Developing a Long Term Air Traffic Demand Forecast Model

Methodology followed by:

Multi-Disciplinary Working Group on Long-Term Traffic Forecasts (MDWG-LTF) under the Aviation Data and Analysis Panel (ADAP)

International Civil Aviation Organization

SUMMARY

This document describes the development and testing of a long-term air travel demand forecasting model for the International Civil Aviation Organization (ICAO). The model produces 30-year forecasts of travel demand for passenger and cargo markets that can be used for aviation policy and planning analyses.

For the purposes of this work, passenger travel demand is modeled as Revenue Passenger Kilometers (RPKs) and divided across 50 ICAO specified route groups (covering both domestic and international travel), and cargo demand is in Revenue Tonne Kilometers (RTKs) and divided across six global regions for total international and domestic cargo. The output from the model includes forecasts of load factors (for both the passenger and cargo markets) and Available Seat Kilometers (ASKs) and Available Tonne Kilometers (ATKs).

ICAO provided historical air traffic data from 1995 through 2012, with the first forecast year starting in 2013. These data, along with historical and forecast economic data from IHS Global Insight, were used for specifying the key economic and behavioral relationships in the forecasting model.

The economic theory of air travel demand formed the basis of model and forecast development, and current econometric techniques employed to ensure the parameter estimates and predictions are as accurate as possible. As part of its construction, the passenger forecasting model reflects the fact that the maturity of air transportation markets and air travel demand will vary by country/region depending upon their level of development.

The forecasting model has been constructed to allow for easily updating the input data to produce new forecasts when required. Aggregate level results from the model, with a 2012 base year and 30-year forecast horizon, are presented in Table 1 below.

Table 1: Aggregate Traffic Forecasts

	10 Year CAGR	20 Year CAGR	30 Year CAGR
RPK Global	4.7%	4.6%	4.5%
RTK Total International Global	4.5%	4.4%	4.2%
RTK Total Domestic Global	3.9%	4.0%	4.0%
ASK Global	4.5%	4.5%	4.3%
ATK Total International Global	4.3%	4.2%	4.0%
ATK Total Domestic Global	3.1%	3.3%	3.4%

TABLE OF CONTENTS

TABLE OF TABLES

TABLE OF FIGURES

Section | Page

1. INTRODUCTION

This paper describes the technical development and testing of a long-term global air traffic demand forecasting (LTF) model for the International Civil Aviation Organization (ICAO). The forecast covers a 30-year period for passenger and cargo air traffic, and is required by ICAO for planning and analysis purposes, including investigating the effects of possible environmental standards.

The global aviation market is defined at an aggregate level by ICAO specified route groups that represent a grouping of specified countries (e.g., the Intra-Europe route group is comprised of 51 countries including, Denmark, Iceland, Switzerland, Russian Federation & Romania). For the passenger market, there are 50 route groups in total, with 10 covering domestic traffic (e.g., North America Domestic route group) and 40 international (e.g., Europe – North America). The cargo market is defined by six global regions, which include Europe, North America, Asia and Pacific, Africa, Latin America and Caribbean, and Middle East.

For the passenger market, demand for air travel is measured by Revenue Passenger Kilometers (RPKs) and in the cargo market by Revenue Tonne Kilometers (RTKs).

Development of the model specification is grounded in economic theory, which is used to identify the most important determinants of air travel demand. An econometric modeling framework is developed to capture statistically significant historical relationships between air travel demand and economic and demographic factors. These identified relationships are then used as the basis for producing traffic demand forecasts.

The model development process incorporates several steps. After an initial review of the economic theory of air travel demand, the first step involves thoroughly examining economic and demographic data that could be used in the modeling process (dependent and independent variables). The next step lays out the basis for model development; this process is initially driven by data availability, but also extends into time series analysis. Concurrent with model development, model specification entails determining the preferred specification of the forecast model, which includes investigating independent variable characteristics, suitable econometric modeling frameworks, data transformations and any adjustments required to ensure the model coefficients are estimated efficiently. The final part of the development process is the selection of the preferred forecasting model.

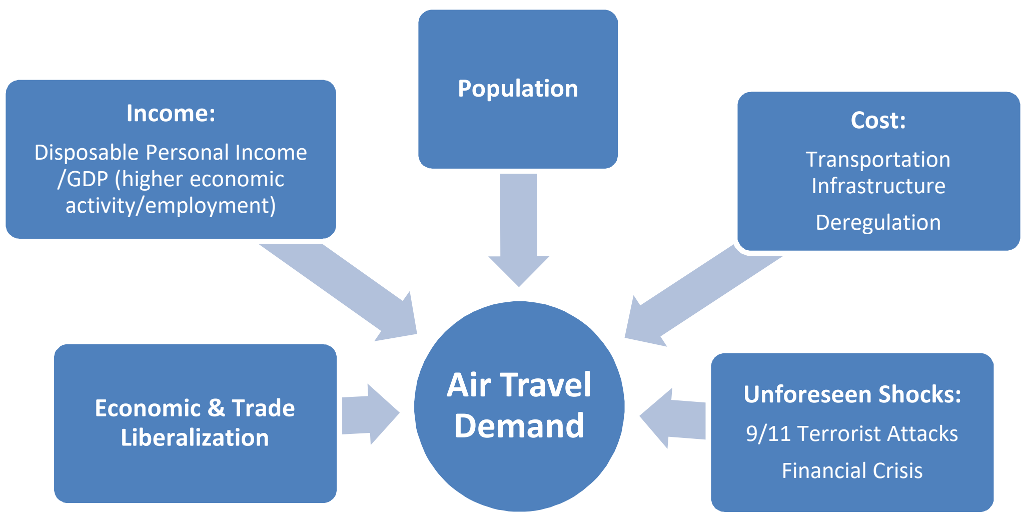
The rest of this report is structured as follows: Section 2 details the development of the methodology; Section 3 details the data used in the modeling process; Section 4 presents the modeling results for the preferred passenger and cargo models; Section 5 presents forecast results, and section 6 has a list of references. Appendix A details the tests used to validate the least squares modeling assumptions and Appendix B contains additional economic and demographic information.

2. METHODOLOGY DEVELOPMENT

2.1. Modeling Air Traffic Demand

Demand for air travel is considered to be a derived demand. Passengers travel not for the sake of travelling, but rather as a means to get from point A to point B for leisure or business. Likewise, the movement of cargo results from the need to move products from the point of manufacture, or distribution, to the end consumer.[1] Based on economic theory, key factors that influence global air travel demand include disposable income, population growth (in conjunction with income growth), economic/business activity, global trade, airline networks, deregulation and the cost of air travel. Figure 1 presents a stylized graphic of inputs to air travel demand.

Figure 1: Factors Influencing Air Travel Demand



To accurately model air traffic demand at a global route group level, it is important to identify regions of the world that exhibit different levels of economic and aviation market maturity. With route groups, which are the primary modeling unit for the forecast, it is possible to observe variation in per capita income levels and infer where the level of air traffic maturity and regulation may differ. In order to take advantage of this variation in the data, sets of route groups based on income tiers are clustered according to their market maturity (e.g., the route groups North America and Europe domestic are considered mature markets).

Finally, when specifying the forecast model, it is also important to control for specific non-economic events that directly affected regional or global air travel such as the terrorist acts of 9/11 or SARs epidemic in 2003. It may also be necessary to control for periods of time during which air travel is being liberalized (e.g., open skies agreements).

[1] This development exercise focuses on commercial air traffic, so general aviation is excluded from the model.

The objective of the modeling exercise is to develop a final model that is parsimonious (minimizing errors associated with input data) and that captures the main economic and demographic drivers of air traffic demand (minimizing specification error).

2.2. Tiered Approach to Forecasting RPKs

The long-term passenger model uses a tiered approach to align and group ICAO route groups by their level of economic development and aviation maturity. This is done so that the relationship between income and air travel demand (in economic terms, the elasticity of air travel demand with respect to income) can be more appropriately aligned with the economic environment of each route group. For example, it allows for clustering route groups with developing economies and aviation markets (e.g., route groups that include China), so they have income elasticities that are consistent with their level of maturity. As incomes grow over time, route groups will move across the tiers.

2.3. Development of Aviation Markets

As countries and regions become wealthier and more connected to the global economy the demand for air travel increases. Rising income per capita leads to increasing trips or revenue passenger kilometers per capita: consumers have more disposable income to spend on travel and growing employment and business activity leads to increasing business travel. Along with increasing incomes, globalization (trade and tourism) and the liberalization of the air travel market will also drive the demand for air travel.[2]

Increased travel results in demand for improvements in transportation infrastructure (both for air travel and other modes that allow for connecting airports to the transportation network). A more efficient transportation infrastructure lowers travel times (increasing traveler utility), and when combined with a regulatory environment promoting free markets and a competitive aviation market, travel costs will be reduced.[3] Network structure (e.g., hub and spoke) will also affect the nature, and efficiency, of the transportation network.

---

[2] For a detailed discussion on the theory of air transportation demand see Peter Belobaba, Amedeo Odoni and Cynthia Barnhart (2015) and Bijan Vasigh, Ken Fleming, and Thomas Tacker (2016)

[3] It is worth noting that improvements in transportation infrastructure that increase the utility of travel by lowering costs (e.g., easing access to airports and lowering travel times) will result in increasing the demand for travel. Therefore, there is an endogenous relationship between travel demand and the development of transportation infrastructure.

Combined, these factors can help increase the connectivity, or concentration, of the aviation network.[4] This is broadly defined as how efficiently a passenger can travel from one point to another, maximizing the traveler's utility (e.g., shortest travel time, no, or minimal, connections, lowest cost).[5]

As a country develops and its income grows the factors noted above will be part of the process via which its aviation market matures. This process is observed in a stronger relationship between real GDP per capita (a national income measure) and air travel demand. For example, in a paper on connectivity growth, the authors point to the fact that trips per capita increase as GDP per capita increases.[6] This relationship is also observed in several other research papers examining the relationship between air transportation and economic growth.[7]

Over time, the relationship between income growth and travel demand will mature (move towards an asymptote), as a country's economy, and aviation sector, matures.[8] Figure 2 below presents this idea in terms of an S-curve. The S-curve, where the y-axis represents RPKs with GDP per capita on the x-axis, shows the strengthening relationship between RPK and income for developing countries relative to early developing countries, depicted by a steepening slope, and then its moderation as the transportation sector matures in more developed economies (shown through a tapering of the slope of the curve). This concept is described in work by the U.K. Department for Transportation (DfT), where they classify markets by differing levels of maturity. While most of this analysis is at the origin-destination (O-D) pair level by route location (domestic or international), and travel type (leisure or business), it does note that less-developed, or newly industrialized countries experience less aviation growth due to lower income levels and the fact they are have less mature markets.[9]

---

[4]Factors that drive connectivity include a country's geography, airport infrastructure, airline models, and regulatory and economic framework.

[5]http://www.icao.int/Meetings/atconf6/Documents/WorkingPapers/ATConf6-wp020_en.pdf, http://cfapp.icao.int/tools/38thAssyiKit/story_content/external_files/Flyer_US-Letter_Econ-Dev_Connectivity_2013-08-20.pdf

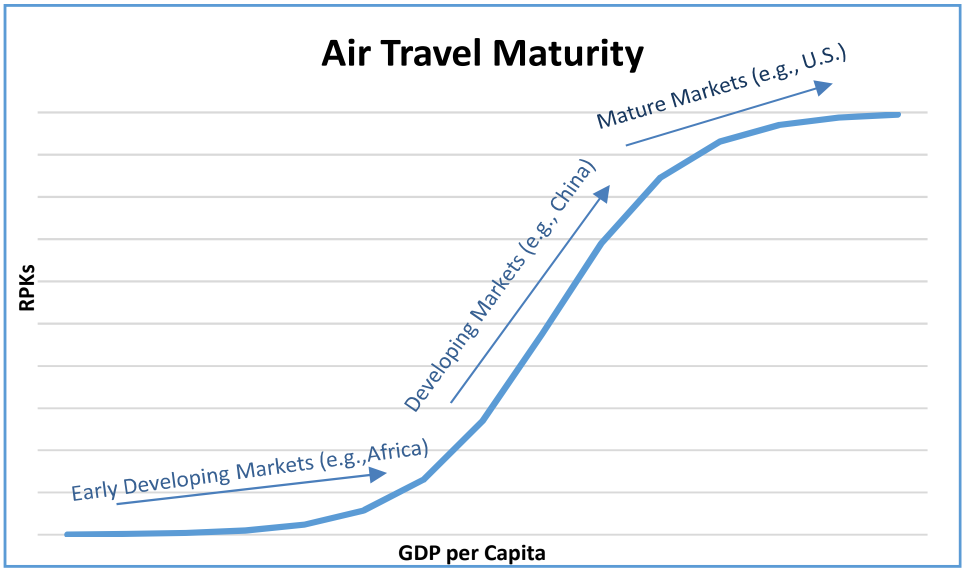
[6] https://www.pwc.com/gx/en/capital-projects-infrastructure/publications/assets/pwc-connectivity-growth.pdf

[7] Analysis of the Interaction between Air Transportation and Economic Activity: A Worldwide Perspective. M. Ishutkina and J. Hansman; Long-Term Trends in Global Passenger Mobility, A. Schafer; The Future Mobility of the World Population, A. Schafer, D. Victor.

[8] http://www.icao.int/Meetings/ICAN2015/Presentations/ITU.KemalUre.pdf

[9]https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/73143/aviation-demand-forecasting.pdf

Figure 2: Development of Air Traffic Markets



An analysis presented by International Air Transport Association (IATA) also suggests a change in the relationship between travel demand and incomes, and they note that there is a noticeable difference in the number of trips per person between low income and high income countries (they suggest there is a break-point at an income of $20,000 per capita).[10]

2.4. Income Elasticities

As economies and aviation markets develop, the relationship between travel demand and income will evolve. This reflects the fact that the elasticity of demand for travel with respect to income will start relatively low, but will then increase as these countries income and aviation connectivity develops. As economies (and aviation markets) develop further and mature, the relative strength of demand will moderate. In general, income elasticities for aviation are expected to be above one (which means aviation demand will respond strongly to changes in income).

Income elasticities, however, will differ based on the nature of the market being examined. This would reflect differences in the demand for travel on domestic or international routes (short-haul or long-haul) and by travel type. For example, the DfT notes the value for UK leisure travel the income elasticity is 1.4 and that the value is around 1.3 for the UK overall.[11] An analysis of income elasticities by IATA estimates that income elasticities are around 1.3 – 2.2 for developed

---

[10] https://www.iata.org/whatwedo/Documents/economics/20yearsForecast-GAD2014-Athens-Nov2014-BP.pdf

[11] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/73143/aviation-demand-forecasting.pdf

economies, and higher for developing economies at around 1.8 - 2.5 (the range of elasticities is dependent upon the type of route: short haul, medium, long and very long).[12] A meta-analysis of income elasticities estimates a value from 1.2 to 1.5 depending upon the whether the route is domestic or international.[13]

2.5. Route Group Tiers

ICAO defined route groups are placed into tiers based on their relative position of real GDP per capita. This is initially done using the start year for the historical data (1995). While the initial tier structure remains fixed (i.e., where each tier begins and ends), over time the position of each route group will generally move up through the tiers as its income grows.

Three tiers are used for the LTF model and are based on the World Bank's 2010 definition of income Tiers and are in real 2010 $US.[14] The first tier represents route groups with early developing countries (e.g., African countries) and goes up to a real GDP of less than US$1,005 per capita. The second tier represents route groups with developing nations (e.g., China) and its range is $1,005 to $12,276. The final tier captures route groups containing mainly developed, or mature, countries (e.g., U.S.) and ranges upward from $12,276.

Route groups were then grouped by their respective combination of Tiers. For example, the Africa – North Atlantic route group would fall into the Low – High grouping, since Africa is low income, while the North Atlantic would fall into the high income Tier. This creates six separate groupings based on all possible combinations of income: Low – Low, Low – Medium, Low – High, Medium – Medium, Medium – High, and High – High.

2.6. Capturing Random Non-Economic Effects on Air Travel Demand

Modeling and forecasting air traffic requires capturing the influence of not only economic and demographic factors on air travel demand, but also the influence of one-time random events. Examples of these events are the September 11 2001 terrorist attacks in the U.S., the 2003 SARS epidemic and the 2010 Icelandic volcano eruption. Other events could also include air travel deregulation and other unobserved factors that may influence the aviation market place.

The influence of significant random effects on model fit and performance was tested during the development process. This was done through the introduction of year specific dummy variables at the points, and for specific route groups, where an event was determined to have an effect on demand. For example, a time dummy was introduced in 2001 and 2002 to capture the effect of the September 11 terrorist attacks in the U.S. The time dummies were specified to capture a permanent shift in the level of air travel following the events of September 2001 that affects the route groups connected to North America. Figure 3 and

---

[12] https://www.iata.org/whatwedo/documents/economics/air_travel_demand.pdf

[13] The income elasticity of air travel: A meta-analysis, Craig A. Gallet, Hristos Doucouliagos, Annals of Tourism Research, October 2014.

[14] World Bank tier reference: http://data.worldbank.org/news/2010-GNI-income-classifications

Figure 4 below show how the level of air travel declined sharply in 2001 and into 2002 for the largest North American related route groups (in terms of RPK per capita), and then began to grow again from this lower level, rather than immediately bouncing back to the previous level after this event.

Figure 3: RPK per Capita for Europe—North America Route Group

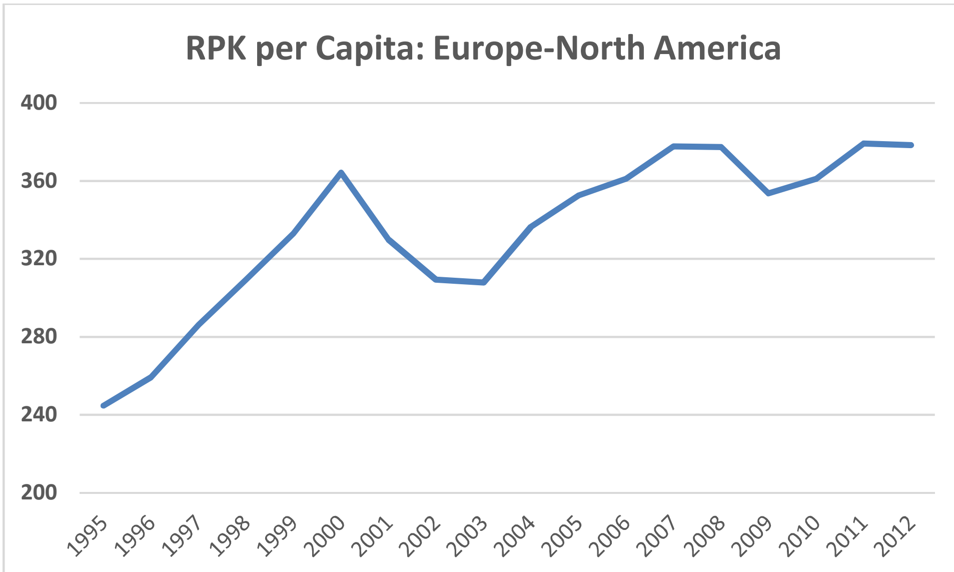
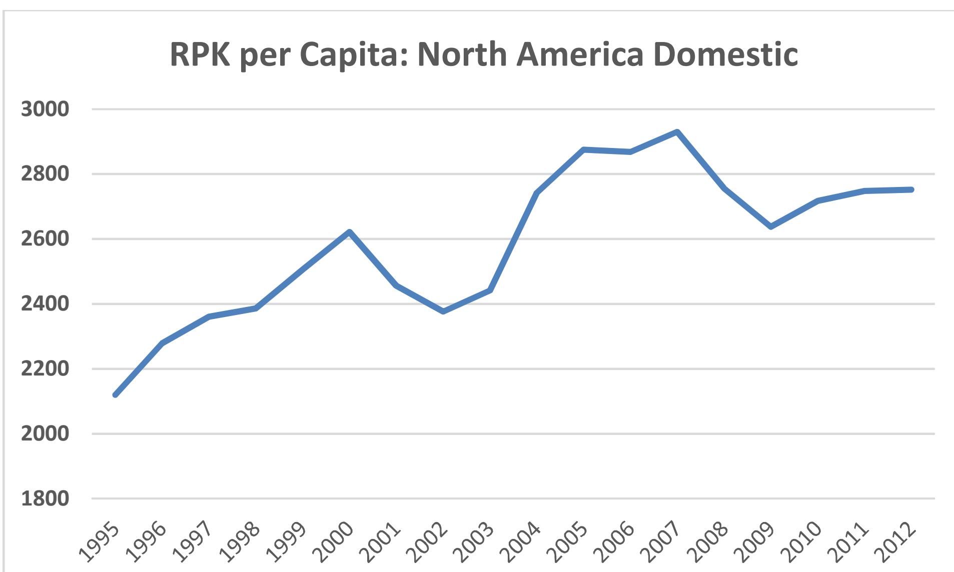


Figure 4: RPK per Capita for North America Domestic Route Group



After testing, time dummies that were found to be significant were introduced into the model to capture the effects of September 11 (2001 and 2002) and the SARS epidemic (2003).[15] The 9/11 time dummy was applied only to route groups connected to North America and the SARS time dummy was used on route groups that included Asia and/or China. In addition, global year time dummies were introduced between 2004 and 2007 and during the recovery from the financial crisis from 2010 and 2011 to capture unobserved factors, such as agreements to liberalize air travel between the U.S. and China and the U.S. and E.U.[16], which would influence the demand for air travel.

---

[15] Time dummies are introduced into the model in level form. During the estimation process, this specification captures the one time effect of the event being captured on the growth rate of RPKs only during the year of interest – estimated growth rates in the preceding or following years are unchanged. When the estimated change in RPKs is converted back to levels, the discrete annual change to the growth rate due to the time dummy will capture the shift in the level of air traffic caused by the event being modeled. Mathematically, a single level time dummy is the equivalent to a series of first differenced time dummies covering the same time span.

[16] http://www.washingtonpost.com/wp-dyn/content/article/2007/05/23/AR2007052301120.html, http://www.state.gov/documents/organization/88275.pdf, http://www.state.gov/e/eb/rls/othr/ata/e/eu/index.htm

3. INPUT DATA

3.1. Air Traffic Data

Historical air traffic data are collected and harmonized from various sources including ICAO's statistics program (Forms A, B, and C) and statistics published by national offices (US Department of Transportation, AvStats (UK CAA) etc.). The harmonized dataset covers over 90 percent of international air passenger traffic and 95 percent of cargo traffic. The Official Airline Guide (OAG) is used to complement the data in regions with low reporting to arrive at 100 percent coverage. The final dataset includes historical data from 1995 to 2012 for passenger and cargo traffic clustered at the route group and regional levels, respectively.

For the passenger market there are 40 international (e.g., Europe – North America), and 10 domestic (e.g., North America Domestic) passenger route groups. Each route group represents a grouping of specified countries (e.g., the Intra-Europe route group is comprised of 51 countries including, Denmark, Iceland, Switzerland, the Russian Federation, etc.). The cargo market is defined by six global regions, which include Europe, North America, Asia and Pacific, Africa, Latin America/Caribbean, and the Middle East.

3.2. Macroeconomic Data

Country specific economic and demographic data have been sourced from IHS Global Insight. Economic data used in the modeling included real Gross Domestic Product (GDP in 2010$) and real oil prices (per barrel of oil in 2010$), and the demographic data used was total population. These data were aggregated by country for route group combination. Route group specific GDP and RPKs were then divided by their respective total population, resulting in GDP and RPK per capita. A simple average of oil prices across countries within each route group was used for modeling. Table 2 presents the aggregate summary statistics of the key variables in the model and Appendix B contains the route group and region specific summary statistics.

Table 2: Aggregate Summary Statistics for the Passenger and Cargo Models

		Observations	Mean	Standard Deviation	Minimum	Maximum
Passenger Model	**RPKs Per Capita**	877	132.39	371.27	0.00	2,930.125
	Real GDP Per Capita	900	$14,918.45	12,727.51	645.96	49,675.16
	Real Oil	900	$61.28	26.78	16.12	110.99
Cargo Model	**RTKs**	108	20,037.06	17,972.76	1,390	68,444
	Real GDP	108	$\$9.13x10^{12}$	$7.13x10^{12}$	$9.58x10^{11}$	$2.11x10^{13}$
	Real Oil	108	$60.17	25.58	19.74	107.93

4. FORECAST MODEL DEVELOPMENT

4.1. Passenger RPK Modeling

Initial work on developing the LTF forecasting approach began with determining the availability of data that could be used in the model. Historical dependent data (i.e., RPKs and RTKs) are available from 1995 through 2012, which limited the number of observations for each series to 18 – even if the economic data are available over a longer time series, there will only be 18 years of information that can be used for estimating the relationship between economic activity and air travel demand.

The limited number of data points for each route group motivated the use of a panel model format. Through grouping the route groups in a single dataset, a panel model has the advantage of providing more observations for estimating the relationship between traffic demand and the economic and demographic variables, and allows for the inclusion of more independent variables (without significantly decreasing model degrees of freedom), increasing confidence in the statistical test results and model coefficient estimations.

The RPK (and RTK), economic and demographic data were transformed into natural logs, which facilitates interpretation (model coefficients become elasticities). In addition, the first difference of the model data was taken to ensure the underlining series were stationary and not serially correlated with the residuals. This also has the effect of removing the individual route group fixed effects. The residuals were also corrected for arbitrary forms of heteroscedasticity and autocorrelation. Appendix A.1 contains a detailed examination of the underlying OLS modeling assumptions.

As mentioned in Sections 2.5 and 2.6, the independent variable list includes six income variables based on the possible combinations of route group pairs' income levels, and event/region and time specific dummy and interaction variables. The variable for the price of oil was instrumented using a two-step generalized method of moments (GMM) approach under the conservative assumption that it could be endogenous to RPKs.[17] Given the time series framework, natural instrumental variables are lagged values of the oil prices and GDP per capita, since they are not correlated with the error term at time *t*.[18] Therefore, we use $\Delta nlog\left(Oil\_price_{i,t-1}\right)$ and $\Delta nlog(GDP\_pc_{i,t-1})$ as instruments for route group i at time *t*, along with the remaining exogenous variables in the demand equation. This has the effect of creating an overly identified instrument matrix, which has the advantage of allowing testing for the validity of the instruments

[17] See Hayashi (2000 pp. 206-13 and 226-27) for more information of GMM IV estimation.

[18] Mathematically speaking, any information at time *t-1* will be orthogonal to the error term at time *t*, so long as the error term is serial uncorrelated. In this case, Newey-West standard errors (at lag = 1) are used to ensure serial uncorrelated errors.

through the Hansen-J test, which is not possible when the endogenous variable is exactly identified.[19]

The specification for the reduced-form passenger RPK demand model is:

$$\textbf{EQ1: } \Delta \ln(\boldsymbol{RPK\_pc_{i.t}}) = \boldsymbol{\beta_{oil}} \Delta\, \boldsymbol{nlog}\big(\boldsymbol{Oil\_price_{i,t}}\big) + \sum_{n=1,j=1}^{6} \boldsymbol{\beta_n}(\boldsymbol{T_j} * \Delta \boldsymbol{nlog}(\boldsymbol{GDP\_pc_{i,t}}) + \mathbf{year\_ind} + \boldsymbol{\varepsilon_{i,t}},$$

Where $\mathrm{RPK\_pc}_{i.t}$ is RPKs per capita, $\mathrm{Oil\_price}_{i,t}$ is oil prices, $\mathrm{GDP\_pc}_{i,t}$ is GDP per capita and year_ind are the year specific indicator.[20] Route groups are represented by i, time t, and income tier by j. The model was only estimated on route groups with complete time series, meaning three were excluded in the estimation because of missing RPK data.[21] Table 3 presents the model estimation results and statistics.

The six income terms are all highly significant with elasticities above one, signifying highly elastic demand for RPKs, with respect to a route groups' specific national income level per capita. The elasticities also provide some empirical evidence to the market maturity hypothesis, with less developed countries having the lowest elasticities, developing countries the highest, and developed or high-income countries somewhere in the middle, reflecting high-income countries relatively high level of maturity in air travel. The elasticity on the price of oil is significant and negative, with a ceteris paribus 1% increase in the price of oil reducing passenger traffic demand by 0.09%. The 9/11 and SARs region specific indicators have the appropriate (negative) sign and reasonable magnitude, while the remaining global time dummies are all positive and significant, reflecting other factors driving growth in the demand for passenger air travel that were not fully captured by the macroeconomic and demographic data.

The overall model fit, measured by the root mean squared error (0.09) and R-squared (0.38) are reasonable, given the panel dataset and first difference transformation. The Hansen-J test p-value of 0.82 is well above the 0.05 cut off for valid instruments. Finally, the global 20- and 30-year compound annual growth rates (CAGRs) of 4.6% and 4.5% are consistent with the growth predicted by the air industry. The route group specific CAGRs can be found in the Forecast Results section in Table 6.

---

[19] Hayashi (2000 pp. 227-8, 407, 417)

[20] Year indicators include 2001 and 2002 for the North Atlantic route groups, 2003 for the Asia route groups, and years 2004-2007 and 2010-2011 for all route groups.

[21] The three excluded route groups were Africa & Middle East – Central America/Caribbean, Latin America/Caribbean – China, and North America – South West Asia. Forecasts for these route groups were prepared through aligning them by income tier and applying the appropriate elasticities from the estimated forecast model.

Table 3: Passenger Panel Model Results

LHS Variable:	**Δ Nlog RPKS PC**
Δ Nlog of Real Oil Prices US$	-0.0932* (0.0456)
Low-Low	1.335** (0.429)
Low-Medium	1.588* (0.718)
Low-High	2.203* (1.068)
Medium-Medium	1.556*** (0.187)
Medium-High	2.058*** (0.308)
High-High	1.437*** (0.313)
Year 2001*NA (9/11)	-0.114*** (0.0232)
Year 2002*NA (9/11)	-0.0871*** (0.0230)
Year 2003*Asia RGs (SARs)	-0.0729* (0.0347)
Year 2004	0.119*** (0.0164)
Year 2005	0.0586*** (0.0147)
Year 2006	0.0244* (0.0123)
Year 2007	0.0325† (0.0169)
Year 2010	0.0579*** (0.0123)
Year 2011	0.0513*** (0.0144)
Observations	752
Adjusted R-squared	0.379
RMSE (Standard Error of the Regression)	0.08997
Hansen J p-value	0.8215
Global 20 Year CAGR	4.6%
Global 30 Year CAGR	4.5%
Notes:	Estimates efficient and robust for arbitrary heteroskedasticity and autocorrelation. First stage instruments of Δ Nlog Oil = Δ NLog GDP PC (-1), Δ Nlog Oil(-1) Model 1 Tiers: Tier 1- <$1,005; $1,005> Tier 2 <$12,276; Tier 3>$12,276

Standard errors in parentheses

† p<0.1 * p<0.05 ** p<0.01 *** p<0.001

4.2. Cargo RTK Modeling

The cargo RTK forecast model development used a more simplified approach; instead of pooling all six regions together to form a panel, six separate OLS equations were estimated. This was done to preserve the relatively large heterogeneity amongst the regions in terms of the relationship between RTKs and GDP. Combining all six regions into a single pool would have constrained them to the same income elasticity. Given that the primary purpose of these models is to forecast RTKs, using the same elasticity for drastically different regions is not a reasonable assumption and would bias forecasts. Despite having a low number of observations to work from, the OLS models produced efficient estimations.

The cargo models were split into two groups based on total international RTKs and total domestic RTKs. All six regions were modeled for total international, while only four of the six regions were modeled for total domestic.[22,23] Similar variables were used in the cargo models as the passenger model, however, RTKs and GDP were not estimated in per capita terms. The price of oil was only included in Latin America and Caribbean region as it was insignificant in all other models.[24] All models were corrected for arbitrary heteroscedasticity and autocorrelation and an autoregressive term was included in select models. Appendix A.2 presents detailed tests of the OLS modeling assumptions for the cargo models. The basic reduced form cargo demand model estimated is:

$$\textbf{EQ2: } \boldsymbol{nlog(RTKs)_t = \alpha + \beta_1 nlog(GDP_t) + \varepsilon_t}$$

Where RTKs = region specific revenue tonne kilometers at time t and GDP = region specific real Gross Domestic Product at time t.

Table 4 presents the total international cargo model results. The large range of coefficients values on GDP (elasticities range from 0.71 in Africa to 2.05 in the Middle East) support the decision to run individual region models instead of using a single panel. The autoregressive term (AR(1)) coefficients are significant in the Africa and Middle East regions, and the oil coefficient is negative and marginally significant (at the 10% level) in the Latin America and Caribbean region. The global 20-year CAGRs (particularly for the larger regions) are also generally in line with the industry forecasted range of potential growth rates of 4.4%. The Forecast Results section (Table 7) contains the 10-, 20-, and 30-year CAGRs for the six regions.

[22] Africa and Middle East were not modeled due to lack of variation and growth in the total domestic RTK market over the historical period. Forecasts for these two regions were pegged to their historical average.

[23] To provide a complete picture of cargo demand, projections of dedicated and belly cargo RTKs were derived from total domestic and international forecasts. In the case of dedicated cargo, growth rates from the total forecast were used as the basis for the forecast (as there is generally a strong correlation between total and dedicated RTKs). Belly cargo is then calculated as the residual between total and dedicated RPKs.

[24] GDP and oil prices were jointly significant (p-value of 0.001) in the Latin American and Caribbean region model.

Table 5 presents the total domestic cargo model results. The Asia and Pacific region uses GDP values for a subset of countries thought to have the greatest impact on domestic RTKs[25], while the North American region includes a trend term and dummy variables from 2003 onwards to capture a structural break in the RTK data. An autoregressive (AR(1)) term was included for the Asia and Pacific, Europe, and Latin America and Caribbean regions. Similar to the total international results, the elasticity on GDP varies across different regions with a low of 0.466 in the Latin American and Caribbean region to a high of 1.741 in the Asia and Pacific region. The forecasted CAGRs can also be found in the Forecast Results section (Table 8) for these four regions.

Table 4: Cargo Region Model Results for Total International RTKs

	Region Model: Africa	Region Model: Asia and Pacific	Region Model: Europe	Region Model: Latin America and Caribbean	Region Model: Middle East	Region Model: North America	
LHS Variable:	**Nlog RTKs**	**Nlog RTKs**	**Nlog RTKs**	**Nlog RTKs**	**Nlog RTKs**	**Nlog RTKs**	
NLog of Real GDP	0.714*** (0.163)	1.045*** (0.074)	1.266*** (0.117)	0.977** (0.320)	2.048*** (0.203)	1.493*** (0.122)	
Nlog Oil				-0.155 (0.093)			
Constant	-12.35** (4.553)	-20.88*** (2.236)	-28.16*** (3.585)	-19.495* (8.944)	-48.47*** (5.702)	-35.37*** (3.707)	
AR(1)	0.495* (0.214)				0.580* (0.268)		
Observations	18	18	18	18	18	18	
Adjusted R-squared	0.971	0.930	0.876	0.572	0.986	0.931	**Global CAGRS**
20 Year CAGR	2.1%	4.7%	2.6%	3.1%	7.1%	3.5%	4.4%
30 Year CAGR	2.2%	4.3%	2.4%	3.0%	6.9%	3.4%	4.2%

Notes: Estimates efficient and robust for arbitrary heteroskedasticity and autocorrelation.
Standard errors in parentheses
† p<0.1 * p<0.05 ** p<0.01 *** p<0.001

Table 5: Cargo Region Model Results for Total Domestic RTKs

	Region Model: Asia and Pacific	Region Model: Europe	Region Model: Latin America and Caribbean	Region Model: North America
LHS Variable:	**Nlog FTKs**	**Nlog FTKs**	**Nlog FTKs**	**Nlog FTKs**
NLog of Real GDP	1.741*** (0.0893)	0.840* (0.409)	0.466* (0.202)	1.672*** (0.271)
NA 2003 Dummy				0.346*** (0.0555)
Trend				-0.0306*** (0.00390)
Constant	-43.98*** (2.687)	-18.84 (12.51)	0.105*** (0.0156)	-41.07*** (8.156)
AR(1)	0.420** (0.153)	0.738 (0.199)***	0.326† (0.179)	
Observations	18	18	18	18
Adjusted R-squared	0.989	0.991	0.9358	0.966
20 Year CAGR	7.8%	0.8%	1.7%	0.7%
30 Year CAGR	7.0%	1.0%	1.6%	0.6%

Notes: Estimates efficient and robust for arbitrary heteroskedasticity and autocorrelation.
Standard errors in parentheses
† p<0.1 * p<0.05 ** p<0.01 *** p<0.001

[25] Only China, India, Japan, South Korea, and Australia were included in the calculation of real GDP.

4.3. Available Seat and Available Revenue Tonne Kilometers

To accompany the RPK and RTK forecasts, predictions of available seat kilometers (ASK) and available tonne kilometers (ATK) were also prepared as part of the model development process. These series were estimated through first developing forecasts of load factors by route group (for the passenger market) and region (for the cargo market) through 2042.Using the load factor forecasts, ASK (and ATK) forecasts can be generated through dividing the RPK (and RTK) forecasts by the appropriate load factor:

EQ3: $ASK_{it} = (RPK_{it}/LF_{it})$

Where ASK = available seat kilometers, RPK = revenue passenger kilometers, LF = load factor, i = route group and t = time.

Load factors are the outcome of economic decisions by households (and businesses) and the airline industry. As a result, they are not behavioral in nature, but rather represent an equilibrium between demand and supply in the air travel market. Consistent with the non-behavioral nature of the data, the load factor models employ straightforward extrapolation methods to produce forecasts. Therefore, the starting point for this work was examining the historical load factor data, which was available from 1995 through 2012.

Passenger load factors were developed by route group using either an exponential smoothing or interpolation approach. The first step in this process was to apply an exponential smoothing algorithm to the historical data and forecast this out through 2042 (both additive and multiplicative approaches were tested).[26] An initial selection of the best forecasting models was done using the Akaike Information Criterion (AIC) test. This approach was then augmented using a cardinal spline interpolation based on establishing a load factor value in 2042 and then interpolating from the end historical value (2012) to the end forecast value. [27] The load factor value at the forecast end data was established through estimating a realistic load factor limit for a route group (e.g., in 2012 the load factor for the North America Domestic route group was 83.2%, and it was determined that this would not get much higher than 85% by the end of the forecast period).

Final forecast selection was done through comparing the two different approaches to determine which of them was more reasonable. In most cases, the two forecast approaches produced similar results and an average between the two was taken. For example, in the case of North America Domestic the exponential approach had a value of 85.4% in 2042, while the interpolation method had a value of 85%. Averaging the two approaches resulted in a value of 85.2% in 2042. If there was wide divergence between the forecasts, then a decision was made to select one approach over the other instead of averaging (e.g., for Intra-North Asia the exponential approach resulted

---

[26] For a good review of this methodology, refer to Exponential Smoothing: The state of the art—Part II, Everette S. Gardener, Jr., International Journal of Forecasting 22, (2006), pages 637-666.

[27] This was implemented using the statistical software program EViews, and was selected so that the interpolation would have some non-linear characteristics.

in a forecast trend that was less aggressive and more plausible than either the interpolation approach or an average of the two).

In the case of the cargo market, the load factors were reviewed and it was determined that there were no noticeable underlying growth trends that would need to be captured in the forecast. For example, the load factor for the Middle East Domestic market was almost constant at around 22% for the entire historical period. In most cases, the historical load factor data were generally stable, and after a upward (or downward) spike, would tend to move back towards a mean value.

Based on the historical information, forecasting cargo load factors was done through interpolating between the historical end point (2012) and the forecast end date (2042). The forecast end point was based on either the value in 2012, a historical average load factor or a 3-year moving average load factor.

Appendix B.3 presents the passenger and cargo market ASKs and ATKs, respectively.

5. FORECAST RESULTS

Table 6: Route Group and Global Compounded Annual Growth Rates of Forecasted RPKs

LTF RG	10 Year CAGR	20 Year CAGR	30 Year CAGR
Africa	4.6%	4.5%	4.3%
Africa & Middle East - Central America/Caribbean	4.5%	4.4%	4.3%
Africa & Middle East - South America	3.1%	3.8%	4.2%
Africa - Asia/Pacific	6.6%	6.1%	5.8%
Africa - Middle East	4.5%	4.9%	4.7%
Africa - North America	3.3%	3.1%	3.1%
Central America/Caribbean	4.0%	4.2%	4.2%
Central America/Caribbean – Europe	3.1%	3.2%	2.9%
Central America/Caribbean - North America	4.2%	4.0%	3.7%
Central America/Caribbean - South America	2.8%	3.8%	4.0%
China & South West Asia - North Asia	9.1%	8.4%	7.7%
China & South West Asia - Pacific South East Asia	8.9%	7.9%	7.4%
China - Europe	6.4%	5.7%	5.0%
China - Middle East	9.1%	8.4%	7.2%
China - North America	7.6%	6.5%	5.6%
China/Mongolia	10.3%	8.7%	7.4%
Europe	2.5%	2.5%	2.5%
Europe - Middle East	3.4%	3.1%	2.9%
Europe - North Africa	3.2%	3.3%	3.3%
Europe - North America	2.9%	2.8%	2.7%
Europe - North Asia	2.3%	2.3%	2.2%
Europe - Pacific South East Asia	3.6%	3.8%	3.6%
Europe - South America	2.8%	3.0%	2.9%
Europe - South West Asia	4.1%	4.3%	4.4%
Europe - Sub Saharan Africa	2.0%	2.1%	2.0%
Intra Africa	4.5%	4.5%	4.3%
Intra Central America/Caribbean	4.1%	4.2%	4.2%
Intra China & South West Asia	10.0%	8.7%	7.7%
Intra Europe	2.5%	2.5%	2.5%
Intra Middle East	4.7%	4.7%	4.4%
Intra North America	3.3%	3.0%	2.9%
Intra North Asia	1.7%	1.6%	1.4%
Intra Pacific South East Asia	5.4%	5.3%	5.1%
Intra South America	2.2%	3.2%	3.5%
Latin America/Caribbean - China	8.0%	7.7%	6.7%

Latin America/Caribbean - North Asia & Pacific South East Asia	2.6%	2.9%	2.7%
Middle East	4.7%	4.7%	4.4%
Middle East - North America	4.4%	3.6%	3.4%
Middle East - North Asia & Pacific South East Asia	4.1%	3.7%	3.5%
Middle East - South West Asia	8.0%	8.6%	8.4%
North America	3.3%	3.0%	2.9%
North America - North Asia	2.8%	2.6%	2.5%
North America - Pacific South East Asia	4.4%	4.3%	4.1%
North America - South America	3.8%	3.7%	3.5%
North America - South West Asia	5.2%	5.0%	5.0%
North Asia	1.7%	1.6%	1.4%
North Asia - Pacific South East Asia	3.7%	3.8%	3.6%
Pacific South East Asia	5.4%	5.3%	5.1%
South America	2.2%	3.2%	3.5%
South West Asia	10.5%	9.4%	8.7%
Total	**4.7%**	**4.6%**	**4.5%**

Table 7: Region and Global Compounded Annual Growth Rates of Forecasted Total International RTKs

Region	10 Year CAGR	20 Year CAGR	30 Year CAGR
Africa	1.6%	2.1%	2.2%
Asia and Pacific	5.2%	4.7%	4.3%
Europe	2.9%	2.6%	2.4%
Latin America/Caribbean	3.4%	3.1%	3.0%
Middle East	6.7%	7.2%	7.0%
North America	3.7%	3.5%	3.4%
Total	**4.5%**	**4.4%**	**4.2%**

Table 8: Region and Global Compounded Annual Growth Rates of Forecasted Total Domestic RTKs

Region	10 Year CAGR	20 Year CAGR	30 Year CAGR
Asia and Pacific	8.7%	7.8%	7.0%
Europe	0.2%	0.8%	1.0%
Latin America and Caribbean	2.0%	1.7%	1.6%
North America	0.8%	0.7%	0.6%
Global	**3.9%**	**4.0%**	**4.0%**

6. REFERENCES

Andreas Schafer, Long-Term Trends in Global Passenger Mobility, University of Cambridge.

Andreas Schafer, David G. Victor, (2000). The Future Mobility of the World Population, Transportation Research Part A.

Anne Graham, (2006). Have the major forces driving leisure airline traffic changed?, Journal of Air Transport Management.

Bijan Vasigh, Ken Fleming, Thomas Tacker (2016). Introduction to Air Transport Economics from Theory to Applications, Routledge 2nd Edition.

Brian Pearce, Chief Economist IATA (2014). The shape of air travel markets over the next 20 years.

Brian Pearce, Mark Smyth (2008). Air Travel Demand, IATA Economics Briefing No.9.

Enhancement of Air Transport Connectivity and Facilitation (March 2013), ICAO Working Paper ATConf/6-WP20.

Everette S. Gardner Jr., (2006). Exponential Smoothing: The state of the art – Part II, International Journal of Forecasting 22.

Fumio Hayashi (2000), Econometrics, Princeton University Press.

Gregg A. Gallet, Hristos Doucouliagos, (2014). The income elasticity of air travel: A meta-analysis, Annals of Tourism Research 49.

Jeffrey M. Wooldridge, (2010). Econometric Analysis of Cross Section and Panel Data (2nd Edition).

M. Ishutkina and J. Hansman, (2009). Analysis of the Interaction between Air Transportation and Economic Activity: A Worldwide Perspective. MIT International Center for Air Transportation (ICAT).

Nazim Kemal Ure, Emre Koyuncu, Gokhan Inalhan and Cengiz Pasaoglu, Air Transportation in 2030-50 and Data Analytics in Aviation.

Peter Belobaba, Amedeo Odoni and Cynthia Barnhart (2015). The Global Airline Industry (2nd), Wiley.

PWC UK (2014). Connectivity and growth, Directions of travel for airport investments.

UK Government Airports Commission, (2013). Discussion Paper 01: Aviation Demand Forecasting.

APPENDIX A:

A.1 Assumptions and Diagnostics for Model Testing and Estimation

The development of an accurate forecasting model requires ensuring that the basic technical assumptions of an OLS regression are met. In general these relate to error terms (or residuals) generated during the estimation process, but also to the relationship between the dependent and independent variables. Four core assumptions are:

1. Linearity between the dependent and independent variables
2. Statistical independence of the errors
3. Homoscedasticity/constant variance of the errors
4. Normality of the error distribution

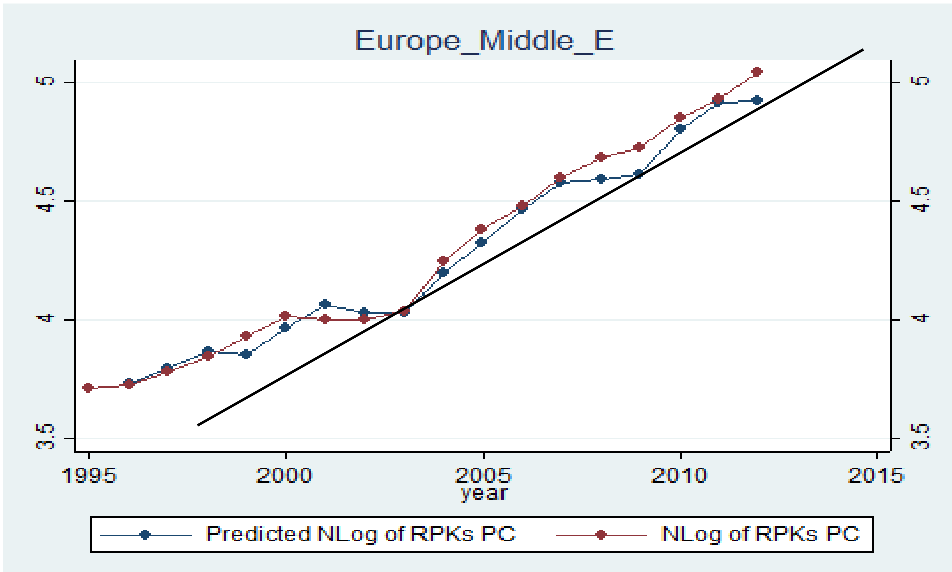
If one or more of these core assumptions is not met then the model being tested may not be appropriate for the purposes of inference or prediction/forecasting. To ensure these conditions are met, a series of diagnostics, tests, and data transformations are used during the development modeling process.

(**Note:** the following discussion focuses on the passenger LTF model. The development/testing of the cargo model is discussed immediately following the passenger section.)

A.1.1. Linearity

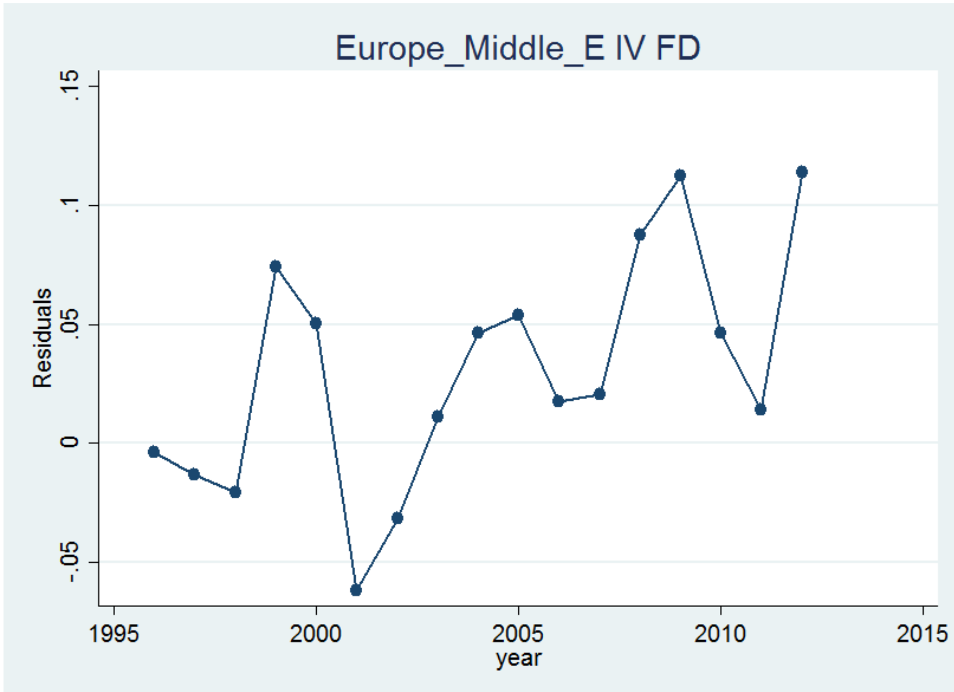
The linearity of the relationship between the dependent and independent variables is a critical assumption of OLS. If this relationship is deemed to be non-linear then the use of a linear model to fit the data will result in misleading estimations. Checking for linearity is easily observed through plotting the predicted against the actual values of the dependent variables, or by plotting the residuals versus the predicted values. In the first case, the expected distribution of data between the predicted versus actual values should be around a diagonal line, while in the second case the expected distribution should be around a horizontal line, with a constant variance. Figure 5 below presents the predicted versus actual natural log of RPKs per capita for the Europe – Middle East route group.

Figure 5: Predicted and Actual Values for Europe – Middle East Route Group



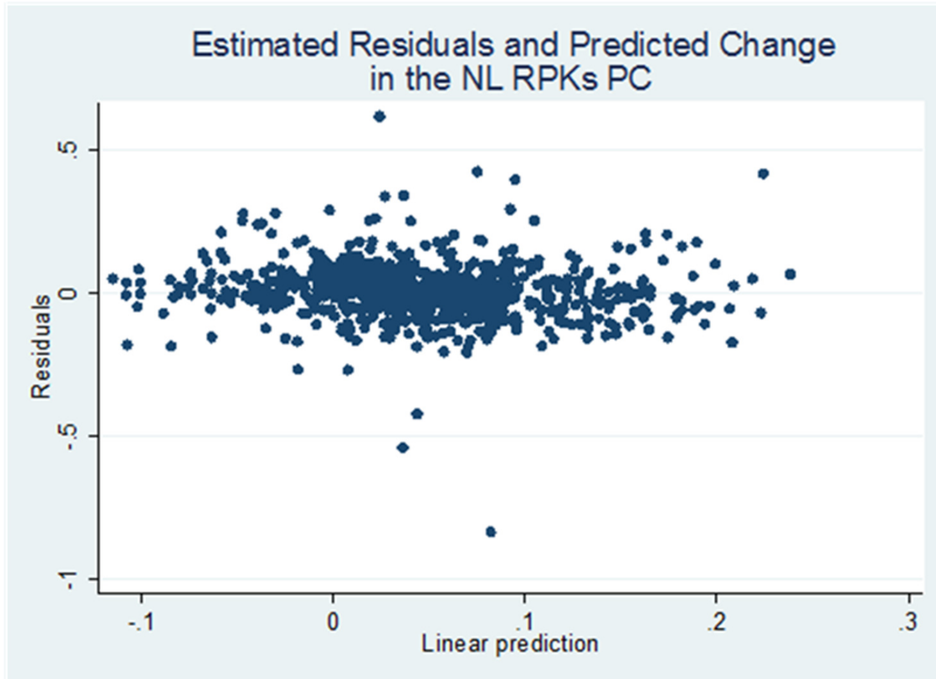
For this route group, the predicted and actual values of the natural log of RPKs per capita fit tightly around a diagonal line, signifying the relationship between the dependent and independent variables is linear in nature. The residual values (Figure 6) show a generally random pattern, consistent with a linear relationship, and the in-sample error for this route group is less than 2%. If the relationship was actually non-linear, the fit would not be as accurate and diverge when plotted together.

Figure 6: Residual Values for Europe – Middle East Group



Examining a plot of all model residuals against predicted values (Figure 7) indicates that the use of a linear model is a reasonable assumption. There is no discernable trend and the variance of the residuals is distributed relatively closely around 0, which shows no evidence of heteroscedasticity. The outliers in the graph (with values +/- 0.5) are Africa & Middle East – South America in 1996, China – Middle East in 1996 and 2003, and Latin America/Caribbean – China in 2009.

Figure 7: Passenger Residuals Values and Predicted Values



A.1.2. Independence (Autocorrelation)

If the error terms are not independent, (i.e., they are correlated across time periods), a key assumption of time series econometrics is violated. Referred to as autocorrelation, this has the effect of causing the regression coefficients to be inefficiently estimated (although the estimates are unbiased) and normal statistical tests of significance are not valid. Correcting for serial correlation is critical in time series regressions and can be addressed by including an autoregressive (AR(n) where n is the number of lag corrections) term in the model. If no recursive behavior is believed to exist in the underlying data, then first difference transformation of the data will remove the presence of autocorrelation in the error terms. Additionally, the use of Newey-West standard errors will adjust (weight) the covariance matrix of the errors to be robust to arbitrary forms of autocorrelation.[28]

Given that the panel model estimated used both first differenced variables and Newey-West standard errors, the error terms will be independent and unaffected by autocorrelation.

[28] Newey and West (1987).

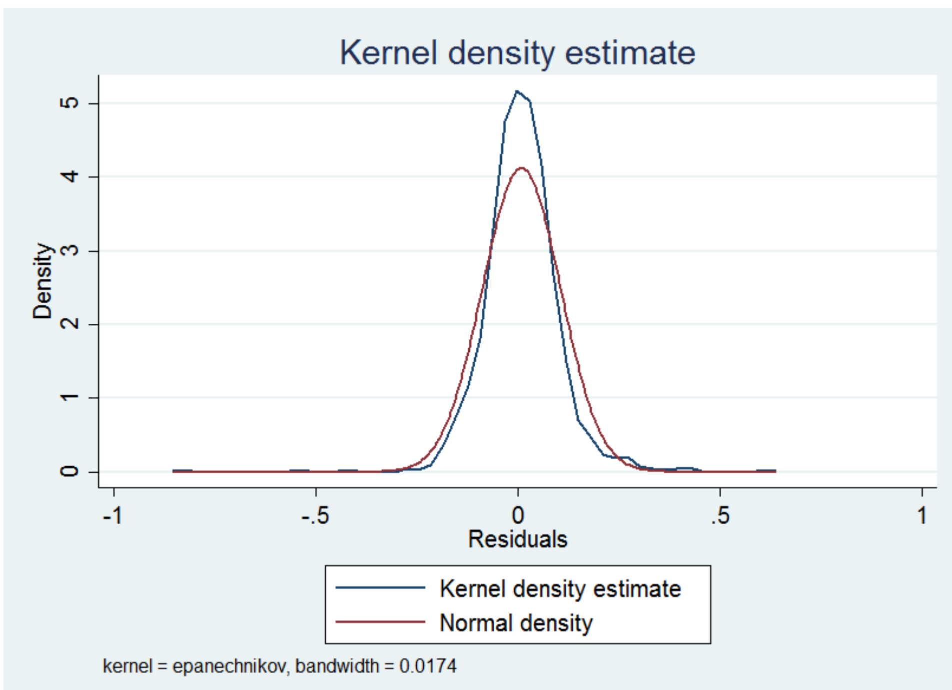
A.1.3. Homoscedasticity (Heteroscedasticity)

A principal of OLS is that the error term is assumed to have a mean of zero and a constant variance (σ^2). Heteroscedasticity occurs when the variance fails to be constant (large outliers in the data, skewed data over time, etc.), which causes the variance to be inconsistently estimated (i.e., the variance will not converge to the population value as more data are added). While the standard errors will be inconsistent under heteroscedasticity, the coefficient estimates are unbiased. Given that panel data sets are prone to heteroscedasticity at the cross-sectional level, robust standard errors are used in parallel with the Newey-West standard errors mentioned above. In other words, the standard errors will be consistent, robust and weighted for arbitrary forms of both heteroscedasticity and autocorrelation.[29]

A.1.4. Normality

In addition to the error term having a mean zero and a constant variance (σ^2), it is also assumed to be normally distributed. If the errors are not normally distributed traditional statistical tests of significance will be inaccurate. A simple test for normality plots the kernel density of the residuals over a normal distribution.[30] Below is the kernel density of the residuals from the panel model estimation over a normal distribution.

Figure 8: Kernel Density Plot



[29] White (1980).

[30] The kernel density estimates the probability density of a random variable (the error term of the model).

Figure 8 clearly shows that the estimated residuals do not violate the normality assumption, allowing the use and interpretation of the traditional statistical tests of significance.

A.1.5. Influence of Outliers

As noted above, an important assumption of OLS is that of homoscedasticity, whereby the variance of the error term is constant. Robust standard errors are used in the model estimation to ensure that the coefficient standard errors are robust and weighted to counter heteroscedasticity.

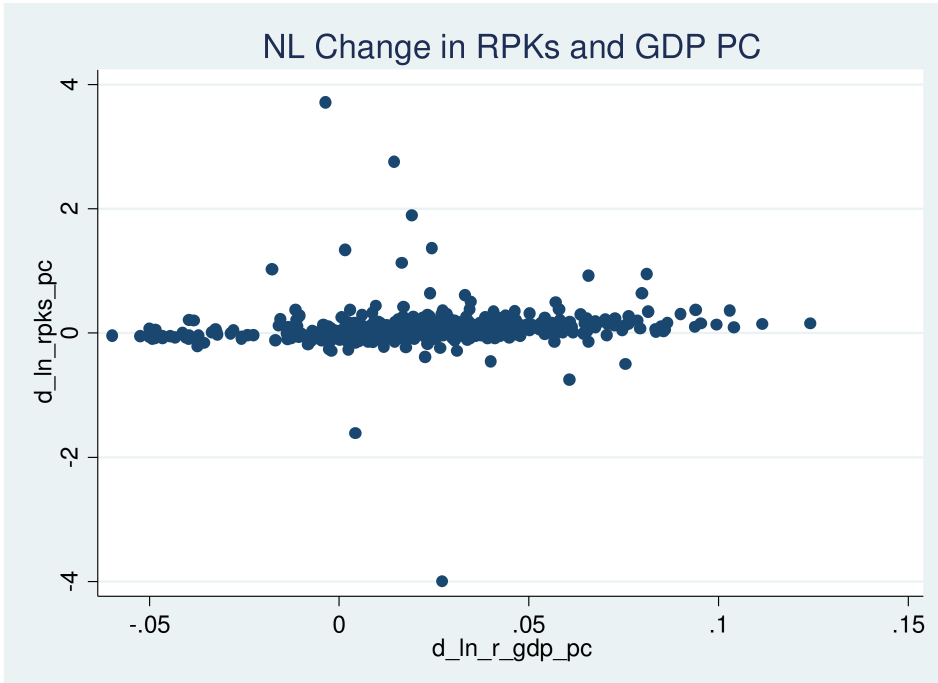
The size of the panel dataset (846 observations[31]) and the type of data (aggregate air traffic and economic/demographic[32]) data means that any outliers in the dataset will be unlikely to be overly influential on the estimated coefficient values.

The presence of outliers in the data was checked through plotting the change (first difference) of the natural log of RPKs and GDP PC (see Figure 9, which shows RPKS on the y-axis and GDP PC on the x-axis). Plotting the primary explanatory variable against the dependent variable allows identification of potential outliers in the data. Overall, the data are well behaved and closely grouped along the horizontal axis. Using a cut off of +/- 2, there are three data points that stick out as being possible outliers. These three points are all from the North America – South West Asia route group for the years 1998, 2001, and 2003. The presence of time specific indicators for 2001 and 2003 means the influence of these points will be diminished as any extra, or unexplained, variation will be captured by these indicators.

[31] Many macroeconomic time series dataset can be small in nature (e.g., less than 50 observations), which can allow outliers to exert an undue influence of the coefficient estimation.

[32] The fact that the estimation data are in natural logs and first differenced will also reduce concerns regarding outliers.

Figure 9: Change in the Natural Log of RPKS and GDP PC



A.2 Cargo Forecast Model

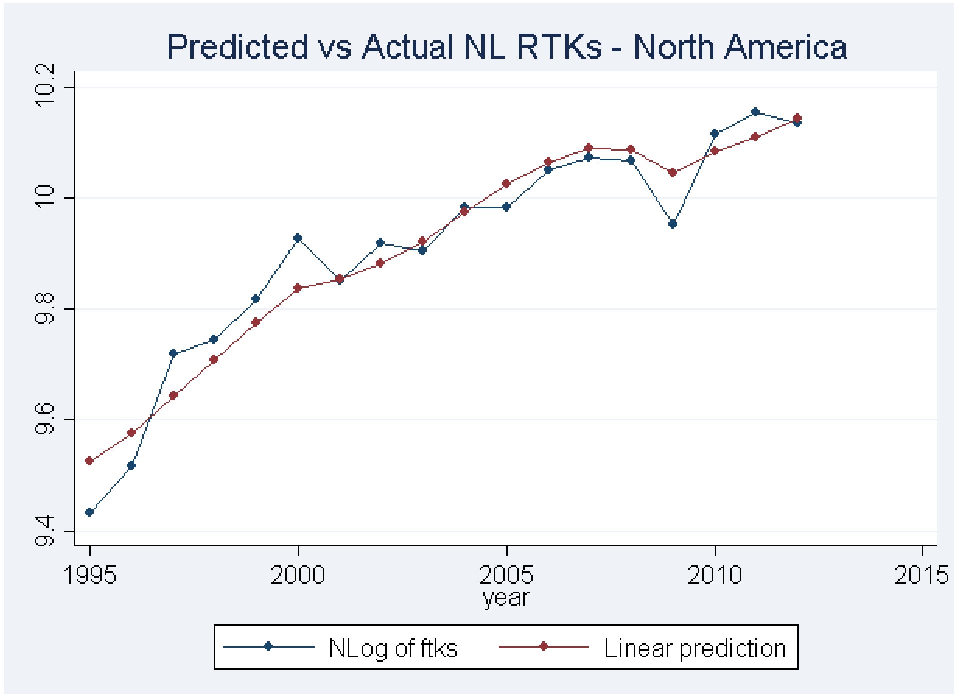
The cargo long-term forecasting model was developed separately from the passenger model. During testing it was determined that using a series of separate OLS equations resulted in a better performing approach compared with a panel model. Consistent with the passenger model, the cargo model variables are specified in natural logs of the level data.

While all of the assumptions of OLS need to be met by the cargo models, since each cargo region was model separately particular attention needs to be paid to the time series aspects of the data (since there is no panel related cross section variation).

A.2.1. Linearity

The assumption of linearity was examined by plotting the predicted and actual RTKs for each cargo region. Figure 10 shows that the overall fit for the North America Region to be relatively tight, indicating that the assumption of linearity holds and that OLS will produce reliable forecasts.

Figure 10: North America Predicted vs Actual NL RTKs



A.2.2. Independence of Errors (Autocorrelation)

Addressing autocorrelation is a common challenge when dealing with time series data. Whether a regression has autocorrelation can be checked using the Durbin-Watson (D-W) statistic. This statistic tests for the presence of autocorrelation with a value around 2 indicating no autocorrelation.[33]

Table 9 below presents the D-W statistic for each of the cargo estimating equations. All of these values, which cannot reject the null of no autocorrelation, indicate that the errors in these models are independent.[34] The cargo model residual plots (shown at the end of this section) also show little evidence of any time series issues.

It is worth noting that similar to the passenger model, the cargo models were estimated with standard errors that were robust to arbitrary forms of heteroscedasticity and autocorrelation.

[33] Durbin and Watson (1950).

[34] Where required autoregressive (AR) terms were added to address autocorrelation.

Table 9: Cargo Model Durban-Watson Statistics

Region	DW-Statistic
Africa	1.5639
Asia and Pacific	1.3906
Europe	1.5208
Latin America/Caribbean	2.0579
Middle East	1.5226
North America	1.4126

A.2.3. Homoscedasticity (Heteroscedasticity)

The use of individual regressions, which have no cross section component, and the log transformed data will reduce the risk of heteroscedasticity in the errors (which is generally not a significant concern in annual time series data). A review of the cargo model residuals (shown at the end of this section) exhibit little evidence of heteroscedasticity. A formal test for heteroscedasticity was also conducted for each cargo region. Table 10 below presents the results of the Breusch-Pagan/Godfrey/ Cook-Weisberg test for heteroscedasticity; the null hypothesis is homoscedastic residuals, which cannot be rejected by these results.[35]

Table 10: Cargo Model Breusch-Pagan/Godfrey Test of Heteroscedasticity

Region	Breusch-Pagan/Godfrey p-value
Africa	0.3359
Asia and Pacific	0.9595
Europe	0.6014
Latin America/Caribbean	0.4416
Middle East	0.4091
North America	0.0827

[35] Breusch & Pagan (1979), Godfrey (1978), and Cook & Weisberg (1983).

A.2.4. Normal Distribution

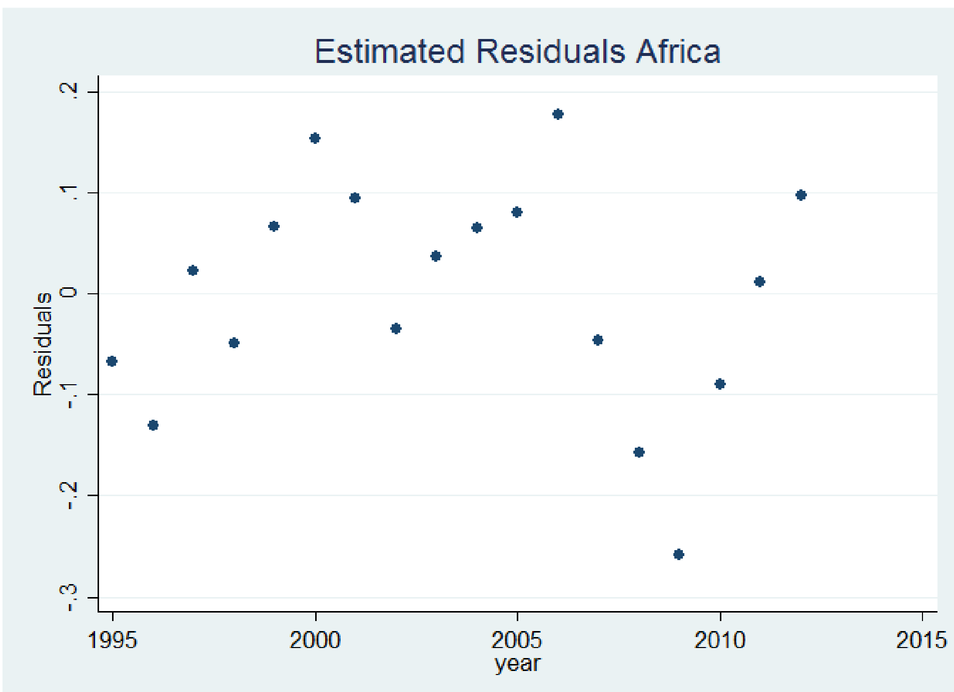
The assumption of normally distributed errors was tested for each cargo region. The Doornik and Hansen omnibus test for normality was used (see Table 11), with the null hypothesis of normally distributed errors.[36] In all cases, the assumption of normality holds.

Table 11: Cargo Model Doornik and Hansen test of normality

Region	Doornik and Hansen p-value
Africa	0.6944
Asia and Pacific	0.4893
Europe	0.7137
Latin America/Caribbean	0.7564
Middle East	0.5781
North America	0.1482

A.2.5. Cargo Model Residual Plots

Figure 11: Africa Region Residuals



[36] Doornik and Hansen (1994, 2008).

Figure 12: Asia and Pacific Region Residuals

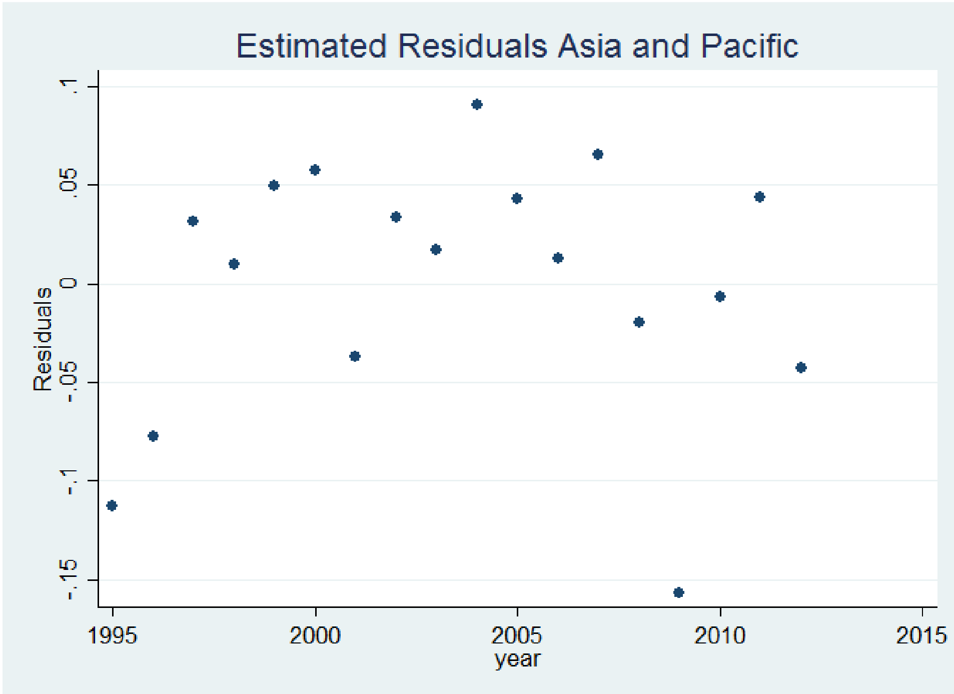


Figure 13: Europe Region Residuals

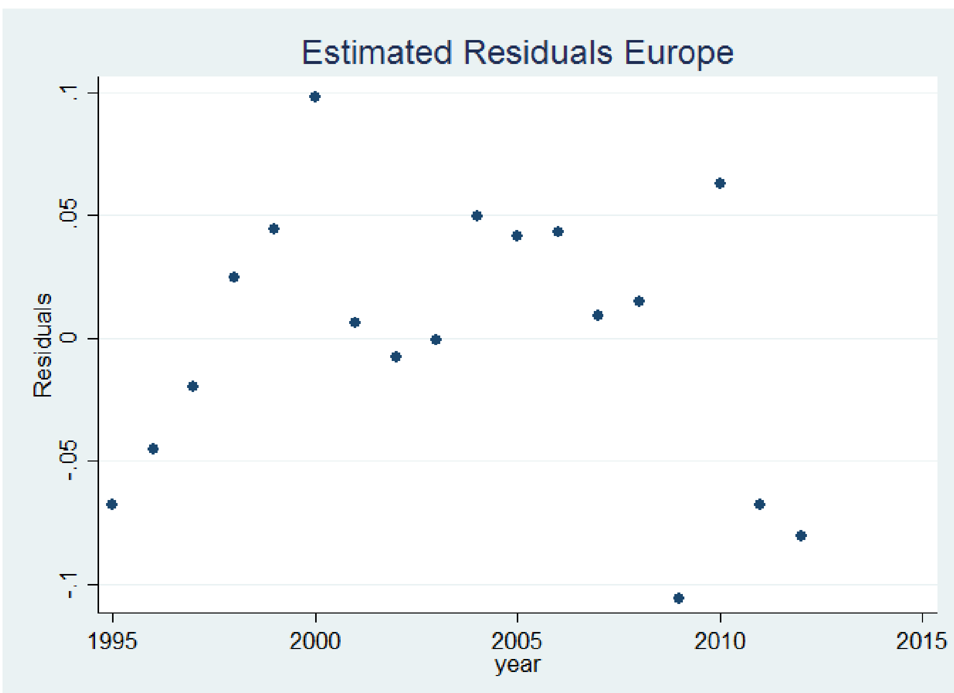


Figure 14: Latin/Caribbean Region Residuals

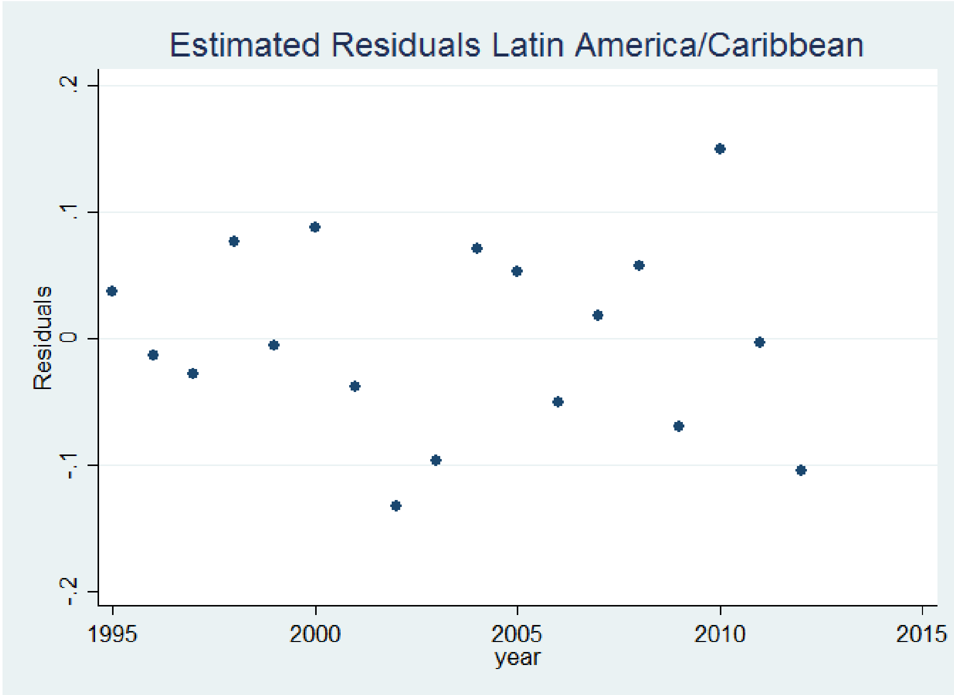


Figure 15: Middle East Region Residuals

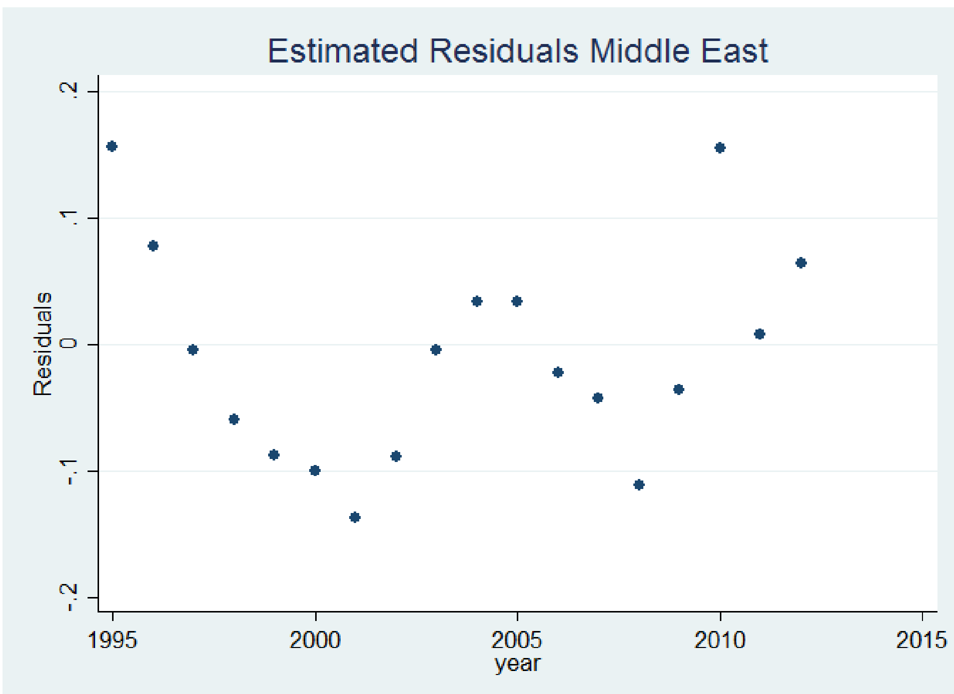
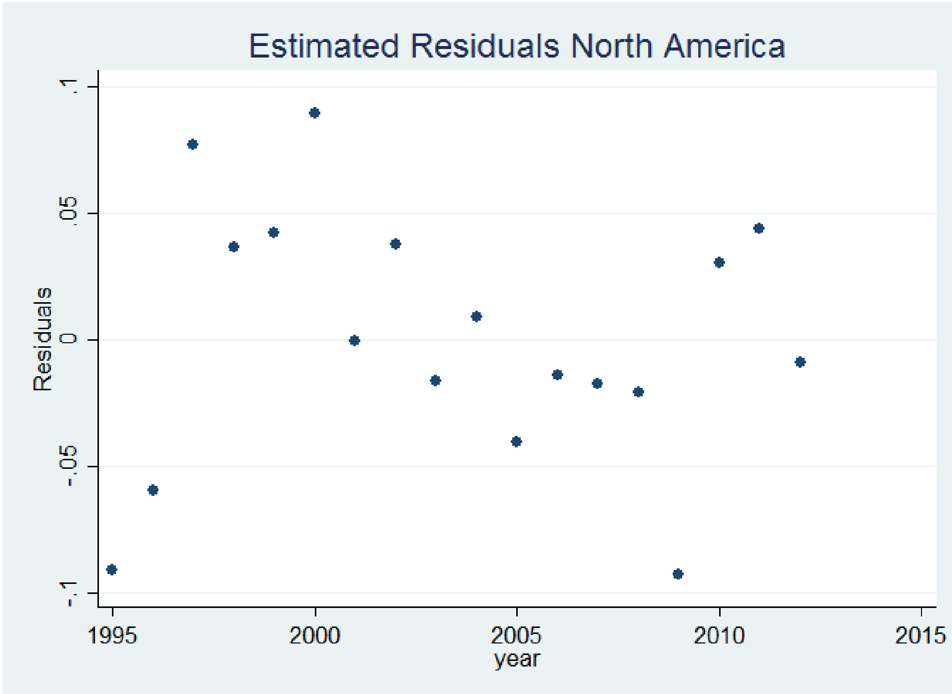


Figure 16: North America Region Residuals



APPENDIX B:

B.1 Route Group Summary Statistics

Table 12: Route Group RPK per Capita Summary Statistics

LTF RG	Observations	Mean	Standard Deviation	Minimum	Maximum
Africa	18	12.88	1.68	10.29	15.89
Africa & Middle East - Central America/Caribbean	10	0.21	0.24	0.02	0.65
Africa & Middle East - South America	18	2.85	2.07	1.1	7.74
Africa - Asia/Pacific	18	3.35	1.16	1.83	5.33
Africa - Middle East	18	21.64	12.17	9.72	45.87
Africa - North America	18	8.88	3.45	5.32	15.33
Central America/Caribbean	18	90.45	16.32	66.38	135.3
Central America/Caribbean - Europe	18	59.77	16.31	27.61	83.43
Central America/Caribbean - North America	18	133.55	35.18	84.2	190.59
Central America/Caribbean - South America	18	17.84	8.43	8.97	39.55
China & South West Asia - North Asia	18	12.03	2.96	8.39	16.77
China & South West Asia - Pacific South	18	25.71	7.84	16.74	41.87
China – Europe	18	30.14	13.33	11.05	52.68
China - Middle East	18	5.68	4.78	1.01	15.29
China - North America	18	43.3	11.59	27.55	63.89
China/Mongolia	18	122.92	84.3	41.38	296.08
Europe	18	181.31	24.16	149.61	229.74
Europe - Middle East	18	79.33	36.37	41.09	154.74
Europe - North Africa	18	30.48	14.65	14.88	59.52
Europe - North America	18	334.53	41.08	244.72	379.25
Europe - North Asia	18	69.72	6.2	55.22	80.35
Europe - Pacific South East Asia	18	81.51	10.83	56.43	95.25
Europe - South America	18	71.27	21.6	39.75	107.38
Europe - South West Asia	18	22.6	7.06	13.62	31.58
Europe - Sub Saharan Africa	18	49.19	7.9	32.54	58.5
Intra Africa	18	21.38	6.11	14.77	31.39
Intra Central America/Caribbean	18	33.25	3.52	28.14	41.15
Intra China & South West Asia	18	6.66	2.72	3.31	12.39
Intra Europe	18	400.43	174.91	174.38	708.28
Intra Middle East	18	81.43	35.8	42.26	147.67
Intra North America	18	95.94	13.9	61	116.18
Intra North Asia	18	42.84	9.95	28.59	59.3
Intra Pacific South East Asia	18	181.77	31.98	139.91	243.54

Intra South America	18	46.09	12.92	31.44	76.85
Latin America/Caribbean - China	5	0.26	0.22	0.06	0.56
Latin America/Caribbean - North Asia & Pacific	18	2.82	1.62	1.06	5.62
Middle East	18	79.35	11.38	63.77	111.34
Middle East - North America	18	58.41	40.79	24.84	142.86
Middle East - North Asia & Pacific South	18	45.41	28.52	19.72	106.15
Middle East - South West Asia	18	23.88	10.73	13.09	48.14
North America	18	2587.3	230.14	2119.43	2930.13
North America - North Asia	18	242.27	19.91	209.03	280.34
North America - Pacific South East Asia	18	50.52	7.82	39.46	63.38
North America - South America	18	69.09	12.09	52.92	96.89
North America - South West Asia	16	2.81	3.26	0	9.04
North Asia	18	432.37	28.88	379.53	467.33
North Asia - Pacific South East Asia	18	109.69	10.12	92.74	125.53
Pacific South East Asia	18	159.37	66.9	96.56	299.42
South America	18	148.32	65.64	82.02	298.22
South West Asia	18	18.19	10.01	9.17	37.51

Table 13: Route Group Real GDP per Capita Summary Statistics

LTF RG	Observations	Mean	Standard Deviation	Minimum	Maximum
Africa	18	1,472.45	182.25	1,243.07	1,758.80
Africa & Middle East - Central America/Caribbean	18	4,021.18	548.54	3,230.30	4,813.04
Africa & Middle East - South America	18	4,997.74	567.52	4,344.38	5,966.73
Africa - Asia/Pacific	18	3,740.02	642.25	2,960.72	4,927.18
Africa - Middle East	18	2,854.06	380.41	2,364.88	3,456.07
Africa - North America	18	18,961.73	953.20	16,913.60	20,201.55
Central America/Caribbean	18	7,007.90	551.80	5,884.86	7,795.71
Central America/Caribbean - Europe	18	22,559.19	1,937.09	19,133.56	24,938.34
Central America/Caribbean - North America	18	31,622.69	2,300.92	26,927.90	34,264.54
Central America/Caribbean - South America	18	7,697.98	789.44	6,689.47	9,168.65
China & South West Asia - North Asia	18	3,829.66	716.06	2,970.26	5,175.15
China & South West Asia - Pacific South	18	2,390.82	726.48	1,513.33	3,760.09
China – Europe	18	10,689.78	1,614.39	8,343.15	13,217.14
China - Middle East	18	3,803.91	1,437.01	2,092.36	6,516.62
China - North America	18	11,453.83	1,828.57	8,610.20	14,462.32
China/Mongolia	18	2,869.80	1,325.68	1,327.79	5,434.73

Europe	18	22,892.84	2,433.11	18,754.58	25,840.04
Europe - Middle East	18	20,452.61	1,955.76	17,124.06	22,851.76
Europe - North Africa	18	20,247.52	1,929.29	16,915.37	22,638.42
Europe - North America	18	30,976.09	2,952.92	25,546.65	34,301.37
Europe - North Asia	18	26,752.00	2,321.25	22,880.48	29,541.87
Europe - Pacific South East Asia	18	16,293.54	1,433.14	13,894.32	18,043.84
Europe - South America	18	19,865.98	1,601.02	17,206.22	21,880.37
Europe - South West Asia	18	8,396.72	619.75	7,380.03	9,188.36
Europe - Sub Saharan Africa	18	12,622.80	606.66	11,545.61	13,592.38
Intra Africa	18	1,552.24	193.83	1,301.94	1,860.15
Intra Central America/Caribbean	18	6,933.30	540.60	5,834.57	7,719.07
Intra China & South West Asia	18	1,912.13	725.87	1,047.34	3,287.07
Intra Europe	18	23,234.28	2,428.55	19,077.56	26,167.77
Intra Middle East	18	8,520.08	1,209.67	6,951.22	10,410.09
Intra North America	18	45,682.18	3,589.14	38,468.62	49,665.95
Intra North Asia	18	35,313.98	2,032.07	32,156.23	38,288.72
Intra Pacific South East Asia	18	4,895.21	666.49	4,039.26	6,112.59
Intra South America	18	8,081.23	950.56	7,115.65	9,903.94
Latin America/Caribbean - China	18	4,074.58	1,269.42	2,532.60	6,499.16
Latin America/Caribbean - North Asia & Pacific	18	18,905.00	1,142.45	17,248.09	20,838.87
Middle East	18	8,397.64	1,188.16	6,862.67	10,258.99
Middle East - North America	18	42,499.25	3,030.02	36,320.08	45,970.11
Middle East - North Asia & Pacific South	18	11,845.04	762.65	10,859.61	13,101.61
Middle East - South West Asia	18	1,739.81	381.24	1,270.80	2,409.43
North America	18	45,685.68	3,595.82	38,460.48	49,675.16
North America - North Asia	18	42,078.86	3,078.92	36,174.46	45,623.25
North America - Pacific South East Asia	18	22,944.42	1,701.44	19,631.97	24,927.24
North America - South America	18	25,726.90	1,915.04	22,095.92	28,148.93
North America - South West Asia	18	9,867.87	662.05	8,552.78	10,624.30
North Asia	18	31,233.17	1,712.58	28,615.19	33,735.89
North Asia - Pacific South East Asia	18	12,381.52	668.63	11,503.85	13,495.41
Pacific South East Asia	18	4,911.13	666.13	4,056.77	6,128.63
South America	18	8,086.58	950.44	7,120.99	9,908.50
South West Asia	18	947.36	252.02	645.96	1,410.81

Table 14: Route Group Real Oil Prices Summary Statistics

LTF RG	Observations	Mean	Standard Deviation	Minimum	Maximum
Africa	18.00	61.59	28.44	22.01	107.93
Africa & Middle East - Central America/Caribbean	18.00	60.35	26.66	22.18	104.49
Africa & Middle East - South America	18.00	61.60	26.98	21.97	103.67
Africa - Asia/Pacific	18.00	61.75	27.81	22.61	105.23
Africa - Middle East	18.00	61.50	25.65	24.09	103.66
Africa - North America	18.00	58.56	26.41	20.78	102.34
Central America/Caribbean	18.00	56.19	30.02	18.55	108.58
Central America/Caribbean - Europe	18.00	57.46	28.41	19.95	106.79
Central America/Caribbean - North America	18.00	56.75	29.87	19.10	108.44
Central America/Caribbean - South America	18.00	59.99	28.93	20.26	106.59
China & South West Asia - North Asia	18.00	63.86	28.85	22.43	110.99
China & South West Asia - Pacific South	18.00	62.75	27.74	24.02	108.07
China – Europe	18.00	60.17	26.27	22.39	106.25
China - Middle East	18.00	62.73	24.54	27.63	101.18
China - North America	18.00	59.54	28.99	20.92	106.13
China/Mongolia	18.00	63.39	28.12	23.41	109.49
Europe	18.00	60.85	25.37	23.66	108.23
Europe - Middle East	18.00	62.29	24.39	25.68	105.51
Europe - North Africa	18.00	60.04	26.02	22.43	107.36
Europe - North America	18.00	59.37	26.41	22.41	108.57
Europe - North Asia	18.00	59.06	26.40	21.76	105.89
Europe - Pacific South East Asia	18.00	60.30	26.38	23.39	104.53
Europe - South America	18.00	61.10	27.42	21.35	104.94
Europe - South West Asia	18.00	63.62	24.25	25.25	105.27
Europe - Sub Saharan Africa	18.00	60.05	27.41	21.75	106.35
Intra Africa	18.00	60.53	27.98	21.61	106.32
Intra Central America/Caribbean	18.00	56.61	30.05	18.87	108.66
Intra China & South West Asia	18.00	67.49	24.55	27.95	109.34
Intra Europe	18.00	60.95	25.33	23.67	107.95
Intra Middle East	18.00	66.55	21.97	32.20	100.35
Intra North America	18.00	57.44	29.20	20.43	108.83
Intra North Asia	18.00	53.42	32.67	16.12	108.5
Intra Pacific South East Asia	18.00	61.09	27.78	24.13	107.1
Intra South America	18.00	65.79	28.01	22.41	108.6
Latin America/Caribbean – China	18.00	60.21	29.66	19.05	106.87
Latin America/Caribbean - North Asia & Pacific	18.00	60.19	28.56	20.70	106.56

Middle East	18.00	66.13	22.73	31.32	100.98
Middle East - North America	18.00	60.48	25.55	25.55	103.11
Middle East - North Asia & Pacific South	18.00	63.70	24.76	29.08	101.6
Middle East - South West Asia	18.00	68.74	22.27	31.66	103.87
North America	18.00	57.38	29.52	20.43	110.4
North America - North Asia	18.00	55.43	30.90	19.28	107.73
North America - Pacific South East Asia	18.00	61.22	27.90	24.43	107.18
North America - South America	18.00	64.59	27.99	22.13	107.84
North America - South West Asia	18.00	71.14	24.86	34.21	106.99
North Asia	18.00	53.60	31.62	16.90	107.77
North Asia - Pacific South East Asia	18.00	60.51	28.05	24.69	105.86
Pacific South East Asia	18.00	60.65	27.99	23.90	106.86
South America	18.00	65.05	27.97	22.11	107.5
South West Asia	18.00	70.03	23.44	30.39	110.08

B.2 Region Summary Statistics for Total International and Domestic RTKs

Table 15: Cargo Model Summary Statistics

Region		Observations	Mean	Standard Deviation	Minimum	Maximum
Africa	**Total International RTKs**	18	2,028.39	407.04	1,390.00	2,907.00
	Total Domestic RTKs	18	81.25	9.34	60.00	102.73
	Real GDP	18	$\$1.44 \times 10^{12}$	3.65×10^{11}	9.58×10^{11}	2.06×10^{12}
	Real Oil	18	58.31	26.52	21.09	101.73
Asia and Pacific	**Total International RTKs**	18	47,014.22	11,712.84	28,871	68,444
	Total Domestic RTKs	18	4,659.40	1,884.12	2,267.00	8,006.80
	Real GDP	18	$\$1.41 \times 10^{13}$	3.34×10^{12}	9.86×10^{12}	2.03×10^{13}
	Real GDP (Domestic Model)	18	$\$1.18 \times 10^{13}$	2.78×10^{12}	8.25×10^{12}	1.70×10^{13}
	Real Oil	18	62.33	25.51	25.28	104.74
Europe	**Total International RTKs**	18	37,295.33	5,724.07	26,430	45,378
	Total Domestic RTKs	18	894.06	129.84	732.00	1,158.59
	Real GDP	18	$\$1.85 \times 10^{13}$	2.14×10^{12}	1.50×10^{13}	2.11×10^{13}
	Real Oil	18	60.22	24.68	23.67	107.93
Latin America/ Caribbean	**Total International RTKs**	18	4,110.61	518.31	3,407	5,459
	Total Domestic RTKs	18	793.75	115.38	593.00	1,097.97
	Real GDP	18	4.28×10^{12}	7.48×10^{11}	3.25×10^{12}	5.64×10^{12}
	Real Oil	18	58.07	28.19	19.74	104.48

Middle East	**Total International RTKs**	18	9,318.89	5,364.62	4,195	20,055
	Total Domestic RTKs	18	92.66	7.98	78.88	101.44
	Real GDP	18	$\$1.64 \times 10^{12}$	3.98×10^{11}	1.11×10^{12}	2.31×10^{12}
	Real Oil	18	65.60	21.81	31.66	98.49
North America	**Total International RTKs**	18	20,454.94	3,772.15	12,492	25,695
	Total Domestic RTKs	18	13,897.61	3,119.41	9,137.00	17,584.94
	Real GDP	18	$\$1.49 \times 10^{13}$	1.87×10^{13}	1.14×10^{13}	1.72×10^{13}
	Real Oil	18	56.49	28.72	20.38	107.73

B.3 Route Group ASK and Region ATK Forecasts

Table 16: Route Group and Global Compounded Annual Growth Rates of Forecasted ASKs

LTF RG	10 Year CAGR	20 Year CAGR	30 Year CAGR
Africa	4.5%	4.4%	4.2%
Africa & Middle East - Central America/Caribbean	4.3%	4.2%	4.2%
Africa & Middle East - South America	2.7%	3.5%	3.8%
Africa - Asia/Pacific	6.2%	5.7%	5.4%
Africa - Middle East	3.9%	4.4%	4.3%
Africa - North America	3.2%	3.0%	3.0%
Central America/Caribbean	3.6%	3.9%	3.9%
Central America/Caribbean – Europe	2.9%	3.1%	2.9%
Central America/Caribbean - North America	3.9%	3.8%	3.5%
Central America/Caribbean - South America	2.3%	3.5%	3.8%
China & South West Asia - North Asia	8.8%	8.1%	7.4%
China & South West Asia - Pacific South East Asia	8.6%	7.7%	7.2%
China - Europe	6.2%	5.5%	4.8%
China - Middle East	8.8%	8.1%	6.9%
China - North America	7.5%	6.4%	5.5%
China/Mongolia	10.3%	8.6%	7.3%
Europe	2.4%	2.3%	2.3%
Europe - Middle East	3.1%	2.8%	2.7%
Europe - North Africa	3.0%	3.2%	3.2%
Europe - North America	2.8%	2.7%	2.6%
Europe - North Asia	2.1%	2.1%	2.0%
Europe - Pacific South East Asia	3.6%	3.8%	3.6%
Europe - South America	2.8%	3.0%	2.9%
Europe - South West Asia	4.0%	4.2%	4.3%
Europe - Sub Saharan Africa	1.9%	2.0%	2.0%
Intra Africa	4.0%	4.0%	3.8%

Intra Central America/Caribbean	3.7%	3.9%	3.9%
Intra China & South West Asia	9.6%	8.3%	7.3%
Intra Europe	1.6%	2.0%	2.1%
Intra Middle East	4.4%	4.4%	4.2%
Intra North America	2.9%	2.7%	2.7%
Intra North Asia	1.5%	1.5%	1.3%
Intra Pacific South East Asia	5.1%	5.1%	5.0%
Intra South America	2.2%	3.2%	3.5%
Latin America/Caribbean - China	7.3%	7.3%	6.4%
Latin America/Caribbean - North Asia & Pacific South East Asia	2.0%	2.4%	2.3%
Middle East	4.6%	4.7%	4.4%
Middle East - North America	4.3%	3.6%	3.4%
Middle East - North Asia & Pacific South East Asia	4.0%	3.6%	3.4%
Middle East - South West Asia	7.9%	8.6%	8.4%
North America	3.1%	2.9%	2.8%
North America - North Asia	2.5%	2.4%	2.4%
North America - Pacific South East Asia	4.1%	4.0%	3.9%
North America - South America	3.8%	3.7%	3.5%
North America - South West Asia	5.0%	4.9%	4.9%
North Asia	1.7%	1.5%	1.3%
North Asia - Pacific South East Asia	3.4%	3.5%	3.4%
Pacific South East Asia	5.1%	5.1%	4.9%
South America	1.9%	3.0%	3.3%
South West Asia	10.1%	9.1%	8.3%
Total	**4.5%**	**4.5%**	**4.3%**

Table 17: Region and Global Compounded Annual Growth Rates of Forecasted Total International ATKs

Region	10 Year CAGR	20 Year CAGR	30 Year CAGR
Africa	1.3%	1.8%	1.8%
Asia and Pacific	5.2%	4.6%	4.2%
Europe	2.8%	2.5%	2.3%
Latin America/Caribbean	3.3%	2.9%	2.8%
Middle East	6.3%	6.9%	6.7%
North America	3.4%	3.2%	3.1%
Total	**4.3%**	**4.2%**	**4.0%**

Table 18: Region and Global Compounded Annual Growth Rates of Forecasted Total Domestic ATKs

Region	10 Year CAGR	20 Year CAGR	30 Year CAGR
Asia and Pacific	8.7%	7.8%	7.0%
Europe	0.1%	0.7%	0.9%
Latin America and Caribbean	1.8%	1.4%	1.3%
North America	0.4%	0.2%	0.2%
Global	3.1%	3.3%	3.4%