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Air transport demand and economic development in sub-Saharan Africa: Direction of causality

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ABSTRACT

Air transport may be a key tool to advance economic development. However, it is uncertain whether air transport boosts economic development, or vice versa. Both views have theoretical and empirical support. In some countries and regions, air transport is important for initiating development, for example by attracting foreign direct investment or granting access to lifelines. Elsewhere, economic development drives air transport demand. Establishing the direction of causality for regions/countries segmented by income level may inform pragmatic policy. This study analyzes the causal relationship between air transport demand and economic development for six sub-Saharan African countries for the period 1981–2018. Vector error correction and vector autoregression models are employed to identify long- and short-run causalities. The results reveal heterogeneous, context-specific causal relationships. In the long-run, for South Africa, Nigeria and Kenya, the direction of causality runs from economic development to air transport demand; for Ethiopia, causality runs in the opposite direction, with increased demand for air transport promoting economic development; and for Senegal and Angola, the relationship is too weak to infer causal directions. Possible explanations for this heterogeneity include differences in per capita income, low-cost carriers' share of national aviation markets, the presence of large home-based airlines, and comparative geographical advantage as a natural hub.

1. Introduction

Previous research has investigated the relationship between air transport demand and economic development (Abate, 2016; Aguirre et al., 2018; Brugnoli et al., 2018; Kasarda and Green, 2005; Njoya and Nikitas, 2020). A strong correlation between the two is well-established, although the identified direction of causality differs (Vijver et al., 2016; Baker et al., 2015; Hakim and Merkert, 2016). Robust empirical evidence on causal direction may indicate key sectors for investment to improve national economic prosperity. Better air connectivity improves access to markets, capital, ideas, and people, and developed economies may also drive demand for air travel. Research is required to determine whether to prioritize investment in air transport infrastructure or in other sectors in order to promote economic development.

Interactions between air transport demand and economic development may indicate correlations and/or causal relationships. As transport infrastructure and service are endogenous to economic activities, correlation between air transport demand and economic development is plausible, but the causal direction requires investigation. Debate remains over whether improved air transport leads to economic development, whether economic growth promotes air transport demand, or whether there are bidirectional (feedback) effects. Each argument has received theoretical and empirical support (Baker et al., 2015; Hakim and Merkert, 2016; Vijver et al., 2016; Chang and Chang, 2009; Mukkala and Tervo, 2013; Lakshmanan, 2011). This study investigates the short-run dynamics and long-run relationships between economic development and air transport demand in sub-Saharan Africa. Air transport services comprise mainly passenger and freight transport, and the interaction of each with economic development is analyzed. The responsiveness of economic development to changes in air transport demand and vice versa is also investigated.

Several empirical studies have examined the causal relationship between economic development and air transport growth (Hu et al., 2015; Aguirre et al., 2018; Baker et al., 2015; Baltaci et al., 2015; Brida et al., 2016; Chi and Baek, 2013; Marazzo et al., 2010). However, many have been conducted in developed economies with mature aviation markets. Whether this evidence holds for low-income regions, like sub-Saharan Africa, where the marginal impacts of transport demand and economic growth may be higher (Profillidis and Botzoris, 2015), remains open to question. This study contributes robust empirical evidence on these causal relationships for sub-Saharan Africa.

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Empirical case-study evidence reveals mixed patterns of interrelationships between air transport demand and economic development, suggesting either unidirectional or bidirectional causality. Hakim and Merkert's (2016) econometric study shows a unidirectional Granger causality from GDP to air passenger traffic and air freight volumes in eight South Asian countries. However, their results are presented overall rather than by country. Van De Vijver et al. (2014) explore the causal relationship between trade and air passenger travel in Asia-Pacific countries. They present their findings using causality scenarios between pairs of countries, rather than comparing conditions in each country. Other country-level studies (Brida et al., 2016; Chang and Chang, 2009; Button and Yuan, 2012; Marazzo et al., 2010; Küçükönal and Sedefoğlu, 2017) provide no explicit comparisons with other countries. This study fills this gap by investigating causal relationships between air transport demand and economic development for each of six sub-Saharan African countries simultaneously, to determine whether the development process is demand-driven or supply-driven in each context. The results enable pragmatic policy suggestions for investments in air transport infrastructure and the overall development of a country or region.

Sub-Saharan Africa has distinct economic structures and air transport connectivity. Compared with other regions, the overall volume of air transport traffic is lower, less dense, more highly regulated, often involves small state-owned flag carriers, and is highly concentrated, with a lack of competition, few hubs and many gateway airports (Abate, 2016; Bofinger, 2017; Pirie, 2014; Njoya, 2016). Given the geography of sub-Saharan Africa, which has 16 land-locked states out of 47 internationally recognized countries and poor land transport infrastructure (Berg et al., 2018; Button et al., 2017), air transport provides the main gateway to international markets. Of the six countries analyzed in this study, only Ethiopia is landlocked. Investigating causal relationships between air transport and economic development is particularly important for this region characterized by poor air connectivity and low economic development.

The study employs supplementary time series analyses to investigate the long-run relationship (cointegration) and Granger causality between air transport demand and economic development for six sub-Saharan African countries (Angola, Ethiopia, Kenya, Nigeria, Senegal and South Africa) for the period 1981 to 2018. These countries were chosen randomly, but with consideration for their geographical location, per capita income and growth in air transport services. In terms of geographical regions recognized by the International Air Transport Association (IATA), Ethiopia and Kenya represent East Africa, South Africa represents Southern Africa, Angola represents Central Africa, and Nigeria and Senegal represent West Africa. The sample countries also represent different income categories in the region (UNDP, 2018; World Bank, 2020), including low income (Senegal, Ethiopia), lower middle income (Angola, Kenya, Nigeria) and upper middle income (South Africa). More importantly, these countries operate notable air transport services in their respective regions and across sub-Saharan Africa.

In the remainder of this paper, Section 2 reviews previous theoretical and empirical literature and describes the case study, Section 3 outlines the research methodology, Section 4 presents and discusses the results of the analyses, and Section 5 draws some conclusions.

2. Theory and literature review

2.1. Theoretical aspects of transport–economy linkages

Transport accessibility and connectivity are crucial in deciding firm location, and hence economic development in a region (Bannò and Redondi, 2014; Saidi and Hammami, 2017). However, the direction of causality between economic development and transport demand is debated.

One theoretical approach to this issue is the microeconomic causal concept, which focuses on improvements to individual firms' productivity (Lakshmanan, 2011; Jara-Díaz, 2007). This approach describes the direct effects, indirect impacts and reductions in external costs resulting from transport improvements. Cost–benefit analysis (CBA) is the favored tool for assessing such benefits. The dominant paradigm for contemporary cost–benefit evaluation employs partial equilibrium as a modeling technique, and economic efficiency as a criterion for assessment (Boardman et al., 2018; Ansar et al., 2016). Travel time and costs can be saved through improved transport, thereby reducing travel distances via network expansion, and congestion via capacity expansion. On the demand side, more trips will be generated at a lower average cost per trip (Goetz and Budd, 2016).

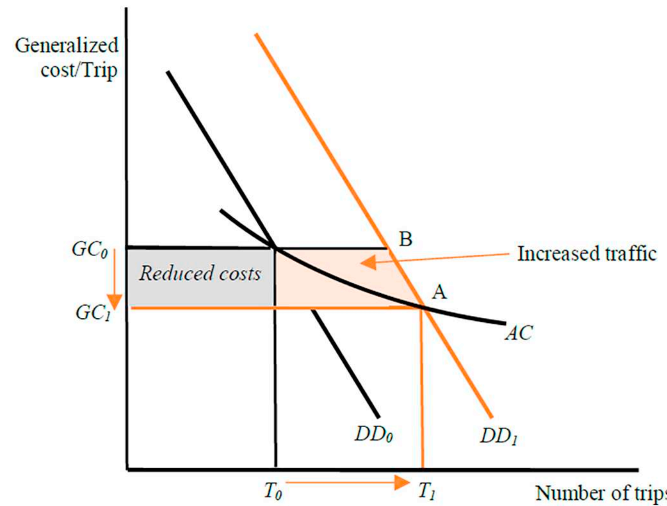


Fig. 1. Transport time and cost savings in CBA analytical framework (*AC*: Average cost).

Factors that increase transportation demand include reduced transport costs, increased income, relocation of industries (or public services) and changes to adjacent transport markets (McCarthy, 2001; Bresson et al., 2003; Prentice and Prokop, 2015). As shown in Fig. 1, when traffic increases, the transport demand curve shifts to the right (from DD_0 to DD_1). This will induce capacity expansion in transport facilities, resulting in economies of scale. Consequently, transport improvements, such as expanded or new airports, increased flights, new routes, expansion of low-cost carriers, new roads and intelligent transportation systems, may reduce the generalized cost per trip (from GC_0 to GC_1) and increase the number of trips (from T_0 to T_1). The justification for and correct timing of a capacity increase can be determined by means of CBA.

Transport improvements benefit society by reducing transport costs for existing users, and by allowing more people and businesses to interact. Reduced transport costs and higher numbers of trips may improve economic efficiency, and may have spillover effects to further strengthen demand for transport. The interaction between transport improvement and economic efficiency will determine the number of trips through a feedback effect. This theoretical argument hints at priority investment areas such as transport and other economic sectors for the well-being of society.

Another approach is the production function approach, which argues that there are externalities to transport improvements that cannot be captured through a microeconomic approach. This approach focuses on economy-wide cost reductions and expansion of outputs relating to transport service improvements. Causal mechanisms linking transport improvements and the economy will be activated by cost and time savings induced by improvements to transport facilities and increased levels of economic output (Ansar et al., 2016; Lakshmanan, 2011).

Demand for transport is a push factor that necessitates transport service improvements. Feasibility analysis of investments in transport infrastructure considers both actual and potential traffic. As shown in Fig. 2, improved transport may provide users with cost savings and increase economic output (Dimitrios and Maria, 2018). Improved transport services shift the marginal cost curve downward (MC_1),

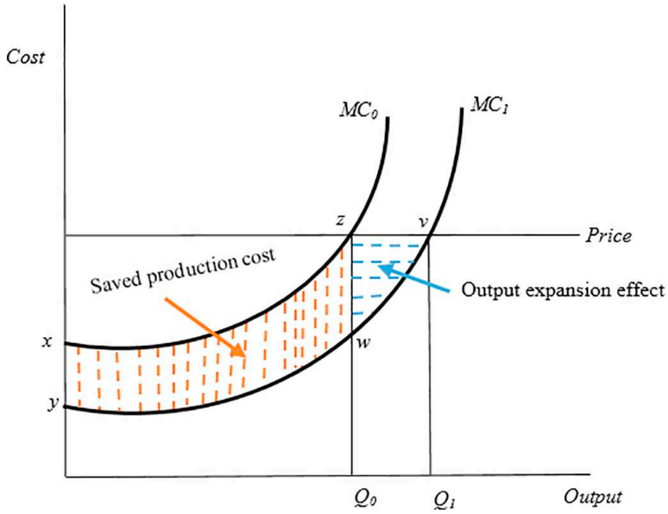


Fig. 2. Transport improvement and efficiency of production.
(MC_0: marginal cost before transport improvement; MC_1: marginal cost after transport improvement)

resulting in output expansion (Q_1 to Q_0). The aggregate consequences may be economies of scale, more competitive markets, innovation and spatial agglomeration economies (Rogoff and Obstfeld, 1996; Carlsson et al., 2013), which in turn trigger greater demand for transport. The general equilibrium of transport–economy linkages determines the magnitude and direction of impacts (Bröcker and Mercenier, 2011). Thus, according to Rodrigue et al. (2016), there should be positive feedback effects (a "virtuous circle") between transport demand and economic activities.

Evidently, economic growth influences travel demand: as people get richer, they travel more frequently and longer distances, and demand for transport services reflects their willingness and ability to pay. Production and demand for infrastructure services may rise, but the nature of the demand will depend on which industry sectors grow most. For example, growth in manufacturing or in services will affect demand for transport differently (Ecola and Wachs, 2012). This demand depends on income levels and costs of services, so its elasticity will vary across countries. The causal relationship between economic development and demand for transport also varies across regions and countries (Brida et al., 2016; Aguirre et al., 2018; Maparu and Mazumder, 2017; Baker et al., 2015). This paper investigates causal relationships between the two in sub-Saharan Africa.

2.2. Air transport demand and economic development: empirical review

Several studies have investigated the causal relationship between air transport demand and economic development, although few have examined sub-Saharan Africa. They show that this causal relationship varies across regions and changes over time, with evidence for both unidirectional and bidirectional causality. The relationship differs for remote versus core regions (see Table 1). For instance, Mukkala and Tervo's (2013) study concludes that in Europe, the causal relationship between regional growth and airport activity is bidirectional in remote regions and unidirectional (from regional growth to airport) in core regions. As previously noted, the causal relationship may also differ between developed and less developed economies. Van De Vijver et al. (2014) deduce a highly heterogeneous relationship between air traffic and trade in the Asia-Pacific region, with no causal relationship for developed economies, and unidirectional causality for less developed economies and countries adopting liberal air transport policies. This study investigates whether these conclusions hold for sub-Saharan African countries.

Previous studies' diverse findings may also be attributable to the different types of data and methodological approaches employed in the case studies. For instance, Chi and Baek (2013) use time series and Button and Yuan (2012) use panel data for the United States, and while the former find long-run unidirectional causality from economic growth to air transport demand, the latter identify unidirectional causality from airfreight transport to economic development. Studies in Taiwan (Chang and Chang, 2009) and Mexico (Aguirre et al., 2018), using similar annual time series data and employing vector error correction models, find a bidirectional causal relationship between economic growth and air transport expansion. However, studies in Europe (Mukkala and Tervo, 2013; Van De Vijver et al., 2016), using similar annual panel data but different estimation techniques (Granger non-causality and heterogeneous Granger causality, respectively) reach the similar conclusion that remoteness matters in the causal process. In view of these differences, this study employs vector error correction (VEC) and vector autoregression (VAR) methods.

2.3. Case description

In this study, six sub-Saharan Africa countries are examined to reveal both features common to the region and disparities between countries in the region. Nigeria, South Africa and Angola have the largest economies in sub-Saharan Africa (World Bank, 2020; UNDP, 2018), whereas Senegal and Ethiopia are amongst the lowest-income countries in the region. For instance, the World Bank (2020) indicates that South Africa's per capita GDP was about $7000 in 2019, four times higher than the average for sub-Saharan Africa ($1800), while for Ethiopia and Senegal the figures were around $1300 and $800, respectively. Fig. 3 shows comparative data on per capita GDP for the six sample countries.

These disparities in per capita GDP are paralleled by disparities in these countries' aviation markets, as measured by indicators such as passenger traffic, freight volume, numbers of domestic and international destinations, levels of aviation liberalization, available seats and frequency of flights. In 2018, the top three countries in terms of passenger traffic in sub-Saharan Africa were South Africa, Ethiopia and Nigeria (see Fig. 4). The composition of total traffic (domestic and international) in each country also differs. For instance, in South Africa, domestic passengers represent about 68% of total air passenger traffic (ACSA, 2018), whereas in Ethiopia about 12% are domestic passengers (EAE, 2018).

Recently, Ethiopia has become connected with more international destinations than other sub-Saharan African countries, followed by South Africa and Kenya (see Fig. 5). While international destinations from Ethiopia have increased by 49.4%, South Africa has experienced a decline of 14.7% in international routes over the last decade. This may be partly because Ethiopia occupies a strategic geographical location, serving as an important gateway to sub-Saharan Africa (ForwardKeys, 2018), whereas South Africa is located at the southern edge of the continent, with less comparative advantage as a natural hub. The rise of Ethiopian Airlines as a dominant airline group in the region may be another factor. Kenya was a fast-growing country in terms of air connectivity at the beginning of the decade but experienced slow growth thereafter. Connectivity has been improving for Nigeria and Angola, but Senegal remains amongst the least connected countries in the region.

Thus, in general, the sub-Saharan countries considered in this study have different economic and aviation market experiences, particularly in terms of economic development and aviation market participation in the region. The empirical results of this study may hold for other sub-Saharan African countries with similar features. The following hypotheses are proposed based on the literature and case study reviews:

H_1. : The long-run causal direction runs from air transport demand to economic development for low-income countries (Ethiopia, Senegal).

H_2. : The long-run causal direction runs from economic development to air transport demand for middle-income countries (Angola, Kenya, Nigeria, South Africa).

Table 1
Empirical literature - causal relationship between air transport and economic development.

Source	Country/region	Major finding
Chang and Chang (2009)	Taiwan (1974–2006)	Long-run bidirectional causality between air cargo expansion and economic growth.
Marazzo et al. (2010)	Brazil (1966–2006)	Unidirectional Granger causality from GDP to air passenger traffic.
Button and Yuan (2012)	US (1990–2009)	Unidirectional causality from airfreight transport to local economic development.
Chi and Baek (2013)	US (1996–2011)	Long-run unidirectional causality from economic growth to air passenger and freight service. Short-run unidirectional causality from economic growth to air passenger traffic.
Mukkala and Tervo (2013)	Europe (1991–2010)	Remoteness matters in the causality process: ● In remote regions, bidirectional causality between regional growth and airport activity ● In core regions, unidirectional causality from regional growth to airport activity.
Van De Vijver et al. (2014)	Asia-Pacific (1980–2010)	Highly heterogeneous causal relationships: ● No causal relationship between air traffic and trade for connections between “developed economies” ● Causality from air traffic to trade for connections between “developed and less developed” countries ● Causality from trade to air traffic for countries that have long adopted liberal air transport policies.
Hu et al. (2015)	China (2006–2012)	Long-run bidirectional Granger causality between domestic air passenger traffic and GDP. Short-run unidirectional Granger causality from domestic air passenger traffic to economic growth.
Baker et al. (2015)	Australia (1985–2011)	Bidirectional causality between regional air transport and economic growth.
Hakim and Merkert (2016)	South Asia (1973–2014)	Long-run unidirectional Granger causality from GDP to air passenger traffic and cargo volumes.
Brida et al. (2016)	Italy (1971–2012)	Long-run unidirectional causality from air transport demand to economic development (GDP).
Van De Vijver et al. (2016)	Europe (2002 – 2011)	Geographically heterogeneous causality patterns between air transport and employment.
Küçükönal and Sedefoğlu (2017)	OECD countries (2000 – 2013)	Short-run unidirectional causality from economic growth, tourism and employment to air transport demand.
Hakim and Merkert (2019)	South Asia (1973–2015)	Long-run unidirectional causality from economic growth to air traffic.
Aguirre et al. (2018)	Mexico (1995–2013)	Bidirectional causality between economic growth and air transport expansion.

H_3. : Elasticities in the interaction between economic development and air transport demand are higher for low-income countries.

H_4. : Air passenger demand is more strongly affected by changes in economic development than in demand for airfreight volumes.

3. Data and methodology

Traditional static correlation and cross-sectional regression models provide limited evidence on causality. However, time series methods involving concepts such as cointegration and Granger causality have emerged to enable investigation of causal relationships between specific variables (Maparu and Mazumder, 2017). A series of these methods are employed in this study.

An important aspect of transport demand is that it is a derived demand—demand for transport stems from factors other than the transport itself. In other words, demand for most things is affected by prices on other markets. Specific to transport demand is the fact that consumption of transport services does not generate utility in itself. Accordingly, factors expected to create and influence air transport demand are identified and included in the model. Table 2 lists these variables with their units of measurements and sources of data. These are transformed into natural logarithms to smooth out large standard deviations across the samples. Parameters estimated from natural logarithm models can also be interpreted as elasticities.

Population (POP) and *education index (EDUC): POP* represents the total population size of a country. In principle, countries/regions with higher populations may have greater air transport demand, ceteris paribus. This reflects not just population trends over time, but also the old-age dependency ratio. According to IATA (2016), younger and working-age populations are typically more likely to fly than older populations. Furthermore, nations with better literacy rates (*EDUC*) will have more involvement in national and international business, for which air transport is a key means of timely travel.

Gross domestic product per capita *(GDP)* and *foreign direct investment (FDI)*: per capita *GDP* approximates national wealth, and *FDI* represents foreign investors' participation in domestic economic activities. According to IATA (2016), countries on a growth curve up to

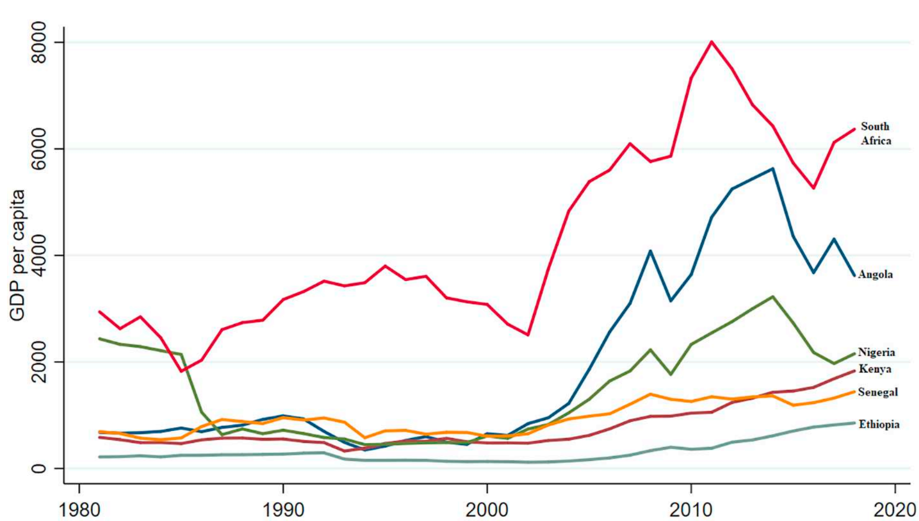


Fig. 3. GDP per capita for selected sub-Saharan African countries (1981–2018).

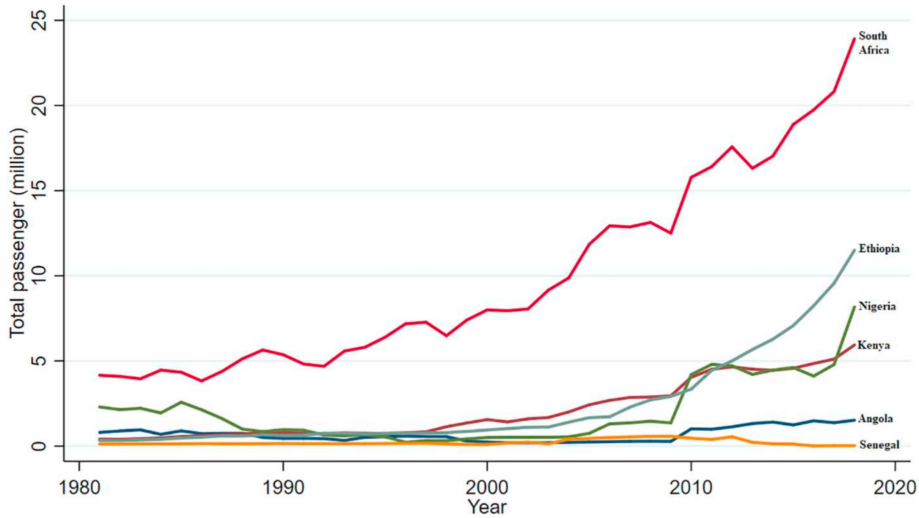


Fig. 4. Trends in total passengers in the sample countries (1981–2018).

approximately $20,000 per capita experience correspondingly faster increases in the number of flights taken per person per year. In countries with developed low-cost carrier services, demand for air travel continues to increase substantially when GDP per capita reaches around $5000 to $10,000 per annum (JADC, 2019). With regard to FDI, improving air transport capacity through investment and strategies to attract both traditional and low-cost airlines is critical to regional policies aiming to attract FDI (Bannò and Redondi, 2014).

Balance of payments (BoP) and *official exchange rate (OER)*: *BoP* is the record of international trade and financial transactions made by a country's residents (Mankiw, 2019). In the long run, a country with negative BoP is a net consumer, and goes into debt to pay for consumption rather than investing in future growth, whereas a country with surplus BoP enables greater spending on investment and less on consumption (Rogoff and Obstfeld, 1996). Net economic growth may nurture demand for travel. With regard to *OER*, large movements in

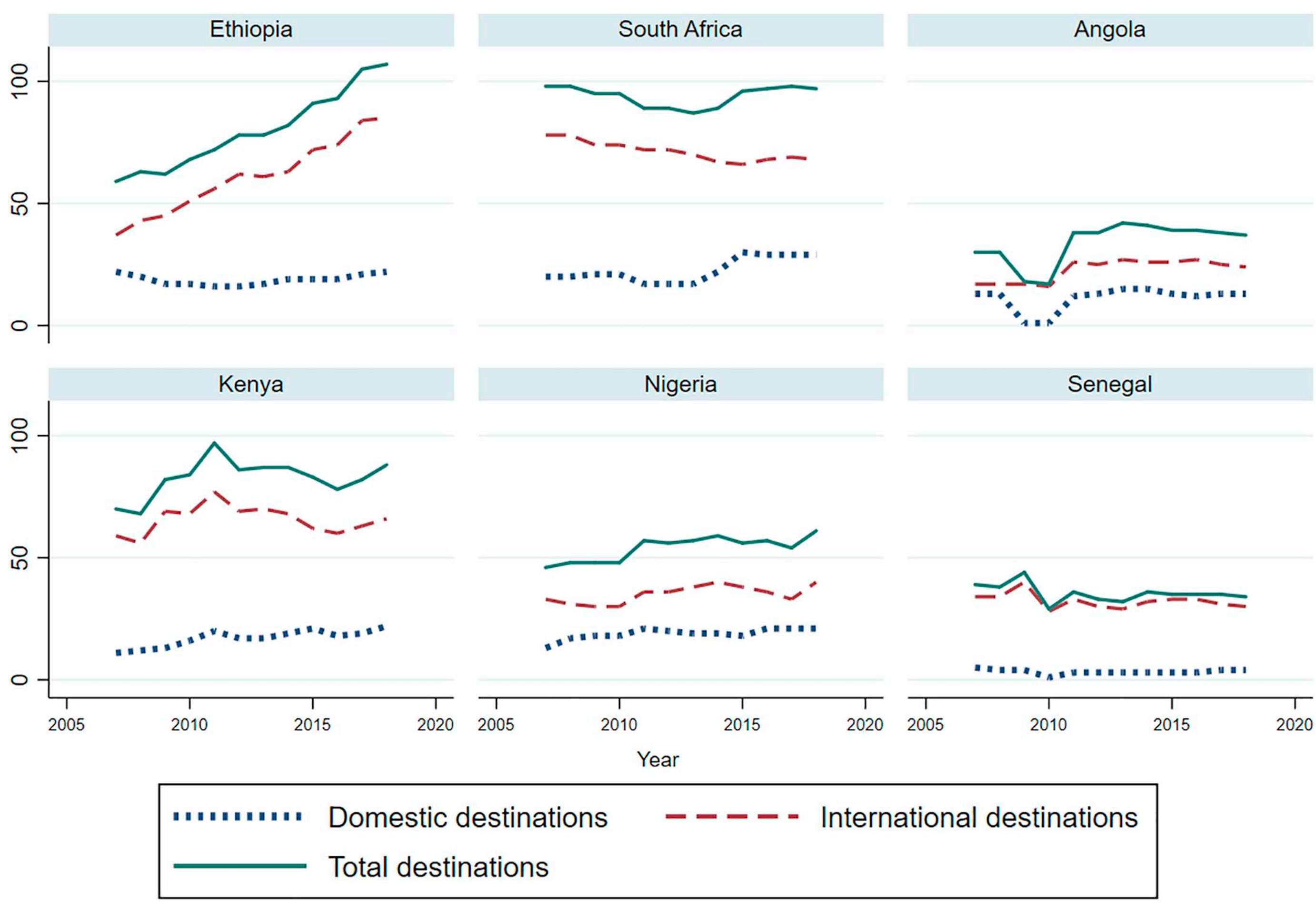


Fig. 5. Trends in total, international and domestic destinations (2007–2018).

Table 2
Lists of variables and their units of measurements.

Variable	Name	Units of measurement	Data source
Population	*POP*	Total number of population	UNDP
Education index	*EDUC*	Measured by combining average adult years of schooling with expected years of schooling for children	UNESCO, UNDP
GDP per capita	*GDP*	GDP per capita in US dollars	IMF, UNDP
Foreign direct investment	*FDI*	FDI in US dollars	UNCTAD
Balance of payments	*BoP*	BoP in US dollars	UNCTAD
Official exchange rate	*OER*	Exchange rate of local currency to US Dollars	UNCTAD, IMF
Number of tourists	*TRT*	International tourist arrivals (0000)	UNWTO, World Bank
Passenger number	*PAX*	Number of air passengers in millions	ICAO Data +
Cargo volumes	*FRT*	Air freight in million km-tons	ICAO Data +

exchange rates affect airlines through three main channels (IATA Economics, 2015): consumer decisions (demand), airline decisions (supply) and financial impacts. Of these, the consumer (demand) response to significant moves in relative prices may be swift, and may prompt a response from airlines, including adjustments to capacity (supply).

Number of tourists (TRT) is the number of international tourist arrivals. Air transport is a main means of tourist transport, and tourism is a driving factor and enabler of developments in air transport (Spasojevic et al., 2017). Moreover, destination accessibility is an incentive for tourists. Air transport has made traveling more accessible and convenient (Pisa, 2018), and in turn, tourism has become more commercialized, with important direct, indirect and induced effects on other sectors.

Passenger traffic (PAX) and *cargo volumes (FRT)* are the variables of interest in this study. *PAX* is the total number of air passengers embarking and disembarking using scheduled flights at airports in the countries examined, and *FRT* is the tonnage of cargo transported. This study investigates the causal relationship between air transport demand (*PAX* and *FRT*) and the sample countries' economic development.

Long- and short-run relationships between air transport demand and economic development can be modeled with the following general cointegration equation.

$$\Delta y_t = \varnothing + \delta y_{t-1} + \sum_{i=1}^{k} \alpha_t \Delta y_{t-i} + x_t{'}\beta + \epsilon_t \tag{1}$$

where Δy_t is a vector of endogenous variables (*GDP*, *PAX* and *FRT*), $\varnothing$ is the constant to be estimated, δy_{t-1} is a vector of the error-correction term, $\sum_{i=1}^{k} \alpha_t \Delta y_{t-i}$ is a vector of the short-run dynamics of endogenous variables, $x_t{'}\beta$ is a vector of the control variables (*TRT*, *OER*, *BoP*, *FDI*, *EDUC* and *LF*), ϵ_t is a white noise error term with zero mean and constant variance, and k is the maximum lag length. Detailed model expressions of the endogenous variables are given in Eqs. (3) to (6).

3.1. Order of integration

Before running cointegration and Granger causality tests, it is essential to know whether the data generating process (DGP) for the variables is stationary, which decides the order of integration. In a stationary stochastic process, the mean and variance are constant over time, and the auto-covariance is constant for each lag between two time periods and is not dependent on the actual time at which the covariance is computed (Shin, 2017). A non-stationary series can be transformed into a stationary series by differencing d times, denoted by $I(d)$ (Pickup, 2015; Wooldridge, 2016; Enders, 2014). The augmented Dickey-Fuller (ADF) test is a popular technique for testing the order of integration of the variables. ADF regulates the problem of serial correlation by including additional lags, and tests the following equation:

$$\Delta y_t = x_t{'}\beta + \delta y_{t-1} + \sum_{i=1}^{k} \alpha_t \Delta y_{t-i} + \epsilon_t \tag{2}$$

where β, δ, and α are parameters to be estimated, and Δ is a difference operator. The null hypothesis H_0: $\delta = 0$ is tested against the alternative hypothesis H_1: $\delta < 0$. If the null hypothesis is rejected, the series is stationary, and if it is true, the series has a unit root and is non-stationary.

3.2. Cointegration

Time series x_t and y_t are said to be cointegrated if both series are integrated to order d and their linear combination is stationary $I(0)$ (Shin, 2017; Enders, 2014; Barnett and Seth, 2014). Theoretically, this means that a long-run equilibrium links the variables, implying that although temporal shocks may drive them apart, they return to their common path in the long run.

This study employs Johansen's (1991, 1995) cointegration approach. This introduces maximum likelihood tests (maximum eigenvalue and trace tests) to check the hypothesis of a maximum number of cointegration vectors. The null hypothesis of no integration is tested against the alternative hypothesis of cointegration between the variables. When two variables with the same order of integration present a long-run relationship, they are said to be cointegrated.

3.3. Granger causality

In Granger causality tests (Granger, 1969), variable y is said to be Granger-causal to variable x if lagged values of y can improve the predictability of x, ceteris paribus. A causal relationship may be unidirectional, bidirectional (feedback), or absent. Bidirectional causality exists between x and y if the coefficients of the lagged x_t and y_t are statistically different from zero when either of the variables is modeled as the dependent variable and the other as the independent variable (Enders, 2014; Wooldridge, 2016). Similarly, there is unidirectional causality from y to x if the coefficients of the lagged y_t are statistically different from zero when x_t is the dependent variable and not when y_t is the dependent variable. If neither the coefficient of the lagged y_t nor that of the lagged x_t is statistically different from zero, there is no causal relationship between the variables.

The integration order and cointegration tests determine whether to use VAR or VEC to test Granger causality between air transport demand and economic development. Air transport demand may be explained by *PAX* and *FRT*. Here, to avoid multicollinearity problems, *PAX* and *FRT* are not modeled as dependent and independent variables in the same equation, and the subsequent matrices are arranged accordingly.

The following matrix shows the VAR model testing for a Granger causal relationship between *GDP* per capita and *PAX*.[1]

$$\begin{bmatrix} lnPAX_t \\ lnGDP_t \end{bmatrix} = \begin{bmatrix} \beta_1 \\ \beta_2 \end{bmatrix} + \sum_{k=1}^{n} \begin{bmatrix} \beta_{11k} & \beta_{12k} \\ \beta_{21k} & \beta_{22k} \end{bmatrix} \begin{bmatrix} lnPAX_{t-k} \\ lnGDP_{t-k} \end{bmatrix} + x_t{'}\mu + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \tag{3}$$

Similarly, the causal relationship between *GDP* per capita and *FRT* can be represented as:

[1] Relevant estimation results for the control variables are available on request from the corresponding author.

$$\begin{bmatrix} lnFRT_t \\ lnGDP_t \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} + \sum_{k=1}^{n} \begin{bmatrix} \alpha_{11k} & \alpha_{12k} \\ \alpha_{21k} & \alpha_{22k} \end{bmatrix} \begin{bmatrix} lnFRT_{t-k} \\ lnGDP_{t-k} \end{bmatrix} + x_t'\mu + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \tag{4}$$

where *β's*, *μ* and *α's* are coefficients to be estimated, *n* is the maximum lag length, x_t' is a transposed vector of control variables (*TRT*, *OER*, *BoP*, *FDI*, *EDUC* and *LF*) and ϵ_t represents the white noise error term. When the coefficients on the lagged variables are statistically different from zero, there is a causal relationship between the variables.

If air transport demand and economic development are cointegrated, VEC is used rather than VAR to investigate the causal relationship; otherwise, VAR, as the standard causality test, is used. The advantage of the VEC model over VAR is that it can distinguish between long- and short-run causality (Kirchgassner et al., 2013; Maparu and Mazumder, 2017). Eq. 5 shows the VEC model to test the causal relationship between *PAX* and *GDP* per capita.

$$\begin{bmatrix} \Delta lnPAX_t \\ \Delta lnGDP_t \end{bmatrix} = \begin{bmatrix} \theta_1 \\ \theta_2 \end{bmatrix} + \sum_{k=1}^{n} \begin{bmatrix} \theta_{11k} & \theta_{12k} \\ \theta_{21k} & \theta_{22k} \end{bmatrix} \begin{bmatrix} \Delta lnPAX_{t-k} \\ \Delta lnGDP_{t-k} \end{bmatrix} + \begin{bmatrix} \delta_1 \\ \delta_2 \end{bmatrix} ECT_{t-1} + x_t'\mu + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \tag{5}$$

Similarly, the VEC model to test the causal relationship between *FRT* and economic development is represented in eq. 6.

$$\begin{bmatrix} \Delta lnFRT_t \\ \Delta lnGDP_t \end{bmatrix} = \begin{bmatrix} \sigma_1 \\ \sigma_2 \end{bmatrix} + \sum_{k=1}^{n} \begin{bmatrix} \sigma_{11k} & \sigma_{12k} \\ \sigma_{21k} & \sigma_{22k} \end{bmatrix} \begin{bmatrix} \Delta lnFRT_{t-k} \\ \Delta lnGDP_{t-k} \end{bmatrix} + \begin{bmatrix} \varnothing_1 \\ \varnothing_2 \end{bmatrix} ECT_{t-1} + x_t'\mu + \begin{bmatrix} \epsilon_{1t} \\ \epsilon_{2t} \end{bmatrix} \tag{6}$$

where *σ*'s and *θ*'s are parameters to be estimated, and ECT_{t-1} is the lagged error correction term (computed from the residuals of the linear combination of the variables) indicating a long-run relationship between air transport demand and economic development. Short-run causality is estimated by the coefficients of the lagged (and differenced) independent variables, whereas a long-run causal relationship is said to exist when the speed of adjustments (δ and $\varnothing$) is negative and statistically different from zero.[2] The absolute values of speed adjustments indicate how quickly equilibrium is restored or a new long-run equilibrium is reached.

4. Results and discussion

Correlation between air traffic and economic development is well established, although its strength varies with the scale and accessibility of air transport. Fig. 6 shows the linear relationships between *GDP* per capita and *PAX* for the six sample countries.

PAX and *GDP* per capita exhibit strong correlation coefficients in countries such as Kenya, Ethiopia and South Africa, which have better air connectivity, whereas this correlation is relatively weak in Senegal and Angola and intermediate in Nigeria. The empirical findings (see Tables 5 to 7 and Appendix B) also support this argument. Linear relationships between *GDP* per capita and *PAX* may not guarantee the existence of causation; in fact, available infrastructure and airlines are part of the country's economy, and their development and profitability should strengthen national economic development. Moreover, economic development must complement the dynamic nature of air transport. The next sub-sections present the empirical results for causal relationships between the variables.

[2] $(-1 \le \varnothing \le 0)$ and $(-1 \le \delta \le 0)$ for the system to be converging to the equilibrium.

4.1. Order of integration and cointegration

Analysis of time series data commonly starts with checking for the stationarity of individual variables and the combined linearity (cointegration) of all variables in VEC/VAR modeling frameworks. The ADF test was used to determine the order of integration, and the results are shown in Table 3. The integration of some variables varies between countries. However, the variables of interest (*PAX*, *FRT* and *GDP*) are integrated at first difference. The variables integrated at level (without a difference) cannot be cointegrated with first-order integrated variables (Enders, 2014; Johansen, 1991). Hence, cointegration tests for variables at the same, first-order level of integration, *I*(1).

Johansen cointegration testing techniques (trace and maximum eigenvalues) were used to test for the presence of cointegration. The results are presented in Table 4. The cointegration order is equal to one if each of the original variables is *I*(1), which indicates a linear combination of variables that are stationary. The series are cointegrated at the 95% confidence level, and the two tests exhibit a single cointegration equation, meaning the series are related and can be combined linearly. This implies that even if there are shocks in the short run, which may affect movement in individual series, they would converge over time (in the long run). *PAX* and *FRT* series have one cointegrating equation, thereby demonstrating a long-run relationship with GDP across the sample countries.

4.2. Long-run relationships

Cointegrated variables were tested for Granger causality in the VEC framework, in which negative and statistically significant lagged error correction terms indicate long-run causal relationships. The results for the long-run relationship between air transport demand and economic development show heterogeneous causal directions for the sample countries. For South Africa, Nigeria and Kenya, the causal direction is unidirectional, from *GDP* per capita to *PAX*. This implies that direct investment in industries other than aviation might better promote economic development, and thus increase air transport demand. This view corresponds with previous empirical findings (Chi and Baek, 2013; Hakim and Merkert, 2019; Marazzo et al., 2010). Moreover, the speed of adjustment (ECT_{t-1}) is shorter for Kenya than for South Africa and Nigeria, implying that a marginal impact of economic development on air transport demand would be swiftly observed in Kenya. Table 5 presents the results of VEC analysis.

The empirical findings from Ethiopia indicate a long-run relationship between air transport demand and economic development, with a causal direction from *PAX* to *GDP* per capita. Hence, investing in air transport may lead to economic development. This observation corresponds with previous findings that passenger traffic (Brida et al., 2016) and freight transport (Button and Yuan, 2012) positively drive economic development. Therefore, air transport demand and complementary infrastructure may be considered as tools for economic growth in Ethiopia. In contrast, Table 5 shows that in Senegal and Angola, although economic development and air transport demand may be positively correlated (see Fig. 6), the relationship between air traffic and economic development is too weak to determine any causal direction. Fig. 4 also reveals that upward trends in air transport traffic in Senegal and Angola are lower than in other countries in this study.

The long-run elasticity between economic development and air transport demand varies between countries (see Table 6). Furthermore, the long-run model shows that the coefficient of airfreight services is less elastic than that of air passenger demand; that is, air passenger demand is more strongly affected by changes in economic development than in airfreight volumes. For instance, if GDP per capita increases by 1% in South Africa, passenger demand and airfreight volume will grow by 0.6% and 0.46% respectively. This seems to show that airfreight is often driven by the value rather than the weight of a commodity, and that airfreight transport is more often used for time-sensitive

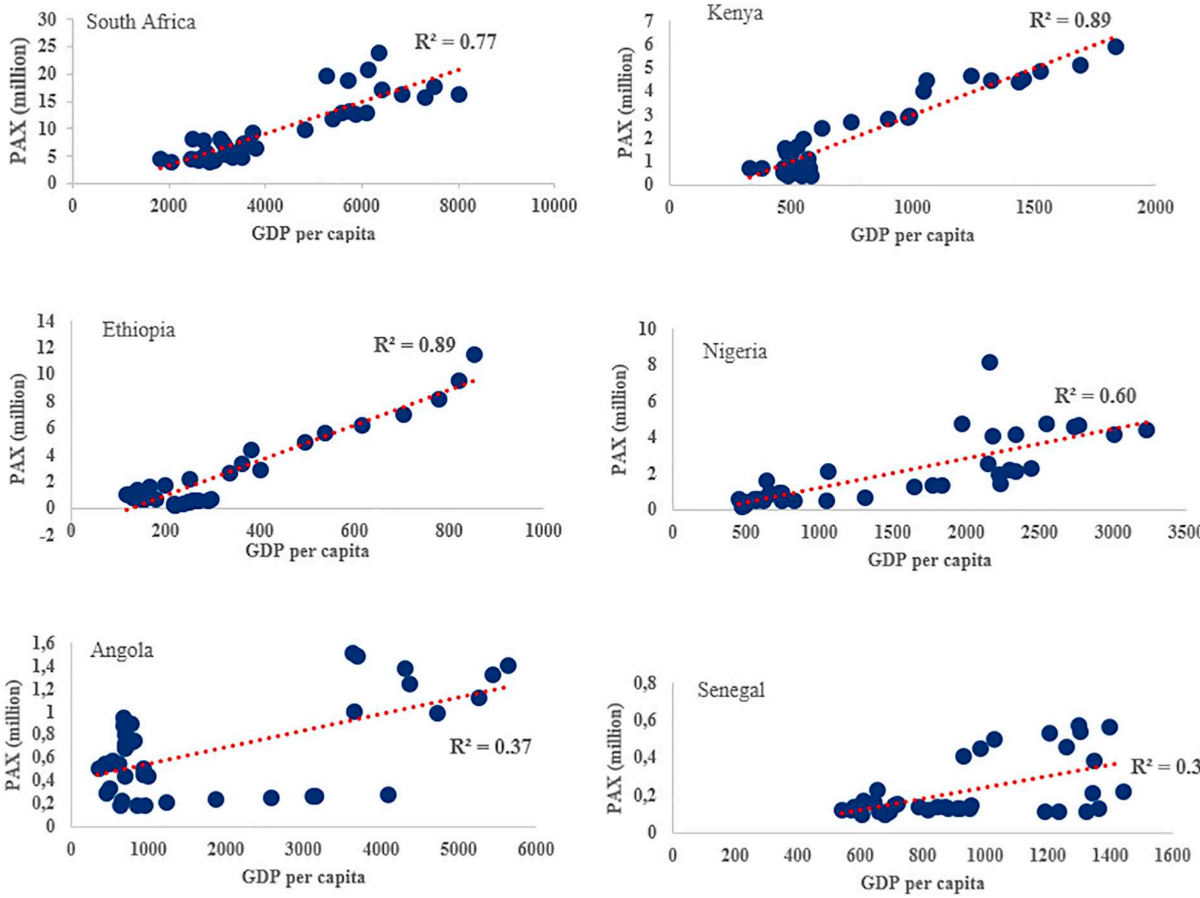


Fig. 6. Linear relationship between PAX and GDP per capita.

commodities than for airfare-sensitive products. Hakim and Merkert (2019) similarly conclude that passenger demand is more elastic than airfreight volume to changes in per capita income. Nigeria and Kenya reveal similar elasticity trends to South Africa, except for the magnitude of the coefficients. For Angola, as stated earlier, there is no causal relationship between air transport demand and economic development, but economic development has a positive marginal effect on improved air traffic demand. Similarly, the causal relationship between air transport demand and economic development for Senegal is statistically insignificant, but there is a positive correlation between air transport traffic and economic development. Senegal is amongst low-income countries and has less developed air transport infrastructure in sub-Saharan Africa.

In Ethiopia, economic growth is more strongly affected by changes in air passenger traffic than in airfreight volume, with elasticities of GDP per capita of 0.80% and 0.27% for unit changes in air passenger demand and airfreight volume, respectively. Brida et al. (2016) also indicate that economic growth in Italy is more strongly affected by changes in air passenger demand than by airfreight volumes. Similarly, marginal changes in the interaction between air passenger demand and economic development are larger for Ethiopia than for South Africa, Nigeria or Kenya. Economic development is lower in Ethiopia (see Fig. 3), and air transport makes a marginal contribution to economic growth. Bourguignon and Darpeix (2016) similarly argue that the effect of economic activity on air traffic does not differ significantly between developing and developed countries, but that the GDP-elasticity of air traffic seems to be higher for developing economies.

Moreover, per capita GDP has a positive long-run relationship with both airfreight services and air passengers, suggesting that, as for other goods and services, an increase in per capita GDP leads to an increase in air transport demand. Increases in passenger traffic and airfreight volume also contribute to economic development. In terms of magnitude, the empirical results indicate that long-run effects lead to proportionately larger growth rates than in the short-run scenario (see Appendix B), because long-run effects encompass spillover and multiplier effects in addition to direct effects.

In general, the long-run causal relationship between air transport demand and economic development is quite heterogeneous and varies between countries. However, the two variables are positively correlated and have appreciable effects on each other. These results partially fail to substantiate hypotheses H1 and H2, but do substantiate hypotheses H3 and H4. The first hypothesis, of a long-run unidirectional causality from air transport demand to economic development for low-income countries, is satisfied for Ethiopia but is not empirically supported for Senegal. The second hypothesis, of a unidirectional causality from economic development to air transport demand for middle-income countries, is supported for South Africa, Kenya and Nigeria, but not for Angola. This implies that the strength of relationships and directions of causalities may vary with countries' levels of economic development and growth in air transport services.

4.3. Short-run relationships

The short-run causal relationship between economic development and air transport demand is a temporary interaction, but may be transformed into a long-run relationship based on sustainability and consistency with public policy. Short-run causality accounts for occasional travelers and is not consistent over a long period; it may reasonably depend on current economic activities.

Bidirectional short-run causality is found between economic development and air passenger demand in South Africa. Air transport is a basic input into service processes, and hence its increase should boost

Table 3
Results of ADF test.

		lnPAX	*lnFRT*	*lnGDP*	*lnTRT*	*EDUC*	*lnPOP*	*lnOER*	*BoP*	*lnFDI*
Angola	Intercept	-0.939	-2.698	-0.350	-0.780	3.669	0.793	-1.002	-5.22**	-3.92**
	+ trend	-1.053	-4.657*	-1.409	-1.317	-1.152	-0.395	-0.216	-5.39**	-3.975*
	Without	0.318	0.220	1.303	1.921	3.372	5.15**	-2.176	-5.09**	-3.99**
Ethiopia	Intercept	2.847	0.483	0.857	-0.894	1.398	-6.09**	0.223	-0.670	-1.638
	+ trend	0.078	-0.607	-0.275	-2.709	-1.759	0.708	-2.022	-1.903	-3.087
	Without	2.617	3.92*	1.718	1.014	4.87**	6.35**	3.39**	-0.124	0.791
Kenya	Intercept	0.079	-1.371	0.948	-1.392	0.514	-19.6**	-2.792	-0.717	-0.326
	+ trend	-1.848	-1.549	-1.440	-2.463	-1.565	-8.12**	-1.458	-2.069	-0.976
	Without	4.88**	2.463	1.766	0.907	5.82**	36.0**	2.69*	0.042	-2.554
Nigeria	Intercept	-0.178	-2.388	-0.985	-1.157	-0.116	3.28*	-1.589	-2.242	-1.532
	+ trend	-0.993	-2.406	-1.978	-2.241	-2.610	0.937	-1.217	-2.244	-1.448
	Without	0.632	-0.660	-0.193	1.054	1.955	3.215*	1.985	-1.849	-0.857
Senegal	Intercept	-1.151	-0.700	-0.863	-0.536	1.830	-2.688	-2.021	-0.017	-2.015
	+ trend	-1.019	-2.588	-1.944	-2.520	-1.590	-1.515	-2.053	-1.725	0.298
	Without	-0.607	-1.358	0.919	2.76**	5.78**	6.31**	0.691	0.850	1.139
South Africa	Intercept	0.578	-1.039	-0.764	-1.804	-0.780	-11.3**	-1.577	-1.199	-3.26*
	+ trend	-3.129	-1.299	-2.335	-0.752	-1.973	-4.37**	-2.188	-2.859	-4.95**
	Without	3.294	0.669	0.921	3.14**	2.49*	20.18**	1.352	-0.780	-2.192

		Δ*lnPAX*	Δ*lnFRT*	Δ*lnGDP*	Δ*lnTRT*	Δ*EDUC*	Δ*lnPOP*	Δ*lnOER*	Δ*BoP*	Δ*FDI*
Angola	Intercept	-6.00**	-9.55**	-4.14**	-4.69**	-3.73**	-0.625	-1.971	-9.12**	-6.08**
	+ trend	-6.35**	-9.43**	-4.065*	-4.64**	-5.37**	-0.569	-2.048	-8.98**	-6.04**
	Without	-6.07**	-9.51**	-4.05**	-4.36**	-2.41*	-1.122	-1.627	-9.25**	-6.16**
Ethiopia	Intercept	-4.53**	-4.21**	-3.69**	-6.17**	-2.773	-0.506	-4.29**	-5.24**	-5.91**
	+ trend	-5.32**	-4.23*	–4.07*	-6.08**	-2.802	-3.64*	-4.26**	-5.25**	-5.81**
	Without	-2.31*	-3.41**	3.57**	-6.01**	-2.16*	-0.353	-3.37**	-5.21**	-5.58**
Kenya	Intercept	-4.59**	-5.03**	-4.77**	-6.19**	-5.81**	-2.404	-5.14**	-6.07**	-8.86**
	+ trend	-4.53**	-5.01**	-5.22**	-6.09**	-5.83**	-1.237	-5.63**	-6.07**	-8.99**
	Without	-3.02**	-4.43**	-4.48**	-6.13**	-3.49**	-8.91**	-4.35**	-5.99**	-8.71**
Nigeria	Intercept	-5.07**	-7.27**	-4.31**	-4.60**	-6.67**	-0.989	-5.08**	-5.00**	-7.07**
	+ trend	-5.73**	-7.19**	-4.65**	-4.57**	-6.71**	-1.372	-5.29**	-4.97**	-7.11**
	Without	-5.09**	-7.39**	-4.37**	-4.55**	-6.07**	-0.128	-4.14**	-5.07**	-7.16**
Senegal	Intercept	-7.09**	-4.97**	-5.198	-5.49**	-3.33*	-0.856	-5.52**	-3.38**	-8.57**
	+ trend	-7.44**	-4.73**	-5.14**	-5.42**	-3.61*	-0.430	-5.45**	-3.54*	-7.94**
	Without	-7.12**	-4.34**	-5.13**	-4.76**	-2.35*	-0.459	-5.56**	-3.29**	-7.48**
South Africa	Intercept	-5.75**	-4.27**	-4.51**	-6.49**	-5.91**	-1.759	-5.61**	-4.14**	-8.79**
	+ trend	-5.82**	-4.22*	-4.43**	-7.01**	-5.84**	-0.553	-5.68**	-4.11**	-8.65**
	Without	-4.52**	-4.29**	-4.44**	-5.12**	-5.10**	-3.43**	-4.97**	-4.17**	-8.89**

Notes: ** significant at the 1% level; * significant at the 5% level.

Table 4
Johansen test for cointegration.

	Maximum rank	Eigenvalue	Trace statistics	Critical value	Max statistics	Critical value
Angola	0	.	70.9414	68.52	26.5816	33.46
	1	0.52211	44.3598*	47.21	22.2451*	27.07
	2	0.46094	22.1147	29.68	13.7782	20.97
	3	0.31800	8.3365	15.41	7.4993	14.07
Ethiopia	0	.	98.8690	94.15	39.3604	39.37
	1	0.66491	59.5086*	68.52	24.3167*	33.46
	2	0.49108	35.1920	47.21	17.4422	27.07
	3	0.38400	17.7498	29.68	10.6865	20.97
Kenya	0	.	118.146	94.15	50.2650	39.37
	1	0.75248	67.8813*	68.52	30.8136*	33.46
	2	0.57511	37.0678	47.21	22.8588	27.07
	3	0.47005	14.2090	29.68	9.7957	20.97
Nigeria	0	.	155.924	124.2	63.3037	45.28
	1	0.82769	92.6210*	94.15	37.5298*	39.37
	2	0.64743	55.0912	68.52	22.7054	33.46
	3	0.46778	32.3858	47.21	14.9538	27.07
Senegal	0	.	123.131	94.15	58.2993	39.37
	1	0.80199	64.8321*	68.52	36.2258*	33.46
	2	0.63442	28.6063	47.21	15.2579	27.07
	3	0.34547	13.3484	29.68	9.0110	20.97
South Africa	0	.	106.759	94.15	39.7249	39.37
	1	0.66828	67.0351*	68.52	34.4304*	33.46
	2	0.61573	32.6047	47.21	13.4973	27.07
	3	0.31266	19.1074	29.68	10.1082	20.97

Notes: * significant at the 5% level; H_0: no cointegrating equation.

Table 5
Long-run causal relationships.

		Angola	Ethiopia	Kenya	Nigeria	Senegal	South Africa
lnPAX → *lnGDP*	ECT_{t-1}	0.017	−0.09*	−0.036	−0.068	−0.543	0.385
		(0.543)	(0.030)	(0.840)	(0.427)	(0.066)	(0.134)
lnFRT → *lnGDP*	ECT_{t-1}	0.012	−0.203	0.082	0.018	−0.460	0.002
		(0.158)	(0.051)	(0.050)	(0.736)	(0.124)	(0.886)
lnGDP → *lnPAX*	ECT_{t-1}	0.044	−0.035	−0.44*	−0.407*	−0.895	−0.307*
		(0.263)	(0.300)	(0.000)	(0.001)	(0.509)	(0.037)
lnGDP → *lnFRT*	ECT_{t-1}	−0.005	0.194	−0.025	−0.257	0.913	−0.043*
		(0.664)	(0.314)	(0.699)	(0.158)	(0.433)	(0.037)

Notes: * significant at the 5% level; p-values in parentheses; $x \rightarrow y$ denotes that x Granger causes y.

Table 6
Coefficients of long-run estimations.

	Angola	Ethiopia	Kenya	Nigeria	Senegal	South Africa
$\frac{\partial(lnPAX)}{\partial(lnGDP)}$	0.13*		0.49*	0.47*		0.60*
	(0.029)		(0.000)	(0.000)		(0.000)
$\frac{\partial(lnFRT)}{\partial(lnGDP)}$	0.15		0.40*	0.06*		0.46*
	(0.734)		(0.000)	(0.002)		(0.000)
$\frac{\partial(lnGDP)}{\partial(lnPAX)}$		0.80*			0.15	
		(0.000)			(0.682)	
$\frac{\partial(lnGDP)}{\partial(lnFRT)}$		0.27*			0.011	
		(0.000)			(0.583)	

Notes: * significant at the 5% level; *p*-values in parentheses.

economic development significantly, given that the service sector contributes around 61.5% percent to South Africa's GDP (Bhorat et al., 2018). This is in line with Pradhan and Bagchi's (2013) findings. On the other hand, economic development results in an expansion of the commercial and industrial sectors, and in particular the service sector, into which air transport is a basic input (Profillidis and Botzoris, 2015). This argument is in line with the short-run unidirectional causality from economic development to increased air traffic in Kenya and Nigeria. Higher disposable income increases demand for better air transport infrastructure for household leisure. On the other hand, as in the long run, there is no causal relationship between air transport demand and economic development in Senegal and Angola, where the positive relationship between the variables is not strong enough to indicate the direction of causality. Empirical evidence for this inference is shown in Table 7 and Appendix B with the respective coefficients.

Furthermore, short-run causality is found to be unidirectional for Ethiopia, from air passenger demand to economic development. This may be because spontaneous transport demand stimulates different industry structures, and also increases demand for seasonal labor in short-run interactions; whereas, as in the long-run scenario, economic development is not strong enough to create demand for either additional air transport infrastructure or extra household trips in a specific period.

No short-run causal relationship is found between demand for freight transport and economic development in any of the sample countries, although a relationship does materialize in the long run in South Africa. This may be because demand for airfreight transportation requires customized infrastructure and prior market arrangements, which are long-run phenomena. The absence of short-run causality between airfreight demand and economic development would allow buffer time to implement appropriate spatial infrastructure policies and invest in frameworks to accommodate forecast freight volumes.

4.4. Discussion

The heterogeneity of the empirical results may imply that in the causal relationship between air transport demand and economic development, the spatial dimensions and contexts of a study influence the direction of causality. The geo-economic situations of the sample countries in this study differ, as reflected in the empirical results showing differing causal relationships between economic activities and air transport. Possible justifications and discussions are presented in the following paragraphs.

Table 7
Test of Granger causality in VEC and VAR frameworks.

		VEC		VAR	
	Relationships	Chi-square	*p* value	Chi-square	p value
Angola	*lnPAX* → *lnGDP*	0.21	0.6501	2.572	0.276
	lnGDP → *lnPAX*	3.15	0.0758	4.875	0.087
	lnFRT → *lnGDP*	0.88	0.3475	1.086	0.581
	lnGDP → *lnFRT*	0.06	0.6772	5.033	0.081
Ethiopia	*lnPAX* → *lnGDP*	4.31*	0.0379	10.71*	0.005
	lnGDP → *lnPAX*	2.33	0.1270	4.123	0.127
	lnFRT → *lnGDP*	0.33	0.5633	0.043	0.979
	lnGDP → *lnFRT*	1.73	0.1881	1.539	0.463
Kenya	*lnPAX* → *lnGDP*	0.31	0.5775	0.282	0.868
	lnGDP → *lnPAX*	11.88*	0.0006	11.96*	0.003
	lnFRT → *lnGDP*	1.21	0.2704	2.827	0.243
	lnGDP → *lnFRT*	0.38	0.5398	0.773	0.679
Nigeria	*lnPAX* → *lnGDP*	0.09	0.7594	2.081	0.353
	lnGDP → *lnPAX*	0.01	0.9070	13.47*	0.001
	lnFRT → *lnGDP*	0.53	0.4677	0.434	0.805
	lnGDP → *lnFRT*	0.07	0.7850	1.437	0.487
Senegal	*lnPAX* → *lnGDP*	0.18	0.6710	0.146	0.929
	lnGDP → *lnPAX*	2.02	0.1551	1.869	0.393
	lnFRT → *lnGDP*	1.78	0.1827	2.732	0.255
	lnGDP → *lnFRT*	0.01	0.6717	0.129	0.938
South Africa	*lnPAX* → *lnGDP*	4.30*	0.0380	0.679	0.712
	lnGDP → *lnPAX*	6.15*	0.0131	13.36*	0.001
	lnFRT → *lnGDP*	1.35	0.2452	4.870	0.088
	lnGDP → *lnFRT*	0.41	0.5214	1.329	0.514

Notes: * significant at the 5% level; x → y denotes that x Granger causes y.

As stated above, there is a long-run unidirectional causality in Ethiopia, where growth in the air transport sector enhances economic development. This indicates that the Ethiopian economy is not strong enough to generate and reinforce air transport demand, and perhaps implies that air transport is important for improving accessibility at a relatively early stage of economic development. As suggested earlier, countries on a growth curve up to approximately $20,000 per capita experience correspondingly faster increases in the number of flights per person per year (IATA, 2016); and in countries with developed low-cost carrier services, demand for air travel increases rapidly when GDP per capita reaches around $5000 to $10,000 per annum (JADC, 2019). As Ethiopia's per capita income is only around $800 (World Bank, 2020), its population has not yet reached the threshold of wealth where discretionary air travel becomes possible. As a result, domestic demand accounts for only 12% of total traffic. South Africa, Nigeria and Kenya show the reverse causality: economic development promotes air transport demand, reflecting these countries' higher GDP per capita, both nominal and at purchasing power parity (PPP), compared with Ethiopia (see Fig. 3). South Africa's per capita income is around $7000, and Nigeria's and Kenya's GDP per capita is also in the middle-income range (World Bank, 2020), nearing JADC's (2019) threshold. Growing GDP per capita will increase the middle-class population, so people may reach the wealth threshold at which discretionary air travel (largely on low-cost carriers) becomes possible. However, higher GDP per capita is not a guaranteed indication of the causal direction between air transport demand and economic development. For example, Angola has the second-highest per capita income of countries involved in this study, after South Africa, but exhibits no causal relationship between economic activities and air traffic. Air transport growth in Angola is weaker than in, for instance, Ethiopia and Kenya, where GDP per capita is lower. The results for Angola indicate that the variables are weakly positively correlated.

The presence of large home-based airlines is another factor that may determine the causal direction. Ethiopian Airlines can be considered to be an important element in the unidirectional causal relationship from air transport demand to economic development in Ethiopia. This large home-based carrier, with its extensive network, is likely to strengthen the Ethiopian economy. Lijesen et al. (2005) suggest that a large home-based carrier enables the host country to exploit economies of density, thereby lowering costs on densely traveled routes and enabling economically viable business operations. The Ethiopian Airlines group is the biggest airline in Africa in terms of revenues and profits (CAPA, 2019; IATA, 2013; Meichsner et al., 2018). With revenues of $3.3 billion in 2018, of which around $232 million was profit, it has about 13,000 permanent employees, operates 126 aircraft and has 47 aircraft on order stock including 31 Boeing, 10 Airbus and 6 Bombardier (Ethiopian Airlines, 2020). The key pillars of this airline's success are a large intra-African network, a strong hub with multiple wave permutations for onward connecting traffic, and deep strategic partnerships with regional African carriers (Meichsner et al., 2018). However, as the only airline in Ethiopia, it is a full-service carrier, and hence naturally excludes people with lower propensity to pay, particularly potential domestic travelers. Senegal has neither a strong economy nor a competitive home-based airline to induce a causal relationship between air transport service and economic improvements. Angola does not have a competitive home-based airline, although it has one of the biggest economies in sub-Saharan Africa, alongside South Africa and Nigeria. Its flag carrier, TAAG Angola Airlines, was banned from entering European airspace because of safety concerns in July 2007, but it was re-authorized to operate in European Union airspace in April 2019 (European Commission, 2019). Table 6 and Fig. 6 also show a weak relationship between air transport and economic development in Angola. South Africa and Kenya have competitive home-based airlines, but these are less profitable than Ethiopian Airlines (CAPA, 2019; Meichsner et al., 2018). Hence, combined with trends in economic development, the strength of home-based airlines may explain the unidirectional causal relationship from air transport demand to economic development in Ethiopia, which is in the reverse direction in Nigeria, Kenya and South Africa.

On the other hand, compared with other sub-Saharan Africa countries, the low-cost carrier (LCC) model is more developed in South Africa, Nigeria and Kenya, targeting lower-income groups through affordable airfares (CAPA, 2013; Bowen, 2019). For instance, about 46% of domestic air passenger demand is served by low-cost airlines in South Africa (Paelo, 2016; SACAA, 2018). This growth may incentivize both air travelers and economic activity. Theoretically, the economic principle underlying LCC is that an important part of the demand is from individuals whose willingness to pay is lower than even the lowest tariff of the full-service carrier, who are hence otherwise excluded from air travel markets (Akgüç et al., 2018). LCCs offer affordable fares that increase air traffic by targeting and capturing this customer segment, thereby increasing connections between people and places. Ceteris paribus, potential drivers of LCC are the availability of short-haul air travel markets and potential travelers' willingness to pay. An aviation market with a reputable LCC will charge individuals affordable airfares, and passengers' willingness to pay (travel demand) will also rise. An aviation market with only a full-service carrier, such as Ethiopia, naturally excludes low-income (low willingness to pay) individuals from the market. Hence, the proportion of LCCs in a country's aviation market may determine the direction of the causal relationship between air transport demand and economic development.

A potential supplementary explanation for the causal relationship between economic development and air transport demand may stem from the comparative advantage of a country's geographical location. For example, Ethiopia connects sub-Saharan African countries with South Asia, the Middle East and Europe. Previous studies (e.g. Dennis, 1994) also indicate that a strategic geographical location may enable the development of air transport hubs in a specific region.[3] According to ForwardKeys (2018), Addis Ababa has overtaken Dubai as the world's gateway to sub-Saharan Africa, bringing various economic benefits to Ethiopia. In contrast, for example, South Africa's and Nigeria's peripheral locations afford little geographical advantage. The final destinations of many international arrivals tend to be these countries themselves, or the Southern and Western African regions respectively. Thus, economic activities in these countries are the main driver of air transport demand.

The population size of the sample countries varies considerably. Nigeria and Ethiopia are the most populous countries with 206 and 115 million inhabitants respectively (World Bank, 2020). However, their passenger per capita has not been proportionate to respective population size. The number of flights being taken by the average person per year is higher in South Africa (0.42) and Kenya (0.12) which has 59 million and 45 million population respectively. The arrival and development of LCCs in these countries could make flying more affordable for more people. The passenger per capita in Nigeria and Ethiopia was 0.04 and 0.11 respectively, see Appendix C. Moreover, Senegal has about 17 million inhabitants and possessed the lowest passenger per capita (0.01) in the study. This could imply that population size may important but would not be a main determinant of air transport demand. On the other hand, the countries with higher urban concentrations like South Africa, Kenya and Nigeria have better domestic air transport traffic and have a unidirectional causality from economic development to air transport demand. Moreover, Angola, Ethiopia, and Senegal each have one large dominating urban area, which limits the potential for domestic air transport, whereas Kenya has two (Nairobi and Mombasa) and South Africa and Nigeria both have about six large urban areas (Worldometer, 2020). A well-managed urban concentration could promote domestic air transport demand.

In general, to promote long-term economic development with reference to air transport demand, South Africa, Nigeria and Kenya may need to follow different approaches to Ethiopia. For the former group, direct investment in industries other than aviation may be a better option to advance economic development, as improving their productivity would in turn boost air transport demand and related infrastructural facilities. On the other hand, for Ethiopia, which has a comparative advantage in its geographical location and strong home-based airline, investment in the aviation sector may enhance economic development. However, Maparu and Mazumder (2017) caution that the causal direction may change with political reforms and economic policy changes.

5. Conclusion

This study examines causal relationships between economic development and air transport demand in six sub-Saharan African countries. The empirical results reveal three patterns in long-run causal relationships between these two factors in this region. First, there is a unidirectional causality from economic development to air transport

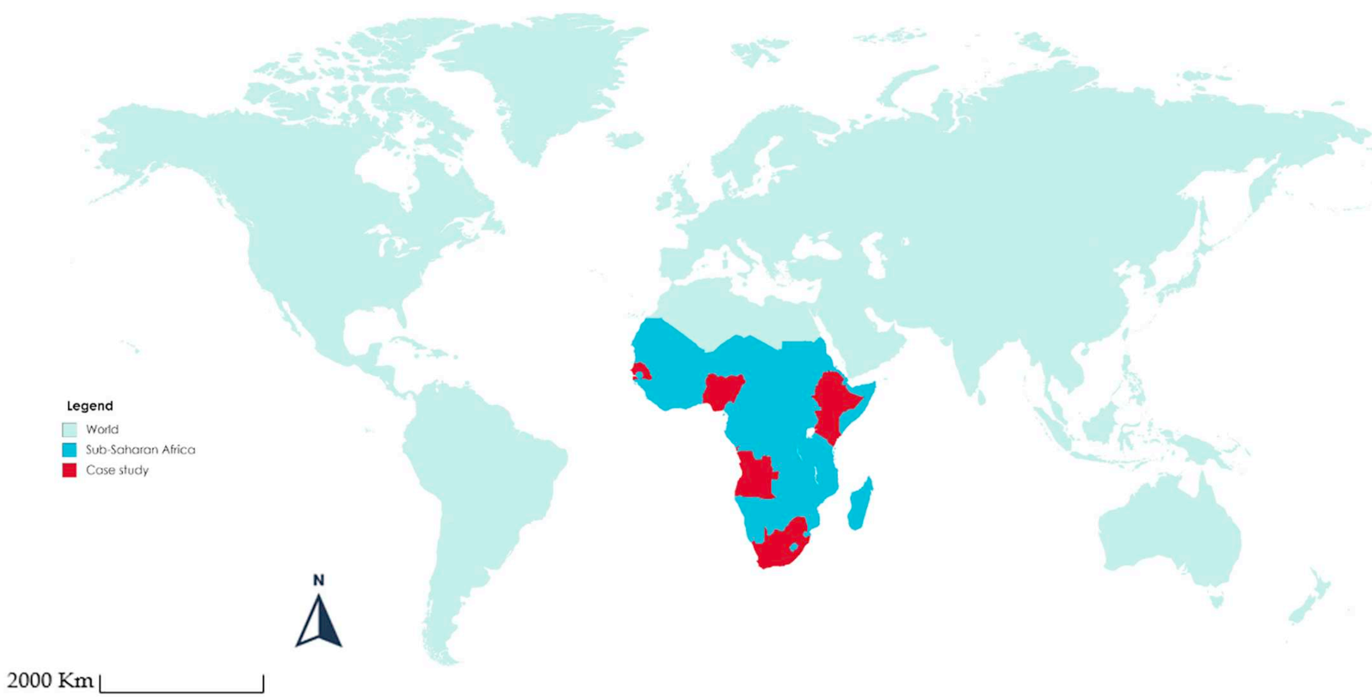
[3] Dennis (1994) identifies Frankfurt as the most location advantageous hub in Europe.

demand for countries like South Africa, Nigeria and Kenya. These are middle-income countries with competitive air transport services in the region. In such contexts, substantial direct investment in industries other than aviation may strengthen economic development, which may in turn increase air transport demand. The second pattern is a unidirectional causation from air transport demand to economic development, as witnessed in Ethiopia. Although Ethiopia is a low-income country, it has a comparative advantage in geographical location as a natural hub, and has the biggest airline group in the region. Therefore, air transport growth may improve its economic development, so economic development strategies should focus robustly on air transport, which will in turn facilitate other industries such as tourism. The final pattern is illustrated by Senegal and Angola, where the relationship between economic development and air transport demand is too weak to determine a causal direction. Other countries with similar economic and air service trends to the countries involved in this study may exhibit similar causal directions. Variations in the empirical results across the region imply that a country's context and spatial dimensions impact on the causal relationships.

However, elasticities of interaction between economic development and air transport demand vary between countries in the short- and long-run frameworks. The coefficient of marginal contribution is more noticeable in lower-income countries such as Ethiopia than in middle-income countries. Moreover, the results of the long-run analysis show that demand for airfreight transport is less elastic than demand for passenger traffic with respect to economic development. In other words, air passenger demand is more strongly affected than demand for airfreight transport by changes in economic development. Demand for airfreight appears to be driven by the value of commodities, and is used for time-sensitive commodities that are less responsive to airfare fluctuations.

In general, it is important to note that the causal direction in any economic or policy-related matter may change with political reforms and changes to economic policy. Regarding the linkage between air transport demand and economic development, the empirical results of this study also suggest that the policy implications will vary across different contexts and spatial dimensions.

Appendix A. Geographical locations of sample countries



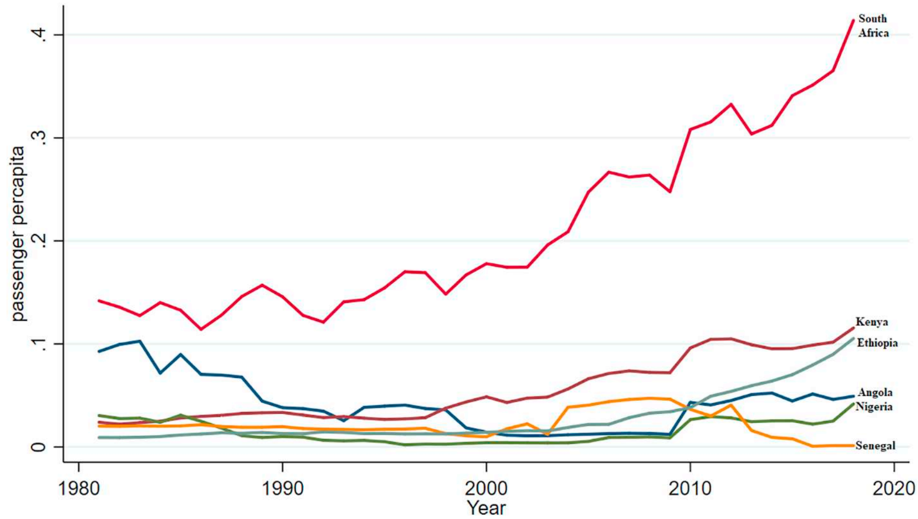
Source: Modified from Mapchart.net (https://mapchart.net/).

Appendix B. Coefficients of short-run estimations

	Angola	Ethiopia	Kenya	Nigeria	Senegal	South Africa
$\frac{\partial(lnPAX)}{\partial(lnGDP)}$	0.46 (0.076)		0.28* (0.001)	0.36* (0.002)		0.48* (0.013)
$\frac{\partial(lnFRT)}{\partial(lnGDP)}$	0.07 (0.977)		0.19 (0.540)	0.21 (0.785)		0.36 (0.521)
$\frac{\partial(lnGDP)}{\partial(lnPAX)}$		0.52* (0.038)			0.02 (0.671)	0.32* (0.038)
$\frac{\partial(lnGDP)}{\partial(lnFRT)}$		0.05 (0.563)			0.06 (0.183)	

Notes: * significant at the 5% level; *p*-values in parentheses.

Appendix C. Average flights per person/year



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