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# Impact of airport infrastructure investment on the growth of the Angolan economy: An auto-regressive distributed lag analysis

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# Abstract

**Purpose:** The airport infrastructure plays capital importance in the development of national trade. It facilitates the flow of people, goods, and services more quickly. Thus, given its importance, this study seeks to analyze the impact of the Angolan investment in airport infrastructure between 2000 - 2020.

**Design/methodology:** This article presents the results of quantitative and qualitative research, based on narrative review and output of the Auto-Regressive Distributed Lag (ARDL) technique, which aimed to analyze the impact of investment in airport infrastructure on the growth of Angola GDP per capita.

*Findings:* The results of the stationarity tests performed shows mixed integration in both I(0) and I(1), which justifies the used ARDL. Similarly, the bounds test showed that there is a very strong relationship between airport infrastructure investment and GDP per capita growth in the short and long run. However, in the Angola case study, the impact that exists is negative, meaning that airport infrastructure negatively impacts per capita GDP growth in both the short run and in the long run.

**Research limitations/implications:** This research has been among the first to analyze the impact of investment in airport infrastructure on the growth of Angola GDP per capita. Besides the contribution of this research, some limitations are the difficulty to find data of investment and the literature about transportation infrastructure in Angola.

**Originality/value:** The analysis of the impact of investment in airport infrastructure in the growth of Angola GDP per capita is a fundamental step that can help public and private entities

in making decisions that aim to improve the management of the Angola transport infrastructure.

Keywords: Angola airport infrastructures, economic growth, imports, exports

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#### 1. Introduction

Economic development is an important indicator for improving the people's standard of living (Alam et al., 2020). Similarly, the development of the trade depends on how each country conducts its trade policy (specialization, main export and import markets, dependence on forms of financing, degree of internationalization of domestic firms, supply chain development, among others) (Allen & Giovannetti, 2011).

Angola with 1.246.700 is the seventh largest country in Africa. It has a continental border of 84.837 km, but the poor quality of its transport infrastructure limits connection with its eastern, northeastern, and southwestern provinces, as well as with neighbor countries (Haddad et al., 2020). Angola is a resource rich country, but a considerable portion of its population lacks access to basic services, such as access to transportation infrastructure (Temudo et al., 2019). After the civil war in 2002, the government set ambitious goals to rebuild the transportation infrastructure (Jensen, 2018). However, twenty years later, Angola still faces a number of difficulties regarding the airport infrastructure (Deloitte, 2014). The poor development of transport infrastructure is one of the main causes of the poor distribution of cement and other products in the Angolan market (Campos et al., 2022).

The weakness of Angola's transportation infrastructure has caused a gap between agricultural, rural, and urban areas, between the east and the coast. It limited the movement of people, goods, and services, compromised the country's growth and socioeconomic development. Subsequently, it caused airfare prices to rise. Currently, flying from Luanda to the center and east of the country is more expensive than flying from Luanda to South Africa.

Therefore, given the importance of airport infrastructure, it is important to analyze the impact of investment in airport infrastructure on the economic development. To this end, the following research question guiding the research was raised:

1) What is the impact of the investment in airport infrastructure on the Angola economy development?

The literature contains a considerable number of articles on airports and there is no doubt that there is a strong correlation between the presence of an airport and economic development in a given region (Greeny, 2007). Airport development and air transport contribute significantly to broader socioeconomic development and are key drives of new business generation (Dimitriou & Sarttzetaki, 2022). But, based on the literature, there are few articles addressing the impact of airport infrastructure on economic growth, for example, (Akinyemi, 2019), (Arbués et al., 2015), (Brugnoli et al., 2018) and (Dimitrios & Maria, 2018). However, there are not scientifically articles addressing this issue in the Angola context. Thus, the lack of literature addressing the impact of airport infrastructure on economic growth in Angola signals a deficit that somewhat hinders the understanding of this sector in the Angolan context.

This article is organized int six sections. Section 1 presents the problem under study, the objective, the research question, and the justification of the need for the research conducted. Section 2 discusses airport infrastructure, its classification, impact, and the management of airport infrastructure. Section 3 it's presented the methodology and research method. Section 4 presented the data, econometric model specification. At Section it is 5 presented the discussion of the empirical results. Finally, the section 6 presents the final considerations.

# 2. Literature review

High quality transportation infrastructure expands the productive capacity of a nation, increases mobility, productivity and economic growth (Pradhan & Bagchi, 2013) and (Barzin et al., 2018). Transportation infrastructure is a vital socioeconomic asset, it structures space and determines the mobility of trade flow as well as the location of industries and markets. It's construction and maintenance absorb significant resources, and its importance and public nature raise political and economic concerns (Short & Kopp, 2005).

# 2.1. Airport infrastructure

Airport infrastructure is classified as either technically efficient or inefficient. The development of airport infrastructure drives a country's economic growth, provides employment, boosts trade, and captivates tourism. For Addie (2014) airports are major catalysts for urban growth and economic development, their economic function, multiscale connectivity and the impact of air transport place airports at the center of transport infrastructure development policy.

Historically, airports were considered state-owned and aimed to provide and operate infrastructure for airlines. However, this sector has changed over the last two decades, many airports are no longer seen as public services, they now operate as modern ventures with commercial objectives. Several airports have been privatized in order to reduce government involvement, increase airport productivity and innovation (Gillen, 2011) and (Adler & Liebert, 2014).

Airport inefficiency can be explained not only by excess input and production deficiencies, but also by exogenous factors over which management has little or no control (Adler & Liebert, 2014).

The literature on measuring and understanding the factors affecting airport efficiency has expanded considerably in recent years, driven primarily by ongoing changes in the airline industry and evolving airport governance models (Assaf & Gillen, 2012).

Privatized airports show more efficiencies than mixed capital or majority government-owned airports (Oum et al., 2008). In general, the Airport industry is varied and heterogeneous, with a high degree of quality differentiation, heterogeneous ownership and regulatory structures, different combinations of service and operational characteristics (Graham & Shaw, 2008). Therefore, assessing and comparing airport performance is a complex task (Carlucci et al., 2018).

However, due to the growing strategic and economic importance of Airport infrastructure, Airport efficiency analysis has become crucial (Sarkis & Talluri, 2004), as it allows airlines to select the most efficient airports, municipalities to understand their ability to attract business and tourists, and governments to optimally allocate resources to improve airport infrastructure (Barros & Dieke, 2007).

Airports play important roles in economic growth, connecting cities and nations. The deal with outbound passage flow and inbound passenger flow. Departures procedures include airport access facilities, check-in security check, immigration, customs, and boarding. Arrival procedures include boarding, immigration, baggage claim, customs, quarantine, and airport departure procedures. The passenger system's boarding flow is most important because it has the greatest impact on the entire operation of the passenger terminals and other elements of the airport (Alodhaibi et al., 2017). Departures at airports involve providing services to passenger that generally require more time than the arrival process (Neufville et al., 2013).

Airports are take-off and arrival spaces for aircraft carrying passengers and goods. Airports are at the heart of air transport operation. A portion of airports serve commercial services such as, shopping centers, parking lots, subway and bus stations (Pius et al., 2017). Air transport enables fast travel over long distances, while airport infrastructure boosts local economic development through several mechanisms (Tveter, 2017). First, it makes a region more attractive. If interpreted as a regional amenity, the impact of airport infrastructure can lead to population growth due to increased attractiveness. Second, airport infrastructure can improve market access. Third, air transport can facilities direct contact between people living far from each other (Glaeser et al., 2001).

Air cargo logistics has an increasing importance in the economic development of a nation, as well as a strong correlation with many economic metrics such as economic growth (Chang & Chang, 2009). As a driver economic development, air cargo stands out as a vehicle that bridges the gap between global trade and the supply chain in a faster and more reliable manner (Kasarda & Green, 2005). The airport's ability to attract transshipment cargo traffic, including existing traffic flow patterns, airport infrastructure capacity and activities, linkage with regional and intercontinental airport network is critical to shaping an air cargo terminal's competitiveness (Wasesa et al., 2015). The performance of the air cargo terminal directly inside on the supply chain (Gardiner et al., 2005).

### 2.2. Airport infrastructure and economic development

The regional connections between infrastructure and economic development have been of interest to geographers, economists, policy makers, and many others for a long time (Cidelly, 2015). An important question in economic geography relate to the scale and nature of the contribution of transportation infrastructure to the overall economy. The ability to utilize transportation infrastructure and transportation services expand opportunities for interaction, as an economy can benefit from these interaction opportunities by increasing its output (Lakshmanan, 2011).

In general, the economic effects of air transport are analyzed based on the impact of air services (Allroggen & Malina, 2014). For example, the flow of air cargo promotes economic development (Button & Yuan, 2013). However, a major specific interest of airports is their role in facilitating the movement of labor. Economic growth theory has largely focused on fixed geographic endowments, but as the importance of extractive industry has declined, factor mobility has gained importance for the economic development of regions (Button et al., 2009). Thus, while substantial aggregate impacts of air transport on economic activity have been identified, their scale and direction may differ across airports (Allroggen & Malina, 2014).

Therefore, the development of large infrastructure such as Airport often requires a high financial investment, time, and the involvement of various stakeholders (London et al., (2017), because a proposal to build an airport in a region not only sparks the interest of politicians and investors, but also impacts the region's economy (Nguyen et al., 2022). For this reason, airports are recognized as essential drives of economic development that support local economic activity as they generate new employment opportunities and stimulate further investment in catchment areas (Robertson, 1995).

Airport infrastructure is part of the underlying basis of an airport system. Its existence and the associated ground infrastructure are an essential factor for regional development. The literature states that the presence of this infrastructure has a direct relationship with the overall economic functioning of the surrounding region (Crockatt & Ogston, n. d.). therefore, Airport services with quality improve economic development, where airport services with less quality hinder the economic development of the region. In general, economic performance is measured in terms of employment growth, population growth, and/or income growth. For example, the literature on economic development focuses on empirical studies of the effect of government policies on economic outcomes (Greeny, 2007).

At airports where a significant increase in capacity is not expected, mitigating air traffic delays may require the implementation of demand management mechanisms aimed at controlling demand for airport access to limit imbalances between demand and capacity (Gilen et al., 2016). Therefore, investments in Airport infrastructure are evaluated based on improvements in transportation infrastructure to meet the demand for transportation. However, evaluating airport investments in terms of maximizing regional development requires a comparison of the regional impact of investments in other sectors, such as manufacturing, education, and health. The investment should positively impact the economic development of the region (Jorge & Rus, 2004).

Air transportation has influenced economic development it is therefore important to know the scale of this effect both for airport development and management and for policy makers making strategic decisions about airport planning and investment. However, studies on the economic impact of air transport have focused

primarily on the links between large airports and regional economic development. Little attention has been paid to the impact of small airports on their local areas (Button et al., 2009).

# 2.3. Impact of airport infrastructure

The transportation infrastructure impact on the economy is seen in economic development and differs in developed and developing countries. Immediate benefits and sustainable growth occur over different time periods (Alam et al., 2020), (Esfahani & Ramírez, 2003) and (Short & Kopp, 2005).

Arbués et al. (2015) when testing the existence of direct and indirect effects of road, rail, airport, and port infrastructure projects by estimating a production function noted that transportation infrastructure impacts the economy, not only of the region in which they are located, but also the economy of adjacent regions (spillovers effect).

Efficient air transport infrastructure can boost regional economic development, enable access to the world market, facilitate labor integration and mobility, and stimulate local industries (Brugnoli et al., 2018). Aviation plays an important role in modern society and economy. It provides connectivity, accessibility, and facilitates trade. Along with the growth of airport infrastructure, business, commercial, residential, and spatial development occurs (Ferrulli, 2016).

Airport infrastructure determines the socio-economic structure of a territory. With globalization, air accessibility has become one of the essential factors for economic development. Airports need to attract passengers and airlines, acting strategically in marketing and route development and differentiating their offer. Thus, efficiency in the management of airport infrastructure is key to ensure and facilitate mobility and economic growth (Burbidge, 2016), (Bucovetchi et al., 2019) and (Bergantino et al., 2020).

Air transport is one of the most important industries in the world, it directly and indirectly contributes to the rapid growth of the world economy. Air transport is a major contributor to global economic prosperity. Aviation directly creates jobs in the industry, as well as other sectors indirectly, providing 62,7 million people worldwide with their livelihoods. GDP, tourism and employment are the main factors causing this growth in air transport and an increase in these factors drives the demand for air transport (ATAG, 2016), (Küçükönal & Sedefoğlu, 2017), and (Dimitrios & Maria, 2018). Already, the evolution of new airline business models has increased passenger demand and the need for more airport infrastructure (Carmona-benítez et al., 2017). However, among the biggest barriers to air cargo trade are customs regulations and procedures that do not keep up with the rapid development of the industry (Zhang, 2002).

Offering high quality infrastructure is important for attractiveness and competitive advantage, it also aims to boost local economic development. For example, (Akinyemi, 2019) report that understanding the causal relationship between economic variables and demand for domestic air travel in Nigeria had policy implications for airlines, airports, local governments and consumers. The policy implication caused by these variables helped policymakers to understand the role of air travel demand in the country's economic growth, guide airport development and operation, and regulate air services.

Therefore, air transport boosts internal and external trade, facilitating the displacement of people for various activities, whether for commercial purposes, health, study, or leisure. Thus, developing the airport infrastructure to guarantee a greater flow of people and goods is fundamental.

# 3. Research methodology, method and data

Based on the approaches by Green et al. (2006), Yuan & Hunt (2009), Gasparyan et al. (2011), Hochrein & Glock (2012) and Ferrari (2016) a systematic literature review was carried out with searches in Scopus, Web of Science, Science Direct and Google Scholar, using the following keywords: "airport infrastructure", "impact of airport infrastructure" and "Angola airport infrastructure". The following filtering criteria were used: (1) publication years: 1990 – 2020; (2) document type: article; (3) source type: journal; (4) language: English. All

extracted articles were manually analyzed considering the following inclusion and exclusion criteria: title analysis, research area, keywords used, contributions and main results.

From the four databases, 127 articles were extracted, 36 duplicates were organized and excluded. The remaining 91 articles were analyzed and 26 were excluded because they are not focused on the airport infrastructure. The remaining 65 articles were again subjected to a more in-depth analysis which resulted in the selection of only 63 articles. Later, 14 supplementary articles were added.

Regarding the research method, In order to answer the research question identified in this research, the present study used the Auto-Regressive Distributed Lag (ARDL) approach developed by Pesaran & Shin (1997) and Pesaran et al. (2001). The ARDL approach was adopted for the following three advantages compared to other traditional cointegration technique:

- $\bullet$  The variables do not have to have the same order of integration, they can be I(0), I(1) or fractionally integrated;
- The ARDL test can be applied to small samples;
- In the ARDL technique, the long-term and short-term factors of the model are evaluated at the same time (Belloumi, 2014).

The ARDL technique employs a single reduced form equation, unlike to other cointegration techniques that require laborious systems of equations to estimate the term relationship. An additional advantage of ARDL is that when evaluating the long and short-term factors of the model, the difficulties in testing the hypothesis of the coefficients, as observed in the Engle-Granger method, are avoided, especially when the samples are small (Narayan, 2005).

Data for this study were obtained from the Angolan Ministry of Finance and the World Bank. The dependence variable is economic growth (GDP). The independent variables are investment in airports infrastructure, exports and imports. The data contains 21 observations, which is why the ARDL approach was adopted. The choice of the study period was due to lack of data on investment in airport infrastructure.

Variables	Symbol	Meaning	Data source
Economic growth	GDP	GDP per capita (current US\$) – is gross domestic product divide by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources.	World bank
Import	М	Imports of goods and services (% of GDP) represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank
Export	X	Exports of goods and services (% of GDP) represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income (formerly called factor services) and transfer payments.	World Bank
Airport	Air	Total investment in airports infrastructure in the country. The	Ministry of

#### Journal of Airline and Airport Management 13(1), 12-30

Variables	Symbol	Meaning	Data source
infrastructures		national currency was converted to U.S dollars on the period-end conversion rate (IMF data)	Transporte

Table 1. Variables in the Models and Data Sources

# 4. The Angolan airport infrastructure

As far as the Angolan airport sector is concerned, except for Luanda, most airports were built in the 1960s to meet the needs of that decade. The aircraft were slow and medium sized, with the Douglas DC3 being a representative type. However, from 1975 to 2005 investment in airport infrastructure did not keep up with the rapid growth in demand for these services. Air navigation services for all airports are the management of the National Air Navigation Company (ENANA) (Bank, 2005). The Table 2 reference the entities that are managing the control of the airports.

Managing Companies	Quantities of airports
ENANA	18
Provincial governments	7
Mining companies	5
Air Force	6
Total	36

Table 2. Companies that manage and control airports in Angola (Bank, 2005)

Despite the importance of airport infrastructure, the number of airports in operation in Angola is decreasing considerably as their wear and tear increases. In Angola there are several municipal airports/aerodromes that do not receive flights. The main concentration of traffic is in Luanda, while the level of traffic in some provinces is decreasing. The airport "4 de Fevereiro" is the main airport in the country being "Transportes Aéreo de Angola (TAAG)" is the main public sectors airline.

The capacity of the Angolan airline has growth. After the restructuring, TAAG expanded its routes and fleet (includes several Boeing 777s) operating on routes to Portugal and Brazil (Pushak & Foster, 2011). Has intercontinental flights to: Lisbon, Dubai, Brussels, Frankfurt, Paris São Paulo, Rio de Janeiro, Havana, and London. In addition to these, there are other continental destinations originating in Luanda: Addis Ababa, Brazzaville, Cape Town, Casablanca, Harare, Johannesburg, Kinshasa, Maputo, Nairobi, São Tomé and Windhoek. Many other countries such as, Germany, United Kingdom, Portugal, Spain, France, Belgium, Netherlands, Qatar and Turkey also have direct flights to Angola. Similarly, China being one of Angola's main trading partners and one of the most significant investors has played an important role in modernizing the country's transportation infrastructure, from ports, roads, and airports (Nonkenge & Luiz, 2018).

However, prior to restructuring, the runways restricted airport capabilities, the runways were and some still are too short, have poor geometry for modern craft, and have rough surfaces and weak bases. Consequently, Boing 737s could not operate across the network and could not use high-pressure tires for risk of damage to the runway by impact loading. More expensive low-pressure tires wear out faster on rough runway surfaces and subsequently haver shorter service life, leading to higher operating costs (Bank, 2005). Figure 1 shows the location of some airports in Angola. There are many other airports/aerodromes in different municipalities that are not shown on this map.

Regarding the restructuring or expansion of airport infrastructure, the Lobito corridor has one international airport, Catumbela, located between Lobito and Benguela. It was built by a consortium of companies including Odebrecht (Brazil), Somangue (Portugal) and Imbodex (Cuba), and financed with government funds and foreign

credit lines. Several provincial airports along the corridor, including Benguela, Huambo, Kuito and Luena were also rehabilitated and modernized (Duarte et al., 2014).

However, not all airport infrastructure has been rehabilitated (Haddad et al., 2020). For example, the airport of Malanje is the only in the province and is located on the outskirts of the city. It was expanded and now has a 2.220, meter asphalt runway that can accommodate only smaller aircraft (Ferreira et al., 2015). The Angolan airport network consists of international airports, national airports, and aerodromes. However, the international airports of Catumbela and Lubango does not receive international flights.



Figure 1. Angola's airport network (Angola, n.d.-a)

However, given the demand for air services at the February 4 international airport, the Angolan government decided to build a new international airport 40 km the capital city of Luanda. The new international airport will serve as a regional hub with capacity for 13,5 million passengers per year (Muzima, 2019).

However, in the distant year 2000, Luanda airport handled 1.405.125 departing passengers and 478.305 metric tons of cargo. 100 aircraft regularly used the parking space designed for 18 aircraft. This statistic shows a high level of demand for airport services (Bank, 2005), as in general, southern African countries of similar size and population in a peaceful state and without an oil-based economy would probably not record these levels of traffic.

According to Campos et al. (2022), in Angola the provincial airports played an important role during the first decade of the 21st century because at that time, the road and rail infrastructures were still at a high level of degradation. According to Bank, (2005), at that time the roads were still mined, in that period aircraft served as a bridge for supplying the hinterland areas not accessible by road and rail carrying basic consumer goods such as, food, building material, fuel and medicines. However, the airports facilities in the provinces are precarious and the levels of comfort and safety are minimal, few airports control the weight of cargo adequately due to the lack of scales and trained personnel.

	N° of passengers	Cargo (tons)	Aircraft (Landings)
Luanda Total	1.405.125	478.305	25.910

	N° of passengers	Cargo (tons)	Aircraft (Landings)
Benguela	75.887	5.932	8.287
Cabinda	87.214	2.036	14.022
Huambo	nbo 61.843		9.610
Lubango	108.991	4.742	7.576
Kuito	5.102	10.809	4.520
Luena	26.264	15.011	4.688
Malange	21.264	1.772	1.496
Menongue	16.548	17.524	3.088
Namibe	18.936	3.821	1.597
Ondjiva	16.759	3.045	1.344

Journal of Airline and Airport Management 13(1), 12-30

Table 2. Passenger and cargo traffic at provincial airports, 2000 (Bank, 2005)

# 5. Empirical results

# 5.1. Trend of the series

A time series can be written as a sum of four elements: trend, seasonality, cycle and random shocks (random term). The graphics in figure 2 illustrate the GDP growth trend, the Airport infrastructure investment trend, Exports, and Imports trade. The trend of the series in figure 2 show that they are not stationary. A time series is said to be stationary when there is not trend in the time series, it is known as stationary series. But why it is important to determine stationary property of the time series?

A stationarity test is necessary before carrying out the regression analysis because if the time series is no stationary, the regression results will become spurious. If the series is not stationary, we need to do the differencing. Differencing can help stabilize the mean of a time series by removing changes in the level of a time series, and therefore eliminating (or reducing) trend.

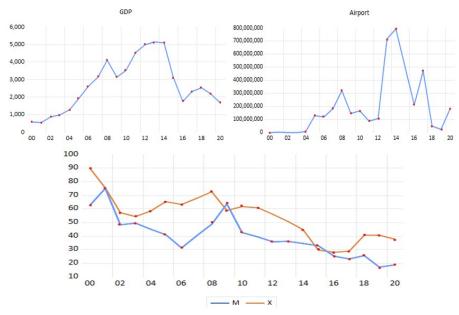


Figure 2. Graphic of the series

#### 5.2. Unit root test

In the analysis of series, before applying the regression, the variables must be tested to verify whether or not they are stationary. A variable is considered to be stationary if its Prob value is between 0 and 5%, that is, with no tendency to grow or decline. To ascertain this fact, in this work the conventional unit root test with the Augmented Dickey-Fuller (ADF) method was used. The results are presented in Table 4.

To understand the analysis, the probability value parameter must be considered, using the following hypotheses with 0,05 or 5% of significance:

#### • H0: the series has a unit root and is not stationary (null hypothesis);

• H1: the series does not have a unit root and is therefore stationary.

If P value is  $\leq 5\%$ , reject H0. For the series to be considered stationary, we have to reject the null hypothesis (H0), concluding with 95% confidence that it is a stationary series.

As can be seen in Table 4, the variables became stationary only in the first difference. At level the variables are in their original state and they are not stationary because they have a trend. If the series is not stationary we must to applied the first difference because the variables need to be significant on 5% of significance. If the Prob value is higher 5%, the variable become insignificant. We cannot used regression in ARDL technique if the Prob value of the series are higher 5%.

Variables	With constant		With constant & With Constant & Trend		Without Constant & Trend	
	t-Statistic	Prob.	t-Statistic	Prob.	t-Statistic	Prob.
			At level		•	
GDP	-1.9486	0.3049	-0.7412	0.9548	-0.4228	0.5177
X	-1.6456	0.4421	-2.9963	0.1572	-1.4908	0.1239
М	-2.1698	0.2222	-2.3006	0.4148	-2.0490	0.0415
Airport	-2.2764	0.1883	-2.3043	0.4130	-1.5258	0.1163
		At	first Differen	ce	•	
GDP	-2.9447	0.0588	-3.3430	0.0950	-3.0258	0.0046
X	-5.9824	0.0001	-3.3370	0.00939	-5.4959	0.0000
М	-3.3715	0.0256	-3.21108	0.1118	-3.3593	0.0020
Airport	-4.4621	0.0027	-4.3886	0.0132	-4.5861	0.0001

Table 4. Unit Root test

#### 5.3. Model specification

To investigate the impact of variables on GDP per capita growth, the economic function was specification as follows:

$$GDP = (f(Airports, Exports, Imports)$$
(1)

In equation (1), Gross Domestic Product (GDP) is declared as a dependent variable on government investment in Airport infrastructure (Airport) and national trade (Imports and Exports). The econometric model of the equation is presented as follows:

$$GDP_{t} = \beta_{0} + \beta_{1} A irport_{t} + \beta_{2} E x ports_{t} + \beta_{3} Imports_{t} + \varepsilon_{t}$$

$$\tag{1}$$

Where GDP indicates GDP per capita. Airport represents investment in airports infrastructure, Exports and Imports represents the sum of exports and imports. The parameters  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are the long-terms elasticity of GDP per capita for investment in Airport infrastructure. t and  $\varepsilon_t$  represents time and the white noise perturbation error term. The expected signs of  $\beta_1$ ,  $\beta_2$  and  $\beta_3$  are positive because an increase in the level of investment capital of Airport infrastructure should grater effects on trade, greater economic activity and higher GDP per capita growth.

#### 5.4. Regression of the ARDL model

ARDL cointegration is used when the considered variables are stationary at level, and some are stationary at first difference. So, in this section we are going to discuss the ARDL cointegration, long run and shot run coefficient and long run adjustment (Error correction form). Figure 4 illustrates the chosen method (ARDL), the selected model criterion (Akaike info criterion (AIC)), the lags for each of the variables, and the resulting characteristics. Equation for ARDL cointegration is formulated as follows:

$$\Delta GDP_{t} = \beta_{0} + \sum_{i=1}^{n} \beta_{1} \Delta Airport_{t-1} + \sum_{i=1}^{n} \beta_{2} \Delta X_{t-1} + \sum_{i=1}^{n} \beta_{3} \Delta M_{t-1} + \mu_{t}$$
(3)

Where  $\Delta$  presents the first difference,  $\beta_0$  denotes the drift component,  $\mu_t$  is the white noise residual and GDP, Airport and Exports and Imports are as defined earlier.

Once the regression was performed, the results obtained were summarized and presented in Table 5. The ARDL technique was used as the method for performing the regression. The long run estimates of the ARDL techniques were selected based on Akaike's information criterion (AIC). The optimal lag length selected for the model is ARDL (1, 0, 0,0). The coefficients of the variables are illustrated in Table 5. The interpretation of the results presented in the Table 5 should be as follows, for example:

• If the variable presents a positive coefficient and its p-value is statistically significant at 5% significance, it means that the variable positively impacts the growth of GDP per capita (GDP);

• If the variable has a negative coefficient and its p-value is statistically significant at 5% significance, it means that the variable negatively impacts the growth of GDP per capita (GDP);

• If the variable presents a positive or negative coefficient and its p-value is statistically insignificant at 5% significance (above 5%), it means that the variable does not impact the growth of GDP per capita (GDP).

Variable	Symbol	Coefficient	Prob.	Impact on DGP
GDP per capita with 1 lag	GDP(-1)	0.798098	0.0000	Positive (+)
Exports	Х	60.86967	0.0001	Positive (+)
Imports	М	-38.49132	0.0044	Negative (-)
Airport	Airport	1.08E-06	0.1335	Insignificant
Constant	С	-1342.157	0.0268	Negative (-)

Table 5. Analysis of the regression results

Finally, can be observed that the Constant (C) presents negative coefficient (-1342.157) and P-value (0.0268) statistically significant, meaning that if everything remains constant the negative coefficients will negatively impact the growth of GDP per capita.

#### 5.5. ARDL long-run form and bound test

The ARDL bounds test is based on the assumption that the variables are I(0) or I(1). To ensure this principle, the order of integration of all variables was determined using root tests. The objective was to ensure that the

variables were not I(2), in order to avoid spurious results, because according to Belloumi (2014), in the presence of I(2) we cannot interpret the values of the F-statistics provided by (Pesaran et al., 2001).

Once the ARDL long-run form was performed, the results obtained were summarized and presented in Table 6.

Regarding the long-run coefficient at levels equations we can see that the variables does not impact de growth of GDP per capita.

Variable	Symbol	Coefficient	Prob.	Impact on DGP
Constant	С	-1372.157	0.0268	Negative (-)
GDP per capita with 1 lag	GDP(-1)	-0.201902	0.0698	Insignificant
Exports	Х	60.86967	0.0001	Positive (+)
Imports	М	-38.49132	0.0044	Negative (-)
Airport	Airport	1.08E-06	0.1335	Insignificant

Table 6. Analysis of the regression results

Variable	Symbol	Coefficient	Prob.	Impact on DGP
Exports	Х	301.4809	0.0878	Insignificant
Imports	М	-190.6433	0.1041	Insignificant
Airport	Airport	5.35E-06	0.0575	Insignificant

Table 7. Analysis of the regression results

To understand the ARDL cointegration or bound test is used the following rules from Pesaran et al. (2001):

- If F-stats is greater than value of upper bound, this shows there is cointegration;
- If F-stats is in between the value of upper bound and lower bound, this shows the result is inconclusive;
- If f-stats is less than value of lower bound, this show there is no cointegration.

Test Statistic	Value	Significance	I(0)	I(1)
			Asymptotic: n=1000	
			Lower bound	Upper bound
F-statistic	7.940061	10%	2.72	3.77
К	3	5%	3.23	4.35
		2.5%	3.69	4.89
		1%	4.29	5.61

Table 8. Analysis of the F-Bounds Test results

After checking the F-Bounds tests in Table 7, it is noted that the calculated F value is 7.940061 which is above the upper and lower bound test. The critical value of the upper bound is 5.61 at 1% significance at level. This means that the null hypothesis of no cointegrating relationship can be rejected which implies that GDP per capita is cointegrated with airport investment, Exports, and Imports. So there exists a long-run relationship between the variables.

Therefore, applying the Error Correction form for short-run coefficient and long-run adjustment we obtained the results shown in Table 9, whose results illustrate that in the short run coefficient of error correction the Constant (C) variable has negative coefficient (-1342.157) and its p-value (0.0001) statistically significant, which means that its coefficient negatively impacts the growth of GDP per capita at short run.

In the long run the adjustment or cointegration equation  $(CointEq(-1))^*$  has a negative coefficient (-0.201902), but its P value (0.0000) is significant. This implies that the speed of adjustment towards long run equilibrium is 20% or system corrects its previous period disequilibrium at a speed of 20% time within one period.

Variable	Symbol	Coefficient	Prob.	Impact on DGP
Short run Adjustment	С	-1342.157	0.0001	Negative (-)
Long run Adjustment	(CointEq(-1))*	-0.201902	0.0000	Negative (-)

Table 9. ARDL error correction regression

Error correction regression are represented by with summation signs while  $\beta_0$  in second part of the equation representing the long-run relationship. The estimation of short-run relationship based on error correction model is specified as:

$$\Delta GDP_{t} = \beta_{0} + \sum_{i=1}^{n} \beta_{1} \Delta Airport_{t-1} + \sum_{i=1}^{n} \beta_{2} \Delta X_{t-1} + \sum_{i=1}^{n} \beta_{3} \Delta M_{t-1} + \lambda ECT_{t-1}$$
(4)

Where  $\lambda$  measures the speed of adjustment and significant and negative coefficient ( $\lambda$ ) of  $ECT_{\iota t}$  implies that any disequilibrium in short-run between the dependent and explanatory variables will converge back to the long-run equilibrium relationship.

In order to analyze the existence of cointegration and the interactions of short-run and long-run dynamics between highway investment and economic growth, this study applied the bounds test developed by (Pesaran et al., 2001). The results show that the calculated value of F-statistics (7.940061) is greater than the critical value of the upper bound. Therefore, the hypothesis of the absence of cointegration is rejected, which implies the existence of a long-run relationship between the variables.

#### 5.6. Residual diagnostics

After the limit test of the long-term and short-term coefficients of the ARDL model, several diagnostic tests were performed whose results showed that the ARDL approach has no problems with autocorrelation. Based on the Jarque-Bera the residuals of the test are normal. The value is 0.563067 and p value (1.148712) is greater than 5%.

Breusch-Godfrey Serial Correlation LM Test proves that the residual obtained from the ARDL model is free from serial correlation. The Obs\*R-squared is 8.234248 and Prob value is 0.0163. Likewise, Heteroskedasticity Tests: Breusch-Pagan-Godfrey proves that the residual obtained from the ARDL model are free heteroskedasticity. The Obs\*R-squared is 4.647826 and Prob value is 0.3254.

#### 5.7. Stability Diagnostics

The Ramsey RESET Test was used to check the appropriate functional form. The probability value of F-statistic is 2.041418 suggesting that the model is well specified.

Having analyzed the Ramsey RESET Test, next the Wald Test was analyzed, taking into consideration the lags presented in Table 10. As can be seen from the results obtained, with the exception of c(1), c(2), c(3) and c(5) which are statistically significant, lag c(4) is statistically insignificant at 5% of significance, which do not impact GDP per capita growth.

After analyzing the lags, figure 3 shows the plot of cumulative sum (CUSUM) Test and cumulative sum of squares (CUSUMSQ) remained between the 5% critical bounds which prove the stability of the parameters. The

model is structurally stable. But, if CUSUM Test and CUSUMSQ exceed the 5%, critical bounds we can confirm instability of the coefficient.

It can be seen in Figure 12 that the CUSUM is well within the critical limits, which implies that all coefficients in the error correlation model are stable. But CUSUMSQ plots is not well within the critical limits in 2014, which implies that not all coefficients in the error correlation model are stable.

Lags	Coefficient	Std. Error	<b>T-Statistic</b>	Prob.
C(1)	0.103418	0.103418	7.717209	0.0000
C(2)	60.869667	11.90155	5.114434	0.0001
C(3)	-38.49132	11.48784	-3.350615	0.0044
C(4)	1.08E-06	6.81E-06	1.586317	0.1335
C(5)	-1342.157	-1342.157	2454695	0.0268

Table 10. Wald Test

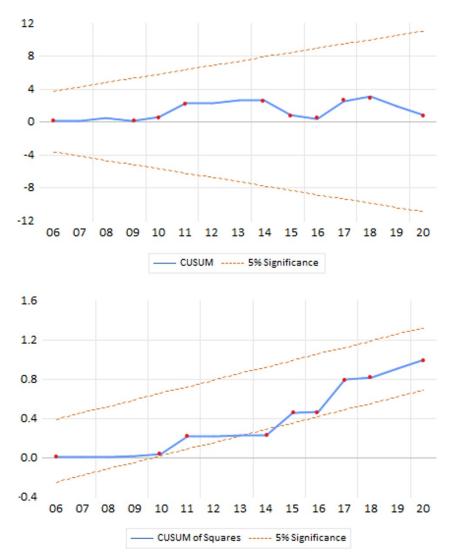


Figure 3. CUSUM Test and CUSUM of Squares

# 6. Conclusion and future work

This work analyzed the relationship between economic growth, investment in airport infrastructure, Exports and Imports in Angola with data from 2000-2020, using the ARDL cointegration test. The results show that the investment in airport infrastructure impact consistently the growth of GDP per capita. However, ARDL Error Correction Regression show that the coefficient of the variables impacts negatively the growth of GDP per capita in short-run and in long-run. This indicates that the investment made in airport infrastructure has no positive return for the Angolan economy. This situation is due to the lack of air connections to the interior provinces, which in turn reduces economic attractiveness. There are several airports/aerodromes in the country, but unfortunately most of them does not receive flights during the year, which makes them an investment without return. This observation is in line with Pontes and Pais (2018) when they point out that the fact that a transportation infrastructure is not used as much as it could be is a cause of low aggregate productivity because it represents low productivity for an important item of social capital. However, this situation may change with the development of logistic platforms, the expansion of the road network, and the construction of the railway network, which are included in the Angolan government's development plan (Angola, n.d.). Regarding limitations, this work consisted only in analyzing the impact of investment in airport infrastructure in Angola, the results obtained were derived from the use of the ARDL technique, which may limit the understanding of the factors that determine the management of Angolan airport infrastructure. Regarding the future, it is intended to develop a study in order to understand the factors that determine the management of airport infrastructure in Angola.

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