estonia, but are (otherwise) unlikely to affect the outcome variables of incumbent firms.

I find that the MNE entry in an industry or a region in Estonia has no short-term impact on incumbent firms' TFP and labour productivity growth. However, the entry of multinational firms results in other important within-firm changes. MNE entry is positively associated with process innovation of incumbents and also with knowledge sourcing from firm's suppliers. It does not affect innovation-related co-operation with other firms.

These results provide a relatively positive view about the FDI spillovers. MNE entry in Estonia facilitates both creation and diffusion of new technology, and therefore could have positive effects on incumbents' performance and productivity in the long-term (despite the evidence of no short term or immediate effects on the total factor productivity growth). These findings show that much caution is needed in studies about FDI spillovers when considering the policy implications and especially when considering whether special incentives for FDI were justified. A detailed study of channels of the spillovers may lead to different conclusions than a study of short-term effects on productivity only.

Notably, the pattern of empirical results about the effects of MNE entry is significantly different from the evidence in Aghion *et al.* (2009) on the UK. Unlike in the UK, in Estonia's case we cannot confirm the predictions from Schumpeterian competition models (Aghion *et al.* 2009, Aghion and Griffith 2005). These predictions were that technologically advanced entry spurs innovation incentives (and productivity) only for incumbent firms that are close to the productivity frontier, in whose case innovating allows to survive the entry. Instead, the results in Estonia are consistent with the view that FDI results in knowledge transfer and spillovers, and that there is more knowledge transfer to incumbent firms that have high absorptive capacity.

A general conclusion from this study is that the effects on productivity of incumbents could take longer time to emerge than assumed in the standard estimation framework in the literature. This can be especially the case in countries like Estonia where the overall ability (absorptive capacity) of domestic owned firms to benefit from FDI spillovers is lower than in Western Europe. The country-level differences in absorptive capacity might explain why researchers are more likely to find positive productivity spillovers in Western Europe than in transition economies.

Chapter 3 shows how entry and market structure affect output price distribution across firms within spatially differentiated markets of a single industry—the passenger aviation sector. This chapter tests some of the key implications of the heterogeneous-producer models from industrial organisation (Syverson 2004a) and trade theory (Melitz and Ottaviano 2008) based on services sector data. In literature, it is well-known standard result that stronger competition is associated with lower average prices in a market.

Recent heterogeneous-producer models of competition and trade outline richer effects. These predict how tougher competition affects also other moments (dispersion) of the across-firm price, productivity and cost distributions in the same sector and market.

To investigate these issues, Chapter 3 has used a case study of the Western European short-haul airline sector and a unique airfare dataset with 1.7 million airfare observations. So far, there are few papers that investigate the selection effects of competition outside the manufacturing industry, or ready-mixed concrete production (Syverson 2007, 2004a). One exception is by Foster *et al.* (2006) who look at the role of entry and exit in productivity dynamics of the US retail sector. Concentrating on a study of a single (transport services) sector with spatially differentiated markets (city-pairs), relatively similar technology and relatively easily substitutable products across firms within these separate markets, enables us to account to some extent for the usual product and technology heterogeneity problem of many of the earlier studies.

I find that stronger competition in the form of entry, larger number of competitors or lower value of the Herfindahl index within a city-pair is associated with lower average airfares. But, I also find evidence that tougher competition on a city-pair is correlated with lower across-carrier price variation and upper-bound prices, as predicted by the heterogeneous-producer models. These results based on price data can be due to similar cost-related selection effects among airlines in different spatial markets.

These findings are economically significant. For example, an increase in the number of competitors on a city-pair is associated with 8-10 per cent fall in upper-bound price and average price and 6-7.5 per cent fall in median price on a city-pair.

The main implication of these results is that competition and product substitutability may account for a significant share of the price dispersion across different producers. In sectors where spatial competition is important, the effect of competition on average output prices is likely to include a more complex (selection) mechanism than described in the traditional homogeneous-producer models of competition. These conclusions are likely to hold not only in the aviation sector, or the ready mixed concrete production (Syverson 2007), but also in many other industries as well. For example, separate spatial markets are an important characteristic of retail industry and many services sectors.

Chapter 4 investigates how one liberalisation event has affected the output of the aviation sector. It studies the May 2004 enlargement of the EU and the Single Aviation Market (SEAM), and its impact on performance and output of the passenger aviation sector in Europe. It employs difference-in-differences and a recently developed synthetic control method to estimate the effects of this liberalisation event on the volume of airline passengers.

The synthetic control method (SCM) by Abadie *et al.* (2009) is an extension to the difference-in-differences approach. It enables us to account for the possibility of non-parallel trends of the group of routes affected by the EU enlargement and the control group. This method accounts for the time-varying unobservable country-pair characteristics which are ignored by the standard difference-in differences approach.

I find that already by the end of 2004 the number of scheduled passengers travelling between UK and the eight Central and Eastern European (CEE) new member states grew by 106 per cent, relative to what it would have been in the absence of the enlargement of the EU and SEAM. The corresponding growth on routes from Norway, a member of the SEAM but not a member of the EU, to the CEE was 80 per cent, relative to a comparable synthetic control without the change in policy. The majority of these effects are concentrated on routes connecting airports outside Oslo and London with CEE countries.

I find also results of similar magnitude from entry of Croatia into the Single Aviation Market in 2006. Croatia became a member of the SEAM in 2006 but did not enter the EU at the same time. That way the effects of the 2006 enlargement round are likely to be more about the liberalisation of the aviation sector, not the combination of this with the overall effects of the EU enlargement.

5.2 Further research

The most natural way how to extend studies in this thesis is to investigate production units in sector(s) that produce rather homogeneous goods and have faced exogenous changes in the competition environment. It pays to search for changes in competition (e.g. a change in competition induced by trade liberalisation) that can be, from the viewpoint of firms in the studied sector, treated as an exogenous shock or natural experiment. Of course, it is most difficult to find an event that can be considered a natural experiment. Policy changes, although sometimes called natural experiments, are very often endogenously determined.

There are many potential connections between competition and productivity that have yet to be thoroughly studied in future research. An obvious, but difficult question that needs to be followed is—which channel of the effects matters the most? Several studies compare the relative importance of the within-firm effects, the entry-exit effect and the between firm re-allocation effects (e.g. Baldwin and Gu 2006, Bartelsman *et al*. 2005). However, these effects are likely to vary in different sectors and markets. For example, Foster Haltiwanger and Krizan (2006) show that entry and exit account for almost all of the aggregate productivity growth in the US retail sector. It is not clear which sector and market level characteristics determine the relative importance of each channel of the effects of competition.

More generally, most of the empirical papers about the determinants of productivity concentrate on the role of one particular determinant: e.g. work practices, competition, innovation, skills, change in entry barriers or technology. The literature has so far been unable to determine the relative importance of these main determinants of productivity.

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