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THE IMPACT OF ROAD, RAIL AND PORT INFRASTRUCTURE ON THE ANGOLAN EXPORT GROWTH: AN AUTO-REGRESSIVE DISTRIBUTED LAG ANALYSIS

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Abstract:
This study seeks to analyze the impact of investment in road, rail, and port infrastructure on Angola's exports growth, using imports and GDP per capita as control variables. This study uses annual data for the period 2000-2020. The Auto-Regressive Distributed Lag is applied to determine the existence of short-run and long-run correlation between the variables. The results of the model suggest that there is a short-run and a long-run relationship between transport infrastructure investment, imports, exports, and economic growth. The coefficient of the variables in the short run and in long run is statistically significant at 5% of significance, which means that all variables impact the growth of exports significantly.

JEL: R40; R41; F10; F15

Keywords: Angolan transport infrastructure; impact of transport infrastructure, import; export; economic growth

1. Introduction

Achieving a sustainable level of economic growth with low import indexes and high export indexes is the main objective of the macroeconomic policies of several countries. Angola's main export product since independence has been crude oil. Already among the imports are foodstuffs, clothing, industrial equipment, automobiles, construction materials, medicines, and hospital equipment, among others.

The literature states that there is a close relationship between transportation infrastructure, exports, imports, and economic growth. The impact of these variables on the lives of citizens and the growth of the country is immediate. Developing roads, railroads and ports positively impact a country's economy. For example, mercantilists

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from the early days of economics as a science believed that the effective way to achieve the greatest wealth of the nation is through foreign trade. According to McConnell *et al.* (2019), in this context, it is essential to increase exports and decrease imports.

Export plays a very important role in economic development. Export increases the total demand in society, which in turn increases the level of national income (Abdulrahman, 2021). Exports represent the value of goods sold abroad to active an increase in national income. Export represents a demand for goods and services produced by an economy for residents outside that economy. In a broad sense, it is the value of all goods, services and capital exported to the rest of the world to achieve an increase in national income *(Morgan et al.,* 2012). The more exports that are made, the greater the level of income in the circular flow of national income.

Angola has an area of 1.246.700 km^2, and is the seventh largest country in Africa. Despite its long continental border of 84.837 km, connections to other economies in the region are limited by poor land transport infrastructure. The country's eastern, northeastern, and southwestern provinces are isolated from the rest of the country due to a lack of good transportation infrastructure (Haddad *et al.,* 2020). The weak development of the Angolan supply chain is strongly linked to the poor development of transportation infrastructure that limits the large flows of goods and services, especially in the interior of the country (Campos *et al.,* 2022) and (Campos *et al.,* 2023).

After independence, a civil war supported by both the capitalist and the communist bloc began (Åkesson & Orjuela, 2019). The war seriously affected the infrastructure, leading the country's economy to rely heavily on imports following the collapse of domestic industry and agriculture (Porto & Clover, 2003). The war devasted the country and destroyed most of its economic infrastructure (Pushak & Foster, 2011). After the war, the government began to rebuild the transportation infrastructure (Jensen, 2018). Peace and political stability set the stage for an economic boom fueled by revenues from oil production. However, despite the significant improvements that have been recorded in the rehabilitation of roads, railways, ports and airports, the country still faces vast infrastructure shortages (Ojukwu *et al.,* 2013) and (Duarte *et al.,* 2014).

Despite the investment made, in terms of infrastructure and logistics Angola still faces serious difficulties in achieving levels of efficiency and services desired by companies operating in the Angolan market. Angolan's supply of logistics services is composed of an inefficient supply of customs, roads and railway (Deloitte, 2014). The levels achieved are still far below what is needed to close the gap (ANEME, 2016) and (Haddad *et al.,* 2020). Thus, given the importance that transport infrastructure (road, railway, and ports) plays in the movement of flows of goods, it is essential to understand the impact they have on the import and export of goods and services at the local level.

The objective of this research is to analyze the impact of investment in roads, railway, and ports on the growth of the Angolan economy. For that, the following research question was raised:

1) What impact does investment in road, rail and port infrastructure have on Angolan export growth?

There are very few scientific papers addressing the state of Angola's transportation infrastructure, as well as the correlation of the variables mentioned above. The existence of little literature signals a deficit that somewhat hinders the understanding of the balance of trade balance as well as the growth and development of the impact of these variables becomes fundamental to understanding the dynamics of the country's economic growth.

This article is organized into 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 transport infrastructure, its classification, impact, export, and import. Section 3 presented the methodology and research method. Section 4 presented the data, econometric model specification. At Section 5 it is presented the discussion of the empirical results. Finally, the section 6 presents the final considerations.

2. Literature review

2.1. The impact of imports and exports on the economy

Hye & Boubaker (2011) developed a study to investigate Tunisia's growth based on exports, imports and sustainability using annual time series data for the period 1960-2008. The authors used the ARDL approach to determine the long-run causality relationship between exports, imports, and GDP. Their results indicate unidirectional causality from exports to economic growth and bidirectional relationship between imports and economic growth.

Exports are a component of aggregate expenditures. Net exports are calculated by adding the trade balance and the services balance (McConnell *et al.* (2019). The trade balance is the difference between the value of services a country exports and the value of services a country import (Enders & Ma, 2011).

Gross domestic product (GDP) measures the value of final goods and services produced in a given country over a given period, usually a year (McConnell *et al.*, 2019) and (Abdulrahman, 2021). Real GDP keeps the price constant, which makes it a better measure than nominal GDP of changes in an output of goods and services from one year to the next. Growth in the economy is almost always measured as real GDP growth (McConnell *et al.*, 2019).

The impact of export promotion on GDP growth has been extensively investigated. Examining growth based on exports, imports and external debt sustainability is important for the following reasons (Hye & Boubaker, 2011):

- It serves as an indicator for the government of the effectiveness of regulations and reforms undertaken, as well as guidelines for policy making and planning;
- Second, export-oriented growth reflects the health of the eternal environment within which the country's trade is evolving.
- Export oriented growth and trade import-oriented growth is fixed in an association or agreement between a group of countries.

Ghirmay *et al.* (2001) studied the relationship between exports and economic growth in nineteen developing countries using a multivariate causality analysis based on error correction model. Their results showed a long-term relationship between the two variables only in twelve developing countries, with export promotion attracting investment and increasing GDP in these countries. Moutinho & Madaleno (2020) in their study on economic growth in African OPEP countries, refer that there is a significant expansion of trade flows of African countries (among them Angola) with China and India, thus increasing exports as well as imports.

Figure 1 show the trends of GDP per capita, exports and imports growth of Angola between 2000 and 2020. Despite the reports on the economic growth that the country achieved in the post-war period, in the broad sense the determinants that should drive or have repelled economic growth and development in the country have not been explored in depth.

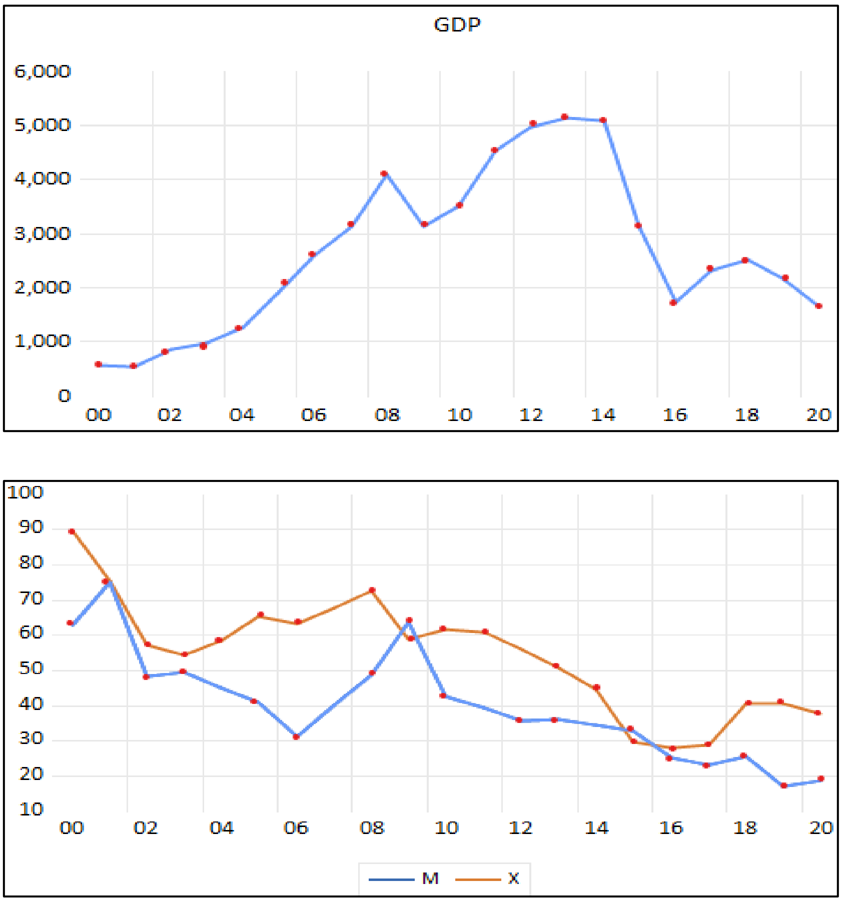


Figure 1: Growth of GDP per capita, import and export of Angolan (% of GDP)
(Source: World Bank)

Thus, it is felt that the challenge for the country today is to explore the transportation infrastructure which are the main drives of economic growth in the country.

2.2. The impact of transport infrastructure on the economy

Different authors, whether in the field of public policy, economics, infrastructure planning, as well as other areas, have analyzed the role of transportation infrastructure. Examining the relationship between transportation infrastructure and economic growth helps clarify some questions regarding transportation improvements and economic development.

A well-developed transport infrastructure provides certain benefits through certain micro and macroeconomic factors of productivity. It has a direct impact on the quality and cost of logistic services, allows reducing the time and cost of transportation, decreases the risk and improves the quality of logistics services, improves comforts, safety and security (Skorobogatova & Kuzmina-merlino, 2017).

Transport infrastructure developments lead to the creation of new economic activities necessary for the construction, maintenance of transport infrastructures and provide comfort to the users of these infrastructures. In this context, high levels of investment in transport infrastructure imply higher economic growth and increased future output, especially, when these investments are properly targeted and managed. Their results impact on social welfare (Grimsey & Lewis, 2002) and (Carnis & Yuliawati, 2013).

Arbués *et al.* (2015) noted that the construction of transport infrastructure between point A and point B causes impacts (direct and/or indirect) on the economy of neighboring regions (spillover effect). Road transport infrastructure positively affects the output of the region in which the infrastructure is located and neighboring regions, while the construction of ports and airport cause less significant impacts. The role that transportation infrastructure plays in a region's economy is determined by the services it provides.

There are many approaches on the impact of investment in transport infrastructure and most of them converge in considering that public spending on infrastructure boosts economic growth. Transport infrastructure increases productivity and economic growth, facilitates the transport of goods between regions, reduces travel time and accident risks, and indirectly generates employment opportunities.

The spillover effects of the economy derived from the construction of transportation infrastructure began to gain notability from Aschauer's studies dating back to 1989 (Condeço-melhorado *et al.*, 2014). The connection between transportation infrastructure investments and economic growth and vice versa has attracted considerable attention from researchers in recent decades (Mohmand *et al.*, 2020). However, the pioneer to suggest a positive relationship between economic growth and infrastructure was Aschauer in 1989. Similarly, Wan & Zhang (2018) in analyzing the direct and indirect effects of infrastructure on firm productivity have distinguished the relevance of the contribution of (Aschauer, 1989) and (Krugman, 1991).

Transportation infrastructure allows firms to serve wider markets more economically, allows firms to obtain skilled labor and transport goods more safely and quickly, thus making them more productive (Ahmed *et al.*, 2013), (Arbués *et al.*, 2015) and (Banerjee *et al.*, 2020).

2.3. The road infrastructure

The road network is one of the most important transport infrastructure (Anor *et al.*, 2012), its rehabilitation contributes to the growth of a country, increases productivity and reduces production costs, especially in the agricultural sector (Peter *et al.*, 2015) on the contrary, poorly maintained roads restrict mobility, significantly increase vehicle operating costs, increase accident rates and exacerbate isolation between regions, poverty, poor health and illiteracy in rural communities (Burningham & Stankevich, 2005).

Road infrastructure is an essential part of everyday life. Its users, logistics companies, and public transportation agents expect a reliable and safe road infrastructure to travel from one place to another and transport goods. Thus, managers need to properly plan, build, maintain, and operate road infrastructure so that it adds value to users (Hartmann *et al.*, 2016). Road infrastructure and all transportation services that use roads, such as private vehicles, public transportation, and freight carriers improve the public's standard of living, support commercial integration, provide social services, and contribute to the development of the economy (Rensburg & Krygsman, 2020).

Road infrastructure performance is closely associated with passenger and freight transportation systems and socioeconomic development. Moreover, it is commonly measured by indicators monitored by sensors (Song *et al.*, 2021). 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. Its construction and maintenance absorb significant resources, and its importance and public nature raise political and economic concerns (Short & Kopp, 2005). As such, transportation infrastructure is a crucial component of economic growth (Barzin *et al.*, 2018).

2.4. Railway infrastructure

Rail transportation is more economical compared to road transportation (Sala & Ravishankar, 2019), it is an important and irreplaceable means of transportation due to its peculiar characteristic such as, high energy efficiency in handling large masses, especially in medium and long distances, high operation speed, comprehensive system and less climate action (Cao *et al.*, 2020).

Several railway infrastructure exhibit very high levels of degradation, which makes the maintenance of these infrastructure a great challenge due to the volume of financial capital required (Rama & Andrews, 2014). However, despite rolling stock wear and tear, rail infrastructure continues to play a vital role in the multimodal freight and passenger transportation market due to its advantages in volume, speed, efficiency, and environmental friendliness (Meng & Corman, 2020). The goal of rail infrastructure is to provide access to destination while ensuring punctuality, safety, comfort, and reliability in the transportation of people and goods as a function of the quality of design, construction, operation, and maintenance (Nathanail, 2014).

2.5. Port infrastructure

Port infrastructure plays a crucial role for the stability and growth of economies. However, its development is quite costly (Aerts *et al.*, 2014). Port and offshore terminals are essential infrastructure and play important roles in the transportation of goods. With over 80% of international trade by volume being conducted by sea, these infrastructures are vital to maritime trade (Mokhtari *et al.*, 2011). Ports are key nodes in supply chains, port authorities focus on increasing their efficiency and effectiveness (Caldeirinha *et al.*, 2020). A port is a geographical area where ships dock to load and unload cargo, generally it is a protected deep-water area. Ports are composed of several terminals (Dwarakish & Salim, 2015) and (Alrukaibi *et al.*, 2020).

The economic relevance of ports stems from the fact that most of a region's foreign trade is conducted by sea. Thus, the level of port efficiency greatly affects a country´s competitiveness, since port efficiency results in lower export tariffs that, in turn, favor the competitiveness of domestic products in international markets (González & Trujillo, 2008).

In general, ports fall into two categories: seaports and dry ports. A seaport is a gateway, connecting regions and countries. Ports generate significant impacts on the regions in which they are located and on adjacent regions (Yudhistira & Sofiyand, 2017). Dry ports are classified into three categories (Roso *et al.*, 2009). Dry ports function as inland hubs to facilitate the movement of cargo between seaports and the hinterland (Nguyen & Notteboom, 2016). Based on the literature, three types of cargo terminal are distinguished: satellite terminals (A), cargo centers (B), and transfer centers (C). Satellite terminals tend to be close to a port facility, but mostly on the periphery (sometimes less than 100 km away). They accommodate additional traffic and empty container depots (Rodrigue & Notteboom, 2012).

2.6. Angola's transport infrastructure

The bulk of public spending on infrastructure was directed to the transport sector, of which more than 2/3 was used for road construction. From 2002 to 2009, Angola spent an average of $2.8 billion per year on road reopening programs. This effort was maintained throughout the 2009-2018 period and about $2.1 billion/year or 2.1% of Angola's GDP was allocated to the road sector. Almost 97% of public expenditure in this sector was allocated to rehabilitation and resurfacing works. Spending on road maintenance represents on average only 5% of total road spending, or $28 million/year (Benmaamar *et al.*, 2020). Angola began rebuilding its infrastructure in 2002. In the transportation infrastructure sector, 13.000 km of roads have been rehabilitated and four major ports have been upgraded (Muzima, 2019).

Despite the investment made, about 2/3 (64%) of the road networks is in critical condition. The quality of Angola's road infrastructure is reflected in the 136th place in a list of 141 countries, based on the 2019 Global Competitive Report. Angola's score is 2.2 out of 7.0 and is one of the lowest in Africa. Angola lags countries that have lower GDP (Ghana, Senegal, Ivory Coast) (Muzima, 2019) and (Benmaamar *et al.*, 2020).

The current asset value of the road network is about $11.20 billion or about 11,0% of Angola´s GDP and every US dollar spent on road maintenance will generate $3.4 in cost savings for the road user. The current asset value as a share of the maximum road asset value is 74.5%. This indicates that over 25% of the asset value of the road network is lost due to lack of maintenance or postponement of road rehabilitation (Benmaamar *et al*., 2020).

Regarding the railway infrastructure, railway construction in Angolan began in 1887, and in 1989 the Luanda railway line was inaugurated, and in 1910 and 1912 the Moçâmedes and Benguela railway lines were inaugurated respectively. In 1961, the Moçâmedes railway was extended to Menongue in the interior (Olukoju, 2020). Currently, the country has a railway network of 2.950 km, of which 2.725 km have been rehabilitated with the investment of more than $3 billion, all the way the railway network still needs interventions (Muzima, 2019).

As for port infrastructure, there are currently seven seaports in Angola (Amboim, Cabinda, Lobito, Luanda, Malongo, Namibe e Soyo), four of which are deep-water (Luanda, Lobito, Amboim and Namibe) and three are shallower (Malongo, Soyo and Cabinda). According to (Muzima, 2019), Angola has four major seaports (Luanda, Cabinda, Lobito and Namibe) that make the country a regional transportation hub for neighboring landlocked countries.

Luanda with 11 berths is the most important port and receives 80% of Angola's import. The second most important port in the country is the port of Lobito. Most of Angola's port are limited by factors such as, poor management, low container flow and poor connection with rail (Golub & Prasad, 2016). The capacity of the port of Lobito has been expanded, but its utilization rate is still less than 25% due to the lack of infrastructure that would allow in to be connected to neighboring landlocked inland countries (Zambia mining companies) (Muzima, 2019). The Malongo port in general is more used for the provision of services to the oil industry, for this reason it is not very busy. To keep control of container flows, the seaport of Luanda is assisted by the dry port of km-30, installed adjacent to the special economic zone of Luanda.

3. Material and Methods

The present study used the unsystematic literature review based on the approach of (Green *et al.,* 2006), (Yuan & Hunt, 2009), (Gasparyan *et al.,* 2011), (Hochrein & Glock, 2012) and (Ferrari, 2016). Searches were conducted in Scopus, Web of Science, Science Direct and Google Scholar, using the following keywords: *"Angolan transport infrastructure"*, *"import"*, *"export" and "growth economic"*. The following filtering criteria were used: (1) p*ublication years: 1990 – 2021; (2) document type: article; (3) source type: journal; (4) language: English.* All extracted articles were manually analyzed considering the following inclusion an exclusion criterion: title analysis, research area, keywords used, contributions, and main results.

Regarding the research method, the present study used the Auto-Regressive Distributed Lag (ARDL) approach to analyze the relationship between variables in the growth and development of the Angolan economy. The implementation of the ARDL approach was adopted for the following reasons:

- the sample use in this study is small, containing 21 annual observations;
- the ARDL cointegration limit tests developed by (Pesaran *et al.*, 2001) fit small samples (Odhiambo, 2009) and (Hye & Boubaker, 2011);
- the ARDL method is superior to other cointegration procedures, since it allows working with variables of different orders I(0), I(1) or factionally cointegrated (Hye & Boubaker, 2011);
- in the ARDL technique, the long-term and short-term factors of the model are evaluated at the same time (Belloumi, 2014).

3.1. Data sources and model variables

This section sets out the analytical framework in this study, providing the model used to examine the impact of investment in transport infrastructure (roads, railway, and ports) on Angola's exports growth, using imports and GDP per capita as a control variable. The data was taken from two databases: Angola's Ministry of Finance and World Bank.

Table 1: Variables in the Models and Data Sources

Variables	Symbol	Meaning	Data Source
Crescimento económico	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
Imports	M	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
Road infrastrucutures	ROAD	Total de investment in road.	Ministry of Transporte
Railway infrastructures	RAIL	Total de investment in railway	Ministry of Transporte

Port infrastructures	PORT	Total de investment in ports.	Ministry of Transporte
Exports	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

To analyze the impact of the variables on X growth, the economic function was specified in equation (1). The independent variables are GDP per capita, imports, and investment in road, rail, and port infrastructure. The dependent variable is exports of goods and services growth. The model is shown as follows:

$$X = f(Road, Rail, Port, GDP, M) \ (1)$$

The econometric form of the equation is presented as follows in equation (2):

$$X_t = \beta_0 + \beta_1 Road_t + \beta_2 Rail_t + \beta_3 Port_t + \beta_4 M + \beta_5 GDP_t + \varepsilon_t \ (2)$$

Where X represents the exports growth. Road represents investment in road infrastructure. Rail represents investment in railway infrastructure, Port represents investment in port infrastructure, import, and GDP per capita represents the control variables. The parameters β_1, β_2, β_3 β_4 and β_5 are the long-terms elasticity of export. *t* and $\boldsymbol{\varepsilon_t}$ represents time and the white noise perturbation error term. The expected signs of β_1, β_2, β_3 β_4 and β_5 are positive because an increase in the level of investment capital of transport infrastructure should grater effects on export, greater economic activity, and higher GDP per capita growth.

4. Results and Discussion

4.1. Trend of the series and Unit Root Test

There are three ways to identify whether a series is stationary or not (graphical method, Autocorrelation Function (ACF) and Dickey and Fuller test (AF)). For this purpose, in this research, to identify whether the series are stationary or not and to understand the order of integration of the variables, we performed the unit root test and the conventional Augmented Dickey-Fuller (ADF) test. The results in Figure 2 show that some variables are stationary at level and other are stationary at first difference. To understand the analysis, two parameters must be considered: the *t-statistic* and the probability value, using the following hypotheses with an α = 0,05 or 5%:

- 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.

For the series to be considered stationary, we must reject the null hypothesis (H0), concluding with 95% confidence that it is a stationary series, as shown in Figure 2.

1	**UNIT ROOT TEST RESULTS TABLE (ADF)**							
2	Null Hypothesis: the variable has a unit root							
3		**At Level**						
4			X	GDP	M	ROAD	RAIL	PORT
5	With Constant	t-Statistic	-2.1698	-1.9486	-1.6456	-2.0891	-2.7660	-3.7246
6		*Prob.*	*0.2222*	*0.3049*	*0.4421*	*0.2505*	*0.0819*	*0.0119*
7			n0	n0	n0	n0	*	**
8	With Constant & Trend	t-Statistic	-2.3006	-0.7412	-2.9963	-1.9158	-2.9350	-3.7030
9		*Prob.*	*0.4148*	*0.9548*	*0.1572*	*0.6091*	*0.1742*	*0.0461*
10			n0	n0	n0	n0	n0	**
11	Without Constant & Trend	t-Statistic	-2.0490	-0.4228	-1.4908	-1.4645	-1.4424	-1.4156
12		*Prob.*	*0.0415*	*0.5177*	*0.1239*	*0.1298*	*0.1350*	*0.1412*
13			**	n0	n0	n0	n0	n0
14		**At First Difference**						
15			d(X)	d(GDP)	d(M)	d(ROAD)	d(RAIL)	d(PORT)
16	With Constant	t-Statistic	-3.3715	-2.9447	-5.9824	-4.5998	-4.1936	-7.8404
17		*Prob.*	*0.0256*	*0.0588*	*0.0001*	*0.0020*	*0.0050*	*0.0000*
18			**	*	***	***	***	***
19	With Constant & Trend	t-Statistic	-3.2108	-3.3430	-3.3370	-4.6572	-4.0667	-7.7763
20		*Prob.*	*0.1118*	*0.0950*	*0.0939*	*0.0079*	*0.0254*	*0.0000*
21			n0	*	*	***	**	***
22	Without Constant & Trend	t-Statistic	-3.3593	-3.0258	-5.4959	-4.7330	-4.3126	-8.0672
23		*Prob.*	*0.0020*	*0.0046*	*0.0000*	*0.0001*	*0.0002*	*0.0000*
24			***	***	***	***	***	***
25								
26	Notes:							
27	a: (*)Significant at the 10%; (**)Significant at the 5%; (***) Significant at the 1% and (no) Not Significant							
28	b: Lag Length based on SIC							
29	c: Probability based on MacKinnon (1996) one-sided p-values.							

Figure 2: Unite Root Test
(Source: the authors)

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.

4.2. Regression of the model using the ARDL method

In this section we are going to discuss the ARDL cointegration, long run and shot run coefficient and long run adjustment (Error correction form). ARDL cointegration is used when considered variables have different order of integration that is some variables are stationary at level and some are stationary at first difference. Thus, when performing the regression, the following results illustrated on the Figure 3 were obtained.

The variable X that represents the Angolan export, with lag presents a positive coefficient (0.519015) and its p-value is statistically significant (0.0206), this means that this variable positively impacts the growth of export. GDP per capita at level presents a positive coefficient (0.010070) and its p-value is statistically significant (0.0168), this means that this variable positively impacts the growth of export. GDP per capita with one and two lags presents a negative coefficient (-0.006276; -0.003555) and its p-value are statistically insignificant (0.1876; 0.2534), this means don't impact the growth of export. M has a positive coefficient (1.325412) and its p-value is statistically significant (0.0065), this means impact positively the export growth. M variable with one and two lags presents a negative coefficient (-0.484609; -0.507612) and its p-value are statistically significant (0.0283; 0.0280), this means impact the growth of export negatively. The road variable at level has negative coefficients (-1.96E-09) and statistically insignificant p-value (0.3373), which mean that do not impact the X growth. The road variable with one lag has negative coefficients (-7.00E-09) and statistically significant p-value (0.0090), which means that impact negatively the X growth.

Dependent Variable: X
Method: ARDL
Date: 11/30/22 Time: 13:48
Sample (adjusted): 2002 2020
Included observations: 19 after adjustments
Maximum dependent lags: 1 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic): GDP M ROAD RAIL PORT
Fixed regressors: C
Number of models evaluated: 243
Selected Model: ARDL(1, 2, 2, 2, 0, 0)

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
X(-1)	0.519015	0.166475	3.117675	0.0206
GDP	0.010070	0.003069	3.281467	0.0168
GDP(-1)	-0.006276	0.004221	-1.486782	0.1876
GDP(-2)	-0.003555	0.002814	-1.263289	0.2534
M	1.325412	0.324291	4.087103	0.0065
M(-1)	-0.484609	0.168715	-2.872357	0.0283
M(-2)	-0.507612	0.176084	-2.882781	0.0280
ROAD	-1.96E-09	1.88E-09	-1.042547	0.3373
ROAD(-1)	-7.00E-09	1.85E-09	-3.793410	0.0090
ROAD(-2)	5.91E-09	1.31E-09	4.509220	0.0041
RAIL	-2.20E-08	9.58E-09	-2.298186	0.0613
PORT	7.29E-09	4.68E-09	1.557337	0.1704
C	18.47746	6.591960	2.803030	0.0310

R-squared	0.981595	Mean dependent var	51.46842
Adjusted R-squared	0.944786	S.D. dependent var	13.70231
S.E. of regression	3.219711	Akaike info criterion	5.392202
Sum squared resid	62.19924	Schwarz criterion	6.038397
Log likelihood	-38.22592	Hannan-Quinn criter.	5.501564
F-statistic	26.66722	Durbin-Watson stat	3.469954
Prob(F-statistic)	0.000326		

*Note: p-values and any subsequent tests do not account for model selection.

Figure 3: Regression of the model ARDL
(Source: the authors)

The road variable with two lags has positive coefficient (5.91E-09) and p-value (0.0041) is statistically significant, meaning that impact X positively. The rail variable at level has negative coefficient (-2.20E-08) and p-value (0.0613) is statistically insignificant, meaning that does not impact X. The port variable at level has positive coefficient (7.29E-09) and p-value (0.1704) is statistically insignificant, meaning that don't impact X. However, the constant (C) presents a positive coefficient (18.44746) and p-value (0.0310) statistically significant at 5%, meaning that if everything remains constant the X will have a positive impact.

4.3. ARDL long run and bound test

The ARDL bounds test is based on the assumption that the variables are I(0) or I(1). 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). The ARDL cointegration equation is formulated as follows:

$$\Delta X_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta Road_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta Rail_{t-1} + \sum_{i=1}^{n} \beta_3 \Delta Port_{t-1} + \sum_{i=1}^{n} \beta_4 \Delta GDP_{t-1} + \sum_{i=1}^{n} \beta_5 \Delta M_{t-1} + \mu_t \quad (3)$$

Where Δ presents the first difference, β_0 denotes the drift component, μ_t is the white noise residual and X, GDP, road, rail, port, and M are as defined earlier.

Interpreting the coefficient of the variables in the Figure 4, we can see that the constant (C) presents a positive coefficient (18.44746) and p-value (0.0310) statistically significant at 5%, meaning that if everything remains constant the X will have a positive impact.

ARDL Long Run Form and Bounds Test
Dependent Variable: D(X)
Selected Model: ARDL(1, 2, 2, 2, 0, 0)
Case 2: Restricted Constant and No Trend
Date: 11/30/22 Time: 13:52
Sample: 2000 2020
Included observations: 19

Conditional Error Correction Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	18.47746	6.591960	2.803030	0.0310
X(-1)*	-0.480985	0.166475	-2.889233	0.0277
GDP(-1)	0.000240	0.001996	0.119970	0.9084
M(-1)	0.333192	0.180228	1.848721	0.1140
ROAD(-1)	-3.05E-09	2.37E-09	-1.286932	0.2455
RAIL**	-2.20E-08	9.58E-09	-2.298186	0.0613
PORT**	7.29E-09	4.68E-09	1.557337	0.1704
D(GDP)	0.010070	0.003069	3.281467	0.0168
D(GDP(-1))	0.003555	0.002814	1.263289	0.2534
D(M)	1.325412	0.324291	4.087103	0.0065
D(M(-1))	0.507612	0.176084	2.882781	0.0280
D(ROAD)	-1.96E-09	1.88E-09	-1.042547	0.3373
D(ROAD(-1))	-5.91E-09	1.31E-09	-4.509220	0.0041

* p-value incompatible with t-Bounds distribution.
** Variable interpreted as Z = Z(-1) + D(Z).

Levels Equation
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	0.000498	0.004189	0.118876	0.9093
M	0.692728	0.251920	2.749797	0.0333
ROAD	-6.33E-09	5.75E-09	-1.102097	0.3127
RAIL	-4.58E-08	2.47E-08	-1.851623	0.1135
PORT	1.52E-08	9.33E-09	1.624353	0.1554
C	38.41587	12.72335	3.019319	0.0234

EC = X - (0.0005*GDP + 0.6927*M -0.0000*ROAD -0.0000*RAIL + 0.0000 *PORT + 38.4159)

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
		Asymptotic: n=1000		
F-statistic	4.799403	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15
Actual Sample Size	19	Finite Sample: n=35		
		10%	2.331	3.417
		5%	2.804	4.013
		1%	3.9	5.419
		Finite Sample: n=30		
		10%	2.407	3.517
		5%	2.91	4.193
		1%	4.134	5.761

Figure 4: Limit test of ARDL
(Source: the authors)

GDP variable with lag has positive coefficient (0.700914) and its p-value (0.0147) is statistically significant at 5% significance, meaning that it positively impacts the growth of GDP per capita. The variable X with lag presents a negative coefficient (-0480985) and its p-value is statistically significant (0.0277), this means that this variable negatively impacts them self. GDP per capita with lag presents a positive coefficient (0.000240) and its p-value is statistically insignificant (0.9084), this means that this variable doesn't impacts the growth of export. M with lag presents a positive coefficient (0.333192) and its p-value are statistically insignificant (0.1140), this means that don't impact the export growth.

Road with lag has a negative coefficient (-3.05E-09) and its p-value is statistically significant (0.2455), this means don't impact the growth of export. Rail at level has a negative coefficient (-2.20E-08) and its p-value is statistically insignificant (0.0613), this means that don't impact the export growth. Port at level has a positive coefficient (7.29E-08) and its p-value is statistically significant (0.1704), this means don't impact the export growth.

The difference of GDP per capita at level has a positive coefficient (0.010070) and its p-value is statistically significant (0.0168), this means that impact the export growth positively. The difference of GDP per capita with a lag has a positive coefficient (0.003555) and its p-value is statistically insignificant (0.2534), this means that don't impact the export growth. The difference of M has a positive coefficient (1.325412) and its p-value is statistically significant (0.0065), this means that impact the export growth positively.

The difference of M with one lag has a positive coefficient (0.507612) and its p-value is statistically significant (0.0280), this means that impact the growth of export positively. The difference of road has a negative coefficient (-196E-09) and its p-value is statistically insignificant (0.3373), this means that don't impact the export growth. However, the difference of road with lag has a negative coefficient (-591E-09) and its p-value is statistically significant (0.0041), this means that impact the export growth negatively.

Regarding the long-run coefficient we see that the GDP per capita has a positive coefficient (0.000498) and its p-value (0.9093) higher that 5% significance, which means that statistically it is insignificant, it does not impact the X growth. The variable M has a positive coefficient (0.692728) and p-value (0.0333) statistically significant at 5% of significance, which means that statistically impact the X positively. The variable *road* has a negative coefficient (-6.33E-09) and p-value (0.3127) statistically insignificant at 5% of significance, which means that statistically don't impact the X.

The variable *rail* has a negative coefficient (-4.58E-08) and p-value (0.1135) statistically insignificant at 5% of significance, which means that statistically don't impact the X. The variable *port* has a positive coefficient (1.52E-08) and p-value (0.1554) statistically insignificant at 5% of significance. However, the constant (C) has a positive coefficient (38.41587) and a p-value (0.0234) statistically insignificant at 5% of significance, which means that statistically impact positively the X at long-run. The constant elucidates that if everything remains constant, the transport infrastructure investment and the control variable in the long-run will impact the X growth positively.

To understand the ARDL bound test is used the following rules from (Pesaran *et al.*, 2001) and (Narayan, 2005):

- 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.

After checking the F-Bounds tests it is noted that, the calculated *F value* is 4.799403 which is above the upper and lower bound test. The critical value of the upper bound is 4.15 at 1% significance at level. This means that the null hypothesis of no cointegrating relationship can be rejected which implies that X is cointegrated with transport infrastructure investment and control variables. So there exists a long-run relationship between the variables.

4.4. Error correction form

Therefore, applying the Error Correction form for short-run coefficient and long-run adjustment we obtained the results shown in Figure 5. Error correction regression are represented by with summation signs while α 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:

$$\Delta X_t = \beta_0 + \sum_{i=1}^{n} \beta_1 \Delta Road_{t-1} + \sum_{i=1}^{n} \beta_2 \Delta Rail_{t-1} + \sum_{i=1}^{n} \beta_3 \Delta Port_{t-1} + \sum_{i=1}^{n} \beta_4 \Delta GDP_{t-1} + \sum_{i=1}^{n} \beta_5 \Delta M_{t-1} + \lambda ECT_{t-1} \quad (4)$$

Where λ measure the speed of adjustment and significant and negative coefficient (λ) of ECT_{t-1} implies that any disequilibrium in short-run between the dependent and explanatory variables will converge back to the long-run equilibrium relationship.

All variables that represent the short run become statistically significant et 5% of significance. The difference of GDP per capita has a positive coefficient (0.010070) and its p-value is statistically significant (0.0001), this means that impact the growth of export positively. The difference of GDP per capita with a lag has a positive coefficient (0.003555) and its p-value is statistically significant (0.0279), this means that impact positively the growth of export. The difference of M has a positive coefficient (1.325412) and its p-value is statistically significant (0.0000), this means that impact the export growth positively. The difference of M with one lag has a positive coefficient (0.507612) and its p-value is statistically significant (0.0004), this means that impact the export growth positively.

The difference of road has a negative coefficient (-196E-09) and its p-value is statistically significant (0.0176), this means that negatively impact the export growth. The difference of road with one lag has a negative coefficient (-591E-09) and its p-value is statistically significant (0.0002), this means that impact the growth of export negatively.
In the long run, the adjustment or cointegration equation (CointEq(-1))* has a negative coefficient (-0.480985), and its P value (0.0002) is significant. This implies that the speed of adjustment towards long run equilibrium is 48% or system corrects its previous period disequilibrium at a speed of 48% time within one period.

ARDL Error Correction Regression
Dependent Variable: D(X)
Selected Model: ARDL(1, 2, 2, 2, 0, 0)
Case 2: Restricted Constant and No Trend
Date: 11/30/22 Time: 17:32
Sample: 2000 2020
Included observations: 19

ECM Regression
Case 2: Restricted Constant and No Trend

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(GDP)	0.010070	0.001115	9.029587	0.0001
D(GDP(-1))	0.003555	0.001233	2.883298	0.0279
D(M)	1.325412	0.110707	11.97225	0.0000
D(M(-1))	0.507612	0.072253	7.025439	0.0004
D(ROAD)	-1.96E-09	6.04E-10	-3.245266	0.0176
D(ROAD(-1))	-5.91E-09	7.18E-10	-8.230695	0.0002
CointEq(-1)*	-0.480985	0.058678	-8.197051	0.0002

R-squared	0.939934	Mean dependent var	-1.973684
Adjusted R-squared	0.909901	S.D. dependent var	7.584769
S.E. of regression	2.276680	Akaike info criterion	4.760623
Sum squared resid	62.19924	Schwarz criterion	5.108574
Log likelihood	-38.22592	Hannan-Quinn criter.	4.819510
Durbin-Watson stat	3.469954		

* p-value incompatible with t-Bounds distribution.

F-Bounds Test — Null Hypothesis: No levels relationship

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	4.799403	10%	2.08	3
k	5	5%	2.39	3.38
		2.5%	2.7	3.73
		1%	3.06	4.15

Figure 5: Error correction regression
(Source: the authors)

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* (4.499403) is greater than the *critical value* of the *upper bound* (4.15). Therefore, the hypothesis of the absence of cointegration is rejected, which implies the existence of a long-run relationship between the variables.

4.5. 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 0.022029 and p value (0.989046) 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 15.57480 and Prob value is 0.0004. Likewise, Heteroskedasticity Tests: Breusch-Pagan-Godfrey proves that the residual obtained from the ARDL model are free heteroskedasticity. The Obs*R-squared is 16.56025 and Prov value is 0.1669.

5.6. Stability diagnostics

The Ramsey RESET Test was used to check the appropriate functional form. The probability value of F-statistic is 1.404058 suggesting that the model is well specified.

As can be seen from the results of the Wald Test in Figure 6, exception lags c(3), c(4), c(8) and c(12) which aren't statistically significant, lags c(1), c(2), c(5), c(6), c(7), c(9), c(10) and c(13) are statistically significant at 5% significance, this means that impact the export growth positively.

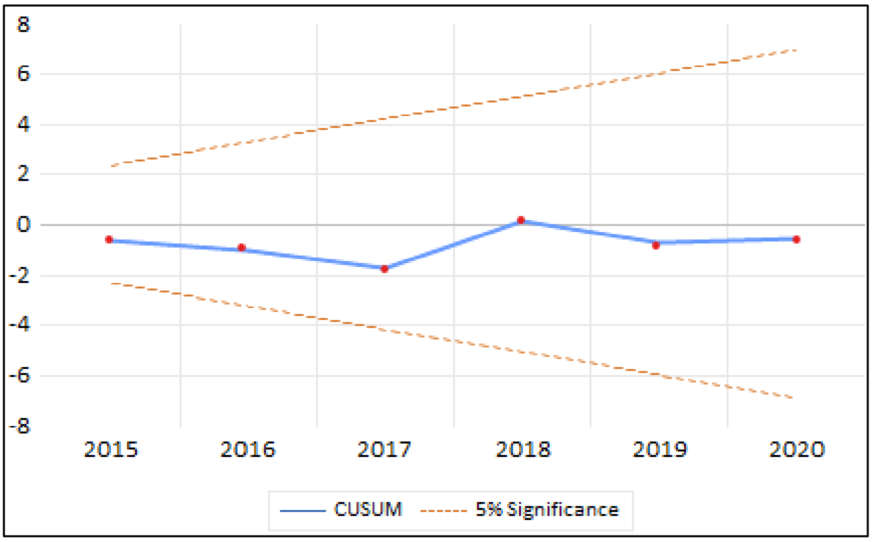
Dependent Variable: X
Method: Least Squares (Gauss-Newton / Marquardt steps)
Date: 11/30/22 Time: 19:44
Sample (adjusted): 2002 2020
Included observations: 19 after adjustments
X = C(1)*X(-1) + C(2)*GDP + C(3)*GDP(-1) + C(4)*GDP(-2) + C(5)*M + C(6)*M(-1) + C(7)*M(-2) + C(8)*ROAD + C(9)*ROAD(-1) + C(10)*ROAD(-2) + C(11)*RAIL + C(12)*PORT + C(13)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.519015	0.166475	3.117675	0.0206
C(2)	0.010070	0.003069	3.281467	0.0168
C(3)	-0.006276	0.004221	-1.486782	0.1876
C(4)	-0.003555	0.002814	-1.263289	0.2534
C(5)	1.325412	0.324291	4.087103	0.0065
C(6)	-0.484609	0.168715	-2.872357	0.0283
C(7)	-0.507612	0.176084	-2.882781	0.0280
C(8)	-1.96E-09	1.88E-09	-1.042547	0.3373
C(9)	-7.00E-09	1.85E-09	-3.793410	0.0090
C(10)	5.91E-09	1.31E-09	4.509220	0.0041
C(11)	-2.20E-08	9.58E-09	-2.298186	0.0613
C(12)	7.29E-09	4.68E-09	1.557337	0.1704
C(13)	18.47746	6.591960	2.803030	0.0310

R-squared	0.981595	Mean dependent var	51.46842
Adjusted R-squared	0.944786	S.D. dependent var	13.70231
S.E. of regression	3.219711	Akaike info criterion	5.392202
Sum squared resid	62.19924	Schwarz criterion	6.038397
Log likelihood	-38.22592	Hannan-Quinn criter.	5.501564
F-statistic	26.66722	Durbin-Watson stat	3.469954
Prob(F-statistic)	0.000326		

Figure 6: Wald Test
(Source: the authors)

After analyzing the lags, Figure 7 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.



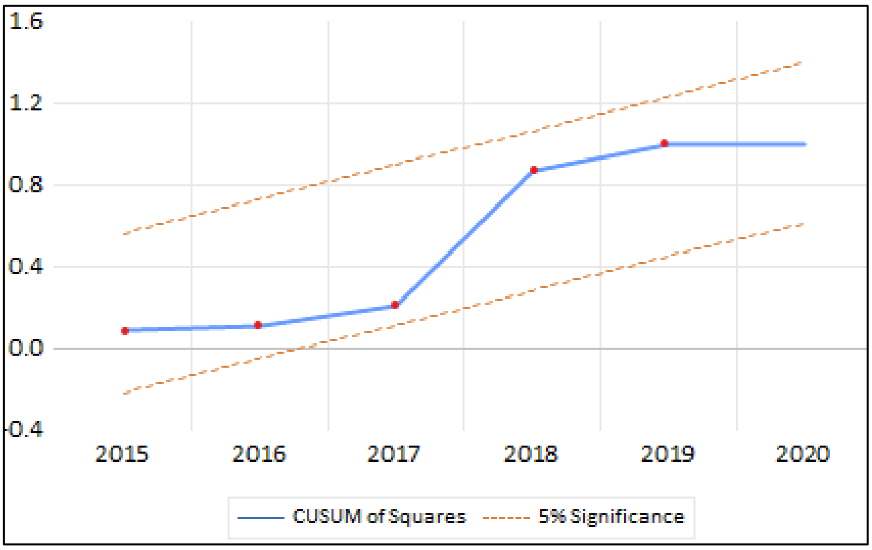


Figure 7: CUSUM Test and CUSUM of Squares
(Source: the authors)

It can be seen in Figure 7 that the *CUSUM* and CUSUMSQ are well within the critical limits, which implies that all coefficients in the error correlation model are stable.

5. Conclusion

The objective of this study was to analyze the impact that Angola's investment in its road, rail and port infrastructure has on the export's growth. For this purpose, annual time series data were used to estimate an econometric model with five variables (roads, railways, ports, imports, and GDP per capita) that basically explain the growth process of the Angolan economy. Angola has a predominantly subsistence economy that is becoming increasingly fragile due to the poor quality of its transportation infrastructure. As verified, the results show that the variables are intrinsically related to each other in the short and long term, significantly impacting the growth of Angolan exports in the short run and in the long run. Overall, the results allow for the conclusion that the poor quality of transportation infrastructure is a determining factor that is hindering agricultural development, supply chains and the subsequent export of products, which results in the hindering of the growth of the Angolan economy.

6. Recommendations

Therefore, to increase the volume of agricultural exports and increase the level of growth of the Angolan economy, it is essential that the Angolan government invest heavily in land transport and port infrastructure. We believe that this infrastructure would boost logistics, the agricultural sector, and supply chain.

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