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Econometric analysis to develop evidence on the links between aviation and the economy

Final Report

Airports Commission

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Disclaimer

Contents

1. Executive summary

1.1. Report commission

This report has been prepared by PricewaterhouseCoopers LLP (PwC) for the Airports Commission (AC). The report was commissioned following the issue of a competitive tender: "Aviation Appraisal: Econometric Analysis to Develop Evidence on International Business Impacts" Contract Reference PPRO 04/08/69. A contract was formed subject to the DfT's terms and conditions that were issued alongside the tender document.

The AC commissioned and financed the work, and the Department for Transport (DfT) and the AC commented on the work at various stages. This final report, however, represents the independent analysis of PwC.

The analysis has been independently peer reviewed by three of the AC's expert panel of academics: Professor Peter Mackie (University of Leeds), Mr David Starkie (Case Associates) and Professor Dan Graham (Imperial College London).[1] This version of the report reflects their comments in so far as we have been able to implement them within the constraints of the available data, the time and budget given to us by the AC to complete this work, and the practical applications of econometrics.

1.2. Purpose of study

In this report, we consider the linkages between the air connectivity of the UK on the one hand, and the UK economy on the other. Air connectivity is a measure of the accessibility to the global air transport network from a country's major airports. It is defined by the DfT as "a combination of the range of destinations served and the frequency of flights" (DfT, 2012).[2] It is a qualitative measure of a country's air transport services – the higher the level of air connectivity, the greater the level of access by air of a particular country or destination to the global economy.

In our analysis we are concerned with the relationship between changes in the UK's degree of connectivity by air to different destinations within the UK and abroad, and changes in the UK economy as measured by gross domestic product (GDP). The hypothesis we investigate is that as the UK's connectivity by air increases, so too do the flows business and leisure travel and in turn so to do the key economic components that underlie GDP (e.g. trade, investment etc.).

In order to quantify any relationship between UK air connectivity and UK GDP, we undertook statistical analysis of historic data, using econometric regression techniques.

Although there have been previous studies that have sought to quantify the link between aviation connectivity and the wider economy, there has been no robust, up-to-date, study for the UK. Also, the scope of previous studies has been limited in the sense that either aviation is not necessarily considered as the primary issue, or the focus of the analysis is on a component of the economy rather than GDP as a whole.

1.3. Our approach

In order to test the relationship between UK air connectivity and the UK economy we need a measure of connectivity that reflects the direct linkage between the UK airport system and the destinations it serves. There are multiple connectivity measures available, which are discussed in more detail in Section 2.4 of the report. We wanted to use as direct a measure as possible of the links between the UK and airport destinations. Flight frequency was one possible option, but as different sized aircraft are used on different routes, this measure does not fully capture the capacity of a route. We therefore chose to use direct seat capacity as our measure of overall passenger activity on a particular airline route. Direct seat capacity is also susceptible to influence through UK

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[1] The peer reviewer comments are summarised in the technical appendix (Appendix 3) of Airports Commission's December 2013 Interim Report and are also published alongside this document.
[2] DfT (2012) Transport Analysis Guidance (TAG), Department for Transport, available at: http://www.dft.gov.uk/webtag/documents/index.php

Government aviation interventions on UK airport capacity, the key concern of the AC. We discuss this further in Section 2.5 of this report.

For the purposes of this study, the AC defined four channels through which the output of the aviation sector might be expected to affect the economy, based on a previous study by NERA (2009).[3] These four channels are cross-border trade, cross-border labour movement, foreign direct investment (FDI) and tourism.

The hypothesis underlying the NERA study is that increased air travel by business and tourism users could lead to an increase in both the inflows and outflows for each of these four specified channels, contributing to a net increase in the level of GDP. This hypothesis forms the basis of our econometric analysis.

The net effects of these channels on GDP are not clear-cut. For instance, an increase in imports will contribute negatively to GDP, but could also be associated with an expansion in industries that use imports as inputs to create their final outputs.

We used a three step approach for our analysis:

- **Step 1**: a review of the economic literature on each channel. This literature review is focussed on published academic studies that have sought to quantify the link between air connectivity, the relevant channel and the economy using econometric techniques.
- **Step 2**: we then consider the relevant data for the econometric models
- **Step 3**: we then incorporated the key lessons from the previous studies described in this literature in our own econometric specification. There are three key challenges relating to applying econometric techniques in this study:
  - constraints on data availability;
  - the issue of causality; and
  - the issue of endogeneity.

The challenges identified for consideration in Step 3 are important, as they impose limitations on the use of regression analysis to analyse the link between aviation and the wider economy.

First, data constraints specific to the UK limit the choice of econometric model that can be estimated. This means that the methods used in some previous studies cannot be replicated in the UK context. For example, in the case of the FDI channel, our analysis has been conducted at both the UK regional and national levels, but the shorter time period for which regional data are available requires the use of a different econometric approach.

Secondly, it is important to recognise the concept of causality in econometrics. Ideally, we would like to establish a causal link between UK air connectivity (as measured by UK direct seat capacity in our work) and UK GDP – to establish that an increase in air connectivity increases GDP. However, the limitations of econometrics mean that it is not possible to establish such a causal link irrefutably.

In Section 3 we apply a technique called “Granger causality”.[4] When we refer to the concept of causality in this document, this is what we are referring to. Granger causality effectively shows whether it is possible to use seat capacity to predict GDP and vice versa.[5] This is a standard and widely applied approach used in econometric research. Where we use econometric approaches other than Granger causality, we refer to the statistical links that we find as “associations”. Again, this is standard practice.

Thirdly, a common issue in our approach that can be found in previous studies is that of endogeneity. This is best explained by a practical example. Consider a situation where a country’s government was to invest heavily in tourism related infrastructure in a bid to attract tourists. In such a situation, whilst this infrastructure may enable tourist arrivals, it is also possible that the need for such an investment was primarily driven by a prior

[3] NERA Economic Consulting (2010) ‘Representing International Business Impacts in Transport Appraisal – Literature Review’.

[4] This concept is named after Sir Clive Granger who invented the concept along with Professor Rob Engle. They were awarded the Nobel Prize in economics for their research into this technique. For further reading on the subject see Engle, R.F and Granger, C.W.J (1991) “Long-run economic relationships: Readings in cointegration”, Oxford University Press.

[5] In technical terms this means: variable A is said to Granger cause variable B, if the lags of A can improve a forecast for variable B.

increase in tourist arrivals. The latter would lead to a simultaneity issue where investment in tourism-related infrastructures can both explain and be explained by tourist arrivals. Our approach is focussed on removing this endogeneity from our analysis, and thus allowing us to examine how improvements in air transport infrastructure drive tourist arrivals.

These issues are common in other academic studies. As part of our literature review we examine the techniques used by academic econometricians to deal with the problem of endogeneity, and draw from these studies information on which economic variables (distance from the UK, language, etc.) might drive the relationship between seat capacity, GDP and the different channels we have been tasked with investigating.

These issues and their implications for our analysis are discussed further in Section 2 of this report.

1.4. Key findings

Of the four channels defined by the AC we were unable to investigate labour mobility as we could not find suitable data. The impact of air connectivity on the other three channels is quantified using econometric regression analysis. In addition to analysing these three channels we also conducted an analysis which tested the link between UK direct seat capacity and UK GDP directly. The results are presented in separate Sections in our report.

Our findings show an association between seat capacity and: GDP; tourism passenger inflows and outflows; import and export values; and inward and outward FDI flows. The strength of this association varies across the four models that we estimate, whilst staying largely significant at the 1%, 5% or 10% levels. We summarise our main findings below.

Model 1: GDP impact

The relationship between UK air connectivity and UK GDP is the only one which we examined where we found a causal effect (using the Granger definition of causality). Our results show that, in the short run, a 10% change in the growth rate of seat capacity "causes" approximately a 1% change in the growth rate of real GDP. Using the Granger approach, our model was tested to determine whether an expansion in seat capacity leads to an increase in GDP or vice versa. Our results show that this result runs both ways, but that it is possible to identify a separate statistical link between an increase in seat capacity causing an increase in GDP. This effect is found to be significant at the 5% confidence level. A detailed discussion of our results can be found in Section 3.

Model 2: Tourism channel

Our modelling suggests that a 10% increase in seat capacity is associated with a 4% increase in tourist arrivals to the UK and approximately a 3% increase in UK residents visits abroad. Both coefficients are significant at the 1% level.

Data is not available on visitor expenditure, so instead we use visitor numbers. Note also that increases in seat capacity cause both increases in inbound and outbound tourism, and we have not attempted to quantify the net effect on UK visitor numbers or on tourism receipts. A discussion of our tourism channel results can be found in Section 4.

Model 3: International trade in goods and services channel

A 10% increase in seat capacity is associated with a 1.7% increase in **UK goods imports** and a 3.3% increase in **goods exports**. These coefficients are both significant at the 1% level.

In addition to trade in goods, we find that a 10% increase in seat capacity is associated with a 6.6% increase in **UK imports of services** and a 2.5% increase in **UK exports of services**. Both coefficients are significant at the 1% level. A more detailed discussion of our international trade results can be found in Section 5.

Model 4: FDI channel

For the FDI channel, in addition to examining the whole economy we were also asked by the AC to split out the manufacturing sector as more data are available for this sector. For manufacturing sector FDI a 1% increase in connectivity is associated with a 1.1% increase in UK manufacturing sector FDI inflows. This coefficient is significant at the 5% level.

For the whole economy a 10% increase in seat capacity is associated with a 4.7% increase in FDI inflows to the UK. This coefficient is significant at the 1% level. Similarly, a 10% increase in seat capacity is associated with a

1.9% increase in UK FDI outflows, also significant at the 1% level. A discussion of the results from our FDI analysis can be found in Section 6.

The quantitative estimates we report for each of the different channels are shown to be statistically significant associations and should be treated as such. With the exception of the Granger causality results we do not recommend that these results be used as a basis for calibrating other economic models.

The analysis that we have undertaken does not explicitly differentiate between transfer and non-transfer traffic. The historical data upon which these regressions are based include a proportion of seat capacity associated with hub traffic.

The remainder of our report is set out as follows. Section 2 discusses the methodological issues and the data used in this report. The subsequent sections introduce our models for GDP (Section 3) and then for tourism, trade and FDI (Sections 4, 5 and 6 respectively). Further details of the data sources we have used, the econometric theory underpinning our models, and the studies we have reviewed in defining our modelling approach, can be found in the appendices.

2. Methodology and data issues

2.1. Overview

In this section we provide a more detailed discussion of the methodology and data used in this report. In particular we cover:

- Our approach to reviewing the academic literature that underpins our study;
- The data used in this report;
- The different measures of connectivity that have been used in previous studies; and
- The methodological challenges for these types of econometric exercises, with a particular focus on the issue of endogeneity.

Our analysis is undertaken in 3 stages, which are set out in Figure 1 below. In stage 1, we draw inferences and methodological insights for our econometric approach from previous academic studies. We focus in particular on the variables and data used in previous studies and use these as a starting point for our analysis. In stage 2 we collect relevant data. In stage 3, we carry out econometric modelling based on the methodological insights drawn from stage 1 and the application of more recent econometric techniques that help correct key analytical problems such as endogeneity.

Figure 1: Proposed staged approach

2.2. Literature review

The literature review was conducted for the tourism, trade and FDI channels. Labour migration was not included, due to lack of data. The findings and methodology of relevant studies are reported in the individual sections covering each channel.

Following an extensive search, it is clear that there is not a large body of evidence that examines the relationship between air seat capacity, GDP and the different channels considered in the scope of this project. However, we do still filter the analysis to include in the literature review so that we can evaluate systematically those articles that are available. We considered the following criteria:

- **How closely related to our study is the article?** This was determined by looking at the aim of the research.
- **When and in what context was the article published?** Although some older articles may be directly relevant to our study, the econometric techniques may have since been superseded.
- **How reputable is the publication?** We considered peer reviewed journals and University working papers

Using our selection criteria, we then assessed each of the articles based on the econometric techniques used by the authors, the size and quality of the dataset used, and the plausibility of the results obtained. There is a broader literature that considers how aviation links to GDP, but our search was limited to econometric studies that relate to the channels in the scope of this project.

This exercise provided us with an initial understanding of the type of econometric issues we were likely to encounter in our study. It helped us to develop an understanding of how best to deal with each issue and which data sources could be of use. It also gave us a set of prior results against which we were able to assess the plausibility of both the direction and magnitude of our regression results.

2.3. Channels through which connectivity might affect GDP

As described above, the AC asked us to examine four channels through which aviation connectivity might affect GDP. These channels are set out in more detail in Figure 2 below.

Hong, Chu and Wang (2011)[6] seek to explain the link between connectivity and business relationships in detail. For instance, they suggest that if increased connectivity leads to travel times falling, it could enable businesses to gain access to a wider marketplace or undertake cross border investment more easily. It also gives scope for businesses to improve the efficiency of existing production and supplier relationships.

There could also be some overlap in the way in which the different channels affect the economy. For instance, FDI and trade might be linked through a UK exporter purchasing an overseas company that forms part of its supply chain.

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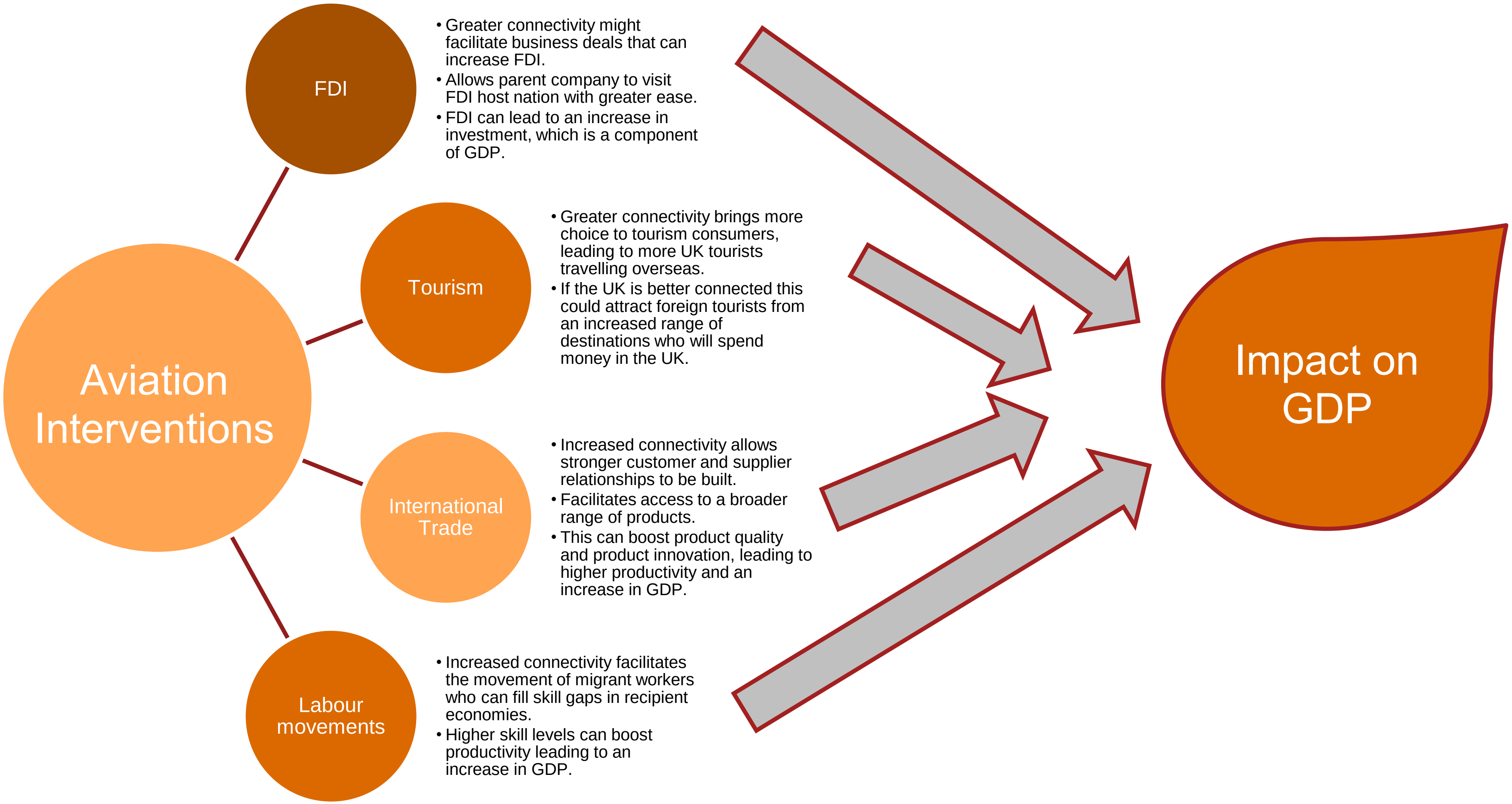
[6] 'Transport infrastructure and regional economic growth: evidence from China', Transportation vol.38, pp.737-752, Hong, Chu and Wang (June, 2011). A similar framework can also be found in; 'Transportation and Economic Development', Button and Reggiani, 2011.

Figure 2: Channels through which seat capacity might influence GDP



2.4. Measures of connectivity

2.4.1. Summary of measures

Connectivity measures can take various forms and are frequently specified as an explanatory variable in studies that use econometrics to analyse the relationship between changes in transport linkages or capacity and the different possible channels through which these might affect GDP. A key challenge for our work was to choose the most suitable variable to represent UK aviation linkages or capacity. This section surveys the approaches used in previous studies and describes the key connectivity variable used in this study.

Connectivity can be measured in a range of ways, which vary in complexity and data requirements. The main measures are listed below:

- Number of destinations served;
- Direct seat capacity, total passengers (direct and indirect, Origin/Destination and transfer);
- Route network concentration (geographic spread of services);
- Route distance/alternative modes/isolation;
- Cost of travel; and,
- Class of travel – premium vs. economy, business vs. leisure etc.

There are also a number of air connectivity indices and measures that aim to capture a range of factors which influence an airport's or region's connectivity. The most prominent of these are the World Bank and IATA connectivity indices. We discuss these below.

2.4.2. Previous use of connectivity measures

Table 1 describes a range of connectivity measures, as discussed in the Airports Commission Discussion Paper 2 (2013)[7] and their limitations.

[7] Airports Commission Discussion Paper 2: Aviation Connectivity and the Economy. This report is available from: https://www.gov.uk/government/publications/discussion-paper-on-aviation-connectivity-and-the-economy

Table 1: Summary of connectivity measures

Measure	Description	Limitations
Destinations served	Number of destinations served by each airport, UK region and total. Can be grouped by destination region, frequency of services (e.g. daily frequency).	Does not take into account onward connection, no indication of frequency or capacity of services.
Frequency of services	Number of flights over a time period.	Does not take into account onward connection, one-dimensional, does not reflect spread of network.
Available seat capacity	Number of available scheduled seats over a time period.	Does not take into account onward connection, one-dimensional, does not reflect spread of network.
Route network concentration	The geographic spread of airline services.	Does not take into account the size of the airport or frequency of services.
York Aviation business connectivity index [8]	Captures economic importance of destinations, measures value of connectivity to businesses.	Does not directly reflect aviation services (but takes into account business location decisions), data not readily available to allow calculation over time.
Netscan connectivity index	Captures seat capacity, accounts for both direct and indirect connections and for transfer time and potential delay time for connecting flights.	Limited available data, unclear how it is calculated.
World Economic Forum connectivity index	Presents data on scheduled available seat kilometres per week in 2012 for a sample of 144 countries.	Does not weigh routes on the basis of frequency, or the economic importance of destinations.

Source: Airports Commission (2013), Discussion paper 2.

2.4.3. World Bank connectivity index

A paper by Arvis and Shepherd (2012)[9] for the World Bank defines connectivity as the importance of a country as a node within the global air transport system. The more overall 'pull' it can exert on the rest of the network, the better is its connectivity score.

A key issue raised by the authors is the importance of capturing hub and spoke relationships as well as distance. The index takes into account the connectivity of the nodes to which each airport/region is connected. The index is normalised, which allows for cross-country comparisons and regional aggregations. Calculating this index is, however, very data intensive, and it would also be difficult to replicate this approach to generate a historical time series.

[8] "The York Aviation Business Connectivity Index "*scores an airport's destinations based on their ranking within research undertaken by the Globalisation and World Cities (GaWC) network. This research identified a hierarchy of world cities based on a detailed analysis of the location decisions of 175 advanced producer service firms in 525 cities around the world. These scores are then weighted by the frequency offered to these destinations to reflect the extent of 'connectedness' to individual points*." "Aviation Services and the City" 2011 update report prepared for the City of London Corporation by York Aviation Published January 2011

[9] Arvis, J-F and Shepherd, B. 'The Air Connectivity Index: Measuring Integration in the Global Air Transport Network' World Bank, Policy Research Working Paper 5722

2.4.4. IATA connectivity index

IATA (2006)[10] has developed a connectivity indicator to measure the degree of integration of a country within the global air transport network. It is a measure of the number and economic importance of the destinations served from a country's major airports, the frequency of service to each destination, and the number of onward connections available from each destination. The IATA connectivity index increases as:

1. •The range of destinations increases;
2. •The frequency of service increases;
3. •The number of seats on the aircraft used increases; and / or
4. •Larger "hub" airport destinations are served (as reflected in the weighting term).

The key drawback of the IATA index is that it is not normalised, and therefore, it is difficult to make cross-country comparisons and generate regional aggregates.

2.5. Choice of a connectivity measure

Following extensive discussion with the AC, we chose available seat capacity as our measure of air connectivity. Our reasons for this are as follows.

As part of our analysis we built and tested measures of direct and indirect seat capacity. Direct seat capacity refers to a flight from a UK destination to either a UK or foreign destination e.g. London to Dubai. Indirect seat capacity refers to an additional second flight from the destination to another destination outside of the UK i.e. London-Dubai-Sydney. The indirect measures were subject to stability problems, which were identified by our econometric approaches, resulting from indirect routes being more prone to being established then cancelled. We therefore preferred direct seat capacity over a measure that took into account indirect seat capacity.

We also considered using a measure of direct flight frequency. We found that there is a correlation of 96% between direct seat capacity and direct flight frequency. This means that the regression coefficients on these two measures of air connectivity tend to be very similar. However, we believe that direct seat capacity is the more appropriate measure of the two as it captures the impact of varying aircraft size whereas flight frequency does not.

The overall connectivity of a given country would have limited value for the AC as a driver of economic growth since this index cannot be directly controlled by policymakers, and therefore we decided not to use this measure. Compared to the overall connectivity index, we believe that direct seat capacity between the UK and a given country is a suitable choice for two important reasons. First, direct seat capacity provides us with a more natural way of assessing the materiality of different routes to UK tourism, FDI and trade. Secondly, this proxy is also likely to be the most impacted through a policy change relating to capacity.

There are some limitations to using seat capacity data in our analysis.

- No passenger load or yield information;
- No breakdown of class of travel; and,
- Lack of clarity on the ultimate origin or destination of the passenger.

To demonstrate the last point, scheduled airline seat capacity between the UK and India has declined in recent years (-4% a year in CAGR terms between 2007-2012), while passengers have increased (1% a year in CAGR terms between 2007 and2012) between the two countries. There has been an increasing trend in passengers transferring at Middle East hub airports (e.g. Dubai) and, therefore, direct capacity has reduced. This trend would not be apparent from simply analysing schedule data, and we believe that sole reliance on this type of tool would be inadequate.

However, when considering alternative measures for connectivity, we think the strengths of a seat capacity measure outweigh the limitations. No measure will be able to deal with all of the associated issues.

[10] IATA (2006), "Measuring the Economic Rate of Return on Investment in Aviation"

2.6. Data collection

We have collected time series data on economic variables that were consistently identified in academic studies as key explanatory variables for the different channels presented in Figure 1. With the exception of the model that compares seat capacity and GDP directly, data are collected on an annual rather than quarterly or monthly basis due to the limited availability, or poor quality, of higher-frequency data. A detailed breakdown of data sources is provided in Annex 2. In each separate section of the report, the specific data used in the regression are discussed in detail.

Given that we were largely constrained to using annual data, the scope of our analysis is limited. For the most part, we have only been able to obtain data for between 8 and 10 years for the more disaggregated economic variables. Longer time series data are available for some macroeconomic variables (e.g. tourism arrivals, exports or FDI flows), but our measures of seat capacity are only available for 10 years.

To construct our connectivity measures we use the Civil Aviation Authority (CAA) traffic data and the Sabre Airport Data Intelligence (ADI) for additional capacity measures at a regional level.

There are other comparable databases but they have shorter time-series data than Sabre/ADI and the CAA. This limits the time scope of any associated connectivity indices, and rules out econometric approaches such as Granger causality as the time series would not be long enough to establish meaningful results.

Essentially the data constraints and the project scope dictated the functional form used in our econometric modelling. The analytical problem was one of a relatively small T[11] (i.e. a short panel time dimension) and a large N (i.e. a large number of cross-sectional units, or entities in our model, each country in our panel being an entity). The adopted econometric approaches used in this report seek to address the econometric issues associated with this problem.

We were able to construct a monthly time series of data from the ADI database. Unlike other key variables used in the modelling (tourism, FDI and trade), which are available on an annual basis, GDP data are available on a quarterly basis. To enable the use of time-series econometric techniques, we have built an additional quarterly dataset that allows the co-analysis of GDP and seat capacity. This quarterly data set allows for Granger causality and cointegration[12] tests to be undertaken. This analysis provides an additional layer of evidence in our examination of the links between aviation and economic growth.

2.7. Econometric methodology

2.7.1. Scope of interpretation

As described above, data limitations constrain the form of economic models used. When interpreting our econometric results, it is important to bear in mind the following factors:

1. **Estimates are partial equilibrium:** the scope of our study does not cover the construction of general equilibrium estimates from the econometric analysis. Estimates are partial equilibrium i.e. they do not fully account for interactions between aviation and other sectors of the economy. They should therefore be treated with caution.

2. **The approach does not correct for the Lucas Critique.**[13] In his seminal 1976 article, Robert Lucas argues that policy changes will affect the coefficients of the relationships which form the basis of econometric models. Models that are intended to attempt to predict the effects of policy changes should be rooted deeply in microeconomic foundations that can capture agents' responses. To overcome the Lucas critique a structural economic model is needed.

The approach applied in this study is designed explicitly to check for correlations between the relevant variables specified in the regressions, in line with previous work undertaken in this area. It is possible to use the results from section 3 to inform the parameters of a structural model, but this exercise would need to be carried out

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[11] A short time-series can lead to an identification problems i.e. the estimated model cannot robustly disentangle the time effects from the idiosyncratic characteristics of each entity.
[12] Two individual variables may seem like they move independently of one another, but in fact have a statistical relationship – these types of relationships can be tested using cointegration tests.
[13] Lucas, Robert (1976). "Econometric Policy Evaluation: A Critique". In Brunner, K.; Meltzer, A. *The Phillips Curve and Labour Markets*. Carnegie-Rochester Conference Series on Public Policy **1**. New York: American Elsevier. pp. 19–46.

with some caution as the econometric relationships are estimated based on correlations in a panel or time series dataset which has not been structurally affected by any past major aviation intervention.

One of the major issues identified in the literature surveyed in this study relates to the problem of endogeneity. The remainder of this section sets out how we seek to deal with this problem.

2.7.2. Dealing with endogeneity

Independence between the errors and the explanatory variables is one of the most important assumptions of the ordinary least squares (OLS) regression method. Where there is a correlation between an explanatory variable and the error term, that variable is described as endogenous, and the estimated equation suffers from a problem of endogeneity. There are a number of possible causes of endogeneity:

- Measurement error;
- Simultaneity, also known as reverse causality; and
- Omitted variables.

In our study we have focussed primarily on the second source of endogeneity listed above, reverse causality. There are two reasons for this.

First, a key motivation of the present study is that existing research often fails to account for this important econometric issue. Secondly, this particular source of endogeneity is directly relevant to our research and thus testing and correcting for it is a critical step towards the credibility of our final results. Thus, a large portion of our research focuses on using a range of statistical tests that address the problems of under-identification or weak-identification as proposed by Baum, Schaffer and Stillman (2007). [14] [Not clear how identification issues relate to simultaneity/reverse causality – need to be clearer why we suddenly switch terminology]

The best way to deal with endogeneity is through the instrumental variable (IV) approach (Shepherd, 2009). [15] An instrument is a variable which is strongly correlated with the potentially endogenous explanatory variable but also uncorrelated with the error term in the model. In addition, the instrument should only influence the dependent variable through the potentially endogenous explanatory variable.

A key drawback of the IV approach relates is the challenge of finding appropriate instruments. In some cases however, lagged values of the variables considered to be endogenous can be used, since lagged values are less likely to be influenced by current shocks. Where we have used the IV approach in our analysis we have also implemented a series of tests to assess the strength of the instruments.

For example, in our tourism model, we include the lag of the dependent variable as an additional regressor to test for destination reputation effect. Since the lagged dependent variable is correlated with the error term in the model, this leads to endogeneity.

To resolve this issue, we use an instrumental variable based approach where higher lag values of the lagged dependent variable are used as instruments. We then use the Sargan test of over-identifying restriction along with the Arellano-Bond test of no autocorrelation in the second order residuals to assess the validity of the instruments used in correcting for endogeneity.

In general, to ensure that our findings do not suffer from endogeneity, we use two different tests on whether a possibly endogenous regressor can be treated as exogenous in each of our three channel models (i.e. the FDI, trade and tourism models). We use the statistical software Stata to conduct our econometric analysis and explain these issues with reference to the commands in Stata that can be used to carry out relevant tests.

The first test of exogeneity we use is by Davidson and MacKinnon (1993)[16] which has been adapted for use in a panel data context by Baum and Sillman (1999)[17], through the *dmexogxt* procedure following Stata's *xtivreg*. A key issue with this method is that the fixed effects instrumental variable (IV) estimator available from Stata's

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[14] Baum, Christopher F, Schaffer, Mark E, Stillman, Steven (2007) "Enhanced routines for instrumental variables/generalized method of moment's estimation and testing." *Boston College Economics Working Paper No.667.*
[15] Ben Shepherd (2009) 'Dealing with Endogeneity' Trade Economist & International Development Consultant www.Developing-Trade.com.
[16] Russell Davidson and James G. MacKinnon (1993) "Estimation and Inference in Econometrics" *New York, Oxford University Press.*
[17] Baum, Christopher and Stillman, Steven (1999) "DMEXOGXT: Stata module to test consistency of OLS vs. XT-IV estimates" Developed for Stata Users.

xtivreg imposes the constraint of constant correlation of individual observations within group (Baum, Shaffer and Stillman, 2003)[18]. As Hoxby and Paserman (1998)[19] demonstrate, however, the presence of intra-cluster correlation can readily cause a standard overidentication statistic to over-reject the null.

We also use a second test based on the endogenous option of Stata's *ivreg2* procedure which can report test statistics that are robust to various violations of conditional homoscedasticity. Each model is then specified accordingly based on both evidence gathered from our literature review and on our endogeneity test results.

Using two distinct tests for endogeneity in our analysis does come at a cost. In some cases, we obtain conflicting results between the two tests as a given explanatory variable is found to be endogenous or exogenous depending on the test we use. In such a situation, we adopt the following approach:

1. We first treat the variable as exogenous, and change our estimator and model specification accordingly.
2. We next treat the variable as endogenous and use the IV estimator depending on our modelling context.
3. We then use a number of key diagnostic statistics to choose, where possible, the most robust model.

There is an argument that there might be forward looking expectations within the aviation industry. If this is true, such forward looking expectation will be detected by our endogeneity test and subsequently dealt with. Although the endogeneity tests cannot tell us what is causing the observed endogeneity problem, they can nevertheless identify any endogeneity caused.

2.8. Labour mobility

We were unable to conduct an econometric analysis on the nature of the potential relationship between labour mobility and aviation intervention due to the poor quality of existing data. We reviewed various ONS data for labour migration and found the following anomalies:

- Migration figures are not collected if migration is below a threshold of 1,000 migrants per country each year.
- Many countries tended to drop out of the sample for certain years leading to a severe problem of missing observations.
- This leads to difficulties in assessing whether a value of zero migrations for certain countries was the result of the no data available or no migration taking place.
- The sample was not fully representative as countries like India, Pakistan or Nigeria had insufficient data for certain years.

Taken individually, some of the issued identified above could be addressed using econometric techniques. For example, censored regression models can be used in dealing with truncation of the dependent variable, whilst the Pseudo-Poisson Maximum Likelihood method can be used to deal with genuine "zero" migration (i.e. no migration) problems. However, these issues taken in their entirety would almost certainly lead to severe biases in most regression coefficients.

[18] Baum, Christopher F, Schaffer, Mark E, Stillman, Steven (2003) 'Instrumental Variables and GMM: Estimation and Testing.' *Boston College Economics Working Paper No.545.*
[19] Caroline Hosby and M. Danielle Pesaran (1998) 'Overidentification Tests with Grouped Data,' *NBER Technical Working Papers 02223,* National Bureau of Economic Research, Inc.

3. *Investigating the link between seat capacity and GDP*

3.1. Section overview

In this section, we analyse whether there is a relationship over time between quarterly GDP and quarterly seat capacity. The GDP measure we use is the non-seasonally adjusted chained volume[20] measure provided by the Office for National Statistics (ONS). We use a proxy for seat capacity in this Section which measures the total UK terminal airport passengers based on CAA data. This data is used because of its quarterly availability.

There are two main steps in our analysis. First, we analyse whether there is evidence of Granger-causality between the two series. We then analyse whether it is possible to build an Error Correction Model (ECM)[21] that describes the dynamics of any potential relationship between the two series.

We base this analysis on quarterly rather than annual data: as noted in Section 2, GDP is one of the few economic data series that is published on a quarterly basis.

Our main finding is that there is a two way Granger causal link between GDP and seat capacity. It is therefore possible to conclude that an increase in the growth rate of seat capacity can “Granger cause” an increase in the growth rate of GDP. Given the inherent limitations of econometrics in this area we advise caution in too literal an interpretation of these results, but we note that Granger causality is a widely used and well established technique for looking at direct links between variables

3.2. Previous studies on the link between aviation and GDP

Few studies seek to examine the link between aviation capacity and GDP. It is typical for these studies to find a strong correlation between connectivity and economic growth. Most find some form of linkage, but not all are able to find Granger causality. Key papers we have reviewed are discussed as follows.

The most recent study we have been able to obtain is by Mukkala and Tervo (2012)[22] who find, using Granger causality tests, a relationship between air traffic and economic growth among different European regions. Their analysis is undertaken at the European level with separate treatment for 86 regions and 13 countries, between 1991 and 2010. Special treatment is given to regional economic differences (i.e. central hubs and more remote airports) and their central finding is that there is a stronger Granger causal relationship between air traffic and regional growth in peripheral regions than in core regions.

Poort *et al.* (2000)[23] conducts a European level study and again uses the Granger approach to test for a statistical link between aviation growth and GDP growth. They find that a 10% increase in aviation growth causes a 1.7% increase in GDP growth for a panel of European countries. Green (2007)[24] finds that there is a causal relationship between the number of passengers and economic growth but the direction of causality cannot be determined from his analysis. Green does, however, suggest that the number of passengers can be a useful predictor of GDP growth.

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[20] The Chained Volume Measure of real GDP produced by the ONS. It strips out price changes and creates and underlying chained index to allow direct real terms annual comparisons to be made.
[21] A step by step mathematical explanation is provided in Appendix explaining the concept of ECM.
[22] Mukkala.K and H. Tervo (2012)"Regional airports and regional growth: which way does the causality run?,"ERSA conference papers 12 p642, European Regional Science Association.
[23] Poort, J.P., K. Sadiraj, C.M.C.M. van Woerkens (2000) “Hub, of spokestad? Regionaal economische effecten van luchthavens Breukelen: NYFER.
[24] Green, R.K., (2007) “Airports and Economic Development”Real Estate Economics 35: 91-112, 2007

A study by Ishutkina, and Hansman (2009)[25] finds a strong positive correlation between air transport passengers and GDP of around 0.99 for the UK and two-way causality i.e. an increase in passenger numbers leads to an increase in GDP and vice versa.

There is no conclusive study that tests for Granger causality between [seat capacity] and [GDP] for the UK economy, so our work seeks to fill this void. The remainder of this section discusses the results of our analysis.

We conduct our analysis in the software package Stata, which is a standard tool for this type of analysis. In order to be as transparent and to aid understanding of our work, where appropriate we include key output tables as produced directly from Stata.

3.3. Testing for causality

3.3.1. Deasonalising and detrending the data

In this section, we assess whether there is a relationship over time between quarterly GDP and quarterly seat capacity. The GDP measure we use is the non-seasonally adjusted chain volume measure and the seat capacity measure represents the total UK terminal airport passengers based on CAA data.

We start by reporting the descriptive statistics of each of the quarterly series used in our analysis.

Table 2 Descriptive statistics non-seasonally adjusted and non-de-trended series.

Variables*	**Observations**	**Mean**	**Standard deviation**	**Minimum**	**Maximum**
GDP	54	12.790	0.0705265	12.63175	12.90892
Seat capacity	54	17.771	0.182458	17.37793	18.09997

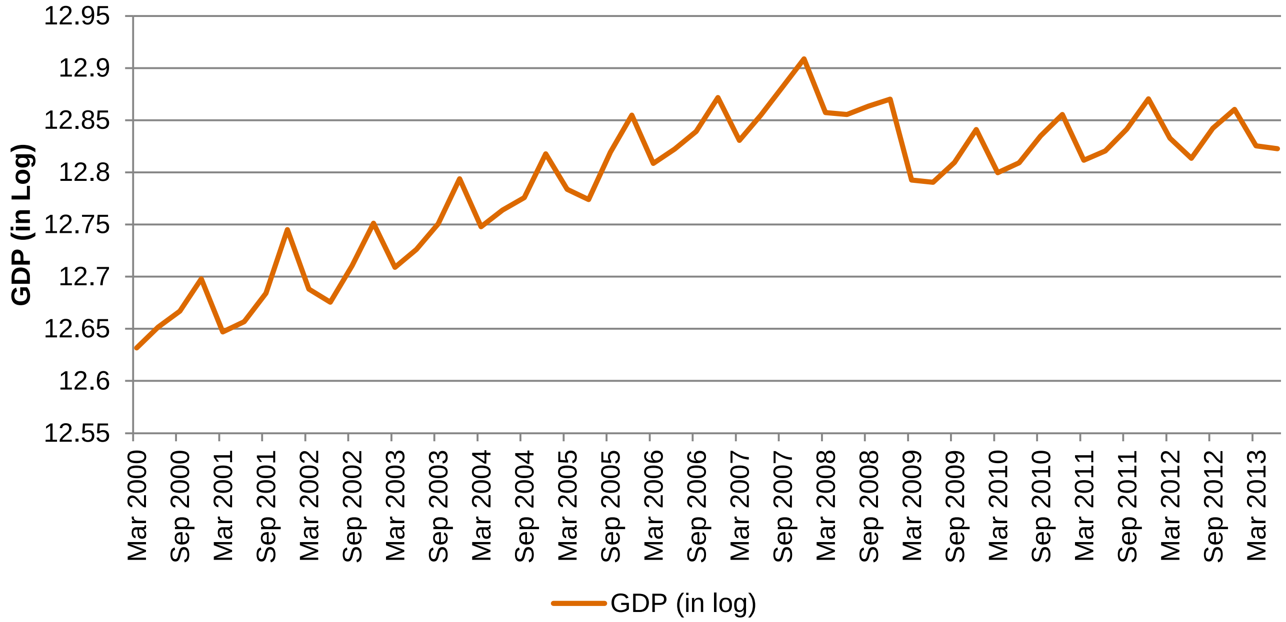
*Both variables are in logs
Source: PwC analysis

We have 54 quarterly observations in our data. We take logs of each variable in line with the reasons given in Wooldridge (2003)[26] as logs will neutralise the effects of negative numbers and extremities for better estimation and a better fit with the classical theoretical models that underpin econometric models. Plots of the data are shown in

[25] Ishutkina, M and Hansman, J (2009) "Analysis of the interaction between air transportation and economic activity: a worldwide perspective", Cambridge (MA) : MIT International Centre for Air Transportation (ICAT), 2009
[26] Wooldridge, J. (2008) Introductory econometrics: A modern approach, South Western College; International ed of 4th revised edition (3 Oct 2008)

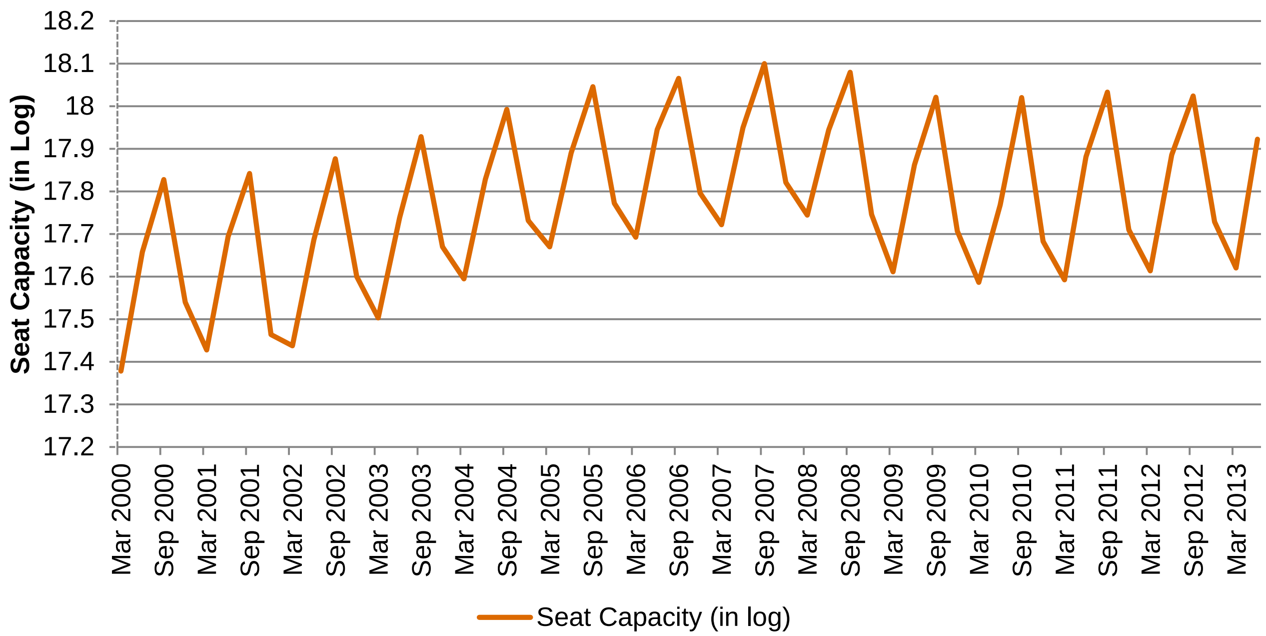
Figure 3 and Figure 4 below.

Figure 3: Log of quarterly GDP



Source: Office for National Statistics, PwC analysis

Figure 4: Log of quarterly seat capacity



Source: CAA data, PwC analysis

Figures 3 and 4 show a substantial amount of seasonality in both series as well as a structural break in trend around the year 2008. It is therefore important to seasonally adjust and detrend both variables before using them in our time series modelling.

A range of seasonal adjustment software can be used to deseasonalise our time series data. We used the software package created by the U.S. Census Bureau and used by the ONS statisticians. This seasonal adjustment software is known as the X-12-ARIMA. After the seasonal adjustment process, the resulting seasonally adjusted series are de-trended by regressing them against a time trend.

Below, we present the Stata output from the descriptive statistics of the seasonally adjusted and de-trended series.

Table 3: Descriptive statistics: seasonally adjusted and de-trended series.

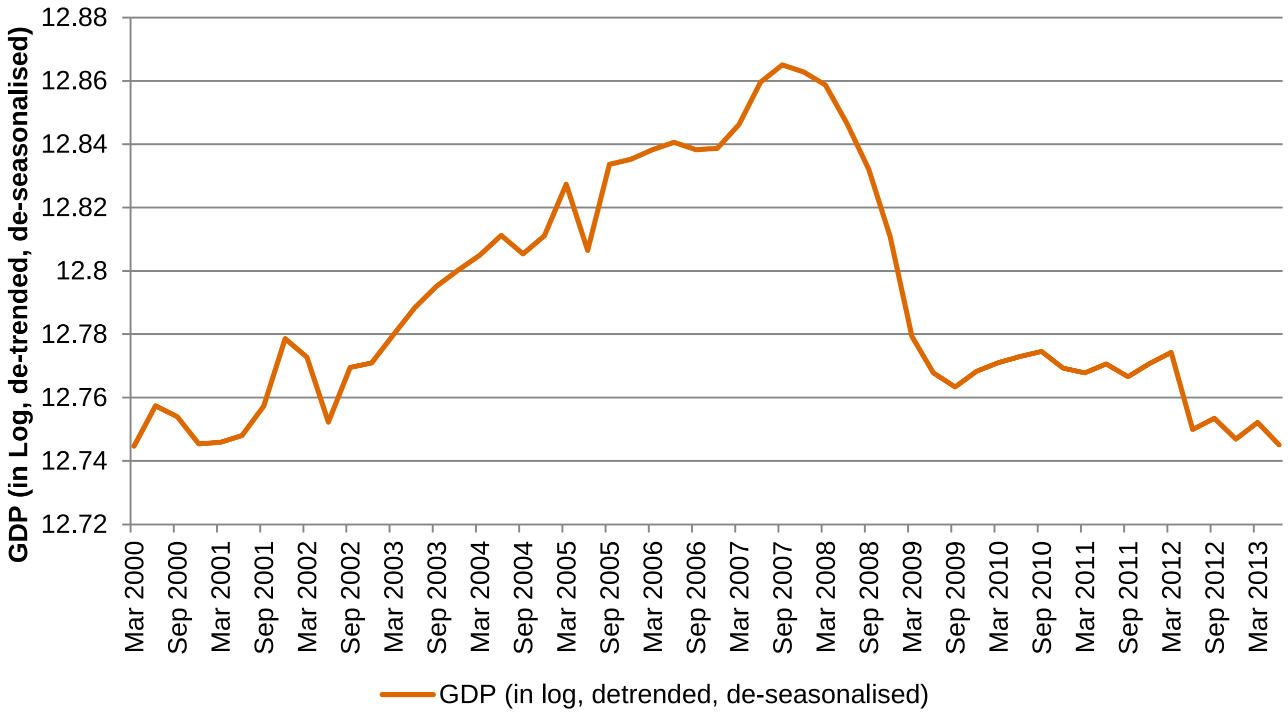
Variables*	Observations	Mean	Standard deviation	Minimum	Maximum
GDP	54	12.790	.0371202	12.74472	12.86504
Seat capacity	54	17.773	.0741008	17.62824	17.90036

*Both variables are in logs

Source: PwC analysis

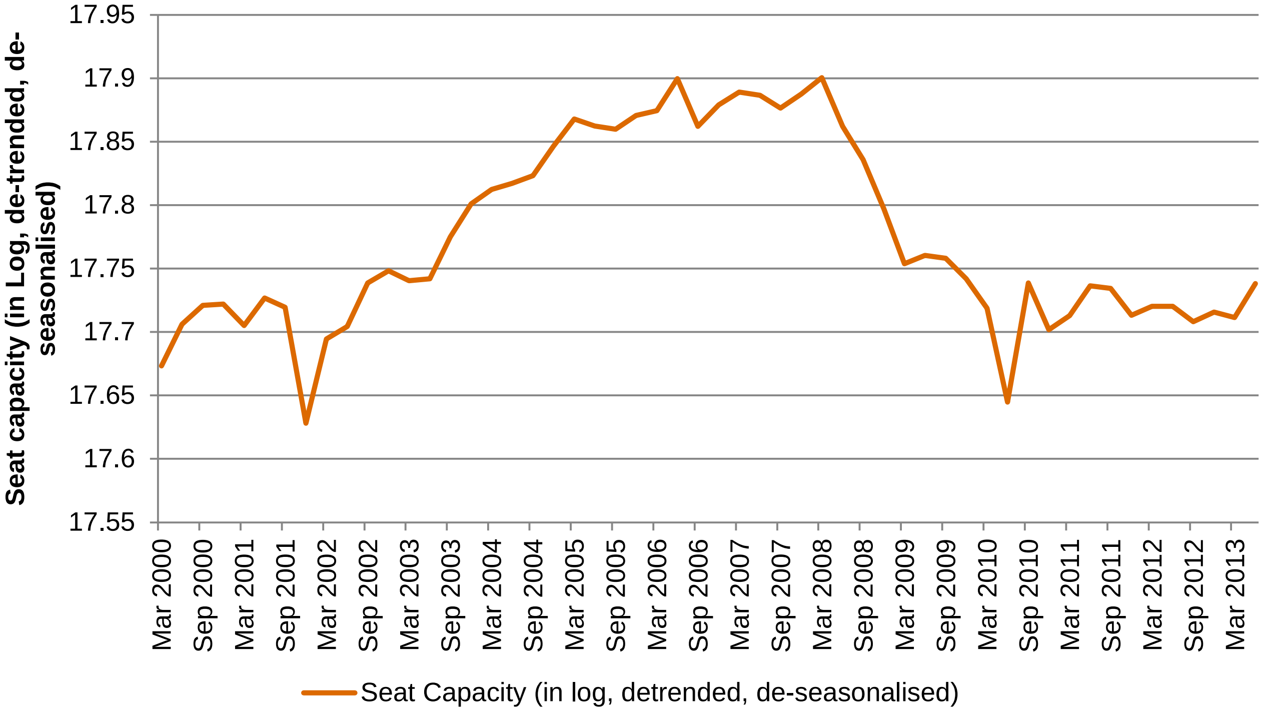
A comparison of Table 2 and Table 3 shows that the mean of the seasonally adjusted and de-trended series is largely preserved relative to the original series that has not had the trend removed. This is important as it shows that the detrending process has not altered the fundamental properties of the data. The standard deviations are now much smaller; this is evidence of the removal of the seasonal element. Figure 5 and 6 show the seasonally adjusted and detracted series.

Figure 5: UK GDP seasonally adjusted and de-trended



Source: ONS, PwC analysis

Figure 6- Seat capacity seasonally adjusted and de-trended



Source: SABRE/ADI, PwC analysis

Having de-trended the series, we analyse whether they are stationary. This involves conducting a set of unit root tests on the variables GDP and seat capacity. However, as Perron (1989) shows, standard analyses of potential unit roots such as the Dickey Fuller or Augmented Dickey Fuller tests, tend to have very low statistical power (i.e. carry a greater risk of predicting the wrong result) if there is a structural break in the data. On this basis we undertake unit root tests that allow for structural breaks. Given that we can observe structural breaks in Figures 5 and 6, we undertake two unit root tests for the sake of caution.

- The Phillips-Perron[27] test which allows for one structural break under the null hypothesis to test for stationarity of GDP; and
- The Clemente-Montañés-Reyes unit root tests, which allow for two structural breaks under the null hypothesis to test for stationarity of seat capacity.

For GDP we report the results of the Phillips-Peron test and for seat capacity we report the Clemente-Montanes –Reyes test. Our unit root tests result using the Phillips-Perron test with critical values at the 1%, 5% and 10% levels are presented in Table 4 below. The test reveals that the null hypothesis of the series having a unit root cannot be rejected (P-value=0.6150>0.05). This result is confirmed by the Clemente-Montañés-Reyes test.

[27] Phillips, P.C.B and P. Perron (1988), "Testing for a Unit Root in Time Series Regression", Biometrika, 75, 335–346

Table 4: Phillips-Perron test results for GDP

	Test statistics	1% critical value	5% critical value	10% critical value
Z(rho)	-3.566	-18.954	-13.324	-10.718
Z(t)	-1.331	-3.576	-2.928	-2.599

MacKinnon approximate p-value for Z(t) = 0.6150
Note: Z(rho) represents an Augmented Dicky-Fuller Z test as documented by Hamilton, J. D. (1994) "Time Series Econometrics", Princeton University press. Z(t) represents a t-test.
Source: PwC analysis

The results for a unit root test allowing for two structural breaks under the null hypothesis for seat capacity are given in Table 5. Despite the Clemente-Montañés-Reyes unit root test finding two structural breaks in our seat capacity series, we cannot reject the null hypothesis of a unit root. The Phillips-Perron test confirms this result for seat capacity.

Table 5: Clemente-Montañés-Reyes unit-root test with double mean shifts for seat capacity

	Dummy 1 for structural break	Dummy 2 for structural break	(rho-1)	Constant
Coefficients:	0.06635	-0.06542	-0.45674	8.09328
t-statistics	4.200	-4.924	-5.074	
p-values	0.000	0.000	-5.490	(5% crit. value)

Optimal breakpoints: 2003q1, 2008q2
Source: PwC analysis

Having established that GDP and seat capacity have a unit root, which is the same as saying that they have the same order of integration, our next step is to test whether a co-integrating relationship exists between the two series. We use two different tests of co-integration: the Engle-Granger two–step method; and the Johansen test. We also test for Granger-causality between the two series.

The Engle-Granger two-step method tests the theory that if two time-series are co-integrated then a linear combination of them must be stationary. The test proceeds in two steps: first, we regress GDP on seat capacity; and second, we conduct a unit root test of the resulting error term. If we find that the error term is stationary, then we conclude that a co-integrating relationship exists between the two variables.

As is a standard practice, we use the Dickey-Fuller unit root test to determine whether the fitted error term is stationary. Results are presented in the Table below.

Table 6: Dickey-Fuller unit root test

	Test statistics	1% critical value	5% critical value	10% critical value
Z(t)	-4.346	-3.576	-2.928	-2.599

MacKinnon approximate p-value for Z (t) = 0.0004
Source: PwC analysis

Our test finds the fitted error term to be stationary, **which is evidence that a co-integrating relationship exists between GDP and seat capacity**.

Next, we use the Johansen test, to see if the above co-integrating relationship can be confirmed in a vector auto-regressive (VAR)[28] setting. The results of the Johansen test are reported in Table 7 below:

Table 7: Johansen test for cointegration

Maximum rank	Parms	LL	Eigenvalue	Trace statistic	5% critical value
0	2	275.54255		20.3768	15.41
1	5	285.05116	0.30150	1.3596*	3.76
2	6	285.73093	0.02533		

Source: PwC analysis

Since the trace statistic at rank=0 exceeds its critical value of 15.41, we reject the null hypothesis of no co-integration. Moreover, since the trace statistic at rank=1 of 1.3596 is less than its critical value of 3.76, we cannot reject the null hypothesis that there is one co-integrating relationship between GDP and seat capacity.

In addition, we also run Granger-causality tests following our VAR model. The test is designed to demonstrate causality by examining whether lagged seat capacity carries explanatory power in the presence of the lagged dependent variable, GDP. A key assumption behind the Granger causality test is that time series are ordered such that effects cannot occur before causes.

The Stata output from the Granger causality tests are presented in Table 8 below. The null hypothesis of the Granger-causality Wald test is that the variables do not Granger-cause each other. **Our findings show that there is evidence of a bi-directional causality between GDP and seat capacity** (i.e. P-values in the last column of Table 8 are smaller than 0.05).

Table 8: Granger causality Wald tests

Equation	Excluded	Chi2	Df	Prob>Chi2
GDP	Seat capacity	5.6249	1	0.018
GDP	Seat capacity	5.6249	1	0.018
Seat capacity	GDP	7.7741	1	0.005
Seat capacity	GDP	7.7741	1	0.005

Source: PwC analysis

In light of all the evidence presented above, we build an error correction model (ECM) to explore the short and long run dynamics between GDP and seat capacity. The ECM allows us to explain changes in GDP in terms of changes in seat capacity, as well as deviations from the long-run relationship between the two series. Following

[28] When building a VAR, it is very important to first determine the number of lags that ought to be used in the model. We used the SBIC (Schwartz Bayesian Information Criterion) approach to determine how many lags should be used in the VAR. As the output table from Stata below shows, the optimal number of lags is 1.

```
   Selection-order criteria
   Sample:  2001q1 - 2013q2                    Number of obs      =        50
```

lag	LL	LR	df	p	FPE	AIC	HQIC	SBIC
0	197.619				1.4e-06	-7.82475	-7.79562	-7.74827
1	268.499	141.76	4	0.000	9.4e-08*	-10.5*	-10.4126*	-10.2705*
2	270.832	4.666	4	0.323	1.0e-07	-10.4333	-10.2877	-10.0509
3	276.44	11.216*	4	0.024	9.5e-08	-10.4976	-10.2937	-9.96224
4	279.276	5.6722	4	0.225	1.0e-07	-10.451	-10.1889	-9.76272

Engle and Granger (1987), two or more integrated time series that are cointegrated can have an ECM representation as follows:

$\Delta gdp_t = \alpha_0 + \alpha_1 \Delta scap_t + \pi \mu_{t-i} + \epsilon_t$

Where μ denotes the equilibrium error term defined as $\mu_{t-i} = gdp_t - \alpha_0 - \alpha_1 scap_t, \epsilon_t$ is the error term, β_1 is the parameter capturing any immediate effect that seat capacity may have on GDP, and $\pi < 0$ is the error correction parameter, representing the principle of negative feedback. If GDP is above (below) its equilibrium level (during the last period), in the current period the error correction term will re-establish the equilibrium by reducing (increasing) GDP. Our findings are reported in Table 9 below.

Table 9: Error correction model results

Explanatory variables	**Coefficients**	**Standard errors**	**T-stat**	**P-value**
Growth rate seat capacity	0.103	0.051	2.01	0.050
Error correction	-0.327	0.102	-3.20	0.002
Constant	0.0000624	0.001	0.04	0.965
Number of observations	53			
Model diagnostics tests		**Tests interpretation (Pass or Fail)**		
Seat capacity	_hatsq t-stats = 0.61	Pass		
Omitted variable test	F(3,47)=1.65 p-value=0.191	Pass		
Breush-Pagan test for heteroskedasticity	chi2(1)=2.78 p-value=0.0957	Pass		
Durbin Watson d statistic	1.65	Pass		

Source: PwC analysis

Our results suggest that, in the short- run, a 10% change in the growth rate of seat capacity leads to approximately a 1% change in the growth rate of GDP. This effect is found to be significant at the 5% level. The error correction term is negative and within the [-1, 0] which indicate a stabile system. A positive error correction term is a sign of an explosive process and would indicate movement away from equilibrium. The error correction term is also significant confirming that the two series are co-integrated. Its coefficient indicates that deviations from equilibrium are corrected at about 32.7% per quarter implying that any deviation would not persist much beyond 3 quarters.

In terms of the robustness of our results, Table 9 shows that the Ramsey's RESET test for omitted variables reveals that there is no functional form misspecification in the linear ECM. The latter finding is confirmed by the Link test for model specification. Furthermore, the Breush-Pagan test finds no evidence of heteroskedasticity and no sign of autocorrelation is found by the Durbin-Watson test.

3.4. Limitations of our analysis

We conclude by listing a number of key limitations of the results presented above.

Firstly, it is important to note that the results of any empirical test for Granger causality are sensitive to the choice of lag length or the methods used to deal with potential nonstationarity of the series (Hamilton, 1994).

With regard to the former, our results suggest when up to 10 lags are introduced, the relationship holds in 8 out of the 10 cases.

Secondly, it is also worth pointing out that the technique we have used to seasonally adjust time series can also have a bearing on the results. One important feature of the time series used in our analysis is the presence of structural breaks. Using the Quandt Likelihood Ratio test for break dates identification, we found no less than eight breaks in the seat capacity series. The results of this test are reported in the table below.

Table 10: Quandt Likelihood Ratio (QLR) test for break dates

Break date	QLR stat
2001q4	460.5408
2002q1	366.6297
2002q2	211.7669
2002q3	5.152957
2008q1	6.308029
2008q2	5.992707
2008q3	5.947501
2010q2	5.838335

Source: PwC analysis

In light of the above structural break dates, the fact that Stata only allows for a maximum of two structural breaks under the null of a unit root using the Clemente-Montanes-Reyes test is a clear limitation of our analysis.

Finally, because we are using pure time series data, we are unable to account for the heterogeneity that exists between different routes in terms of seat capacity. To undertake this type of analysis requires a panel data set linking seat capacity by key routes to economic variables.

On balance, while these limitations are present, our view is that they are not substantive enough to challenge the main finding in this section of Granger causality between GDP and our seat capacity proxy.

4. The relationship between tourism and seat capacity

4.1. Section overview

This Section examines whether there is a relationship between seat capacity, and overseas tourism arrivals to the UK and UK residents' visits abroad. The links between tourism and GDP are complex. When UK residents fly overseas, this is a leakage from the UK economy and has a similar economic effect to an imported service (i.e. they have a negative effect on GDP). Conversely, foreign tourists arriving in the UK generate foreign currency earnings so have an equivalent economic effect to exported services (i.e. they have a positive effect on UK GDP).

This Section is laid out as follows:

1. A description of the data and econometric specification;
2. Endogeneity test;
3. Model estimation;
4. Model comparison and robustness tests; and
5. Discussion of our findings.

Our literature review indicated that is particularly important to address issues relating to endogeneity and destination "reputation effects". With regard to the latter, we therefore use a dynamic panel data wherein the lag of the dependent variable is included as an additional explanatory variable. With regard to the former, our estimation techniques are chosen so that we can account for potential endogeneity.

Overall we find a strong positive relationship between seat capacity and tourism. Our modelling suggests that a 10% increase in seat capacity is associated with a 4% increase in overseas tourism arrivals to the UK and a 3% increase in UK residents' visits abroad. These regressions are conducted separately as models of inbound and outbound UK tourism need to be specified with different variables.

4.1.1. Model specification and data sources

We use panel data for 44 countries observed over the period 2002-2012 to investigate the potential relationship between measures of seat capacity, and tourism in the UK. Our analysis explores tourist flows in both directions: the arrival of overseas tourists in the UK (inbound), and UK residents' visits abroad outbound). Due to the many similarities between the inbound and outbound tourism models, we only describe the former in full detail.

Our specification follows the classical demand function for international tourism along the lines of Witt and Witt (1995)[29] and Naudee and Saayman (2005)[30], which we have augmented with the variable seat capacity and a language dummy. There is always potential for model improvement (e.g. in the future it might be worth including airfares as a variable) but we considered it reasonable to use the existing literature as a foundation for our regression analysis. The general tourism demand function is:

$$Tr_{it} = f(GDPCC_{it}, RP_{it}, ROOM_{ukt}, DISTANCE_i, LANGDUMMY_i, SCAP_{it}) \quad \textbf{(4.1)}$$

Where:

[29] Witt, S., & Witt, C. (1995) 'Forecasting tourism demand: A review of empirical research' *International Journal of Forecasting*, 11, 447–475.

[30] Naudee, W. A., & Saayman, A. (2005) 'Determinants of tourist arrivals in Africa: A panel data regression analysis' *Tourism Economics*, 11(3), 365–391.

- Tr_{it} = Total number of arrivals per annum, is a measure of the demand for tourism to the United Kingdom. We use annual ONS data in thousands of tourists' visits to the UK over the period 2002-12. This is our dependent variable.
- $GDPCC_{it}$ = Real domestic product per capita in country of origin is used as a proxy for the spending capacity of tourists (Khadaroo and Seetanah, 2007). The GDP per capita expressed in 2010 prices and were collected from the IMF for the period 2001-12.
- RP_{it} = Relative prices. We follow the approach of Eilat and Einav (2004)[31] and construct an index number for relative prices across countries. This variable is an exchange rate weighted cross-country CPI measure. We first take the CPI in the UK and weight it by the CPI in the destination country. CPI in the destination country is weighted by the exchange rate which has been adjusted for purchasing power parity (PPP). This approach is designed to capture both cross country price differences caused by real and nominal variables. Naudee and Saayman (2005) argue that the inverse of this indicator shows how many 'baskets' of goods a tourist has to give up in his or her home country to buy a basket of goods in the destination country. While Eilat and Einav (2004) suggest that this measure captures changes in the real exchange rate over time as well as cross-sectional variation in the cost of travel. The CPI and Exchange rate data were collected from the IMF website for the period 2002-2012. More specifically, the CPI represents the annual average CPI index with the base year 2005, and the exchange rate is the implied PPP conversion rate between (i.e. the national currencies for each of the 44 countries per current sterling).
- $ROOM_{ukt}$ = Following the standard literature, we use the number of hotel rooms available in the UK over the period 2002 – 2012 as a proxy for tourism infrastructure in the UK. We use the growth rate of the number of hotels rooms rather than the level as the latter is a stock measure whilst using the growth rate allows for a better comparison with tourists arrivals which is a flow measure. For our UK residents outflow model, the equivalent figures were collected from the World Tourism Organisation (WTO) and cover the period 2007-2012. As Khadaroo and Seetanah (2007)[32] argue, a minimum number of rooms must be available for a destination to reach its critical mass and also to convince airlines to establish routes.
- $DISTANCE_i$ =Distance in kilometres between the capital of the foreign country and London. The data was collected from CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) for the time period 2002-2012. This variable is widely used in tourism demand model (see Witt and Witt, 1995). The longer the distance, the higher the level of discomfort and opportunity costs involved with travelling (Khadaroo and Seetanah, 2007).
- $LANGDUMMY_i$ = Language dummy, we include this variable to account for whether there is a language barrier (1 if English is the official language in foreign country). The language dummy data was also collected from CEPII for the time period 2002-2012.
- $SCAP_{it}$ = Seat capacity, this variable represents a key independent variable in our model as it plays the role of a proxy for connectivity. The national-level annual data for 2002-2012 comes from the UK Civil Aviation Authority. This variable measures the yearly seat capacity on all scheduled flights between the destination (i.e. UK) and the tourist's origin country.

[31] Eilat, Y., & Einav, L. (2004) 'Determinants of international tourism: A three dimensional panel data analysis' Applied *Economics*, 36, 1315–1327.
[32] Jameel Khadaroo and Boopen Seetanah (2007) 'The role of transport infrastructure in international tourism development: A gravity model approach' *Tourism Management* 29, 831–840

Table 11 below shows the key summary statistics of the variables used in our model.

Table 11: Summary statistics for the inbound tourism model

Variables *	No. of observations	Mean	Standard deviation	Minimum	Maximum
Tourists arrivals	495	5.423	1.548	1.098	8.268
GDP per capita	495	9.650	1.216	6.197	11.646
Relative price	495	49.723	38.773	0.429	151.506
Seat capacity	474	13.657	1.386	7.021	16.743
Language dummy	495	0.156	0.363	0	1
Distance	495	7.340	1.079	5.283	9.342
Tourism infrastructure	405	0.137	0.168	-0.076	0.424

*All the variables are in log except for the language dummy.

Source: PwC analysis

To estimate the model, we rewrite the regression specification (from 4.1) in log-linear form:

$$tr_{it} = \beta_0 + \beta_1 gdppc_{it} + \beta_2 rp_{it} + \beta_3 room_{it} + distance_{it} + LANGDUMMY_{it} + scap_{it} + \mu_{it} \qquad \textbf{(4.2)}$$

We use the lower case to denote where the variables are in natural logarithms. Our estimation of model (4.2) is discussed in the results section.

Khadaroo and Seetanah (2007) found that destination reputation plays an important role in tourism demand, as tourists tend to return to a particular destination when they have had a good experience (although this is only one aspect of reputation). As a static model (i.e. the variables included in model (4.2) are considered over the same time period t), model (4.2) cannot capture the dynamics of reputation effects. Hence, we adopt a dynamic panel framework in line with Khadaroo and Seetanah (2007) by subtracting the lag of tourists' arrivals from both sides of the model (4.2) as follows:

$$tr_{it} - tr_{it-1} = \theta_t + \delta tr_{it-1} + \beta\omega_{it} + \varepsilon_{it} \qquad \textbf{(4.3)}$$

Where tr_{it-1} is the log of arrivals in year $(t-1)$, ω_{it} is a vector of explanatory variables (i.e. $gdppc_{it}$, rp_{it}, $room_{it}$, $distance_{it}$, $LANGDUMMY_{it}$, $scap_{it}$), $\theta_t$is a period specific intercept term that captures changes common to all countries and ε_{it} is the error term.

Taking the tr_{it-1} term in equation (4.3) to the RHS, we have:

$$tr_{it} = \theta_t + (\delta + 1)tr_{it-1} + \beta\omega_{it} + \varepsilon_{it} \qquad \textbf{(4.4)}$$

Finally, we rewrite model (4.4) above in first-difference:

$$\Delta tr_{it} = \theta_t + (\delta + 1)\Delta tr_{it-1} + \beta\Delta\omega_{it} + \Delta\varepsilon_{it} \qquad \textbf{(4.5)}$$

Although the above dynamic specification allows us to account for some element of reputation effects, through first differencing, we lose distance and language dummy variables, as these are time invariant[33]. Furthermore, including the lag of the dependent variable Δtr_{it} as an explanatory variable Δtr_{it-1} leads to endogeneity (i.e. $tr_{it-1}$is correlated to a part of the error term through Δ). Hence, in order to estimate model (4.5) we use the instrumental variables approach. In the next section, we show results from our estimation of the model set out in equation (4.5).

4.1.2. Results

As discussed above, including a lag of the dependent variable in our model (5) as an additional explanatory variable leads to endogeneity. This means that the standard Fixed Effects (FE)[34] is not consistent for a finite number of time periods in an autoregressive panel data model. This means that we need to use an alternative estimation approach: one of the Bias-Corrected Least Square Dummy Variable (or LSDVC), the Arellano-Bond (1991)[35] Difference GMM[36] (DGMM) estimator or the Arrelano-Bover (1995)[37]/Blundell-Bond (1998)[38] GMM estimator also known as System GMM[39] (SGMM). According to Bruno (2005), an important limitation of the LSDVC is that, as opposed to IV-GMM estimators, no version of LSDVC is applicable in the presence of endogenous, or even weakly exogenous, regressors. Given that one of our main concerns has been to deal with any endogeneity issues in a robust way, we use the DGMM and GMM approaches.

[33] In static panel frameworks, some researchers tend to use the FEVD (Fixed Effects Vector Decomposition) of Plumper and Troeger (2007a) approach, an emerging popular technique for estimating time-invariant variables in panel data models with group effects (see Belke and Spies (2008), Caporale et al., (2009), Mitze (2009), Krogstrup and Walti (2008), Albu et al., (2009)). However, we do not explore this avenue due to the conflicting views that prevail in the literature regarding the validity of this approach (see Breusch *et al* (2010) and Greene (2011)).

[34] We provide a description of all the key estimators used in our study in Appendix A.

[35] Manuel Arellano and Stephen Bond, (1991) 'Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations' *The Review of Economic Studies,* Vol. 58, No. 2 (Apr., 1991), pp. 277-297

[36] This estimator uses values of the dependent variable lagged by two or more periods (data permitting) as instruments for the endogenous regressor.

[37] Arellano, M. and O. Bover. (1995) 'Another look at the instrumental variable estimation of error-components models.' *Journal of Econometrics*, 68, 29-52.

[38] Blundell, R. and S. Bond. (1998) 'Initial conditions and moment restrictions in dynamic panel data models.' *Journal of Econometrics,* 87(1), 115-143.

[39] This estimator uses lagged first differenced values of endogenous regressors as instruments for the level equation (i.e. the original model) in addition to lagged levels as instruments for the differenced equation.

Before presenting the results from our estimations, we report the endogeneity test results Table 12 below.

Table 12: Endogeneity tests

	Test 1	**Test 2**
Variables	**Davidson-MacKinnon test**	**Endogeneity test**
GDP per capita	P-value = .5903	Chi-sq(1) P-val = 0.0595
Relative price	P-value = .1625	Chi-sq(1) P-val = 0.5017
Seat capacity	P-value = .2499	Chi-sq(1) P-val = 0.5586
Tourism infrastructure	P-value = .5831	Chi-sq(1) P-val = 0.8677
Hansen test to assess validity of the instruments used in the endogeneity test (Test 2)		
GDP per capita	Chi-sq(1) P-val = 0.0344	
Relative price	Chi-sq(1) P-val = 0.6772	
Seat capacity	Chi-sq(1) P-val = 0.1657	
Tourism Infrastructure	Chi-sq(1) P-val = 0.9527	

Legend: *Test 2 is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H_0) under Test 1 and 2 is that the variable can be treated as exogenous. When The P value is bigger thanP-value > 0.05 one cannot reject H_0 whereas when the value is below 0.05, H_0 should be rejected. The Hansen test can be obtained following Test 2. This test tells us whether the instruments used in assessing endogeneity are valid. Here H_0 is that the instruments are valid. Same interpretation of the P value applies.*
Source: PwC analysis

Tests 1 and 2 reveal that all our four variables can be treated as exogenous (P-values are bigger than 0.05). However, the Hansen statistics for instruments' validity show that the instruments used in testing for GDP per capita exogeneity are not valid (P-value = 0.0344 smaller than 0.05). Furthermore, the Hansen statistic for tourism infrastructure is abnormally close to 1. This is a sign of instrument proliferation. According to Rodman (2009)[40], instrument proliferation is commonly undetected by econometricians. As Anderson and Sørensen (1996)[41] and Bowsher (2002)[42] show; instrument proliferation impairs the efficiency of the Davidson MacKinnon test. Bowsher's Monte Carlo simulations of Difference GMM show that when there are a large number of instruments, the test becomes undersized and tend to never reject the null of joint validity at 0.05 or 0.10, rather than rejecting it 5% or 10% of the time as a well-sized test would. Roodman (2009) argues that instrument proliferation produces Hansen statistics with implausibly perfect P values of 1. There are two main consequences of instrument proliferation (Rodman, 2009):

1. By being numerous, instruments can overfit instrumented variables, failing to expunge their endogenous components and biasing coefficient estimates towards those from non-instrumenting estimators.

[40] David Roodman, (2009) 'Practitioners' Corners, A note on the Theme of Too Many Instruments' *Oxford Bulletin of Economics and Statistics,* 71, 1.
[41] Andersen, T. G. and Sørensen, B. E. (1996). 'GMM estimation of a stochastic volatility model: a Monte Carlo study', *Journal of Business and Economic Statistics*, Vol. 14, pp. 328–352.
[42] Bowsher, C. G. (2002). 'On testing overidentifying restrictions in dynamic panel data models', *Economics Letters*, Vol. 77, pp. 211–220.

2. Imprecise estimates of the optimal weighting matrix used in the two-step variants of DGMM and SGMM estimations: in other words, the standard errors in two-step GMM will tend to be severely downward biased[43] (Roodman, 2009).

The absence of formal tests and accepted rules of thumb with regard to the instrument proliferation problem means that we use instead the following procedure to ensure that our GMM results are robust[44].

First, in our estimations we report the following sets of results in Tables 13 and 14 below: (i) treat both GDP per capita and tourism infrastructure as exogenous (DGMM and SGMM), (ii) treat GDP per capita as endogenous (DGMM* and SGMM*), (iii) treat tourism infrastructure as endogenous (DGMM** and SGMM**) and (iv) treat both variables as endogenous (DGMM*** and SGMM***).

Second, we use Windmeijer's (2005)[45] finite-sample correction for the two-step covariance matrix to address the issue of imprecise estimates of the weighting matrix. All the results are then assessed against a number of criteria to determine which model ought to be used.

[43] The poorly estimated weighting matrix does not affect the consistency of parameter estimates—the first moments of the estimators—it does bias statistics relating to their second moments (Rodman, 2009).
[44] Reducing the instruments count is the ideal thing to do in this context, this was done but the results only improved marginally.
[45] Windmeijer, F. (2005). 'A finite sample correction for the variance of linear efficient two-step GMM estimators', *Journal of Econometrics*, Vol. 126, pp. 25–51.

Table 13: Tourists arrivals (pooled OLS, FE, Arellano-Bond and system GMM estimates)

Explanatory variables (in levels)	OLS	FE	DGMM	SGMM	DGMM*	SGMM*
Lag of tourists arrivals to the UK	0.967***	0.320***	0.186	0.507***	0.352	0.366*
	(0.012)	(0.038)	(0.163)	(0.155)	(0. .239)	(0.221)
GDP per capita	-0.004	0.165**	0.289*	0.115*	0.162	-0.092
	(0.009)	(0.068)	(0.162)	(0.062)	(0.190)	(0.131)
Relative price	0.000	-0.003	-0.002	-0.003*	-0.001	-0.002
	(0.000)	(0.003)	(0.003)	(0.001)	(0.005)	(0.003)
Distance	-0.033**	(omitted)	(omitted)	-0.194***	(omitted)	-0.301***
	(0.013)			(0.075)		(0.106)
Language dummy	-0.062	(omitted)	(omitted)	-0.181	(omitted)	0.054
	(0.044)			(0.286)		(0.566)
Tourism infrastructure	0.333***	0.325***	0.328***	0.344***	0.244*	0.267**
	(0.055)	(0.076)	(0.056)	(0.064)	(0.126)	(0.124)
Seat capacity	0.015	0.322***	0.320***	0.349***	0.262***	0.494**
	(0.016)	(0.042)	(0.074)	(0.129)	(0.090)	(0.199)
Constant	0.251	-2.191***	(omitted)	-1.700	(omitted)	-0.180
	(0.286)	(0.808)		(1.305)		(1.677)
Number of observations	388	388	344	388	344	388
Diagnosis tests						
Sargan test			Pr>chi2= 0.240	Pr>chi2= 0.195	Pr>chi2= 0.030	Pr>chi2= 0.000
Hansen test			Pr>chi2= 0.114	Pr>chi2= 0.036	Pr>chi2= 0.040	Pr>chi2= 0.063
AB test 2nd order autocorrelation			Pr > z = .911	Pr > z = .840	Pr > z = 0.875	Pr > z = .909

Legend: *the stars represent significance levels. * represents 10 % significance level, ** for 5% and *** for 1%. All the variables are in logs except for the dummies.*
Source: PwC analysis

The rest of our results from Table 13 above are reported in Table 14 below. In Table 14 GDP per capita and tourism infrastructure are treated as endogenous in turn. Under DGMM and SGMM, GDP per capita and Tourism infrastructure are assumed to be exogenous. Under DGMM* and SGMM*, we treat both variables as endogenous. Under DGMM** and SGMM** we treat GDP per capita as endogenous. Under DGMM*** and SGMM*** we treat tourism infrastructure as endogenous. Variables that are constant over time will drop out from the FE and DGMM models by virtue of these estimators being based on differencing.

Table 14: Tourist arrivals (Pooled OLS, FE, Arellano-Bond and SGMM estimates)

Explanatory variables (in levels)	**DGMM****	**SGMM****	**DGMM*****	**SGMM*****
Lag of tourists arrivals to the UK	0.296** (0.126)	0.561*** (0.115)	0.314*** (0.113)	0.455*** (0.163)
GDP per capita	0.172 (0.118)	-0.143 (0.141)	0.170* (0.097)	0.115** (0.053)
Relative price	-0.001 (0.002)	-0.003 (0.002)	-0.001 (0.002)	-0.003** (0.001)
Distance	(omitted)	-0.284*** (0.085)	(omitted)	-0.219*** (0.083)
Language dummy	(omitted)	-0.029 (0.382)	(omitted)	-0.206 (0.247)
Tourism infrastructure	0.333*** (0.055)	0.260*** (0.078)	0.326*** (0.050)	0.356*** (0.061)
Seat capacity	0.327*** (0.062)	0.364*** (0.087)	0.308*** (0.054)	0.400*** (0.141)
Constant	(omitted)	0.951 (1.521)	(omitted)	-1.919 (1.350)
Number of observations	344	388	344	388
Diagnosis test				
Sargan test	Pr>chi2=0.515	Pr>chi2= 0.047	Pr>chi2=0.569	Pr>chi2= 0.240
Hansen test	Pr>chi2=0.387	Pr>chi2= 0.129	Pr>chi2=0.425	Pr>chi2= 0.141
AB test 2nd order autocorrelation	Pr > z = 0.999	Pr > z = 0.821	Pr > z = 0.974	Pr > z = 0.864

Legend: *the stars represent significance levels. * represents 10 % significance level, ** for 5% and *** for 1%. All the variables are in logarithm except for the dummies. Standard errors are in parentheses.*
Source: PwC analysis

Before we interpret the results, it is important to assess their validity based on a number of key statistical diagnostics. We use four key criteria to assess the validity of our sets of results:

Criterion 1: According to Hsiao (1986)[46] the OLS coefficient of the lagged dependent variable is expected to suffer from an upward bias due to the fact that it ignores individual specific effects whereas Nickel (1981)[47] argues that the fixed effects model is expected to be downward biased. Hence, Blundell and Bond (1998) argue

[46] Hsiao, C. (1986) 'Analysis of panel data' Cambridge: Cambridge University Press
[47] Nickell, S. (1981) 'Biases in dynamic models with fixed effects.' *Econometrica*, 49, 1417 – 1426.

that a plausible parameter estimate should lie between the within the Fixed Effects and the OLS estimate. For simplicity, we refer to this criterion as the Blundell-Bond plausibility check.

For the lags of the endogenous variable/variables to be valid instruments, they need to be independent from the error term. Criteria, 2, 3 and 4 all aim to test this under different modelling assumptions.

Criterion 2: The null hypothesis (H0) of the Sargan test is that all instruments are valid. Rodman (2009) argues that the Sargan test is prone to weakness, in part as it is not robust to heteroskedasticity or autocorrelation. This suggests that its results should be treated with caution since heteroskedasticity has been identified as a problem in our model.

Criterion 3: Arellano and Bond (1991) find their test to have a greater power than the Sargan test in detecting lagged instruments being made invalid through autocorrelation. This test is applied to the residuals/error term in differences. In model (5) because $\Delta\varepsilon_{it}$ is mathematically related to $\Delta\varepsilon_{it-1}$via the shared ε_{it-1} term, negative first-order serial correlation is expected in differences and, therefore, cannot be used as evidence to assess instruments validity. Thus, the test should instead be based on the second-order correlation in differences (AR (2) above), on the basis that this will detect correlation between the $\varepsilon_{it-1}$and $\Delta\varepsilon_{it}$and the ε_{it-2} in $\Delta\varepsilon_{it-2}$ (Rodman, 2009)[48].

Criterion 4: H_0 of the Hansen test is that the instruments used are valid. Unlike the Sargan test, the Hansen test is robust to the presence of heteroskedasticity. According to Roodman, (2009) although the Hansen test is usually and reasonably thought of as a test of instrument validity, it can also be viewed as a test of structural specification. Omitting important variables could move components of variation into the error term and make them correlated with the instruments, where they might not be in the correct model.
Table 14 compares our results along the four criteria discussed above.

[48] David Roodman, (2009) 'How to do xtabond2: An introduction to difference and system GMM in Stata' *The Stata Journal*, Number 1, pp. 86–136

Table 15: Inbound Tourism models comparison

Models	Criterion 1: Blundell-Bond plausibility check	Criterion 2 Sargan test	Criterion 3: Hansen test	Criterion 4: Arellano-Bond 2nd order autocorrelation test
OLS	Upward bias (0.967***)	n/a	n/a	n/a
Fixed effect		n/a	n/a	n/a
Difference GMM	Downward bias (0.320***)	✓	✓	✓
System GMM		✓	✗	✓
Difference GMM*	✗	✗	✗	✓
System GMM*	✓	✗	✓	✓
Difference GMM**	✓	✓	✓	✓
System GMM**	✓	✗	✓	✓
Difference GMM***	✗	✓	✓	✓
System GMM***	✓	✓	✓	✓

Source: PwC analysis

The only model to pass all the tests is the System GMM***. Under this model, we treat tourism infrastructure as endogenous. Most of our dependent variables are significant except for the language dummy. The effect of the relative price of tourism turns out to be very small, with the expected sign and significance level at the 5% level.

As Fei *et al.* (2010)[49] argue, both tourists' arrivals and tourists' expenditure are plausible measures of tourism demand. These authors find that an indicator of tourists' arrivals is more likely to be affected by origin country income and 'word-of-mouth'/habit persistence effects, whilst tourists' expenditure is driven mainly by destination prices relative to those in the origin country. Our results support their findings. In addition, we find that the lag of tourists' arrivals to the UK is positive and significant at the 1% level. This result suggests that UK generates repeat visits with a 10% increase in the lag of tourists' arrivals to the UK being associated with a 4.6% increase in arrivals.

We find that distance tends to have a negative effect on tourists' arrivals with a 10% increase in distance being associated with a 2.2% reduction in arrivals. On the other hand, a growing tourism infrastructure encourages arrivals, with a 10% increase in tourism infrastructure being associated with a 3.6% increase in arrivals. We include these variables to be consistent with the other studies in this field listed above, but they are perhaps less relevant in this policy context.

The language dummy is found to be insignificant with a negative sign. The insignificance of this variable is not surprising. According to the ONS, in 2010 for example, only two out of the top five countries' residents with the most visits to the UK, had English as a first language (i.e. the US and the Republic of Ireland with 2.7 and 2.6 million visitors respectively). The other countries were France, Germany and Spain with 3.6, 3 and 1.8 million visitors respectively.

[49] Fei, B., Witt, S., Li, G., and Song, H., (2010) 'Tourism demand modelling and forecasting: how should demand be measured?' *Tourism Economics*, 16 (1), 63–81

4.2. Outbound tourism model

4.2.1. Data and modelling issues

Next we turn to our model for UK residents' visits abroad. As Athanasopoulos *et al.* (2013)[50] argue, the demand for international tourism arrivals has attracted predominant research interest in the tourism economics literature, while little attention has been paid to the demand for domestic tourism. The authors argue that one of the reasons for the dominance of international tourism in the tourism demand literature is related to international tourism's greater visibility and economic significance, as well as better data availability and quality (Pearce, 1987[51], Stabler, Papatheodorou, & Sinclair, 2010[52]).

The number of hotel rooms available in the destination country in our model has a lot of missing data points, which has restricted the time dimension of our panel data to the period 2007 – 2011, losing four countries in the process. In the context of panel data modelling, estimating a model over a five year period is not uncommon. Indeed, in Appendix B we provide a list of model specifications where some authors use as little as four years in their analysis of panel data. As Beck (2001) explains[53], there is a difference between a panel data and a time series cross sectional data (TSCS). Whilst the former have large number of cross-sections (big N) with each unit observed only a few times (small t), the TSCS data have reasonable sized t and not very large N. Indeed, for panel data, asymptotics are in N, t is fixed, whereas for TSCS data, asymptotics are in t, N is fixed.

Table 16: Summary statistics for the outbound tourism model

Variables	No. of observations	Mean	Standard deviation	Minimum	Maximum
Log of UK residents visits abroad	200	6.31	1.30	4.05	9.54
Log of UK GDP per capita	200	10.59	0.10	10.48	10.74
Relative price	200	54.42	41.77	0.54	143.80
Log of seat capacity	200	13.83	1.30	11.26	16.74
Language dummy	200	0.10	0.30	0.00	1.00
Log of distance	200	7.18	1.02	5.28	8.70
Log of unit of rooms	200	11.72	1.47	8.75	15.40

Source: PwC analysis

The limited number of model specifications we were able to obtain often used only two explanatory variables to explain domestic tourism demand: the real aggregate income of the domestic country; and a tourism relative price (see Halicioglu, 2008[54], Athanasopoulos *et al.*, 2012).[55] Time series models are often used in estimating

[50] George Athanasopoulos, Minfeng Deng Gang Li and Haiyan Song (2003) 'Domestic and outbound tourism demand in Australia: a System-of-Equations Approach' *Department of Econometrics and Business Statistics Working Paper* 06/13 http://www.buseco.monash.edu.au/depts/ebs/pubs/wpapers/
[51] Pearce, D. G. (1987). 'Tourism Today: A Geographical Analysis.' *Harlow*: Longman.
[52] Stabler, Papatheodorou, & Sinclair, (2010) 'The Economics of Tourism' *Second Edition, Routledge*.
[53] Nathaniel Beck, 2001, 'Longitudnal (Panel and Time Series Cross-Section) Data' *University of san Diego* http://www.nyu.edu/classes/nbeck/longdata/longitude20011short.pdf
[54] Halicioglu, Ferda., (2008) 'An Econometric Analysis of Aggregate Outbound Tourism Demand of Turkey', MPRA Paper 6765, University Library of Munich, Germany.
[55] Athanasopoulos, G. and A. de Silva (2012). Multivariate exponential smoothing for forecasting tourist arrivals. *Journal of Travel Research* 51, 640-652.

these models but we cannot use a time series model because many of our key independent variables are unavailable over a long enough time period.

Having considered the issues outlined above, we retained the key elements of our inbound model specification with only minor alterations. This allowed us to capture more covariates that pertain to domestic tourist demand. Hence, our specification is designed to reflect the fact that the UK is now the origin country not the destination country of tourists. We use UK GDP per capita as a proxy for UK residents income and the relative price of tourism is calculated as the ratio of the CPI of the different destinations adjusted by the £ - exchange rate.

4.2.2. Results

We first discuss the endogeneity test results before showing the model estimation results below.

Table 17: Endogeneity tests

	Test 1	**Test 2**
Variables	**Davidson-MacKinnon test**	**Endogeneity test**
UK GDP per capita	P-value = .5329	Chi-sq(1) P-val = 0.5451
Relative price	P-value = .4873	Chi-sq(1) P-val = 0.6843
Seat capacity	P-value = .068	Chi-sq(1) P-val = 0.0745
Tourism infrastructure	P-value = .9189	Chi-sq(1) P-val = 0.1127
Hansen test to assess validity of the instruments used in the endogeneity test (Test 2)		
UK GDP per capita	Chi-sq(1) P-val = 0.000	
Relative price	Chi-sq(1) P-val = 0.3911	
Seat capacity	Chi-sq(1) P-val = 0.0587	
Tourism infrastructure	Chi-sq(1) P-val = 0.7981	

Legend: *test 2 is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the endog option following the ivreg2 command). The null hypothesis (H0) under Test 1 and 2 is that the variable can be treated as exogenous. When the P-value > 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test can be obtained following Test 2. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. Same interpretation of the P value applies.*
Source: PwC analysis

Tests 1 and 2 reveal that all our explanatory variables can be treated as exogenous but the Hansen statistic for UK GDP per capita points to the invalidity of the instruments used in Test 2. Furthermore, the Hansen test for seat capacity is just above the critical threshold so, given the importance of this variable in our model, this finding ought to be treated with caution. We therefore treat UK GDP per capita and seat capacity together and in turn as endogenous and exogenous in our subsequent estimations. Our estimation results are presented in Table 18 and 19 below.

Table 18: UK residents visits abroad (pooled OLS, FE, Arellano-Bond and system GMM estimates)

Explanatory variables	OLS	FE	DGMM	SGMM	DGMM*	SGMM*
Lag of UK residents visits abroad	0.976*** (0.022)	0.172 (0.110)	0.423* (0.251)	0.467*** (0.109)	0.498*** (0.154)	0.549*** (0.046)
UK GDP per capita	0.663*** (0.149)	0.756*** (0.198)	0.922*** (0.167)	0.518*** (0.112)	0.878*** (0.224)	0.873*** (0.147)
Relative price	0.000 (0.000)	-0.011* (0.007)	-0.005 (0.011)	0.004** (0.002)	0.001 (0.007)	0.002 (0.001)
Distance	-0.010 (0.05)	(omitted)	(omitted)	-0.042 (0.066)	(omitted)	-0.291*** (0.102)
Tourism infrastructure	0.020 (0.014)	0.348* (0.192)	0.405 (0.304)	0.136** (0.057)	0.314 (0.283)	0.245*** (0.062)
Seat capacity	-0.009 (0.014)	0.060 (0.200)	-0.140 (0.178)	0.310*** (0.087)	-0.014 (0.269)	-0.020 (0.126)
Language dummy	0.004 (0.041)	(omitted)	(omitted)	0.159 (0.196)	(omitted)	0.375*** (0.123)
Constant	-6.926*** (1.660)	-7.067* (3.884)	(omitted)	-7.945*** (1.366)	(omitted)	-7.095*** (1.227)
Number of observations	160	160	120	160	120	160
Diagnosis test						
Sargan test			Pr>chi2= .770	Pr>chi2= .648	Pr>chi2= .593	Pr>chi2= .421
Hansen test			Pr>chi2= .666	Pr>chi2= .380	Pr>chi2= .724	Pr>chi2= .934
AB test 2nd order autocorrelation			Pr > z = .157	Pr > z = .259	Pr > z = .176	Pr > z = .253

Legend: *the stars represent significance levels. * represents 10 % significance level, ** for 5% and *** for 1%. All the variables are in logarithm except for the dummies. Under DGMM and SGMM, UK GDP per capita and seat capacity are assumed to be exogenous. Under DGMM* and SGMM*, we assume UK GDP per capita and seat capacity to be endogenous. Standard errors are in parentheses.*
Source: PwC analysis

The rest of our results are presented in table 19 where we treat seat capacity as endogenous first, then tourism infrastructure as endogenous.

Table 19: UK residents visits abroad (pooled OLS, FE, Arellano-Bond and system GMM estimates)

Explanatory variables	OLS	FE	DGMM**	SGMM**	DGMM***	SGMM***
Lag of UK residents visits abroad	0.976*** (0.022)	0.172 (0.110)	0.473** (0.209)	0.541*** (0.072)	0.497** (0.208)	0.465*** (0.112)
UK GDP per capita	0.663*** (0.149)	0.756*** (0.198)	0.851*** (0.217)	0.805*** (0.143)	0.906*** (0.181)	0.576*** (0.109)
Relative price	0.000 (0.000)	-0.011* (0.007)	-0.001 (0.008)	0.003* (0.001)	-0.000 (0.007)	0.004** (0.002)
Distance	-0.010 (0.05)	(omitted)	(omitted)	-0.268** (0.104)	(omitted)	-0.044 (0.070)
Tourism infrastructure	0.020 (0.014)	0.348* (0.192)	0.386 (0.262)	0.232*** (0.060)	0.315 (0.300)	0.146*** (0.052)
Seat capacity	-0.009 (0.014)	0.060 (0.200)	-0.035 (0.255)	0.014 (0.109)	-0.072 (0.202)	0.295*** (0.099)
Language dummy	0.004 (0.041)	(omitted)	(omitted)	0.403*** (0.133)	(omitted)	0.108 (0.224)
Constant	-6.926*** (1.660)	-7.067* (3.884)	(omitted)	-6.827*** (1.199)	(omitted)	-8.442*** (1.420)
Number of observations	160	160	120	160	120	160
Diagnosis test						
Sargan test			Pr>chi2= .952	Pr>chi2= .529	Pr>chi2= .666	Pr>chi2= .676
Hansen test			Pr>chi2= .964	Pr>chi2= .957	Pr>chi2= .653	Pr>chi2= .365
AB test 2nd order autocorrelation			Pr > z = .158	Pr > z = .160	Pr > z = .153	Pr > z = .255

Legend: *the stars represent significance levels. * represents 10 % significance level, ** for 5% and *** for 1%. All the variables are in logarithm except for the dummies. Under DGMM** and SGMM**, seat capacity is assumed to be endogenous. Under DGMM*** and SGMM***, UK GDP per capita is assumed to be endogenous. Standard errors are in parentheses.*
Source: PwC analysis

We adopt the same model comparison as the one used for our arrivals model. Although, in addition to the 4 criteria we used in the previous section, we now consider two more criteria. The first criterion looks for signs of instrument proliferation. This criterion was not considered our arrival model because there were no signs of instrument proliferation with the models we estimated. The second is based on the each model Wald chi2

Table 20: Outbound tourism models comparison

Models	Criterion 1: Blundell-Bond plausibility check	Criterion 2 Sargan test	Criterion 3: Hansen test	Criterion 4: Arellano-Bond 2nd order autocorrelation test	Wald Chi2 for model fit	Sign of instrument proliferation
OLS	Upward bias (0.976***)	n/a	n/a	n/a	n/a	n/a
Fixed effect	Downward bias (0.172***)	n/a	n/a	n/a	n/a	n/a
Difference GMM	✓	✓	✓	✓	112.92 (p-value=0.00)	No
System GMM	✓	✓	✓	✓	939.68 (p-value=0.00)	No
Difference GMM*	✓	✓	✓	✓	189.2 (p-value=0.00)	No
System GMM*	✓	✓	✓	✓	707 (p-value=0.00)	Yes (Hansen = .934)
Difference GMM**	✓	✓	✓	✓	145.96 (p-value=0.00)	Yes (both Sargan =.952 and Hansen = .964)
System GMM**	✓	✗	✓	✓	721.96 (p-value=0.00)	Yes (Hansen = .957)
Difference GMM***	✓	✓	✓	✓	166.21 (p-value=0.00)	No
System GMM***	✓	✓	✓	✓	813.78 (p-value=0.00	No

Source: PwC analysis

(pronounced as Wald chi square). This statistic tests for overall model fit. The higher the Wald chi2 test statistic the better. A significant p-value of this test (p-value smaller than 0.05) would lead us to conclude that at least one of the regression coefficients in the model is not equal to zero. Table 20 above shows a comparison of our models.

In light of the various test results above, we identify two models, namely SGMM and SGMM***, which pass all of our tests. SGMM treats all the explanatory variables as exogenous whilst SGMM*** treats UK GDP per capita as endogenous. Although the former model has a better fit (i.e. Wald Chi2=939.68, the higher this statistic is, the better the fit of the regression to the original data) than the latter, our regression coefficients for these two models are very similar indeed as shown in Table 21.

*Table 21: Comparing SGMM and SGMM*** coefficients*

Explanatory variables	**SGMM**	**SGMM*** **
Lag of UK residents visits abroad	0.467*** (0.109)	0.465*** (0.112)
UK GDP per capita	0.518*** (0.112)	0.576*** (0.109)
Relative price	0.004** (0.002)	0.004** (0.002)
Distance	-0.042 (0.066)	-0.044 (0.070)
Tourism infrastructure	0.136** (0.057)	0.146*** (0.052)
Seat capacity	0.310*** (0.087)	0.295*** (0.099)
Language dummy	0.159 (0.196)	0.108 (0.224)
Constant	-7.945*** (1.366)	-8.442*** (1.420)

Source: PwC analysis

Our modelling also suggests that a 10% increase in seat capacity is positively associated with approximately a 3% increase in UK residents visits abroad. Our findings suggest that seat capacity plays a marginally more important role in determining tourists' arrivals to the UK than explaining UK residents' visits abroad. In addition, the income of the tourist also seems to play a relatively more important role in explaining outbound tourism than it does in explaining inbound tourism. We also find the distance factor to be more important for inbound tourism than outbound tourism. The language dummy is found to be not significant.

5. The relationship between international trade and seat capacity

5.1. Section overview

In this section we examine the relationship between seat capacity and UK exports and imports. As described in Figure 1, aviation can facilitate increased exports by connecting producers to new markets. It can also help UK producers strengthen links with overseas suppliers. This could lead to increased imports, or lower prices paid for existing imports, so the effect on the trade balance through this mechanism is ambiguous.

The analysis in this section differentiates between exports and imports of goods and services. Key results are as follows:

- We find that a 10% increase in UK GDP and foreign country GDP are associated with respectively a 3.2% and 6.6% increase in UK goods imports;
- A 10% increase in seat capacity is associated with a 1.7% increase in UK goods imports.
- A 10% increase in seat capacity is associated with a 3.3% increase in goods exports;
- A 10% increase in seat capacity is associated with 6.6% increase in UK imports of services; and
- A 10% increase in seat capacity is associated with a 2.5% increase in exports of services by the UK.

5.2. Comparing the trade and tourism approaches

Before presenting our various model specifications and results, it is important to note that there are a number of key differences between our tourism and our trade models. Whilst the former were estimated using dynamic panel data (i.e. the lag of tourists' arrivals was included to capture destination reputation effects), our trade model is based on a static panel. The significance of this is that we can no longer use DGMM or SGMM estimators but rather the Pseudo-Poisson Maximum Likelihood (PPML) estimator, which is a popular approach used in estimating gravity models. We later discuss why this model is appropriate in this context.

A second important distinction between using a DGMM or SGMM and the simple PPML approach is that whilst the former models account for the unobserved country fixed effects (FE) element, the latter approach using its simplest form does not. To account for unobserved country FE in a PPML framework we adopt a similar approach to that used by Fally (2012)[56]. Fally uses importers' and exporters' FE, allowing him to account for the unobserved country FE which, by construction, is nested in the importers' and exporters' FE.

Fally was able to use importers' and exporters' FE because the data considered in his study consisted of various country pairs trading with one another. In our panel data, the idea of importers' and exporters' FE does not apply since each country pair is made up of the UK and a given country i, with the dependent variable being either UK imports from or UK exports to that country i. Instead, we use the World Bank (2013) list of economies to group countries according to the following income groups: high income (this is composed of OECD countries and non OECD countries), upper middle

income, lower middle income and low income. These groups will nest the country fixed effects elements thereby allowing our PPML to account for unobserved time invariant country heterogeneity.

In the following sections, we provide a description of the data and report our econometrics results.

[56] Thibault Fally, (2012) "Structural Gravity and Fixed Effects" University of Colorado-Boulder http://spot.colorado.edu/~fally/Gravity_PPML.pdf

5.3. Model specification and data sources

To conduct our econometrics analysis we use a gravity model based on a panel of 164 countries (UK trading partners) over the period 2001-2011. The name 'gravity' is derived from the fact that in its nonlinear form, the model resembles Newton's law of gravity. The model considers exports to be directly proportional to the exporting and importing countries' economic 'mass' (GDP), and inversely proportional to the distance between them. The gravity model predicts that larger country pairs would tend to trade more, whilst countries that are further apart would trade less, perhaps because transport costs between them are higher (Arvis and Shepherd, 2013)[57]. Our rationale for choosing a gravity approach is due to the fact the model has become a standard approach in the applied international trade literature as Arvis and Shepherd (2013) argue. Furthermore, according to Leamer *et al.*, (1995)[58] the model has produced some of the clearest and most robust findings in empirical economics.

To study the effect of aviation intervention on trade, we apply a gravity model separately to the imports and exports flows between the UK and its world trade partners. The model is specified in line with general gravity model specifications (see Melitz (2007)[59], Abedini and Peridy (2008)[60] or Grant and Lambert (2008)[61]) augmented with the variable seat capacity:

$$T_{it} = f(GDP_{ukt}, GDP_{it}, EXR_{it}, DISTANCE_i, COLLINK_{it}, LANGDUMMY_i, LANDLOK_i, SCAP_{it}) \quad \textbf{(5.1)}$$

Where:

- The value of imports/exports in millions of dollars between the UK and its trading partners over the period 2001-2011. T_{it} is our dependent variable, and the variables described below are explanatory variables.
- GDP_{ukt} = UK gross domestic product in current prices and billions of dollars over the period 2001-2011.
- GDP_{it} = UK trading partner gross domestic product in current prices and billions of dollars over the period 2001-2011. The two GDP figures in our model make up the measures of country 'mass' and together with distance comprise the core gravity model.
- EXR_{it}= This variable represents the implied PPP conversion rate between sterling and each trading partner country (i.e. the national currencies for each of the 165 countries per current sterling). The data was collected from the IMF for the period 2001-2011. We would expect an appreciation of sterling to discourage exports and encourage imports.
- $DISTANCE_{it}$ = Distance in kilometers between the capitals of the foreign country i and London. The data was collected from CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) for the time period 2001-2011.
- $COLLINK_{it}$= Dummy variable depending on whether a country is a former British dependent territory. Retrieved from the CEPII database.
- $LANGDUMMY_{it}$ = Language dummy. We include this variable to take into account whether or not there is a language barrier (the dummy takes a value of 1 if English is the official language in country i). The language dummy data was also collected from CEPII for the time period 2001-2011.
- $LANDLOCKED_{it}$ = A dummy which allows us to take into account whether or not a country trading with the UK is landlocked. It takes a value of 1 for a landlocked country, and 0 for countries with coastlines. This is obtained through CEPII.

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[57] Jean-Francois Arvis & Ben Shepherd, (2013) 'The Poisson quasi-maximum likelihood estimator: a solution to the 'adding up' problem in gravity models' *Applied Economics Letters,* Taylor and Francis Journals, vol. 20(6), pages 515-519, April.
[58] Leamer, Edward E. and James Levinsohn, (1995) 'International Trade Theory: the Evidence' in Gene M. Grossman and Kenneth Rogoff, eds., Handbook of International Economics, vol. 3, Amsterdam: Elsevier Science B.V., 1339-94.
[59] Melitz J. (2007) 'North, South and distance in the gravity model' *European Economic Review*, 51(4): 971-991.
[60] Abedini J, Peridy N. (2008) 'The greater Arab free trade area (GAFTA): an estimation of the trade effects.' *Journal of Economic Integration*; 23(4): 848-72.
[61] Grant JS, Lambert DM. (2008) 'Do regional trade agreements increase members' agricultural trade?' *American Journal of Agriculture Economy*; 90(3): 765-82

- $SCAP_{it}$ = Seat capacity. The national-level annual data for 2001-2011 were sourced from the UK Civil Aviation Authority. This variable measures the yearly seat capacity on all scheduled flights between the UK and the trading partners.

Next, we report the key summary statistics of the variables we will be using in our trade models.

Table 22: Summary statistics for the trade models

Variables	No. of observations	Mean	Standard deviation	Minimum	Maximum
Log of import of goods	1637	11.57	3.33	0.00	18.31
Log of export of goods	1638	11.95	2.58	0.00	17.98
Log of import of services	1266	11.74	2.39	3.95	17.33
Log of export of services	1303	11.96	2.40	0.00	17.97
Log of UK GDP	1639	7.72	0.16	7.38	7.95
Log of GDP in partner country	1637	3.17	2.34	-4.20	9.62
Log of distance	1629	8.49	0.81	5.84	9.86
Relative price	1637	327.23	1124.88	0.00	12765.24
Log of seat capacity	951	12.22	1.89	5.99	16.74
Language dummy	1639	0.27	0.44	0.00	1.00
Landlocked dummy	1639	0.20	0.40	0.00	1.00
Colonial link dummy	1639	0.36	0.48	0.00	1.00

Source: PwC analysis

In order to estimate our models, we use the following approaches: a pooled OLS approach, a RE approach, and a PPML approach. The rationale for using the pooled OLS and RE approaches is that it makes for good modelling practice to start with the simplest models. Notice that we have omitted the simple FE model because such a model would involve eliminating variables that form the basis of our gravity model, namely distance and the language dummy.

We use a PPML approach in all of our trade equations because it has a number of desirable properties when estimating gravity models. First, unlike the Pooled OLS and RE techniques, the PPML allows us to account for the presence of zero bilateral trades in the dataset. In our panel data, zero bilateral trade amounts to 20% and 22% respectively of the observations relating to UK services exported and imported. Other desirable properties of the PPML are that:

- This approach is robust to the presence of heteroskedasticity,

- Its coefficients are easy to interpret and follow the same pattern as OLS, and the estimation procedure is fairly easy to implement and robust to misspecifications (Gourieroux, Monfort and Trognon, 1984);[62]
- Santos Silva and Tenreyro (2006)[63] show that the PPML consistently estimates the gravity equation for trade and it is robust to different patterns of heteroskedasticity and measurement error. This makes it preferable to alternative procedures, such as OLS specified in log;
- PPML can be used even if there are no zero values in the dataset as long as the expectation of the dependent variable is positive; and[64]
- PPML allows us to estimate the gravity model in its non-linear form.

In the next section, we present our results based on the estimators described above.

5.4. Goods imports model

A closer inspection of the data for our goods imports model suggest the presence of heteroskedasticity . The results the modified Wald test for group wise heteroskedasticity following a fixed effect regression model is reported in Table 23 below.

Table 23: Modified Wald test for group wise heteroskedasticity

H0: sigma(i)^2 = sigma^2 for all i
Chi2 (108) = 1.5e+28
Prob>chi2 = 0.0000

Source: PwC analysis

The null hypotheses of no groupwise heteroskedasticity is decisively rejected. This means that we must use the Hansen test which accounts for groupwise heteroskedasticity to assess the validity of the instruments used in the endogeneity test. The regression technique used for this model is the PPML estimator. This is a relatively new approach, and as such there is currently no way of generating the Sargan or Hansen tests following this procedure. Hence, we will rely on the Hansen test under our endogeneity test procedure.

The table below reports the Stata output from the endogeneity tests

Table 24: Endogeneity tests – goods imports

Variables	**Endogeneity test (p-values)**	**Hansen Overidentification test**
UK GDP	Chi-sq(1) P-val = .2618	Chi-sq(1) P-val = .0017
Foreign country GDP	Chi-sq(1) P-val = .8186	Chi-sq(1) P-val = .7385
Exchange rate	Chi-sq(1) P-val = .4027	Chi-sq(1) P-val = .1498
Seat capacity	Chi-sq(1) P-val = .3151	Chi-sq(1) P-val =.3140

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When The P value is bigger than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. The same interpretation of the P value applies. Source: PwC analysis*

[62] Gourieroux, C., Monfort, A. and Trognon, A. (1984). 'Pseudo maximum likelihood methods: Applications to Poisson models,' *Econometrica*, 52, 701-720.
[63] Santos Silva, J.M.C. and Silvana Tenreyro (2006). 'The log of gravity' *The review of Economics and Statistics*, 88, 641-658.
[64] Following a correspondence with Professor Santos Silva.

According to our test results, all explanatory variables can be treated as exogenous. We report the Stata output from the imports of goods model results in Table 25 below.

Table 25: Imports of goods OLS and RE estimates (2002 – 2011)

Explanatory variables	**Pooled OLS**	**RE**	**PPML**
UK GDP	-0.356 (.316)	-0.080 (0.211)	0.315*** (0.072)
Foreign country GDP	0.855*** (.082)	0.906*** (0.0998)	0.660*** (0.068)
Distance	-0.377 (0.191)	-0.531*** (0.172)	-0.472*** (0.057)
Exchange rate	-0.000 (0.0001)	-0.000*** (0.000018)	-0.001*** (0.00007)
Seat capacity	0.312** (0.081)	0.085 (0.0676)	0.167*** (0.049)
Language dummy	0.724 (0.349)	1.165*** (0.423)	0.089 (0.121)
Landlocked dummy	-0.217 (0.106)	-0.354* (0.202)	-0.445*** (0.166)
Colonial link dummy*	(omitted)	(omitted)	(omitted)
Dummy for high income countries	0.082 (0.291)	1.049** (0.415)	-0.317 (0.367)
Dummy for upper middle income countries	0.253 (0.182)	0.855*** (0.198)	0.182 (0.265)
Dummy for lower middle income countries	-0.454** (0.156)	0.067 (0.189)	-0.790*** (0.188)
Constant	11.439** (3.243)	12.190*** (2.159)	10.833*** (0.675)
Number of observations	947	947	947

Legend: *the stars represent significance levels, and standard errors are shown in brackets. * represents 10 % significance level, ** 5% and *** 1%. All the variables are in logarithms except for the dummies.* Colonial Link dummy is omitted due to multicollinearity with language dummy . *Source: PwC analysis*

Care must be taken in comparing our findings to other published work. Most gravity models in the trade literature tend to be based on a panel of countries trading with one another. In our case, our panel data format consists of the UK trading with a range of partner countries. Thus, although we would still expect a variable such as distance to have an adverse effect on trade; one could argue that the importance of this effect is likely to be stronger for a poorer nation.

There seems to be some evidence of collinearity between the language dummy and colonial link. Using a correlation matrix, we find the correlation between these two dummies to be 70%. Thus we drop the dummy which is insignificant, namely colonial link, from our models.

Most of our estimated coefficients in the PPML model have the expected signs and are significant at the 1% level. We find that a 10% increase in seat capacity is associated with a 1.7% increase in UK goods imports. This model strongly supports the predictions of the gravity model. We find that a 10% increase in UK GDP and foreign country GDP are associated with respectively a 3.2% and 6.6% increase in UK goods imports. Distance discourages imports, with a 10% increase in distance being associated with a 4.7% decrease in imports.

5.5. Goods exports model

Next, we turn to our UK exports of goods model. Stata output for the endogeneity tests are shown in the table below.

Table 26: Endogeneity tests – Goods exports

Variables	**Endogeneity test (p-values)**	**Hansen overidentification test**
UK GDP	Chi-sq(1) P-val = 0.9657	Chi-sq(1) P-val =. 0.000
Foreign country GDP	Chi-sq(1) P-val =0558	Chi-sq(1) P-val =3496
Exchange rate	Chi-sq(1) P-val =.2645	Chi-sq(1) P-val =.8580
Seat capacity	Chi-sq(1) P-val =.0778	Chi-sq(1) P-val =.8487

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When the P value is greater than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. The same interpretation of the P value applies. Source: PwC analysis*

Our test finds all the variables to be exogenous. However, the Hansen test rejection of validity of the instruments used in testing the endogeneity of the UK GDP is very strong, prompting us to treat this variable as endogenous. The results of our modelling are presented in Table 27 below.

Table 27: Export of goods OLS, RE, PPML estimates (2002 – 11)

Explanatory variables	Pooled OLS	RE	PPML	IVPPML
UK GDP	-0.204* (0.113)	0.155** (0.061)	0.165*** (0.034)	-11.191*** (0.214)
Foreign country GDP	0.670*** (0.037)	0.646*** (0.030)	0.476*** (0.045)	0.447*** (0.069)
Distance	-0.283*** (0.095)	-0.429*** (0.118)	-0.461*** (0.118)	-0.420*** (0.107)
Exchange rate	0.000 (0.000)	-0.000* (0.000)	-0.000*** (0.000)	-0.000** (0.000)
Seat capacity	0.275*** (0.046)	0.030 (0.024)	0.333*** (0.061)	0.431*** (0.096)
Language dummy	0.398** (0.171)	0.562*** (0.195)	0.647*** (0.132)	0.562*** (0.206)
Landlocked dummy	-0.399** (0.178)	-0.576*** (0.208)	-0.509*** (0.073)	-0.461*** (0.167)
Colonial link dummy	(omitted)	(omitted)	(omitted)	(omitted)
Dummy for high income countries	0.252 (0.216)	0.960*** (0.280)	0.746*** (0.113)	0.515** (0.250)
Dummy for upper middle income countries	-0.026 (0.218)	0.250 (0.286)	0.763*** (0.072)	0.690*** (0.235)
Dummy for lower middle income countries	-0.098 (0.202)	0.259 (0.272)	0.317*** (0.050)	0.241 (0.237)
Constant	10.921*** (1.202)	11.925*** (1.189)	9.329*** (1.730)	82.274 n/a
Number of observations	947	947	947	725

Legend: *the stars represent significance level, and standard errors are shown in brackets s. * represents 10 % significance level, ** 5% and *** 1%. All the variables are in logarithms except for the dummies. IVPPML treats UK GDP as endogenous.*
Source: PwC analysis

The negative sign on the UK GDP variable in the IVPPML model provides evidence that this variable ought to be considered as exogenous as suggested by our endogeneity test. Treating UK GDP as exogenous, the PPML model suggests that a 10% increase in seat capacity is associated with a 3.3% increase in exports.

The language dummy and landlocked dummies are found to play an important role in explaining UK export patterns. Sharing a common language with the UK seems to encourage exports whilst being landlocked strongly discourages exports.

We find the distance factor once more to be a factor which discourages trade, with a 10% increase in distance being associated with a 4.6% decrease in exports. In addition, our model suggests that the high income country group receives 74.6% more UK exports relative to low income countries. Note that all the coefficients on the dummies are interpreted relative to the base dummy, that for the low income country group, which is dropped in this case to avoid multicollinearity.

5.6. Services imports model

Next, we look at the UK exports and imports of services models. The table below shows our endogeneity tests results for services imports.

Table 28: Endogeneity tests – services imports

Variables	Endogeneity test (p-values)	Hansen overidentification test
UK GDP	Chi-sq(1) P-val = 0.6027	Chi-sq(1) P-val =.0606
Foreign country GDP	Chi-sq(1) P-val =0.9806	Chi-sq(1) P-val =.3318
Exchange rate	Chi-sq(1) P-val =0.6086	Chi-sq(1) P-val =.1846
Seat capacity	Chi-sq(1) P-val =0.0316	Chi-sq(1) P-val =.6705

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When The P value is greater than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. The same interpretation of the P value applies.*

Source: PwC analysis

Seat capacity is found to be endogenous. Following our endogeneity test, Table 29 shows our results.

Table 29: Import of services PPML estimates (2002-2011)

Explanatory variables	**OLS**	**RE**	**PPML**	**IVPPML**
UK GDP	0.274 (0.151)	0.782*** (0.116)	0.357*** (0.121)	0.495* (0.272)
Foreign country GDP	0.402*** (0.494)	0.507*** (0.0497)	0.354*** (0.049)	0.335*** (0.033)
Exchange rate	-0.000* (0.0001)	-0.000*** (0.00002)	-0.000*** (0.00008)	-0.000*** (0.0001)
Distance	-0.052 (0.083)	-0.283** (0.139)	-0.114*** (0.0094)	-0.079* (0.047)
Seat capacity	0.550*** (0.074)	0.156** (0.077)	0.577*** (0.048)	0.664*** (0.05)
language dummy	0.653*** (0.068)	1.142*** (0.079)	0.154 (0.102)	0.218*** (0.071)
Landlocked dummy	-0.089 (0.127)	-0.367** (0.177)	-0.114*** (0.032)	0.046 (0.088)
Colonial link dummy	(omitted)	(omitted)	(omitted)	(omitted)
Dummy for high income countries	-0.037 (0.205)	0.968* (0.452)	0.194** (0.085)	0.102 (0.250)
Dummy for upper middle income countries	-0.053 (0.109)	0.449*** (0.158)	0.060 (0.139)	0.054 (0.231)
Dummy for lower middle income countries	-0.425** (0.096)	0.010 (0.145)	-0.005 (0.068)	0.034 (0.227)
Constant	2.485 (1.708)	3.989*** (1.47)	2.267 (1.466)	-14.074*** (2.151)
Number of observations	824	824	947	725

Legend: *the stars represent significance levels, and standard errors are shown in brackets. * represents 10 % significance level, ** 5% and *** 1%. All the variables are in logarithms except for the dummies. IVPPML treats seat capacity as endogenous.*
Source: PwC analysis

We find that a 10% increase in seat capacity is associated with a 6.6% increase in UK imports of services. Relative to the small elasticity we obtained in our goods exports model, this result is in line with the fact that one would expect trade in services in general to be highly correlated with the movement of people. In addition, the fact that the UK is an island coupled with London's position as a financial hub, suggests that air connectivity is likely to play a significant role in the trade in services.

Our findings also show that UK GDP is relatively more strongly associated with UK trade in services than its trade in goods. We find that a 10% increase in UK GDP is associated with a 3.6% increase in imports of services. Furthermore, although still negative, distance seems to play a less important role in trade in services. A 10% increase in distance is now associated with a 1.1% decrease in UK services imports.

5.7. Services exports model

The Stata output of our endogeneity test for our services exports model is reported in Table 30. The P-values are all larger than 0.05, what means that all the variables in the model can be treated as exogenous.

Table 30: Endogeneity tests – exports of services

Variables	Endogeneity test	Hansen overidentification test
UK GDP	Chi-sq(1) P-val = .5870	Chi-sq(1) P-val = .3102
Foreign country GDP	Chi-sq(1) P-val = .2840	Chi-sq(1) P-val = .2305
Exchange rate	Chi-sq(1) P-val = .1784	Chi-sq(1) P-val = .3987
Seat capacity	Chi-sq(1) P-val = .2325	Chi-sq(1) P-val = .2057

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (This test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When the P value is greater than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. The same interpretation of the P value applies.* *Source: PwC analysis*

Table 31 reports the findings of our regression models. We report results for the basic OLS specification, the RE model and the PPML model. Most of our independent variables have the expected signs and tend to be significant at the 1% level. The results from the PPML model show that a **10% increase in seat capacity is associated with a 2.5% increase in the export of services by UK businesses.** The intuition behind this result can be taken from the AC's discussion paper 02: A*viation connectivity and the economy, March 2013*, which states that*: "As such, connectivity facilitates exports of UK services, enabling UK entrepreneurs to have easier and more effective access to a variety of international customers. Conversely, UK residents may benefit from a wider choice of services when overseas services suppliers get easier access to the British market."*

UK GDP plays an important role in explaining services exports with a 10% increase in GDP being associated with a 7.6% increase in services exports.

Table 31: Exports of Services PPML estimates (2002 – 2011)

Explanatory variables	**OLS**	**RE**	**PPML**
UK GDP	0.489*** (0.112)	0.621*** (0.092)	0.764*** (0.078)
Foreign GDP	0.644*** (0.052)	0.709*** (0.046)	0.535*** (0.054)
Exchange rate	-0.000** (0.000)	-0.000*** (0.000)	-0.000*** (0.000)
Distance	-0.066 (0.122)	-0.137 (0.117)	-0.297*** (0.097)
Seat Capacity	0.289*** (0.067)	0.110*** (0.041)	0.246*** (0.084)
Language dummy	0.548*** (0.191)	0.726*** (0.078)	0.877*** (0.164)
Landlocked	0.118 (0.296)	0.078 (0.287)	0.368 (0.321)
Colonial link dummy	(omitted)	(omitted)	(omitted)
Dummy for high Income	0.365 (0.240)	0.676** (0.276)	1.307*** (0.353)
Dummy for upper middle income	-0.159 (0.259)	-0.089 (0.275)	0.812*** (0.288)
Dummy for lower middle income	-0.319 (0.230)	-0.194 (0.253)	0.485* (0.288)
Constant	3.097* (1.639)	4.375*** (1.339)	3.115** (1.481)
Number of observations	825	825	947

Legend: *the stars represent significance levels. * represents 10 % significance level, ** 5% and *** 1%. All the variables are in logarithms except for the dummies.* *Source: PwC analysis*

The language dummy emerges as a more important explanatory variable than was the case for our UK trade in goods model. Although still negative and significant at the 1% level, distance plays a relatively smaller role. A 10% increase in distance is associated with approximately a 3% decrease in UK exports of services. There is also some evidence that export of services seems to be larger when we look at the high income group countries compared to any other income country groups.

6. The relationship between FDI, seat capacity and connectivity

6.1. Section overview

In this section we examine the impact of a change in seat capacity on UK FDI inflows and outflows at both the regional and national levels. We test the following three models:

- A regional model looking at the effect of regional connectivity on regional FDI inflows in manufacturing - the regions considered are the 11 UK Government Office Regions (GORs);
- A national model which looks at total FDI inflows from the rest of the world into the UK; and
- A national model focusing on total FDI outflow from the UK to the rest of the world.

As in the previous Sections, it is structured as follows:

1. Description of the data and econometric specification;
2. Endogeneity test;
3. Model estimation; and,
4. Discussion of our findings.

In our regional model, we find much heterogeneity between the different GORs. Such heterogeneity is likely to lead to the presence of outliers in the dataset. Hence, we use a robust regression approach which is less influenced by the presence of outliers. In our FDI inflow and outflow models, the presence of zeros in the dataset prompts us to use a Pseudo Poisson Maximum Likelihood (PPML) estimator.

It is important to note that whilst seat capacity is used as the measure of air connectivity in our national FDI econometric models, we have used the IATA connectivity index in our regional model. This is due to the fact that we did not have data for seat capacity between the different UK GORs and the countries providing inward FDI. However, this does not affect the integrity of our regional model, since the theory we are looking to test is whether there is an association between the disparities in regional connectivity and manufacturing FDI inflows.

Our key findings are as follows:

- A 1% increase in connectivity is associated with approximately a 1.1% increase on average in the amount of manufacturing related FDI going to each GOR;
- Our modelling also suggests that a 10% increase in seat capacity is associated with a 4.7% increase in UK FDI inflows; and
- A 10% increase in seat capacity is associated with a 1.9% increase in FDI outflow.

A detailed explanation of the specification of each model is provided below.

6.2. Regional model specification and data sources

Our regional model is based on a panel of 11 UK GORs observed over the period 2003-2012. For our dependent variable, we use manufacturing FDI inflows into the following 11 UK GORs: East of England, East Midlands, London, North East, North West, Scotland, South East, South West, West Midlands, Wales and Yorkshire and the Humber. Due to issues relating to data availability, our analysis is restricted to FDI inflows.

Driffield *et al*. (2009)[65] argue that distinguishing between different types of FDI facilitates a more informed analysis of the different types of impacts FDI can have. Although our study looks at the association between air connectivity and FDI, we believe that considering a particular type of FDI rather than total FDI, in this case FDI in manufacturing, helps gain a better understanding of the relationship we wish to examine. Had the relevant data been available, we would have adopted a similar approach in modelling FDI at the national level, but total FDI figures are used instead in these models.

Our regional model specification is in line with Arromdee, V., Coughlin, C., and Terza, J., (1989)[66] augmented with the explanatory variables migration and air connectivity. The model is as follows:

$$RFDI_{it} = f(GVA_{it}, WAGE_{it}, UNEMP_{it}, MIGRATION_{it}, INFRAST_{it}, CON_{it})$$

Where:

- $RFDI_{it}$ = Our dependent variable, regional foreign direct investment inflow in millions into the 11 UK GORs. The data are available from the Financial Times through its fDi Markets service reports on yearly capital expenditure by regions.
- GVA_{it} = Gross Value Added in the manufacturing sector data in UK pounds, collected from ONS for the period 2003-2010. This variable is used in our model as a proxy for productivity.
- $WAGE_{it}$ = A wage variable, being weekly regional compensation in manufacturing, also in UK pounds, collected from ONS for the period 2003-2011.
- $UNEMP_{it}$ = An unemployment variable, being regional claimant counts in manufacturing. Figures for the period 2003-2010 are used, collected from the ONS.
- $MIGRATION_{it}$ = Regional migration data, collected from the ONS, expressed as the ratio of inflows and outflows for each of the GORs. We use the lag annual regional migration inflow data (thousands) for 2003-2011.
- $INFRAST_{it}$ = Regional infrastructure measured as the ratio of the length of motorway to the area size of the GOR. There are precedents for the inclusion of such an explanatory variable. For example, Coughlin, C., and Eran, S., (1999) use the total length of paved roadway in a province, divided by its area. Hill and Munday (1991)[67] illustrate the importance of infrastructure (roads) in attracting inward investment.
- CON_{it} = Regional air connectivity index for each of the GORs. The connectivity indices were calculated following the IATA connectivity index formulae as follows:

$$\frac{\sum Frequency * Available\ seats\ per\ flight * Weighting\ of\ destination\ airport}{1000}$$

Where:

- $Frequency$ = Number of flights to a given destination in a year.
- $Available\ seats\ per\ flight$ = Defined as the number of seats available to each destination served by any given airport in the country being analysed. Data are drawn from the SABRE/ADI database.
- $Weighting\ of\ destination\ airport$ = Number of seats available weighted by the size of the destination airport (in terms of the number of passengers handled each year).
- 1000 = The weighted totals are summed for all destinations (and divided by a scalar factor of 1000) to determine the connectivity indicator.

Next we report the key summary statistics for the variables used in our regional model.

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[65] Driffield, N., Love, J. H. and Taylor, K. (2009) 'Productivity and labour demand effects of inward and outward foreign direct investment on UK industry.' *The Manchester School*, vol 77 (2) pp 171–203.
[66] Coughlin, Cletus C & Terza, Joseph V & Arromdee, Vachira, (1989). 'State Characteristics and the Location of Foreign Direct Investment within the United States,' *Federal Reserve Bank of St. Louis*.
[67] Hill, S; Munday, M; (1992).'The UK Distribution of Foreign Direct Investment: Analysis and Determinants', *Regional Studies*, vol. 26.6, pp. 535-544.

Table 32: Summary statistics for the regional FDI model

Variables	No. of Observations	Mean	Standard Deviation	Minimum	Maximum
Log of manufacturing FDI	91	4.80	1.46	-0.92	7.45
Log of regional GVA	88	9.34	0.33	8.68	9.84
Log of wages	88	9.02	0.31	8.41	9.47
Connectivity index	110	25.82	38.89	0.41	157.63
Log of unemployment Index	88	10.91	0.40	10.02	11.87
Log of migrant level	99	1.68	0.55	0.76	3.71
Log of infrastructure index	77	-4.53	0.74	-5.79	-3.56

Source: PwC analysis

6.3. National specification and data sources – FDI inflow

There are various specifications for models of national FDI inflows in the literature with different strengths and weaknesses. For the purpose of our analysis we chose to specify our model broadly in line with that of Coughlin and Eran (1999)[68]. We chose this particular specification because it is frequently cited in other research and because key explanatory variables used in the model are readily available to us. We augmented the model by including additional explanatory variables for patents, the lending rate, the tax rate and seat capacity. Our model is therefore specified as follows:

$$NFDII_{it} = f(GDPPC_{it}, PRODUCT_{it}, DISTAN_{it}, OPEN_{ukt}, PATENT_{it}, LENDINGR_{ukt}, TAXR_{ukt}, LANGDUMMY_i, SCAP_{it})$$

Where:

- $NFDII_{it}$ = Total capital expenditure inflows into the UK over the period 2005-2012 in US dollars (millions).
- $GDPPC_{it}$ = The GDP per capita of country of FDI origin are in current US dollars and were collected from the IMF for the period 2005-11.
- $PRODUCT_{it}$ = We use GDP per employed person as a proxy for a country's productivity.
- $DISTAN_{it}$ = Distance in kilometres between the capital of the foreign country and London. The data was collected from CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) for the time period 2005-2012.
- $OPEN_{ukt}$ = We also look at the UK openness measure, which is calculated by adding total exports and total imports data, and dividing the sum by GDP. Data for this measure is collected from the World Bank's World Development Indicators (WDI) database.
- $PATENT_{it}$ = Total patents application data for the country of FDI origin. The data come from the World Bank database and are recorded on an annual basis for 2005-2011.

We account for the ease of doing business in the UK through the use of two variables.

[68] Coughlin, C., and Eran, S., (1999) 'Foreign Direct Investment in China: A Spatial Econometric Study' *Federal Reserve Bank of St. Louis.*

- $LENDINGR_{ukt}$ = UK lending interest rate in annual percentage available from the World Bank collected for 2005-2012.
- $TAXR_{ukt}$ = UK private sector corporate tax rate in annual percentage available from the World Bank collected for 2005-2012.
- $LANGDUMMY_i$ = We use CEPII data to construct a language dummy which accounts for whether or not there is a language barrier (the dummy equals 1 if English is the official language of the trading partner).
- $SCAP_{it}$ = Seat capacity. National-level annual data for 2005-2011 are sourced from the UK Civil Aviation Authority. This variable measures the yearly seat capacity on all scheduled flights between the destination (i.e. UK) and the country from which the FDI originates.

The table below reports the key summary statistics of the variables used in our national FDI inflow model.

Table 33: Summary statistics for the national FDI inflow model

Variables	No. of observations	Mean	Standard deviation	Minimum	Maximum
Log of FDI inflow	279	5.05	2.20	-1.20	9.51
Log of GDP per capita	343	9.70	1.19	7.02	11.75
UK openness index	343	60.70	3.35	56.50	66.57
Log of distance	392	8.03	1.04	5.84	9.86
Log of seat capacity of direct flights	360	13.65	1.34	9.90	16.74
Log of UK GDP per employed person	343	10.78	0.01	10.77	10.81
Log of total patent application	283	8.30	2.08	2.08	13.17
Language dummy	392	0.22	0.42	0.00	1.00
UK lending rate	392	2.70	2.18	0.50	5.52
UK private sector tax rate	392	36.08	0.73	35.30	37.30

Source: PwC analysis

6.4. National specification and data sources – FDI outflow

Our model specification is in line with that of Hisarcikilar and Kayam (2009)[69] augmented with seat capacity. These authors examine the determinants of Turkish outward FDI using a gravity model. We specify our model as follows:

$$FDIO_{it} = f(GDPPC_{ukt}, GDPPC_{it}, POP_{it}, GDP_{it} DIST_{it}, INFLA_{it}, PRODUCT_{it}, OPEN_{i,t}, TranCost_{i,t}, Corrupt_{it}, SCAP_{it})$$

Where:

- $FDIO_{it}$ = Total capital expenditure outflows from the UK over the period 2005-2011 in US dollars (millions).
- $GDPPC_{ukt}$ = GDP per capita of the UK. The data was collected from the IMF for the period 2005-2011.
- $GDPPC_{it}$ = GDP per capita is used to capture the purchasing power of the FDI recipient country. The data was collected from the IMF for the period 2005-2011.
- POP_{it} = This variable represents the total population of country i. The data was collected from the World Bank for the period 2005-2011.
- GDP_{it} = GDP of destination country i. The raw data was collected from the IMF for the period 2005-2011.
- $DISTAN_{it}$ = Distance in kilometres between the capital of the destination country i and London. The data was collected from CEPII (Centre d'Etudes Prospectives et d'Informations Internationales) for the period 2005-2011.
- $INFLA_{it}$ = A measure of inflation, in the form of annual CPI for the years 2005-2011 collected from the ONS. This variable is intended to act as a proxy for macroeconomic stability.
- $PRODUCT_{it}$ = We use the ratio GDP per person employed as a proxy for productivity. These data were collected from the World Bank for the period 2005-2011.
- $OPEN_{i,t}$ = We include a proxy for trade openness of the recipient country i. This variable is calculated as the ratio of the destination country's total trade to its GDP. Total trade is the sum of total export and imports of goods (values in $ dollars) for each country i over the period 2005-2011. The data were collected from the International Trade Centre website.
- $TranCost_{i,t}$ = Transport cost is proxied through relative values of as imports (c.i.f) by the UK from the destination country divided by exports (f.o.b) of destination country to the UK.
- $Corrupt_{i,t}$ = We also include in our model a variable to capture corruption in country i. This variable is based on the World Bank corruption percentile rank where a higher rank is indicative of less corruption. Hence the sign of the coefficient for this variable is expected to be positive.
- $SCAP_{it}$ = Seat capacity. National-level annual data for 2005-2011 are sourced from the UK Civil Aviation Authority. This variable measures the yearly seat capacity on all scheduled flights between the UK and the country i to which FDI flows.

Next we report the key summary statistics of the variables used in our national FDI outflow model.

[69] Saime S. Kayam and Mehtap Hisarciklilar. (2009) 'Determinants of Turkish FDI Abroad' *Istanbul Technical University, Faculty of Management.*

Next we report the key summary statistics of the variables used in our national FDI outflow model.

Table 34: Summary statistics for the national FDI outflow model

Variables	No. of observations	Mean	Standard deviation	Minimum	Maximum
Log of FDI outflow	369	5.79	1.75	0.10	9.29
Log of GDP per capita	378	9.61	1.17	7.02	11.75
Log of UK GDP per capita	378	10.59	0.09	10.48	10.74
Log of population in partner country	378	16.93	1.67	13.05	21.02
Transport cost index	378	0.22	0.88	-2.50	3.62
Inflation index	364	4.36	3.79	-4.87	25.20
Corruption index	378	65.17	26.48	10.73	100.00
Log of seat capacity (Direct flights)	329	13.57	1.37	9.90	16.74
Openness index (Trade as a % of GDP)	377	0.98	0.77	0.22	4.46

Source: PwC analysis

6.5. Results

Below we present the results of each of the models presented above and explain the rationale for our choice of estimation techniques in each case.

6.5.1. Results – Regional study

The table below shows results from the endogeneity tests.

Table 35: Endogeneity tests – Regional FDI model

Variables	Endogeneity test	Hansen overidentification test
GVA	Chi-sq(1) P-val = 0.0707	Chi-sq(1) P-val = 0.3983
Wage	Chi-sq(1) P-val = 0.0527	Chi-sq(1) P-val = 0.4160
Connectivity	Chi-sq(1) P-val = 0.1787	Chi-sq(1) P-val = 0.2468
Unemployment	Chi-sq(1) P-val = 0.2386	Chi-sq(1) P-val = 0.6392
Migration	Chi-sq(1) P-val = 0.1547	Chi-sq(1) P-val = 0.4331

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (this test is implemented in Stata using the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When the P-value is greater than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here H0 is that the instruments are valid. The same interpretation of the P value applies.* *Source: PwC analysis*

All the variables are found to be exogenous.

Our choice of estimation technique is guided by the following issues. First, the inclusion of London in our dataset exacerbates the heterogeneity among the 11 GORs and leads to the issues of outliers.

In order to deal with the bias caused by potential outliers, we use a quantile regression (QR) approach. This does not allow us to account for fixed effects (FE) by region, so we also use the MM – Robust regression technique which allows account to be taken of regional FE whilst addressing any potential issue caused by outliers.

We also note that fDi markets data only reports FDI above a certain threshold. Thus of 109 observations of manufacturing FDI in our data set, 18 are zeros (although most of these observations are outside our estimation period). Results are reported in Table 36.

Table 36: Regional Manufacturing FDI inflows OLS, Quantile Regression (QR), and MM robust regression with regional fixed effects

Explanatory variables	**OLS**	**QR**	**MM Robust Regression with FE**
Regional GVA	8.736**	8.121***	9.016***
	(3.196)	(1.627)	(3.00)
Wages	-9.990**	-8.935***	-10.344***
	(3.484)	(1.628)	(2.885)
Connectivity	0.016**	0.013**	0.011**
	(0.005)	(0.006)	(0.005)
Unemployment	-0.056	-0.226	-0.707*
	(0.244)	(0.309)	(0.382)
Migration lagged	1.356*	1.615***	1.032**
	(0.697)	(0.437)	(0.496)
Infrastructure*	(omitted)	(omitted)	(omitted)
Region id	n/a	n/a	0.122*
			(0.064)
Constant	12.912*	10.965*	20.174***
	(5.82)	(6.499)	(6.304)
Number of observations	53	53	53

Legend: *the stars represent significance levels. * represents 10 % significance level, ** 5% and *** 1%. All the variables are in logarithms except for the dummies.*
Source: PwC analysis

The magnitudes of the coefficients on the GVA and wage variables are large and significant, with the expected signs. In fact, a similar study by Arromdee, V., Coughlin, C., and Terza, J., (1987) titled 'State Characteristics and the Location of Foreign Direct Investment within the United States' found the natural logarithm of state per capita income to vary between 8.5 and 7.5 whilst the logarithm of average state wage varied between -6.6 and -5.04. Based on the MM Robust regression estimates, our results suggest that **a 1% increase in connectivity is associated with approximately a 1.1% increase on average in the amount of manufacturing related FDI inflowing to each GOR.**

6.5.2. Results – National FDI Inflow

The table shows the results of our endogeneity tests prior to modelling FDI inflow.

Table 37: Endogeneity tests –FDI Inflow model

Variables	Endogeneity Test	Hansen Overidentification Test
GDP per capita	Chi-sq(1) P-val = .3024	Chi-sq(1) P-val = 0.5151
UK openness	Chi-sq(1) P-val = .3244	Chi-sq(1) P-val = 0.7287
Seat capacity	Chi-sq(1) P-val = .0978	Chi-sq(1) P-val = 0.2649
UK productivity *	Chi-sq(1) P-val = .1847	Chi-sq(1) P-val = 0.2181
Patents	Chi-sq(1) P-val = .4343	Chi-sq(1) P-val = 0.1014
UK lending rate	Chi-sq(1) P-val = .1119	Chi-sq(1) P-val = 0.8275
UK tax rate	Chi-sq(1) P-val = .5170	Chi-sq(1) P-val = 0.9825

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (this test is implemented in Stata using the **endog** option following the **ivreg2** command). The null hypothesis (H0) is that the variable can be treated as exogenous. When the P value is greater bigger than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here the H0 is that the instruments are valid. The same interpretation of the P value applies. * UK productivity is measured as the UK GDP per person employed following Hisarciklilar and Kayam, 2009.*
Source: PwC analysis

Our test shows that all our explanatory variables can be treated as exogenous. We run an OLS benchmark as a comparison as well as a PPML model Table 38 below shows our results.

Table 38: National FDI inflows OLS and PPML estimates

Explanatory variables	OLS	PPML
GDP per capita	0.345 (0.225)	0.305 (0.234)
UK openness	0.031 (0.044)	0.070*** (0.013)
Distance	-0.547** (0.243)	-0.616*** (0.221)
Seat capacity	0.636*** (0.137)	0.470*** (0.113)
UK productivity	3.591 (8.036)	11.434** (4.715)
Patents	0.394*** (0.089)	0.434*** (0.059)
Language dummy	0.842** (0.385)	0.718*** (0.227)
UK Lending rate	-0.173* (0.098)	-0.247*** (0.037)
UK tax rate	-0.556** (0.233)	-0.778*** (0.108)
Dummy for high income	-0.422 (0.653)	0.079 (0.359)
Dummy for middle income	-0.855 (0.726)	-0.308 (0.464)
Constant	-25.899 (86.433)	-101.629** (50.2)
Number of observations	200	257

Legend: *the stars represent significance levels, and standard errors are shown in brackets.*
** represents 10 % significance level, ** 5% and *** 1%.*
Source: PwC analysis

Our final results show that UK productivity, the language dummy, and seat capacity all play an important role in attracting FDI into the UK nationally, whilst a higher UK corporate tax rate is a factor which would discourage FDI. **The PPML model suggests that a 10% increase in seat capacity is approximately associated with a 4.7% increase in UK FDI inflows**, whilst a similar increase in the UK tax rate would discourage FDI inflows by almost 8%. Productivity and the language dummy have the expected signs and are significant at the 1% level.

6.5.3. Results – national FDI outflow

The table below shows our endogeneity tests results for our FDI outflow model.

Table 39: Endogeneity tests –FDI outflow model

Variables	Endogeneity test	Hansen overidentification test
GDP per capita	Chi-sq(1) P-val = .4138	Chi-sq(1) P-val = 0.0115
UK GDP per capita	Chi-sq(1) P-val = .8422	Chi-sq(1) P-val = 0.0023
GDP of destination	Chi-sq(1) P-val = .0017	Chi-sq(1) P-val = 0.4406
Population	Chi-sq(1) P-val = .3158	Chi-sq(1) P-val = 0.0917
Transport cost	Chi-sq(1) P-val = .4475	Chi-sq(1) P-val = 0.1930
Inflation	Chi-sq(1) P-val = .3933	Chi-sq(1) P-val = 0.7212
Corruption	Chi-sq(1) P-val = .0008	Chi-sq(1) P-val = 0.4447
Seat capacity	Chi-sq(1) P-val = .7662	Chi-sq(1) P-val = 0.1078
Trade as a % of GDP	Chi-sq(1) P-val = .6710	Chi-sq(1) P-val = 0.3049
GDP per person employed	Chi-sq(1) P-val = .0550	Chi-sq(1) P-val = 0.0001

Legend: *The Hansen test is robust to various violations of conditional homoscedasticity (this test is implemented in Stata for the* ***endog*** *option following the* ***ivreg2*** *command). The null hypothesis (H0) is that the variable can be treated as exogenous. When the P-value is greater than 0.05 one cannot reject H0 whereas when the value is below 0.05, H0 should be rejected. The Hansen test is also reported. This test tells us whether the instruments used in assessing endogeneity are valid. Here the H0 is that the instruments are valid. The same interpretation of the P-value applies.*
Source: PwC analysis

Our endogeneity test finds that the GDP of the destination country and corruption in the destination country are both identified as endogenous. The presence of endogeneity means we favour the IV PPML approach; the OLS model is not suitable. Our results are reported in the **Error! Not a valid bookmark self-reference.** below.

Table 40: National FDI outflow PPML estimates

Explanatory variables	**OLS**	**PPML**	**IVPPML***
GDP per capita	0.528** (0.199)	0.357** (0.172)	0.332** (0.134)
UK GDP per capita	-0.265 (0.774)	-0.266 (0.492)	-0.368 (0.576)
Population	0.949*** (0.159)	0.714*** (0.128)	0.664*** (0.083)
Transport cost	-0.079 (0.211)	-0.107 (0.145)	-0.117 (0.115)
Inflation	0.068* (0.036)	0.055** (0.023)	0.050** (0.022)
Corruption	0.007 (0.011)	0.002 (0.009)	0.000 (0.006)
Seat capacity	0.157 (0.160)	0.181 (0.135)	0.192** (0.098)
Trade as % of GDP	0.709*** (0.212)	0.443*** (0.142)	0.447*** (0.128)
Dummy for High Income	0.251 (0.48)	0.220 (0.449)	0.150 (0.369)
Dummy for middle Income	0.390 (0.418)	0.063 (0.359)	-0.075 (0.263)
Constant	-16.473* (8.91)	-9.637* (5.288)	-7.335 (6.51)
Number of observations	308	314	224

Legend: *the stars represent significance levels, and standard errors are shown in brackets. * represents 10 %, ** 5% and *** 1% significance levels. All the variables are in logarithms except for the dummies, and those variables which are in percentage form (e.g. trade as % of GDP). IVPPML treats the GDP of destination and corruption as endogenous.*
Source: PwC analysis

GDP per person employed is dropped to avoid multicollinearity. GDP of the destination country and corruption are treated as endogenous. **In the IVPPML model we find that a 10% increase in seat capacity is associated with a 1.9% increase in FDI outflow.** GDP per capita of the foreign country, population (which proxies for foreign demand) and trade openness are important in determining the destination for FDI outflows.

Appendix A – Description of econometric techniques

A1: Fixed Effects and Random Effects models

An FE model is a useful econometric application when the user is interested in analysing the impact of variables that vary over time. In the context of this report, we use the FE approach to explore the relationship between predictor variables (i.e. GDP per capita, Relative price, Seat capacity and Tourism infrastructure) and the outcome variable (i.e. Tourist arrivals) within an entity (i.e. a given country i's tourists). The FE model assumes that each entity is considered to have its own individual characteristics (i.e. Tourists from country's characteristics cannot be correlated with tourists from country j's characteristics) that may or may not influence the predictor variables.

Consider the following static panel data model:

$$y_{it} = c + \beta x_{it} + \mu_i + \varepsilon_{it} \quad i = 1, \ldots N; t = 1, \ldots, T.$$

For the purposes of this discussion it is assumed that the micro data available have an N that is much larger relative to T. μ_i is known as the fixed effects elements. This is the structure of the data that has been available to use for the purposes of analysing the different channels in this report.

A crucial assumption of the FE model is that μ_i, which is also referred to as the entity's individual characteristics are fixed over time. This assumption allows the FE model to remove the effect of those time-invariant characteristics from the predictor variables so we can assess the predictor's net effect. The fixed effect is eliminated via the within transformation as show below

$$(y_{it} - \bar{y}_i) = \beta(x_{it} - \bar{x}_i) + (\varepsilon_{it} - \bar{\varepsilon}_i)$$

Where $\bar{y}_i = \frac{1}{T}\sum_{t=1}^{T} y_{it}$; $\bar{x}_i = \frac{1}{T}\sum_{t=1}^{T} x_{it}$; $\bar{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_{it}$ are the time averages. The individual fixed effect μ_i and the intercept c cancel. Also note that any time-invariant regressors (e.g. constant) will also cancel.

The FE estimator or within estimator of the slope coefficient β estimates the within model by OLS under the assumption that the x_{it} is indenependent from the ε_{it} in the model described above.

Unlike the FE model, the RE model assumes the variation across entities to be random and uncorrelated with the independent variables included in the model. More specifically, the RE assumes that the individual specific effect is uncorrelated with the explanatory variables of all past, current and future time periods of the same individual.

"...the crucial distinction between fixed and random effects is whether the unobserved individual effect embodies elements that are correlated with the regressors in the model, not whether these effects are stochastic or not" [Green, 2008, p.183]

The Hausman test is used to evaluate which model between the FE and RE should be used. This is simply based on testing whether the entity's error terms are correlated, if they are a FE is not suitable and a RE model should be used instead. Note that the Hausman test is only valid under homoskedasticity and cannot include time fixed effects. A better alternative to the Hausman test for choosing between FE or RE models is the Sargan-Hansen test, which is robust in the presence of heteroskedasticity.

Furthermore, in order to determine whether an RE model should be used rather than a Pooled OLS approach, we can use the Breusch – Pagan Lagrange multiplier (LM) to test whether the variances across entities is zero.

A2: GMM estimator for dynamic panel:

We first explain how the GMM estimator is derived in its general form, and then we show how the approach is applied in a dynamic panel data framework. Recall that our tourism model was based on a dynamic panel data model.

GMM is based on moment functions that depend on observable random variables and unknown parameters, and that have zero expectation in the population when evaluated at the true parameters. Assume the following expectation function:

$$E[g(w_i,\theta)] = 0,$$

where: g is the moment function, w_i is a vector of observable random variables and is θ a $P \times 1$ vector of unknown parameters. The moment function g can be linear or nonlinear. We will consider the former case, since the latter requires numerical methods treatments.

In linear models a natural way of writing the moment function is as

$$Z_i'(y_i - X_i\theta), \text{since } E[Z_i' \ (y_i - X_i\theta)] = 0$$

Provided we have a random sample, we can assume that the random sample is an analogy of the population and replace population moments by sample moments. This enables us to estimate the econometric model using a sample of data.

Hansen (1982)[70] proposes to bring the sample moments as close to zero as possible by minimizing the following quadratic form

$$\min_{\theta} \underbrace{\left[\sum_{i=1}^{N} g(w_i,\theta)\right]'}_{(1\times L)} \cdot \underset{(L\times L)}{C} \cdot \underbrace{\left[\sum_{i=1}^{N} g(w_i,\theta)\right]}_{(L\times 1)}$$

with respect to the parameters θ, where C is a positive definite $L \times L$ weighting matrix. It can be shown that this yields a consistent estimator of θ, under certain regularity conditions (see theorem 14.1 in Wooldridge, 2002)[71].

Provided that the moment functions are continuously differentiable, the GMM estimator satisfies the first-order condition:

$$\underbrace{\left[\sum_{i=1}^{N} \nabla_{\theta} g(w_i,\hat{\theta})\right]'}_{(P\times L)} \cdot \underset{(L\times L)}{C} \cdot \underbrace{\left[\sum_{i=1}^{N} g(w_i,\hat{\theta})\right]}_{(L\times 1)} \underset{(P\times 1)}{=} 0$$

$$\nabla_{\theta} g(w_i,\hat{\theta}) = \begin{bmatrix} \frac{\partial}{\partial\theta_1} g(w_i;\hat{\theta}_1,\hat{\theta}_2,\ldots,\hat{\theta}_p)' \\ \frac{\partial}{\partial\theta_2} g(w_i;\hat{\theta}_1,\hat{\theta}_2,\ldots,\hat{\theta}_p)' \\ (\ldots) \\ \frac{\partial}{\partial\theta_p} g(w_i;\hat{\theta}_1,\hat{\theta}_2,\ldots,\hat{\theta}_p)' \end{bmatrix}$$

Where $\nabla_{\theta} g(w_i,\hat{\theta})$ is an $L \times P$ vector of derivatives of the moment function g with respect to the first, second, etc. element of the parameter vector θ.

Re-writing the above for the linear model, we have

$$g(w_i,\theta) = Z_i'(y_i - X_i\theta),$$

Hence:

[70] Lars Peter Hansen (1982), “Large Sample Properties of Generalized Method of Moments Estimators”, *Econometrica*, vol. 50, issue 4, pages 1029-54.

[71] Wooldridge, J. (2002), “Econometric Analysis of Cross Section and Panel Data”, MIT Press.

$$\frac{\partial}{\partial\theta_1} g(w_i;\theta_1,\theta_2,...,\theta_p) = -Z_i'x_{1i} \quad (L\times 1)$$
$$\frac{\partial}{\partial\theta_2} g(w_i;\theta_1,\theta_2,...,\theta_p) = -Z_i'x_{2i} \quad (L\times 1)$$
$$(...)$$
$$\frac{\partial}{\partial\theta_p} g(w_i;\theta_1,\theta_2,...,\theta_p) = -Z_i'x_{pi} \quad (L\times 1)$$

and so:

$$\nabla_\theta g(w_i,\theta) = \left\lfloor -Z_i'x_{1i} \;\; -Z_i'x_{2i} \;\; (...) \;\; -Z_i'x_{pi} \right\rfloor = -Z_i'X_i$$

the FOC becomes:

$$\left[\sum_{i=1}^{N} Z_i'X_i\right]'.C.\left[\sum_{i=1}^{N} Z_i'(y_i - X_i\hat{\theta})\right] = 0$$

it follows that:

$$\left[\sum_{i=1}^{N} Z_i'X_i\right]'.C.\left[\sum_{i=1}^{N} Z_i'y_i\right] = \left[\sum_{i=1}^{N} Z_i'X_i\right]'.C.\left[\sum_{i=1}^{N} Z_i'X_i\hat{\theta}\right]$$

hence the solution

$$\hat{\theta} = \left(\left[\sum_{i=1}^{N} Z_i'X_i\right]'.C.\left[\sum_{i=1}^{N} Z_i'X_i\right]\right)^{-1}\left[\sum_{i=1}^{N} Z_i'X_i\right]'.C.\left[\sum_{i=1}^{N} Z_i'y_i\right]$$

writing the above in matrix form:

$$\hat{\theta}^{GMM} = \left((Z'X)'.C.Z'X\right)^{-1}(Z'X)'.C.Z'y$$

Or simply:

$$\hat{\theta}^{GMM} = \left((X'Z).C.(Z'X)\right)^{-1} X'Z.C.Z'y$$

This is the conditionality function for the GMM estimator. Now that we have described how the estimator works, we now explain how the concept of GMM works in a dynamic panel data framework.

Consider the following example of a dynamic panel data model:

$y_{it} = \alpha y_{it-1} + \beta x_{it} + \mu_i + \varepsilon_{it} \qquad i = 1, \dots N; t = 1, \dots, T.$

Again we assume that he have a typical micro data where N is much larger relative to T. μ_i is the fixed effects elements. For example in our tourim model, the country fixed effects elements represent all the unobserved time invariant characteristic s of a given country. Whilst in a static panel, the main issue is whether the fixed effects are correlated with the regressors or not, in a dynamic panel mode the fixed effects are always correlated with lagged dependent variable. To see this it suffices to write

$$y_{it-1} = \alpha y_{it-2} + \beta x_{it-1} + \mu_i + \varepsilon_{it-1}$$

In the above, eliminating the fixed effects via the within transformation cannot solve the problem of correlation, GMM can be used to deliver consistent estimators of the model parameters instead. The Within transformation yields the following model

$$(y_{it} - \bar{y}_i) = \alpha\left(y_{it-1} - \bar{y}_{i,-1}\right) + \beta(x_{it} - \bar{x}_i) + (\varepsilon_{it} - \bar{\varepsilon}_i)$$

Where; $\bar{y}_i = \frac{1}{T}\sum_{t=1}^{T} y_{it}$; $\bar{y}_{i,-1} = \frac{1}{T}\sum_{t=1}^{T} y_{it-1}$; $\bar{x}_i = \frac{1}{T}\sum_{t=1}^{T} x_{it}$; $\bar{\varepsilon}_i = \frac{1}{T}\sum_{t=1}^{T} \varepsilon_{it}$ are the time averages. Although the within transformation has eliminated the fixed effects, we still have endogeneity problem because

$$Cov\{(y_{it-1} - \bar{y}_{i,-1}), (\varepsilon_{it} - \bar{\varepsilon}_i)\} \neq 0$$

Given that within estimator is not consistent, we need a different estimation strategy to obtain consistent estimators of the model parameters.

The first step is to first-difference the model as

$$(y_{it} - y_{it-1}) = \alpha(y_{it-1} - y_{it-2}) + \beta(x_{it} - x_{it-1}) + (\varepsilon_{it} - \varepsilon_{it-1})$$

$$\Delta y_{it} = \alpha\Delta y_{it-1} + \beta\Delta x_{it} + \Delta\varepsilon_{it}$$

As long as the assumption of no serial correlation in the error terms of the original model is valid, values of the dependent variable lagged by two or more periods (data permitting) can be used as instruments for the endogenous regressor. That is $y_{it-2}, y_{it-3}, \ldots$ can be used as instruments for Δy_{it-1}. These are valid instruments because:

$E(\varepsilon_{it}\varepsilon_{is}|X_i, \mu_i) = 0, t \neq s \;\rightarrow Cov\{y_{it-k}, \Delta\varepsilon_{it}\} = 0,$ For $k = 2,3, \ldots.$

Note that the first-difference error term follows a MA (1) (i.e. moving average integrated of order 1).

$$\Delta\varepsilon_{i2} = \varepsilon_{i2} - \varepsilon_{i1}$$

$$\Delta\varepsilon_{i3} = \varepsilon_{i3} - \varepsilon_{i2}$$

$$\Delta\varepsilon_{i4} = \varepsilon_{i4} - \varepsilon_{i3}$$

Fortunately, GMM can easily accommodate this serial correlation.

To sum up, whenever model passes the Arellano-Bond, Sargan, or Hansen test what this effectively means is that the lags we have chosen to act as instruments are not correlated with the error and therefore the can be used as valid instruments.

In the context of the above, what the DGMM does is to simply use values of the dependent variable lagged by two or more periods (data permitting) as instruments for the endogenous regressor. The SGMM uses lagged first differenced values of endogenous regressors as instruments for the level equation (i.e. the original model) in addition to lagged levels as instruments for the differenced equation.

A3: The Pseudo-Poisson Maximum Likelihood estimator

As Santos Silva and Tenreyro (2006) argue, there are two potential sources of bias in using pooled OLS, or in fact any type of log-linear model, in the trade gravity model:

- Firstly, the trade value is bounded below by zero, and coefficient estimates from linear models may be biased because of a truncated sample.
- Secondly, because of the Jensen inequality, $E(\ln y) = \ln(E(y))$, only under very specific cases that the independence assumption that underpins the independence linear models would be fulfilled. In particular, the log-linear models are prone to bias if heteroskedasticity were present.

As an alternative to log-linear models, Santos Silva and Tenreyro (2006) suggest a method based on the Pseudo-Poisson Maximum Likelihood (PPML) estimator, in which the coefficient of interest, β, is estimated by solving the following set of first-order conditions:

$$\sum_{i=1}^{n}[y_i - \exp(x_i\beta)]x_i = 0$$

One of the attractions of such a formulation is that it gives the same weight to each observation. The estimator is underpinned by the assumption that $E(y_i|x) = \exp(x_i\beta) \;\alpha\; V(y_i|x)$, and therefore the effect of higher conditional mean that stems from the curvature of the exponential function, $\exp(x_i\beta)$ would be exactly offset by larger variance, $V(y_i|x)$. However, it is also important to note that it is unlikely for the estimator to take full account for the heteroskedasticity without knowing its explicit functional form> Hence the Eicker-White (Eicker, 1963; White, 1980) robust covariance should be used to generate the model standard errors.

A4: The MM-Robust estimator[72]

Following Huber (1981) robustness signifies insensitivity to deviations from the assumptions the model imposes. A model is said to be robust if it is

(1) reasonably efficient and unbiased,
(2) small deviations from model assumptions will not substantially impair the performance of the model and
(3) somewhat larger deviations will not invalidate the model completely.

Robust regression is concerned with distributional robustness and outlier resistance. The strong impact of outliers on the least square regression estimator is known for a long time (Croux and Verardi, 2009). Consequently, a large literature has been developed to find robust estimators that cope with the "atypical" observations, and have a high breakdown point[73]. In addition, the statistical efficiency of the robust estimators needs to remain sufficiently high. As Croux and Verardi (2009)[74] argue, in recent years, it seems that a consensus has emerged to recommend the MM-estimators as the best suited estimation method, since they combine a high resistance to outliers and high efficiency at regression models with normal errors.

Providing a good description of the MM –Robust approach is not a trivial exercise owing to the complexity of the steps involved in MM estimation. Here we give only a brief overview of approach. For the curious reader, Croux and Verardi (2009) offer a gentle introduction to this estimator.

The “MM” in the name of the estimator refers to the fact that more than one M-estimation procedure is used to calculate the final estimates. This estimator combines a high breakpoint (50%), bounded influence function and high efficiency under the normal errors (≈ 95%). 3 key steps are involved in computing the MM-estimates. First, note that whilst OLS simply minimizes the sum of squares function, the robust estimators attempt to find the solution with the smallest possible dispersion of the residuals:

$$\min \hat{\sigma}\left(E_1(\hat{\beta}), \dots, E_n(\hat{\beta})\right)$$

The three steps are as follows:

1. Initial estimates of the coefficients $\boldsymbol{B}^{(1)}$ and corresponding residuals $e_i^{(1)}$ are taken from a highly resistant robust regression (i.e. a regression with a breakdown point of 50%).
2. The residuals $\boldsymbol{E}^{(1)}$ from the from the S-estimation[75] stage 1 are used to compute an M-estimation of the scale of the residuals.
3. The initial estimates of the residuals scale σ_E from stage 2 are used to compute the single-step M-estimate.

$$\sum_{i=1}^{n} w_i \left(\frac{E_i^{(1)}}{\hat{\sigma}_E}\right) x_i$$

Where the w_i are typically the Huber or bisquare weights. In other words, the M-estimation procedure at this stage needs only a single iteration of the weighted least squares.

In conclusion, it is important to note that robust estimators protects against long-tailed errors, but not against problems with model choice and variance structure. These latter problems are often more serious than non-normal errors.

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[72] Our description of the MM Robust estimator follows Dave Armstrong Lecture not which can be found here: http://www.quantoid.net/reg3/Lecture10_2013_4up.pdf

[73] The breakpoint of an estimator is the maximum proportion of observations that can be changed without changing the estimator. In other words, the breakdown point is the smallest fraction of “bad” data (outliers or data grouped in the extreme tail of the distribution) the estimator can tolerate without taking on values arbitrarily far from the ones returned by the chosen estimator. For example, in the presence of outliers, the breakpoint for OLS is 0%.

[74] Vincenzo Verardi and Christophe Croux, (2009) “Robust Regression in Stata” *The Stata Journal*, 9, Number 3, pp. 439-453.

[75] The S-estimation minimizes a robust M-estimate of the residual scale $\hat{\sigma}$
$\sum_{i=1}^{n} p\left(\frac{E_i}{\hat{\sigma}_E}\right) = (n-p)K \ where\ K = 0.5$ ensures consistency at the normal distribution of errors.

A5: Error Correction Modelling

Model Derivation

We start from a simple, proportional, long-run equilibrium relationship between GDP and seat capacity:

$$GDP_t = cSCAP_t$$

Re-writing the above in log form we have:

$gdp_t = c + scap_t \qquad (*)$

Now, we write down a general dynamic relationship between gdp_t and $scap_t$:

$gdp_t = \beta_0 + \beta_1 scap_t + \beta_2 scap_{t-1} + \alpha_1 gdp_{t-1} + \mu_t \qquad (**)$

By including the lagged values of both variables this specification allows for a wide variety of dynamic patterns in the data.

We now ask: Under what conditions is the generic dynamic equation (*) consistent with the long-run equilibrium relationship (*)? To assess this, we "zero out" the factors that could cause divergence from equilibrium, namely changes in $scap_t$and stochastic fluctuations, μ_t. That is, we set $gdp_t = gdp^*$ and $scap_t = scap^*$ for all t, and set μ_t=0, we get

$$gdp^* = \beta_0 + \beta_1 scap^* + \beta_2 scap^* + \alpha_1 gdp^*$$

$$(1 - \alpha_1)gdp^* = \beta_0 + (\beta_1 + \beta_2)scap^*$$

$$gdp^* = \frac{\beta_0}{(1 - \alpha_1)} + \frac{\beta_1 + \beta_2}{(1 - \alpha_1)} scap^*$$

If the above corresponds with equation (*) we have

$$c = \frac{\beta_0}{(1 - \alpha_1)}$$

$$1 = \frac{\beta_1 + \beta_2}{(1 - \alpha_1)}$$

From the above relationships, we can see that$\beta_1 + \beta_2 = 1 - \alpha_1$. Let θ denote the common value of these two terms. Then β_2 can be written as $\theta - \beta_1$and α_1 can be written as 1- θ. Therefore, equation (**) becomes

$$gdp_t = \beta_0 + \beta_1 scap_t + (\theta - \beta_1)scap_{t-1} + (1 - \theta)gdp_{t-1} + \mu_t$$

$$gdp_t = \beta_0 + \beta_1 scap_t - \beta_1 scap_{t-1} + \theta scap_{t-1} - \theta gdp_{t-1} + gdp_{t-1} + \mu_t$$

$$gdp_t - gdp_{t-1} = \beta_0 + \beta_1(scap_t - scap_{t-1}) + \theta(scap_{t-1} - gdp_{t-1}) + \mu_t$$

Hence the model:

$\Delta gdp_t = \beta_0 + \beta_1 \Delta scap_t + \theta(scap_{t-1} - gdp_{t-1}) + \mu_t \qquad (***)$

Where $\Delta x_t \equiv x_t - x_{t-1}$. Model (***) represents the characteristic "error correction" specification, where the change in one variable is related to the change in another variable, as well as the gap between the variables in the previous period.

Appendix B – Model specifications

Section Overview

This section summarises the previous literature and model specifications that have been used to analyse the link between aviation and key macro variables. These specifications inform our modelling throughout the report.

Trade

Year	Authors	Objective	Dataset	Dependent variables	Explanatory variables	Estimation Technique
1999	Kalirajan	Incorporation of stochastic aspects in the gravity model coefficients	Panel Data, Australia and Indian Ocean rim trading partners, 1990-1994	Exports	GDP, GDP per capita, distance	Stochastic varying coefficients model
1999	Breuss and Egger	Examination of East - West Europe trade potentials	Cross sectional data, old (24) OECD countries, averages of the period 1990-1994	Exports	GDPs per capita, population, distance, common language, EU12 and NAFTA memberships	OLS
2000	Nitsch	Investigation of natural border effect in trade in the EU	Panel data, EU-12 countries, 1979-1990	Exports	GDP, distance, common border, common language, country remoteness	OLS and fixed effects model
2001	Soloaga and Winters	Analysis of regionalism and trade agreement effects in trade in the 1990s	Cross sectional, 58 countries, 1980-1996, analysis per year and averages	Imports and Exports	GDP, population, remoteness, distance, land area, common border, island, common language, trade agreement membership	Tobit, fixed effects.
2008	Boriss Siliverstovs, Dieter Schumacher	Comparison of the OLS approach applied to the log-linear form of the gravity model with the Poisson Quasi Maximum Likelihood (PQML)	1988-1990, 22 OECD countries	Bilateral trade flows	Distance, adjacency, membership in a preference area: European Union, European Free Trade Agreement, Free Trade	OLS, Poisson Quasi Maximum Likelihood (PQML)

Year	Authors	Objective	Dataset	Dependent variables	Explanatory variables	Estimation Technique
		estimation procedure			Agreement between the USA and Canada, Asia-Pacific Economic Co-operation, ties by language, historical ties.	

Source: PwC analysis

Foreign direct investment

Year	Authors	Objective	Dataset	Dependent variables	Explanatory variables	Estimation Technique
1999	Coughlin and Eran	Investigate the determinants of Foreign Direct Investment in China.	1990 – 1997, panel of Chinese provinces.	Sum of total yearly FDI inflows to each province from 1990 to 1997 in US dollars.	Gross provincial product (GPP) - WAGE - Overall labour productivity in each province - Regional illiteracy rate - Infrastructure proxied by HIWAY (total length of paved roadway in a province, divided by its area) and AIRSTAFF (the number of total staff and workers in state-owned units of airway transportation in a province, divided by its population) - Dummy variable to differentiate among provinces that lie on the coast and those that do not.	Spatial Econometric approach
1992	Hill and Munday	Investigates the determinants of the UK Regional Distribution of Foreign Direct Investment.	1980 – 1989, panel of UK Government Office regions.	Regional share of FDI new jobs (projects) from 1980 - 1989.	Regional share of preferential assistance - Regional share of spending on new trunk roads - Ratio of regional to UK average male earnings - Regional share of employees in employment.	Pooled OLS
1989	Coughlin, Terza, and Arromdee	Looks at State Characteristics and the Location of manufacturing related Foreign Direct Investment within the United States.	Cross sectional study, year chosen 1981. Cross section of US states.	FDI originating from a population of foreign manufacturing firms	State manufacturing employment per square mile of state land excluding federal land - WAGE - Percentage of unionised employees - Dummy variable equal to one if a state has right-to-work legislation and zero otherwise – Unemployment in manufacturing - energy costs per dollar of value-added in manufacturing - HIWAY NL of highway miles per square mile of state land area - railroad miles per square mile of state land area - the number of public airport facilities per square miles of state land area - state and local taxes per capita - state and local taxes as a percentage of state personal income - variable equal to one if a state has 'total worldwide combination'	Maximum Likelihood Estimation of a Conditional Logit Model and a Minimum Chi-Square estimator.

					unitary taxation and zero otherwise - state expenditure to attract foreign direct investment.	
2009	Kayam and Hisarciklilar	Study examines the determinants of Turkish FDI Abroad	Panel data of countries receiving the bulk of Turkish FDI over the period 1999-2005.	FDI Outflow from Turkey to destination country (real million USD)	Real GDP of destination country, Real GDP per capita of Turkey (dollar) , Real GDP per capita of destination country (dollar) , Population of destination country, Distance between source and destination countries measured as the distance between respective capitals (km), Transportation cost is measured as imports (c.i.f) by Turkey from destination country/exports (f.o.b) of destination country to Turkey, Openness measured as Trade/GDP , GDP per person employed , Annual inflation rate measured as average consumer prices (2000=100), Corruption.	Panel data random effects technique

Source: PwC analysis

Tourism

Year	Authors	Objective	Dataset	Dependent variables	Explanatory variables	Estimation Technique
2011	Khadaroo et al	Investigate the role of infrastructure in tourism development in Mauritius	Tourists arrivals on the island of Mauritius is presented whereby total tourist arrivals as well as arrivals from Europe/America, Asia and Africa are modelled using a panel framework between 1985 – 2006.	Total annual tourist arrivals rate between 1985-2006.	RELATIVE Price of tourism - The real gross domestic product per capita in country of origin - the number of rooms available in the destination country is used to capture tourism infrastructure - air distance in kilometres between the origin and destination countries - infrastructure is proxied by public capital stocks which is constructed using the Perpetual Inventory Methodology (PIM).	Fixed effects (FE) and random effects (RE) models are used. A System GMM approach issued to capture destination reputation effect.
2004	Eilat and Einav	The paper objective is to look at the determinants of international tourism.	A three dimensional panel data analysis over the period 1985 – 1998.	Annual origin-to-destination tourist flows.	Proxy for cost of living is the reciprocal of the PPP conversion factor, which represents the purchasing power of one dollar in the country -the log of the ratio of destination cost to country of origin cost - Country pair dummies - log trade - log distance - language dummy - common border dummy - destination dummy - log land area - destination risk index- Origin dummy - log origin GNP per capita.	Multinomial logit estimation

Source: PwC analysis

Appendix C – Description of variables used

Variable	Tourism - Inbound	Tourism - Outbound	Trade - Goods Import	Trade - Goods Export	Trade - Services Import	Trade - Services Export	National FDI Inflow	National FDI Outflow	Regional FDI	Source	Years covered
Tourists Arrivals	✓ LD									Total number of arrivals each year, as recorded by ONS, in thousands.	2002-2012
UK Tourists going abroad		✓ LD								Total number of arrivals each year, as recorded by ONS, in thousands.	2002-2012
Goods Imports			✓ LD							From the International Trade Centre database, in millions of dollars	2001-2011
Goods Exports				✓ LD						From the International Trade Centre database, in millions of dollars	2001-2011
Services Imports					✓ LD					From the International Trade Centre database, in millions of dollars	2001-2011
Services Exports						✓ LD				From the International Trade Centre database, in millions of dollars	2001-2011
FDI flowing into UK							✓ LD			Data retrieved from Financial Times fDi Markets service reports	2005-2011

Variable	Tourism - Inbound	Tourism - Outbound	Trade - Goods Import	Trade - Goods Export	Trade - Services Import	Trade - Services Export	National FDI Inflow	National FDI Outflow	Regional FDI	Source	Years covered
FDI flowing out from UK								✓ LD		Data retrieved from Financial Times fDi Markets service reports	2005-2011
FDI inflow into regions									✓ LD	Data retrieved from Financial Times fDi Markets service reports	2003-2012
GDP per capita of partner country	✓ L		✓ L	✓ L	✓ L	✓ L	✓ L	✓ L		Real gross domestic product per capita in the partner country, as recorded by IMF World Economic Outlook (WEO) Database. Used as proxy for spending capacity.	2001-2012
UK GDP per capita		✓ L	✓ L	✓ L	✓ L	✓ L				Real gross domestic product per capita of the UK as recorded by IMF World Economic Outlook (WEO) Database. Used as proxy for spending capacity.	2001-2012
Relative Price	✓	✓								Ratio of the CPI of the destination country over the country of origin. Both data are retrieved from the IMF World Economic Outlook (WEO) Database, with base year in 2005.	2002-2012
Rooms	✓ L	✓ L								Data for the UK are from Eurostat, while those for partner countries are from World Tourism Organisation (which covers only 2007-2012)	2007-2011

Variable	**Tourism - Inbound**	**Tourism - Outbound**	**Trade - Goods Import**	**Trade - Goods Export**	**Trade - Services Import**	**Trade - Services Export**	**National FDI Inflow**	**National FDI Outflow**	**Regional FDI**	**Source**	**Years covered**
Distance between Capital	✓	✓	✓ L	✓ L	✓ L	✓ L	✓ L	✓ L		Straight line distance between London and the partner country's capital. Data was collected from CEPII in Paris	n/a
Capacity by Seat	✓ L	✓ L	✓ L	✓ L	✓ L	✓ L	✓ L	✓ L			2002-2012
Variable	Tourism - Inbound	Tourism - Outbound	Trade - Goods Import	Trade - Goods Export	Trade - Services Import	Trade - Services Export	National FDI Inflow	National FDI Outflow	Regional FDI	Source	Years covered
Colonial Link			✓	✓	✓	✓				Whether the partner country is a former British dependent territory. Retrieved from CEPII database	n/a
Landlocked			✓	✓	✓	✓				Whether the partner country is landlocked. Retrieved from CEPII database	n/a
Language Dummy	✓	✓	✓	✓	✓	✓	✓	✓		Whether the partner country uses English as a main language. Retrieved from CEPII database	n/a
PPP Exchange Rate			✓	✓	✓	✓				Implied PPP conversion rate between sterling and foreign currency, based on IMF World Economic Outlook (WEO) database	2001-2012

Variable	Tourism - Inbound	Tourism - Outbound	Trade - Goods Import	Trade - Goods Export	Trade - Services Import	Trade - Services Export	National FDI Inflow	National FDI Outflow	Regional FDI	Source	Years covered
Labour productivity							✓	✓		Annual labour productivity as reported by The Conference Board Total Economy Database	2005-2011
Trade as % of Recipient's GDP							✓ L	✓ L		As collected from the World Bank's World Development Indicator (WDI).	2005-2012
Total Patent Application in Partner Country							✓ L			Total patents application in a certain country, as reported by the World Bank's World Development Indicators (WDI)	2005-2012
UK Lending Rate							✓			UK Lending Interest Rate, as reported by World Bank's WDI	2005-2012
UK Tax Rate							✓			UK private sector tax rate as reported by the World Bank	2005-2012
GDP growth								✓		Growth in GDP as reported by the IMF WEO database.	2005-2011
Real minimum wage								✓		Real minimum hourly wages as reported by the OECD database	2005-2012
Inflation								✓		Inflation rate in that country as reported by IMF. This acts as a proxy for macroeconomic stability.	2005-2012

Variable	Tourism - Inbound	Tourism - Outbound	Trade - Goods Import	Trade - Goods Export	Trade - Services Import	Trade - Services Export	National FDI Inflow	National FDI Outflow	Regional FDI	Source	Years covered
Infrastructure (Railway per area)								✓		Length of railway per km squared of that country	2005-2011
GVA									✓ L	Gross Value Added in Manufacturing, as reported by the ONS	2003-2010
Weekly Wage									✓ L	Weekly regional compensation in manufacturing, as reported by ONS	2003-2010
Connectivity Measure									✓	Regional air connectivity index, as described in section 5.1.1	2003-2012
Unemployment									✓ L	Regional claimant counts in manufacturing	2005-2012
Immigration									✓ L	Ratio of inflow of population over outflow for each regions, as collected from ONS.	2003-2011
Infrastructure (Motorway per area)									✓ L	Ratio of length of motorways in the region over its area size.	2005-2011

Legend: *'✓' means a variable was used in that equation, while 'L' means the logarithm was used in regression. 'D' means that variable was used as a dependent variable, while those without 'D' are explanatory.*
Source: PwC analysis

Appendix D – Correlation tables

Correlation table for tourism equations

	Tourists Arrivals	UK Tourists going abroad	GDP per capita of partner country	UK GDP per capita	Relative Price	Rooms	Distance	Capacity by Seat	Language Dummy
Tourists Arrivals	1.00								
	-								
UK Tourists going abroad	0.49	1.00							
	0.00	-							
GDP per capita of partner country	0.58	0.16	1.00						
	0.00	0.00	-						
UK GDP per capita	0.09	0.09	0.15	1.00					
	-0.05	-0.05	0.00	-					
Relative Price	0.11	0.21	0.26	0.02	1.00				
	-0.02	0.00	0.00	-0.67	-				
Rooms	-0.01	-0.05	0.00	-0.43	0.04	1.00			
	-0.90	-0.46	-1.00	0.00	-0.58	-			

	Tourists Arrivals	UK Tourists going abroad	GDP per capita of partner country	UK GDP per capita	Relative Price	Rooms	Distance	Capacity by Seat	Language Dummy
Distance	-0.23	-0.26	-0.24	0.00	-0.41	0.00	1.00		
	0.00	0.00	0.00	-1.00	0.00	-1.00	-		
Capacity by Seat	0.21	0.21	-0.04	0.15	0.07	-0.15	0.42	1.00	
	-0.01	-0.01	-0.59	-0.06	-0.39	-0.07	0.00	-	
Language Dummy	0.06	0.01	0.17	0.00	0.00	0.00	0.47	0.42	1.00
	-0.21	-0.76	0.00	-1.00	-0.94	-1.00	0.00	0.00	-

Note: *Numbers in red are p-values of the correlation coefficients. Source: PwC analysis*

Correlation table for trade equations

	Goods Import	Goods Export	Services Import	Services Export	GDP per capita of partner country	Distance	Capacity by Seats	Colonial Link Dummy	Landlocke d-ness Dummy	Language Dummy	Implied PPP Exchange Rate
Goods Imports	1.00										
	-										
Goods Exports	0.86	1.00									
	0.00	-									

	Goods Import	Goods Export	Services Import	Services Export	GDP per capita of partner country	Distance	Capacity by Seats	Colonial Link Dummy	Landlocke d-ness Dummy	Language Dummy	Implied PPP Exchange Rate
Services Imporst	0.84	0.89	1.00								
	0.00	0.00	-								
Services Exports	0.85	0.93	0.90	1.00							
	0.00	0.00	0.00	-							
GDP per capita of partner country	0.60	0.63	0.63	0.64	*1.00*						
	0.00	0.00	0.00	0.00	-						
Distance	-0.40	-0.52	-0.43	-0.44	*-0.41*	1.00					
	0.00	0.00	0.00	0.00	*0.00*	-					
Seat Capacity	0.77	0.83	0.86	0.82	*0.60*	-0.43	1.00				
	0.00	0.00	0.00	0.00	*0.00*	0.00	-				
Colonial Link Dummy	-0.03	-0.08	0.06	0.00	*0.03*	0.35	-0.01	1.00			
	-0.23	0.00	-0.03	-0.87	*-0.25*	0.00	-0.68	-			
Landlocked Dummy	-0.22	-0.24	-0.20	-0.16	*-0.27*	-0.06	-0.14	-0.14	1.00		
	0.00	0.00	0.00	0.00	*0.00*	-0.02	0.00	0.00	-		
Language Dummy	-0.05	-0.12	0.01	-0.01	*-0.06*	0.33	-0.04	0.69	-0.09	1.00	
	-0.05	0.00	-0.78	-0.69	*-0.02*	0.00	-0.27	0.00	0.00	-	
Implied PPP	-0.01	-0.02	-0.11	-0.06	*-0.18*	0.13	-0.19	-0.12	0.04	-0.07	1.00

	Goods Import	Goods Export	Services Import	Services Export	GDP per capita of partner country	Distance	Capacity by Seats	Colonial Link Dummy	Landlocked-ness Dummy	Language Dummy	Implied PPP Exchange Rate
Exchange Rate	-0.81	-0.39	0.00	-0.04	*0.00*	0.00	0.00	0.00	-0.12	0.00	-

Note: *Numbers in red are p-values of the correlation coefficients. Source: PwC analysis*

Correlation table for regional FDI regression

	Manufacturing FDI	Gross Value Added (GVA)	Weekly Wage	Connectivity	Claimant Count/Unemployment	Immigration	Motorway per area
Manufacturing FDI	1.00						
	-						
Gross Value Added (GVA)	-0.24	1.00					
	-0.05	-					
Weekly Wage	-0.28	0.99	1.00				
	-0.02	0.00	-				
Connectivity	0.09	-0.09	-0.14	1.00			
	-0.39	-0.40	-0.19	-			
Claimant Count/Unemployment	0.01	0.10	0.11	-0.26	1.00		
	-0.92	-0.44	-0.38	-0.02	-		
Immigration	0.08	-0.03	-0.03	-0.08	0.10	1.00	

	Manufacturing FDI	Gross Value Added (GVA)	Weekly Wage	Connectivity	Claimant Count/Unemployment	Immigration	Motorway per area
	-0.49	-0.81	-0.77	-0.45	-0.34	-	
Motorway per area	-0.11	0.73	0.77	0.39	0.00	-0.06	1.00
	-0.39	0.00	0.00	0.00	-0.97	-0.62	-

Note: *Numbers in red are p-values of the correlation coefficients. Source: PwC analysis*

Correlation table for FDI inflow regression

	FDI Inflow	GDP per capita	Trade as % of GDP, UK	Distance	Capacity by Seats	GDP per employed person	Total Patents	Language Dummy	UK Lending Rate	UK Private Sector Tax Rate
FDI Inflow	1									
	-									
GDP per capita	0.37	1								
	0	-								
Trade as % of GDP, UK	0.06	0.03	1							
	-0.38	-0.52	-							
Distance	-0.22	-0.41	0	1						
	0	0	-1	-						

	FDI Inflow	GDP per capita	Trade as % of GDP, UK	Distance	Capacity by Seats	GDP per employed person	Total Patents	Language Dummy	UK Lending Rate	UK Private Sector Tax Rate
Capacity by Seats	0.61	0.42	0.04	-0.46	1					
	0	0	-0.48	0	-					
GDP per employed person	-0.04	0.03	-0.19	0	0.02	1				
	-0.55	-0.63	0	-1	-0.68	-				
Total Patents	0.42	-0.05	0	0.41	0.24	0	1			
	0	-0.37	-0.95	0	0	-1	-			
Language Dummy	0.16	-0.05	0	0.41	0.26	0	0.32	1		
	-0.01	-0.36	-1	0	0	-1	0	-		
UK Lending Rate	-0.03	-0.01	-0.64	0	-0.04	0.69	0	0	1	
	-0.6	-0.79	0	-1	-0.48	0	-0.95	-1	-	
UK Private Sector Tax Rate	0.02	0.01	0.7	0	0.01	-0.45	0	0	-0.58	1
	-0.69	-0.78	0	-1	-0.8	0	-0.96	-1	0	-

Note: *Numbers in red are p-values of the correlation coefficients. Source: PwC analysis*

Correlation table for FDI outflow regression

	FDI Outflow	GDP per capita	UK GDP per capita	Population	Transport Cost	inflation	Lack of Corruption	Capacity by Seat	Trade as % of GDP
FDI Outflow	1								
	-								
GDP per capita	0.01	1							
	-0.84	-							
UK GDP per capita	0.05	0.02	1						
	-0.34	-0.7	-						
Population	0.54	-0.55	-0.01	1					
	0	0	-0.92	-					
Transport Cost	0.08	-0.08	0	0.15	1				
	-0.12	-0.11	-0.93	0	-				
inflation	0.04	-0.5	0.17	0.25	-0.18	1			
	-0.5	0	0	0	0	-			
Lack of Corruption	0.04	0.85	0.01	-0.49	0.09	-0.62	1		
	-0.48	0	-0.9	0	-0.07	0	-		
Seat	0.38	0.44	0.02	0.15	0.15	-0.37	0.58	1	

	FDI Outflow	GDP per capita	UK GDP per capita	Population	Transport Cost	inflation	Lack of Corruption	Capacity by Seat	Trade as % of GDP
Capacity	0	0	-0.73	-0.01	-0.01	0	0	-	
Trade as % of GDP	-0.06	0.26	0.04	-0.47	0.01	-0.13	0.32	-0.06	1
	-0.24	0	-0.48	0	-0.89	-0.01	0	-0.31	-

Note: *Numbers in red are p-values of the correlation coefficients. Source: PwC analysis*