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Bachelor Thesis.
The influence of landlocked geographical position and transport infrastructure on economies of Sub-Saharan Africa

Thesis Supervisor:
Jan-Jelle Witte
Department of Regional, Port and Transport Economics (RHV)

Student:
Tatiana Gorigledhzhan
356912
International Bachelor Economics and Business Economics (IBEB)

Abstract: Despite the rich natural resources and foreign aid, Africa remains the poorest continent in the world. This research aims to investigate the impact of the landlocked geographical position on the economic performance of the countries in Sub-Saharan Africa; the influence of domestic and transit transport infrastructure on GDP per capita and how transport facilities might alter the effects of unfavourable geographical position. Using a sample of 39 countries of Sub-Saharan African it has been concluded that on average landlocked states suffer from 28% lower GDP per capita; development of road and rail infrastructure domestically and in particular in the countries of transit facilitate better economic performance. These findings can be used for the creation of effective policies and contribute to future reduction of poverty in Africa.

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Introduction

The first Millennium Development Goal set by United Nations in 2000 strived to halve inequality and poverty by 2015 (United Nations, 2000). According to the annual reports on Millennium Goals Progress there is improvement in reaching the desired results. However Sub-Saharan Africa is lagging far behind the general trend and is highly unlikely to meet the set up goals (New Vision, 2014). Despite rich deposits of natural resources, Africa remains the poorest continent in the world and every third African suffers from hunger (DCA globally, 2013). Created reports highlighted that Sub-Saharan Africa is the only developing region in the world where the number of people living in extreme poverty increased since 1990 (New Vision, 2014). In 2008, half of the people in Sub-Saharan Africa lived on less than 1.3$ per day contributing to spread of starvation and diseases; shifting the countries of Africa away from the world's standards of life (United Nations, 2012). Over the past years governments of developed countries were fairly generous with their donations, charity and foreign aid to African countries. More than one trillion dollars was sent to Africa from the Western world (Edemariam, 2009). Nevertheless it seems that simple transfers of money from government to government or through institutions like The World Bank seem not work (Edemariam, 2009). One of the ways to fight the extreme economic situation in countries of Sub-Saharan Africa is to look into institutional issues faced by the countries and to try to solve the issues.

It is generally admitted that landlocked developing countries face more difficulties in economic development than countries with access to the coastline. The average value of GDP per capita in landlocked developing countries is 43% lower. The economies of landlocked developing countries are especially vulnerable to external economic shocks; they suffer from low diversity of export products, mainly natural resources and agricultural products (UNCTAD, 2013).

Changing patterns of geographical advantages were observed through centuries of human history. Early civilizations of living near Nile, Indus, Euphrates, Yellow and Yangtze rivers achieved high performance due to favourable geographical position in fertile lands. In the 16th century development of coastal-based trade shifted economic advantages from the Middle East and Mediterranean to the North Atlantic. With

technological development geographical positionig became less important, nevertheless the benefits of sea-based location still play an important role (Gallup, Sachs, & Mellinger, 1998).
Figure 1 represents the pattern of Gross domestic product per capita from 1970 to 2010. As can be observed, landlocked developing countries suffer from lower rates of economic development.

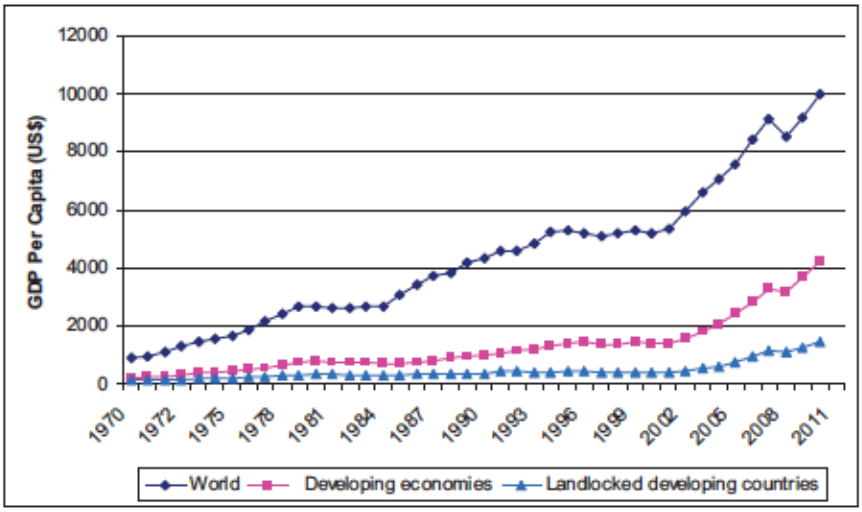

Figure 1, GDP per capita (US$)
Source: (UNCTAD, 2013)

Africa has the largest number of landlocked countries in the world, 16 out of 31 landlocked developing countries are located on the African continent. Landlocked countries such as Rwanda, Malawi, Burundi, DR Congo and Zambia are one of the slowest developing countries in the world (World Bank, 2012).

The problem of landlocked geographical position is mostly discussed on macro-economic level and focused on three measures: transport infrastructure, cross-border cooperation and international laws and treaties (Arvis, Raballand, & Marteau, 2007). Poorly developed transport infrastructure is one of the main obstacles in establishment of adequate transit system beneficial for both landlocked and coastline countries (UN-OHRLLS, 2003). Almaty Declaration and Treaty of Action signed in 2003 aims to address the problems faced by landlocked countries (UN-OHRLLS, 2014). One of the priorities stated in the treaty is infrastructure development and maintenance. It emphasized the importance of rail equipment availability, improvements in maintenance service level and implementation of international conventions regarding road transport (UN-OHRLLS, 2003). Among other stated priorities named in the Almaty Treaty are development of transit policies, facilitation of international trade and the use of international measures and control systems (UN-OHRLLS, 2003).

This research paper aims to find the link between poor performance of Sub-Saharan Africa and economic disadvantages typical for landlocked countries. It wishes to investigate the impact of landlocked geographical positioning on economic performance and how this effect can be changed by transport infrastructure.

It follows that the research question of this paper is:
"Does a country's landlocked geographical position have an impact on its economic performance and if so how transport infrastructure can alter the effect of this geographical disadvantage?"

Answering this question might contribute to the on-going research in the scientific world on the causes of extremely slow development in African countries. Numerous causes were researched during investigation of this economic phenomenon; corruption, lack of institutions and democracy, frequent military conflicts and famines are often named as main causes of the poor economic performance. Drawbacks of geographical positioning and the influence of transport infrastructure were barely investigated in existing literature.

The scientific relevance of this paper is to approach this problem from a new angle by considering country's geographical position away from the coastline and corresponding transport infrastructure as determinants of economic performance. It differs from existing literature as main attention of this paper is drawn to importance of geographical position and transport infrastructure rather than other political and social factors investigated before. Millennium Development Goals, aid organizations and international charity programs show that international community is concerned with present situation in Africa. It becomes apparent that there is no single step solution to the current situation in Africa. The social relevance of this paper is to propose one of the possible ways to decrease extreme poverty in Africa, direct government authorities and charity organizations to one of the efficient ways to improve economic performance in Africa.

In order to solve the research question data obtained from official sources of African development Bank Group, World Bank and some other organizations for 39 countries of Sub-Saharan Africa is investigated using ordinary least squares method (OLS). The first part of the paper is dedicated to examination of existing literature, followed by a description of the data used in the analysis and the used throughout of models performed in the research. After running the regression equations the results are summarised and hypotheses are evaluated. Taking into account all the factors discussed in the paper, research question is answered and general conclusion is drawn. Finally, the limitations of this paper are discussed.

Literature review

This research aims to investigate the main factors influencing slow development of landlocked countries, in particular the importance of available transport infrastructure in landlocked countries themselves and their maritime neighbours. In the following analysis a county is considered to be landlocked if it is fully enclosed by land (Merriam-Webster, 2013). Most of the landlocked countries outside Europe are suffering from poor economic performance (Gallup, Sachs, & Mellinger, 1998). European landlocked countries appear to be exceptions as strong cultural and economic connections as well as relatively small distances between countries decrease the negative consequences of landlocked locations (Sachs & Warner , 1997). Already in 1776 Adam Smith observed that the landlocked regions of Africa and Asia appear to be the poorest regions in the world (Faye, McArthur, Sachs, & Snow, 2004). More than two centuries later the world map has changed significantly, however the problem of underdeveloped landlocked countries in Africa remains.

The impact of landlocked geographical position is influenced by several factors. One of the most important determinants is the available transport infrastructure in the region in general, and in particular landlocked country and its transit neighbours. Well-developed transport infrastructure of the country itself and its transit neighbours might eliminate the negative effect of geographical location. The analysis is constructed in order to estimate the effect of existing transport infrastructure on the economic performance of the landlocked countries (UNCTAD, 2013).

In order to achieve reliable estimates it is important to take into consideration other factors that might influence the development of landlocked regions, such as the political stability in the country and in its transit neighbour, amount of export and import, main type of export, ethnical differentiation, life expectancy level, amount of governmental savings and whether the country is has a tropical climate or not (Sachs & Warner, 1997).

First, analysis of existing literature aims to prove the fact that landlocked geographical position has a negative impact on economic development of the countries. Furthermore, the research is focused on the importance of transport infrastructure for the development of the country. Lastly the control variables required to perform reliable estimations are carefully investigated.

Negative impact of landlocked geographical position

Landlocked countries suffer from problems with high transportation costs, remoteness from the world market, long distances and complicated cross-border procedures (Park, 2011). Problems facing landlocked developing countries are similar around the world, however it is noteworthy that Sub-Saharan Africa shows the lowest economic performance and contains the highest number of landlocked countries in the world. Africa has sixteen landlocked countries; most of them are extremely poor and have the lowest GDP per capita in the world (World Bank, 2012). The only exception is Botswana, which takes the 84th place on the list due to the well-managed diamond mines (Gallup, Sachs, & Mellinger, 1998).

The most important economical limitation arising from the landlocked geographical position is prohibition to fully participate in international trade. Adam Smith claimed that due to difficulties in international trade landlocked countries are not able to realise gains on specialisation. He argued that landlocked countries are prohibited to perform in the world trade as they face extremely high transportation costs (Faye, McArthur, Sachs, & Snow, 2004). Most modern economists agree on positive influence of trade development of the income of the country, Frankel and Romer (1999) applied regression analysis, which included income per capita as dependent variable, value of trade and population as independent variables, capturing remaining unexplained varience in the error term. In the cross-country study they came to the conclusion that trade has statistically significant effect on the economy.

By the end of the last century and the beginning of the new millennium the world observed the radical economic development of China. By 2014 it grew into one of the moist economically powerful countries in the world. Using cross-country empirical analysis it was disclosed that, in combination of private enterprise development and higher education, openness to international trade plays a leading role in outstanding performance of the Chinese economy (Chen & Feng, 2000). From 1979 to 1997 the GDP of the country and external trade grew on average by 9% and 15% respectively (Liu, Burridge, & Sinclair, 2002). Using data for one of the fastest growing countries in the world researchers conducted a multivariate analysis proving the existence of a causal relationship between economic growth, FDI and volume of export (Liu, Burridge, & Sinclair, 2002). Taking into consideration political, geographical and cultural differences between Africa and China, it can be said that the example of Chinese economy shows that an increase in foreign trade leads to a rise of wealth in a given country, attracts more foreign direct investment and facilitates faster economic growth. At the same time, barriers for access to the international trade have a negative influence on the development of the country and its economic performance.

According to the research of Faye, McArthur and Snow (2004) there are several factors preventing landlocked African countries from faster development. The ability of landlocked countries to trade is affected by high trade costs. On average landlocked countries are forced to pay 9% more for transport and insurance than their maritime neighbours. Due to high transportation costs and their remote locations relative to the coastline, countries surrounded by land are exporting less than a half of the per-capita amount of the neighbouring countries with maritime access. In their work, Faye, McArthur and Snow, empathised the fact that landlocked countries' performance are dependent on three major factors, such as transit infrastructure, political relations with neighbours, political stability and the transit administrative processes. Landlocked countries are dependent not only on the level of infrastructure in their own country, but also on the development of road transportation in the transit region. The impact of weak infrastructure is especially important for the least developed countries as their export goods mostly have low value to cost ratio. One of the examples of such dependence is the economy of Central African Republic as the poor infrastructure in Cameroon limits its foreign trade. Nevertheless countries primarily exporting goods, which do not require road transportation, are less dependent on transport facilities of maritime neighbours.

Sachs and Warner (1997) dedicated their research on the slow development of the African region and tried to investigate the causes of the poor economic performance. They based their model on the work of Barro and Sala-i-Martin (1995) in which economic growth was seen as the convergence from the current level of GDP to the steady state. According to their econometric model the dummy for landlocked countries is significant; on average a country without access to the coastline performs 0.58 percentage points worse than other states. It also was estimated that the openness of an economy has a positive effect on economic growth. An open economy improves the economic performance by encouraging the more efficient allocation of scarce resources, promotes market competition and technological innovation. The volumes of import and export are influenced directly by the accessibility to the maritime transport routes.

Participation of a country in world trade and consequently its economic performance is linked with transportation costs incurred by the country. High costs of delivering goods to foreign consumers limits the ability to compete on the international level, in particular for countries exporting low-technological goods (raw materials, agricultural products, simple manufactured goods). (Limao & Venables, 2001). This issue is specifically relevant for Africa, as most of the countries on the continent are developing.

Gallup, Sachs and Mellinger (1998) estimated the AK model of economic growth and adjusted it for the transportation costs.

$$\gamma = \left(\frac{sA}{\alpha}\right)(P^m)^{-(1-\alpha)}\tau^{-(1-\alpha)} - \delta.$$

Where γ states for the growth rate of the economy, A for underlying total factor productivity, $P^m$for the exogenous market price, transport rate is denoted by τ, national saving rate is considered fixed and presented as s and rate of depreciation is δ. The equation is obtained from a Cobb-Douglas function and the fact that the landed price, including cost of purchase, transportation, insurance and all other costs till point of final destination, of an imported good is equal to $\tau P^m, where\ \tau > 0\ as$ the price on the domestic market also includes the costs for insurance and freight. Transport costs have a significant impact on the relative price of the capital goods, which has a strong effect on the developing countries as most of the technological intensive equipment is imported to Sub-Saharan Africa from other regions. Growth rates are negatively dependent on the transportation costs (Gallup, Sachs, & Mellinger, 1998).

Importance of transport infrastructure

Research of Limao and Venables (2001) reached important conclusions regarding the connection of economic performance and the level of infrastructure in general and in particular in Sub-Saharan Africa though investigation of the transportation costs and the level of transport infrastructure present in the region. On average landlocked countries suffer from 55% higher transportation costs than a mean coastline state and higher isolation of the country from world trade. Transport infrastructure plays an extremely important role in the determination of transport costs; poor infrastructure accounts for 40% and 60% of the total transportation costs for the coastline and landlocked countries respectively (Limao & Venables, 2001). Transportation infrastructure includes the quality of available roads, railways and telephone facilities. Improvement of transport infrastructure inside the country itself and infrastructure of the transit neighbours has a strong positive effect on the volume of export and import through lowering the transportation costs. If a country is listed among the 75th percentile of the poorest domestic transport infrastructure, than improvement in the country's transport facilities would reduce the extra costs incurred by landlocked countries from 60% to 41%; development of roads, railways and telephone connections in a county of transit limits the penalty arising from being landlocked to 48%; and the simultaneous improvement of domestic and transit infrastructure to the level of the best 25th percentile would decrease the costs to 33% (Limao & Venables, 2001). Evidence of the poor transport infrastructure among African countries is the fact that the volume of trade inside the region is lower than the average estimation, because the low infrastructure level drives up the price of transportation costs per kilometre (Limao & Venables, 2001). Investment in infrastructure in Africa is highly profitable. For instance it was estimated that an increase of telephones per capita from the current 5% level to 10% would improve the GDP growth rate by 0,4 percentage points (Ndulu, 2006). Calderon and Serven (2004) proved that growth is positively affected by the development of infrastructure and that income inequality is reduced by improvement in quality and quantity of transport infrastructure in the region.

From the review of existing research it follows that on average landlocked countries outside Europe have poorer economic performance then the coastal countries ceteris paribus. The aim of this research is to investigate the effect of the domestic transport infrastructure, level of development of the roads and railways in transit countries on the economic performance of the landlocked states of Sub-Saharan Africa in order to provide more information regarding the causes of slow development of the African region and give further advice for the possible solutions to this issue. However, in order to reliably estimate the factors of influence it is important to take into consideration other factors, which affect the level of income in the country and thus might influence the results. Numerous studies were performed to investigate the causes of slow economic development of the African region.

Life expectancy influences the level of GDP as it represents both the quality of health care and the spread of diseases in the region. Poor health conditions reduce the productivity of labour and affect the economic performance of the country. Influence of an increase of life expectancy by one year is very high in the countries with originally low average lifetime. As opposed to the developed world, where increase in life expectancy is achieved by decreasing the rates of old-age mortality, in African countries increase in average life duration enlarges the labour force and has direct positive economic consequences (Sachs & Warner, 1997). This fact plays an important role as through the years of analysis the life expectancy in the developing countries of Sub-Saharan Africa was growing, causing relative improvements in income. Nevertheless, inference taken from life expectancy should be done with care, as it appears to not only be the cause but also the consequence of low income per capita (Collier & Gunning , 1999).

It is also suggested that the level of public savings has a direct positive influence on the GDP growth if it doesn't come at the cost of private savings. The data for the savings rate is considered not very reliable in its estimation, however it is important to include in the analysis (Sachs & Warner, 1997).

According to the work of Faye, McArthur and Sachs (2004) political instability in the transit country, military conflicts with the neighbours and civil conflicts have severe consequences on the volume of foreign trade. Even through the rights of the landlocked states are protected by Article 125(1) of the United Nations Convention of the Law of the Sea (United Nations General Assembly, 2000), in reality the transit of goods has to be agreed on with neighbouring countries and determined by the diplomatic relationship and political stability. The Ethiopian economy stagnated due to the conflict with Eritrea as most of the Ethiopian goods were shipped through the Eritrean port of Assab. Civil wars and political instability inside the country itself directly lead to a decline of GDP, but the landlocked countries are not only dependent on the political situation inside their country, but are severely affected by the peace in the transit states. Civil wars and internal conflicts mean that transit routes can be damaged or closed; transportation of goods cannot be considered safe, demanding planning of new transit routes causing delays and increases transportation costs. Until recently, despite relative stability inside the country, Mali experiences significant losses in trade as its coastal neighbours were not political stable, affecting the quality of road infrastructure and safety of goods (Faye, McArthur, Sachs, & Snow, 2004). High administrative burdens also play an important role; high tariffs and long bureaucratic procedures limit trade opportunities of the landlocked states.

Research of Sachs and Warner (1997) came to the conclusion that apart from landlocked geographical position and openness of the economy the tropical climate has a significant negative effect on the country's development. Among the top countries with the highest GDP per capita in the world only two are located in a tropical climate: Hong Kong and Singapore. Poor economic performance of the tropical countries is usually explained by a high rate of disease and low development of the agricultural sector (Gallup, Sachs, & Mellinger, 1998). Nevertheless including a variable for tropical climate in the analysis should be treated with care as it could cause multicollinearity with other independent variables; tropical climate leads to more diseases present in the region, lower life expectancy and poorer labour capital formation (Ndulu, 2006).

High level of transit charges and heavy bureaucratic procedures contribute to isolation of the landlocked countries from world trade. Nearly every transit country requires payment of transit fees for passing through its territory. Some of the payments are made upfront and some are charged on route, but even combined they are account only for relatively small share of the total expenditures. The transport requires intensive paperwork, which comes at a high financial costs and delay in time. The time delay causes inefficient management of resources and does not allow shippers to reach their full potential. The administrative problem commonly arises in Western Africa; customs procedure for goods at the border of the Central African Republic and Cameroon often takes around two weeks (Faye, McArthur, Sachs, & Snow, 2004). Unreliable rail connections do not allow for the efficient shipping planning; on average delays in the port of Abidjan (Cote d'Ivoire) used by Burkina Faso are around 10 days; waiting time for the port of Doula used by the Central African Republic and Chad goes up to 30 days. The main cause of losses due to inefficient planning is lack of coordination and cooperation between transit and landlocked countries (Faye, McArthur, Sachs, & Snow, 2004).

Another factor, which might contribute to the slow development of the African countries, is the low population density, causing low integration on different levels (from international to local) and high transport costs. Besides, it leads to high volume of natural resource endowments per capita. High value of natural resource endowments might lead to the appreciation of the local currency (the phenomenon is known as Dutch disease) and be the cause of civil conflicts (Collier & Gunning , 1999). Likewise population density, ethnical diversification and fractionalisation cause slower economic development of African countries. According to research of Collier (1999) ethnical fragmentation under non-democratic governments leads to decrease of 3% in economic growth, while in countries with strong democratic traditions ethnical differentiation has no influence. (Collier & Gunning , 1999).

Finally, several financial policies adopted by African governments affected the economic development of the region, such as overvaluation of the exchange rates, accumulation of foreign debts and attracting international financial aid. The consequences of these financial policies vary across countries and their affect is ambiguous (Collier & Gunning , 1999).

Based on the analysis of the existing literature it can be concluded that on average countries located away from the seacoast suffer from lower economic performance. It is suggested that transport infrastructure might improve the economy of the countries and increase the level of GDP per capita. The analysis will be focused on the effect of rail and road infrastructure, taking into consideration important control variables.

Data and methodology

Data

In order to investigate the influence of the landlocked geographical position and specifically the impact of transport infrastructure on the development of the countries of Sub-Saharan Africa, ordinary least squares method (OLS) is applied to the available data regarding 39 countries of Sub-Saharan Africa. All the countries located to the South of the Saharan desert are classified as Sub-Saharan. Due to economic, cultural and social peculiarities of countries of Northern Africa, they are excluded from the sample; outstanding economic performance of South Africa means it will not be included in the analysis. Appendix table 1 presents the list of the countries used in the research.

<u>Availability of the data</u>

The data is analysed using ordinal least square regression, applying tools for cross-sectional analysis. Cross-sectional analysis is the best method for analysing differences between countries in the region and finding a common pattern. There is no time-series data available for transport infrastructure in Sub-Saharan Africa as data collection is complicated and costly and is not necessary as infrastructure in Sub-Saharan Africa changes very slowly. The most recent measurement of road and rail networks was performed in 2008. This year is taken as the base year of analysis; the value of all other variables is also taken for this year.

Most of the data regarding availability and quality of transport infrastructure was obtained from the official website of African Development Bank Group. The Africa Infrastructure Country Diagnosis (AICD) was created after G8 summit of 2005. The study was found as recognition that Sub-Saharan Africa suffers from extremely poor development of infrastructure, which is a key in poor economic growth of the region (AICD, 2014). Data regarding social and economic performance of Sub-Saharan Africa was obtained from the official website of the World Bank (World Bank, 2012) and information about the level of corruption was taken from Transparency International, a free movement aiming for a world without corruption (Transparency International, 2008).

Taking the previous research of Sachs & Warner (1997) as the basis a new regression equation is estimated. Gross national product is considered to be one of the best indicators of the level of economic development of a country in a selected period of time. Due to substantial differences in size of the countries, the dependent variable taken is *GDP per capita (constant US$)*. The dependent variable is regressed against a number of independent variables selected for the models.

To investigate the importance of geographical position it is required to create a reliable model with sufficient explanatory power. Following the research of Sachs & Warner (1997) control variables used in the analysis are *domestic savings per capita, life expectancy at birth for total population and value of export per capita.* The data was obtained from the World Bank African Development Index.

To focus on the main area of research the level of GDP is analysed with respect to the geographical location and available transport infrastructure, a *dummy for landlocked geographical position* is added to the regression equation. The variable takes value of 1 for fifteen [1] landlocked countries and 0 for all other.

Most economists argue that landlocked states have slower economic development due to difficulties accessing the world market through participation in global trade, dominated by sea shipment. Bulky, heavy goods from the countries located away from the coastline can only be delivered by the means of railways and roads present in the country itself and its transit neighbours; data for transport infrastructure is subdivided into two major categories: railways and roads. The dependent variable is GDP per capita, so all the variables are corrected for the size of the country. Appendix table 2 presents the list of used variables.

<u>*Domestic road network*</u>

The first way to evaluate the impact of the road network in a country is to use the *total* number of kilometres of the road network as an independent variable. The *density of total road network* is measured as the total number of kilometres of roads divided by thousand square kilometres of land. This measurement includes all types of roads: classified (roads that were registered by the local government), non-classified (small private roads) and urban.

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[1] South Sudan is a landlocked country, however it got independent from Sudan only in 2011 and is not considered in the analysis as an independent country,

[2] In some cases Lesotho and Swaziland are considered subtropical as they are

An alternative way to represent relevant information about used road networks is the density of *primary roads*. Primary roads include only large motorways outside urban areas excluding private and community roads, not used for freight transportation.
Taking into account specifics of the region it is required not only to include the analysis of the network length, but also the state of the classified roads. All the primary roads are subdivided into three groups according to their condition: good, fair and poor. *Density of poor roads, density of good roads and density of fair roads* are calculated by multiplication of the share on the density of primary roads.

An asset value of the existed road network gives an indication of the total price of the entire transport system. The indicator seems valuable and reasonably from an economic point of view, nevertheless taking into account specifics of the region, such as the high level of corruption, existence of remotely located regions with extremely bad accessibility and low level of education creates a problem of equating economic (asset) value of the infrastructure to its contribution to the development of accessibility of the country.

<u>Domestic rail network</u>
Density of rail lines (number of kilometres of rail lines per thousand square kilometres of land) can be used for estimation of availability of rail network in the country.
Total kilometres of rail lines can be highly inaccurate as some countries' railways were built in the times of colonies and since then were never maintained properly. It is more reliable to take into consideration *density of operating rail lines.*

<u>Infrastructure of the transit countries</u>
As mentioned earlier, landlocked countries are not only dependent on their infrastructure, but they also have to rely on the level of transport infrastructure of the transit states; its availability and quality. Both railways and roads should be taken into account separately.
The *average density of the primary roads of all surrounding countries* is calculated by summing up the number of kilometres of roads in all neighbouring countries and dividing the value by the total sum of area.
The *average density of operating railways of all surrounding countries* represents the weighted average of the available rail infrastructure in the surrounding countries.

The former two variables provide information about transport infrastructure in all the countries with no specification to transport corridors for landlocked countries. Using existing literature the main transport corridors for fifteen landlocked countries were found; most of the countries' export and import pass through those transit countries. Table 1 presents the list of transit countries for landlocked states of Sub-Saharan Africa.

Landlocked country	Transit countries
Botswana	South Africa
Burkina Faso	The Guinea (port Lome), Cote d'Ivoire (port Abidjan), Ghana (port Tema)
Burundi	Tanzania, Kenya
Central African Republic	Cameroon (port Douala)
Chad	Cameroon (port Douala)
Ethiopia	Djibouti
Lesotho	South Africa
Malawi	Mozambique
Mali	Ghana (port Tema), Senegal (port Dakar) and Cote d'Ivoire (Abidjan)
Niger	Benin (port Cotonou)
Rwanda	Tanzania, Kenya
Swaziland	South Africa
Uganda	Tanzania, Kenya
Zambia	*Mozambique, South Africa, Namibia*
Zimbabwe	*Mozambique, South Africa, Namibia*

Table 1, list of transit countries for landlocked states of Sub-Saharan Africa
Source (Nathan Associates Inc., 2013), (UNCTAD, 2013)

The *transit road corridor variable* is dedicated only to the weighted average of the roads in main transit countries for landlocked states. If export and import of landlocked state passes only through one country then density of primary road infrastructure is used, in other cases the weighted average of roads in transit countries is calculated. *Transit rail corridor* is created in a similar way for the density of operating railways.

Corruption

Corruption Perception Index (CPI) is used in the analysis to value the level of corruption present in the country. Specialists of Transparency International analyse various aspects of public life and based on the research give a valuation from 0 (highly corrupted) to 100 (absolutely no corruption) (Transparency International, 2008).

Methodology

Model 1

The first model is represented by a simple regression equation and used to observe the effect of landlocked geographical position on economic performance.

$$GDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \varepsilon$$

The regression equation might signal the presence of a significant relationship between being landlocked and its economic performance, but due to its simplicity low explanatory power is expected. Model 1 is used as a zero step in determination of a potential effect. Evidence of a negative impact of the dummy for landlocked geographical position is expected.

Model 2

Using the research of Sachs and Warner (1997), additional explanatory variables are added to the model. Among the independent variables are life expectancy, the level of domestic savings, amount of export and dummy variables for landlocked geographical position. The dummy for a tropical climate is excluded from the analysis, as all the countries of Sub-Saharan Africa are located in a tropical climate[2]. When excluding the dummy for a tropical climate the new regression equation will look as follows:

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \varepsilon$$

Adding independent variables is expected to increase the explanatory power of the model and to observe the significance and coefficient of the main predictor of

[2] In some cases Lesotho and Swaziland are considered subtropical as they are positioned directly on the borderline of the tropical climate zone, however it is still a subject of consequences of tropical climate, such as tropical diseases and long period of tropical precipitation.

analysis: dummy for landlocked geographical position. It is anticipated that the dummy for landlocked geographical position will have a significant negative effect on the economic performance of the country. Therefore the first hypothesis is:

H1: Landlocked geographical position has negative effect of GDP per capita.

<u>*Model 3 and 4*</u>

This research aims to determine the impact of transport infrastructure on economic performance of the countries and how transport infrastructure could alter the effect of landlocked geographical position.

The effect of domestic transport facilities is analysed by adding predictor variables for density of total roads and density of total rail lines. Model 3 hence looks as following:

$$GDP_{per\ capita} = \alpha + \beta_{12} savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 total\ railways + \beta_6 total\ roads + \varepsilon$$

The indicators for the total number of kilometres for railways and roads might be severely biased. Non-operating rail lines are registered and used in estimation of density of total railways while density of total road network includes private small paths not useful for transportation of large volumes of freight. For instance the Guinea has 1000 kilometres of registered rail lines, but by 2008 none of them were operating.

In order to correct for this influence a new model is implemented in which the density of primary roads replaces density of total roads and density of total railways is changed for density of solely operating railways.

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 primary\ roads + \varepsilon$$

It is expected that the density of road and rail networks will have positive significant impact of the GDP per capita. So the following hypothesis is evaluated:

H2: The densities of rail lines and road network have a positive significant effect on GDP per capita and alter the effect of landlocked geographical position.

Model 5

It can be suspected that not the availability, but rather quality of roads matters. Roads of better quality might lead to higher economic performance of the country. In 2008 the African Bank of Infrastructure development subdivided all classified primary roads into three categories: good, fair and poor. GDP per capita is regressed against the density of qualitatively different types of roads: density of good roads and density of the sum of good and fair roads. The results are compared coherently and with model 4. The following regression equations are used:

$$\begin{aligned} GDP_{per\ capita} = {} & \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ & + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} \\ & + \beta_5 operating\ railways + \beta_6 good\ primary\ roads + \varepsilon \end{aligned}$$

and

$$\begin{aligned} GDP_{per\ capita} = {} & \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ & + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} \\ & + \beta_5 operating\ railways + \beta_6 good\ and\ fair\ primary\ roads + \varepsilon \end{aligned}$$

Better quality roads are expected to lead to higher economic performance and have stronger effect on GDP per capita than the density of roads of different quality. For model 5 the following hypothesis is examined:

H3: The density of roads of better quality has a higher positive effect on the GDP per capita than density of all types of roads combined.

Model 6

After investigating the impact of domestic transport infrastructure on economic performance it is important to analyse the influence of transport infrastructure of transit states. The main products of Sub-Saharan Africa are raw materials (crude oil) and agricultural products (cocoa and cotton) mostly demanded on the international market (UNCTAD, 2013). Landlocked countries of Africa are more than any other developing landlocked countries are dependent on transit facilities of coastline neighbouring countries.

The first step is to include the weighted average of the density of rail and roads of all the countries around the state of interest. From that it would be possible to deduce the influence of transport infrastructure of the neighbours on all the states of Sub-Saharan

Africa. In order to observe the effect of transport infrastructure in neighbouring countries on GDP per capita an interaction variable between the dummy for landlocked geographical position and the corresponding transport infrastructure is added to the regression equation.

Equation 1:

$$GDP_{per\ capita} = \alpha + \beta_{12} savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 transit\ road\ all + \beta_7 transit\ road\ all * landlocked + \varepsilon$$

Equation 2:

$$GDP_{per\ capita} = \alpha + \beta_{12} savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 transit\ rail\ all + \beta_7 transit\ rail\ all * landlocked + \varepsilon$$

Not all neighbouring countries enable transportation of freight to the sae ports. Instead of variables for weighted average density of road and rail network, data regarding transport infrastructure specific to countries of transit corridors are used. The new variable is denoted as *transit_corr.* The equations will look as follows:

Equation 3

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 transit\ \ corr\ road + \beta_7 transit\ corr\ \ road * landlocked + \varepsilon$$

Equation 4:

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 transit\ \ corr\ rail + \beta_7 transit\ corr\ \ rail * landlocked + \varepsilon$$

The analysis is focused on the interpretation of the interaction terms as they represent the effect of foreign transport infrastructure on the economic performance of landlocked countries. Data obtained by estimating the facilities of transport corridors are not fully accurate, as it was calculated manually using the available information about transport facilities in Sub-Saharan Africa

It is suspected that good density of transport infrastructure in the countries of transit will influence economic performance positively and increase the level of GDP. Similar effect is expected for railways.

H4: Density of rail network in transit countries will influence GDP per capita of the landlocked countries positively.

H5: Density of road connections in transit countries will increase GDP per capita.

<u>Model 7</u>

The product mainly exported has a crucial role in investigating the performance of a country. All the products of export were subdivided into four main categories: agriculture, oil, diamonds and technical products, such as cathodes or technical rubber. Two categories of interest are mining of diamonds and extraction of oil. The dummy predictor variables were used for specified export products and analysed separately. Special attention is drawn to export of diamonds and gold as it is predicted that mining those natural resources offsets the effect of unfavourable geographical position because of high price for those natural resources and possibility to replace transportation by sea by airplanes. Hypothesis six states that diamonds as the main product of export will offset the effect of landlocked geographical position and contribute to economic development of the country.

H6: The dummy for diamonds as the main product of export has a positive influence on GDP per capita and changes the effect of landlocked geographical position.

The regression equations of analysis are following:

Equation 1:

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 dummy_{export_{oil}} + \varepsilon$$

Equation 2:

$$GDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 operating\ railways + \beta_6 dummy_{export_{diamonds}} + \varepsilon$$

Assumptions of OLS:

Due to sample size it is allowed to use a 10% significance level (Field, 2009).

In order to build a reliable and statistically significant model, a number of assumptions should be met.

Homoscedasticity implies that at each level of independent variables, the value of residuals should be constant (Field, 2009). In every model of this assumption is checked using scatterplot.

Independence of errors, also known as absence of autocorrelation infers that for any two observations the residual terms are independent (Field, 2009). This assumption is checked by a Durbin-Watson test; the value of the test statistics can vary from 0 to 4 and values around 2 signal of absence of serial correlation. The critical value of Durbin-Watson depends on the number of predictors and the sample size. Exact critical values are not tabulated; instead the obtained values are checked with lower and upper bounds. If the obtained value of Durbin-Watson test is smaller than the lower bound than the null hypothesis of absence of serial correlation should be rejected in favour of alternative hypothesis of presence of positive first-order autocorrelation; if the obtained value exceeds the upper bound than the null hypothesis should not be rejected; in case the value lies between the lower and upper bounds test should be considered inconclusive. In order to test the null hypothesis against alternative of negative first order correlation the obtained statistic value should be subtracted from 4 and compared with tabulated measurements in similar way (Simoncini, 2014). All the created models contain less than 20 predictor variables, including intercept and the sample size does not exceed 200 observations. It gives the right to use the table of Savin and White (1977) to test the null hypothesis of absence of serial correlation. For all the models the upper and lower bounds are found individually based on number of observations and predictor variables.

Normally distributed errors show that the residuals in the model are normally distributed. This assumption can be verified through the use of residual histograms and PP-plots.

No perfect multicollinearity proves that the dependent variables are not correlated among each other.

Exogeneity assumption suggests that the predictors are not correlated with external variables. For all the models exogeneity is assumed by construction.

The last assumptions are *variable types*; all predictor variables are quantitative or categorical, *non-zero variances*, the predictors vary in value, *linearity and independence.* Those assumptions can be verified by observing the dataset and it can be confirmed that all last four assumptions are successfully satisfied. Appendix models 1-6 contain all the output tables, corresponding PP plots and histograms.

Dependent variable of the analysis is required to be normally distributed Results of Shapiro-Wilk and Komogolov-Smirnov tests are highly significant, indicating deviation from normality (Appendix, output 1). A histogram supports this finding (Appendix graph 1). The problem of non-normality is addressed by logarithmic transformation. The issue is partly solved, *lnGDP per capita* is nearly normally distributed; *lnGDP per capita* will be used as the dependent variable for all models described above.

Results

Model 1

The effect of landlocked geographical position on economic performance of the country is checked using a dummy for landlocked geographical position. The regression equation used is:

$$lnGDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \varepsilon.$$

Analysing the sample of 39 countries shows no significant effect of landlocked geographical position at 10% significance level (presented in Table 2). The results differ from expectations followed from literature review.

Some of the landlocked countries in the sample have unusual values for GDP per capita. GDP per capita of Botswana, Swaziland and Mauritius substantially exceeds the average value of GDP per capita of the region.

Diamonds account for 30% of GDP of Botswana and 70% of export. As opposed to other African countries Botswana has relatively low level of corruption and efficient plan for extraction of natural resources. (Hillbom, 2008) A combination of factors led to outstanding GDP per capita equal to 4223 US $ while the average for Sub-Saharan Africa is 778 US$ despite being landlocked.

Another country with outstanding GDP per capita is Swaziland. Close economic, social and cultural connections with South Africa together with a small population helped the country to achieve a GDP per capita of 1794 US$ notwithstanding the recent spread of HIV (Akinlo & Egbetunde , 2010).

Finally effective policy of tourism taxation and small population size made the economy of Mauritius the most successful out of all countries in Sub-Saharan Africa (Durbarry, 2010).

This simple regression model is not able to correct for the differences in economies; results are strongly affected by outliers. To avoid the biased results, the same regression analysis was performed on the sample of 36 countries, excluding outlaying values. The results of analysis are presented in Table 2.

It is observed that the dummy for landlocked geographical position is significant at 10% significance level. As was expected the dummy for landlocked geographical position has a negative impact on the economic performance of the country; on average landlocked countries have 60.5% lower GDP per capita ceteris paribus.

	β	Sig.
Model 1 (all countries of Sub-Saharan Africa)		
(Constant)	6.254	.000
Landlocked	-.386	.214
Model 1 (sample excluding Botswana, Swaziland and Mauritius)		
(Constant)	6.254	.000
Landlocked	-.605	.018

Table 2, results of Model 1

Dependent variable lnGDP per capita

The assumptions of OLS are met, but need further improvement (Appendix, Model 1). According to the PP plot residuals are relatively normally distributed, scatterplots shows no signs of heteroscadesticity. The sample excluding Botswana, Swaziland and Mauritius contains 36 observations and one predictor variable, obtained value of Durbin-Watson test is 2.354, which exceeds the corresponding value of upper bound of 1.525; the null hypothesis of no autocorrelation is not rejected The explanatory power of the equations is low; more predictors should be added for improvement of explanatory power and better fit for OLS assumptions.

Model 2

An extended regression model is based on the research of Sachs and Warner (1997) and includes predictors for the volume of export, domestic savings and life expectancy at birth. The performed regression equations is:

$$lnGDPper\ capita = \alpha + \beta_1 savingsppc + \beta_2 export_{per\ capita} + \beta_3 lifeexp + \beta_4 dummy_{landlocked} + \varepsilon\ .$$

The additional independent variables are able to correct for the effect of outliers listed in Model 1. The sample of 39 countries is small, so it appears to be inconsistent to exclude some countries when it is possible to keep them in the sample. The results of the performed regression analysis are summarised in Table 3.

	β	Sig.
Constant	5,791	0,000
Savingsppc	0,000	0,623
Exportppc	0,001	0,000
Lifeexp	-0,001	0,957
landlocked	-0,278	0,096

Table 3, output Model 2, dependent variable lnGDP per capita

lnGDP per capita is GDP per capita after logarithmic transformation

savingsppc are savings per capita

exportppc export per capita

lifeexp is life expectancy at birth, total

landlocked is dummy for landlocked geographical position.

The model fits the assumptions of OLS. According to the scatterplot there is a homoscedasticity of errors, the PP-plot shows normality of residuals. The critical value of the upper bound for Durbin-Watson with 39 observations and four predictor variables is 1.722, the obtained value (2.57) is greater that the upper bound, so the null hypothesis of absence of serial correlation is not rejected. There is no evidence for perfect multicollinearity; exogeneity of the variables is assumed from the structure of the model.

The extended regression model proves that the dummy for landlocked geographical position has a significant negative effect on the economic performance of the country. The coefficient for the dummy is significant at a 10% significance level and proposes that countries located away from the coastline on average perform 28% worse, holding everything else constant. The differences between the coefficients for the dummy for landlocked geographical position between models 1 and 2 can be explained by including predictors for export and total domestic savings. The obtained coefficient in absolute terms is lower than the average disadvantage due to geographical position experienced by landlocked developing countries around the world, nevertheless the negative effect is strongly significant. The differences between the average negative impacts can be explained by overall very low development of most African countries, both landlocked and with direct access to the sea.

Despite insignificance of the coefficient for predictor variable domestic savings per capita the predictor variables should remain in the model as the growth theory proposed by Sachs and Warner (1997) showed importance of domestic savings in explaining the development of GDP per capita and might alter the influence of dummy for landlocked geographical position.

Hypothesis 1 is not rejected. There is evidence of a strong negative effect of landlocked geographical position on GDP per capita.

As mentioned in the literature review, most of the landlocked states experience difficulties in export of goods and services. Which means negative correlation between the dummy and value of export per capita might be present. Kendal's tau[3] is used to explore the correlation between the dummy for landlocked geographical position and export per capita. Weak but negative significant correlation was observed (-.225) (Appendix, output 2). The outcome serves as evidence that landlocked countries have *some* difficulties in trade solely from their location far away from the sea. High transportation costs and long delivery times constrain landlocked countries from international trade (UNCTAD, 2013). Export has a positive impact on GDP through reduction of import shortages, increasing efficiency of resource allocation and labour productivity; those factors are especially important for developing countries (Esfahani, 1991).

<u>*Model 3 and 4*</u>

Model 3 is focused on the impact of total rail network and total available roads, while model 4 analyses the effect of railways currently in use and density of primarily roads. In the original form regression equations are:

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + +\beta_5 density\ t.roads + \beta_6 d\ ensity\ t.railways + \varepsilon$$

and

[3] Kendal's tau is used as the dummy variable for landlocked geographical position is nominal and the sample size is small

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 export_{per\ capita} + \beta_4 dummy_{landlocked} + \beta_5 density\ prim.roads + \beta_6 density\ op.railways + \varepsilon$$

for models 3 and 4 respectively.

Performing regression analysis discloses the presence of multicollinearity: with relatively high explanatory power (adjusted R-square equal to 0,81) most of the predictors variables are insignificant; the direction and values of the coefficients for export, road network and density of the railways are different from the ones proposed by the literature review.

To confirm the presence of multicollinearity between operating railways, primary roads and value of the export per capita a Pearson correlation statistics was used as all the variables are interval variables (Field, 2009). A Pearson correlation disclosed the existence of a significant positive correlation between the value of export and density of primarily roads in the country (0.575) and low insignificant correlation with density of operating railways (0.21) (Appendix output 3).

Positive dependency between those variables aligns with the theoretical framework suggesting that better transport infrastructure enables higher volumes of export. Regressing export per capita against the independent variable of density of operating railways and primary roads shows that primary roads have a positive significant influence on the value of export; addition of one kilometre of primary road network per thousand kilometres of land increases export per capita by 5.4 US dollars (significance=0.000) and density of operating railways are close to be significant at a 10% significance level (sig=0.11).

Multicollinearity remained in the model even after logarithmic transformation of predictor variables. As the main purpose of the research is to investigate the impact of transport infrastructure on the economic performance it has been decided to exclude the value of export per capita from the regression equation as it biases the results. Excluding the predictor variable for export led to new regression equations denoted models 3 and 4:

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ t.roads + \beta_5 density\ t.railways + \varepsilon$$

and

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ prim.roads + \beta_5 density\ op.railways + \varepsilon$$

Table 4 summarises the output obtained by running the regressions.

	Model 3		Model 4	
	β	Sig.	β	Sig.
Constant	3.367	0.038	3.571	0.031
Savings_ppc	.000	0.15	.000	0.008
Life_exp	0.44	0.151	0.039	0.175
Landlocked	0.004	0.99	-0.074	0.809
Corr_total_road	.001	0.208	-	-
Density_total_rail	0.030	0.353	-	-
Corr_prim_roads	-	-	0.004	0.091
Density_op_rail	-	-	0.086	0.043
Durbin-Watson	1.994		2.049	

Table 4, output Models 3 and 4

Dependent variable lnGDP per capita

Savings_ppc domestic savings per capita

Life_exp average life expectancy at birth

Landlocked dummy for landlocked geographical position

Density_total rail density of total rail line per thousand of sq. km of land

Density_op_rail density of operating rail line per thousand sq. km of land

Corr_total_road km of total roads per sq. km of land

Corr_prim_roads km of primarily roads per sq. km of land

Both models 3 and 4 satisfy the assumptions of OLS regression (Appendix model 3 and 4). According to created scatterplots the null hypothesis of presence of heteroscadesticity is rejected; PP plots signal normality of errors. Both models 3 and 4 include five predictor variables and are using a sample of 39 countries. The obtained values for the models (1.944 and 2.049 respectively) are higher than the upper bound (1.789) listed in the table so null hypothesis of no autocorrelation cannot be rejected. Meeting the assumptions of OLS enables to interpret the model in terms of the coefficients.

From model 3 it can be observed that the density of total roads, including small community paths and private roads, do not contribute to the economic performance of the country, the predictor variable for the total roads is insignificant at 10% significance level. Similarly, it is observed that density of the total rail lines present in the country has no effect on the performance of the state and is insignificant and should not be inferred as such. The explanatory power of the model is very low with an adjusted R squared equal to 0.239.

From the results it may be inferred that the total amount of transport facilities has no effect on the economy as a considerable share of the infrastructure is either out of order or cannot be used for transportation of large volume of freight or passengers, so cannot contribute to better economic performance of countries in Sub-Saharan Africa.

Using Model 4, it is admitted that operating railways and primary roads in the analysis provide different outcome. Both density of operating railways and number of kilometres of primary roads per thousand kilometres of land are statistically significant at a 10% level. The explanatory power of model 4 (0.342) exceeds the explanatory power of model 3 indicating that density of operating railways and primary roads better explains the variations in GDP per capita.

Construction of an additional kilometre of primary road per thousand square kilometres of land increases the value of GDP per capita by 0,4%. The model accounts for the average effect of density of the roads without taking into consideration the size of the area[4]. Applied on a large scale of construction of new motorways stretching for hundreds kilometres, advanced road network might have strong positive influence on economies of the countries.

[4] Increase in density of transport infrastructure might influence the lnGDP per capita differently depending on the size of the country, however the built model cannot account for this effect.

The density of railways also has a positive significant effect on the economic performance. Increasing the density of operating rail lines by one kilometre increases the average level of GDP per capita by 8.6% ceteris paribus.

From the obtained results it is observed that building of new transport facilities lead to better economic performance; the marginal effect of increasing the density of the rail lines is higher than marginal effect of road connection. Additional kilometres of rail lines are more efficient in their outcome despite high initial investment.

The performed regression equations could be subjects of endogeneity. Endogeneity might arise from a confounding variable for dependent and independent variables (Field, 2009). Countries with stronger economic performance might have more financial resources to invest into development of transport infrastructure. It was observed that higher investment in transport facilities increases productivity and as a result the economic performance. However it is argued that the opposite direction of causality might take place; better economic performance of the country might lead to higher economic investment in public infrastructure, including transport sector. Nevertheless mutual influence might also be present (Munnell, 1992). From analysis of available statistical data it follows that there is no clear pattern in distribution of density of primary road network; not all countries with GDP per capita above average show better performance in density of road network. However, in most of the countries with higher level of GDP per capita, the density of the railways exceeds the mean value for the region in general. The problem of endogeneity might be present in the model, however statistically it has not been proven; so the results should be treated with care.

Adding predictor variables for rail lines and primary roads makes the coefficient for landlocked geographical position insignificant.

Hypothesis two is not rejected. Increase in the density of operating railways and primary roads lead to higher GDP per capita for selected countries. Addition of extra explanatory variables to the model alters the effect of landlocked geographical position, making it insignificant.

Model 5

Roads of better quality are presumed to have higher positive influence on economic development of the countries in Sub-Saharan Africa. The model assumes that either solely the roads of good quality lead to higher GDP per capita or combined density of fair and good roads facilitate faster economic growth. This inference is based on hypothesis that roads of poor quality might not be used for transportation of large volume of freight thus has no impact on economic development of the country.

Regression equations of analysis are:

Equation 1:

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ good\ roads + \beta_5 density\ op.railways + \varepsilon$$

Equation 2:

$$\ln GDP\ per\ capita = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ good\ and\ fair\ roads + \beta_5 density\ op.railways + \varepsilon$$

Table 5 presents the coefficients obtained by model 5. The critical value of Durbin-Watson test is equal to the one used in models 3 and 4 as the sample size and number of predictor variables remained unchanged; the obtained statically value is higher that the upper boundary, signalling the absence of serial correlation, both PP plots diagnose normal distribution of errors; scatterplots do not provide any evidence of heteroscadesticity being present (Appendix model 5).

	Equation 1		Equation 2	
	β	Sig.	β	Sig.
Constant	3.664	0.029	3.571	0.031
Savings_ppc	0.000	0.009	0.000	0.008
Life_exp	0.038	0.186	0.039	0.175
landlocked	-0.074	0.810	-0.074	0.809
Density_op_rail	0,082	0.051	0.08	0.058
Dens_good	0.002	0.078	-	-
Dens_good_and_fair	-	-	0.002	0.086
Durbin-Watson	2.040		2.028	

Table 5 Output model 5. Dependent variable lnGDP per capita

Savings_ppc domestic savings per capita

Life_exp average life expectancy at birth

Landlocked dummy for landlocked geographical position

Density_total rail density of total rail line per thousand of sq. km of land

Density_op_rail density of operating rail line per thousand sq. km of land

Dens_good kilometres of roads considered good per thousand sq. km of land

Dens_good_and_fair kilometres of roads considered in good and fair condition per thousand sq. km of land

From the constructed model it can be observed that both the density of roads considered good and the sum of good and decent roads are significant at a 10% level and have a positive influence on the economic development. Good condition of the roads facilitates easier access to the main ports of the region and reduces trade barriers enabling countries to develop economic growth. An additional kilometre of good (or good and fair) road per thousand kilometres of land increases GDP per capita by 0.2%. Even a marginal increase can contribute to better economic performance of all countries in particular and the entire region in general.
Nevertheless the effect of the density of good roads does not exceed the influence of the density of total primarily tracks.

Hypothesis three is rejected. The impact of density of only good and fair roads does not have stronger positive influence on economic performance than the density of all primary roads, including good, fair and bad.

The finding proposes that in further analysis the density of primary roads (including all three types of road conditions) should not be replaced by other variables as the combined effect of density of roads of all type, investigated in model 4, show higher positive influence then the effect of only good roads or good and fair. Even roads of poor quality might contribute to the economic development and facilitate GDP growth. Research on impact of road quality on economic performance in China showed evidence that investment in poor roads has four times higher return than investment in good roads. Money invested into construction of the low quality roads raise more people out of poverty resulting in stronger economic performance (Fan & Chan-Kang, 2005).

Model 6

The next model aims to investigate the influence of transport infrastructure of the neighbouring countries on economy. To see the impact of transport infrastructure on the most vulnerable countries from economic point of view, an interaction terms between the dummy for landlocked geographical position and different predictors for infrastructure were estimated. The first two equations are focused on analysis of the effect of transport infrastructure in all neighbouring countries. Table 6 gives the results for the equations.

Equation 1

$$\begin{aligned} lnGDP_{per\ capita} &= \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ &+ \beta_1 dummy_{landlocked} + \beta_4\ primary\ roads \\ &+ \beta_5 operating\ railways + \beta_6 transit\ road\ all \\ &+ \beta_7 transit\ road\ all * landlocked + \varepsilon \end{aligned}$$

Equation 2:

$$\begin{aligned} lnGDP_{per\ capita} &= \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ &+ \beta_1 dummy_{landlocked} + \beta_4\ primary\ roads \\ &+ \beta_5 operating\ railways + \beta_6 transit\ rail\ all + \beta_7 transit\ rail\ all \\ &* landlocked + \varepsilon \end{aligned}$$

In the first two steps logarithm of GDP per capita is regressed against the predictor variables used in previous models and variables for the weighted density of the road network in all neighbouring countries (tr_road_all) and rail lines (tr_rail_all) and interaction variables between the new variables and the landlocked dummy.

As it can be see from the Table 6 there is no significant effect of neither roads in transit countries or rail lines. Countries do not experience economic growth from infrastructure development in surrounding states. However even though transport infrastructure predictor variables are insignificant at 10% significance level, the values of predictor variables are positive.

The interaction terms account for the effect of transport infrastructure only for landlocked countries. Interaction terms in both equations are insignificant at a 10% significance level.

	Equation 1		Equation 2		Equation 3		Equation 4	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.
Constant	2.414	0.156	2.279	0.146	2.994	0.055	2.130	0.133
Life_exp	0.059	0.045	0.062	0.031	0.051	0.057	0.065	0.013
Savings_ppc	0.000	0.009	0.000	0.008	0.000	0.013	0.000	0.011
landlocked	-0.437	0.414	-0.173	0.621	-1.146	0.062	-0.472	0.172
Corr_prim_roads	0.001	0.675	0.003	0.182	0.003	0.316	0.003	0.136
Dens_op_rail	0.043	0.337	0.027	0.558	0.052	0.191	0.026	0.496
Tr_road_all	0.014	0.650	-	-	-	-	-	-
Tr_road_all*landlocked	0.044	0.245	-	-	-	-	-	-
Tr_rail_all	-	-	0.086	0.190	-	-	-	-
Tr_rail_all*landlocked	-	-	0.009	0.903	-	-	-	-
Tr_corr_road	-	-	-	-	0.003	0.919	-	-
Tr_corr_road*landlocked	-	-	-	-	0.067	0.073	-	-
Tr_corr_rail	-	-	-	-	-	-	0.086	0.150
Tr_corr_rail*landlocked	-	-	-	-	-	-	0.028	0.670
Adjusted R square	0.390		0.430		0.463		0.527	
Durbin-Watson	1.992		2.003		2.149		1.987	

Table 6, Output Model 6.

Dependent variable lnGDP per capita

Savings_ppc domestic savings per capita

Life_exp average life expectancy at birth

Landlocked dummy for landlocked geographical position

Density_op_rail density of operating rail line per thousand sq. km of land

Corr_prim_roads km of primarily roads per sq. km of land

Tr_road_all weighted average of the density of road network in all neighbouring countries

*Tr_road_all*landlocked* interaction variable between the value of weighted average for road network of all neighbouring countries and landlocked dummy

Tr_rail_all weighted average of the density of rail lines in all neighbouring countries

*Tr_rail_all*landlocked* interaction variable between the value of weighted average for road network of all neighbouring countries and landlocked dummy

Tr_corr_road weighted average of the roads corresponding only to transit countries

*Tr_corr_road*landlocked* interaction variable between the weighted average of roads in transit countries and dummy for landlocked geographical position

Tr_corr_rail weighted average of rail lines corresponding solely to countries of transity

*Tr_corr_rail*landlocked* interaction variable between the weighted average of transit rail and dummy for landlocked geographical position

In the following equations 3 and 4 transport infrastructure of neighbouring countries was estimated differently. For landlocked countries, the corresponding density of transport infrastructure was calculated only for the transit countries named in Table 1 (states through which goods pass mostly to reach the port of use).

Equation 3:

$$\begin{aligned} lnGDP_{per\ capita} &= \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ &+ \beta_1 dummy_{landlocked} + \beta_4\ primary\ roads \\ &+ \beta_5 operating\ railways + \beta_6 transit\ \ corr\ road \\ &+ \beta_7 transit\ corr\ \ road * landlocked + \varepsilon \end{aligned}$$

Equation 4:

$$\begin{aligned} lnGDP_{per\ capita} &= \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy \\ &+ \beta_1 dummy_{landlocked} + \beta_4\ primary\ roads \\ &+ \beta_5 operating\ railways + \beta_6 transit\ \ corr\ rail \\ &+ \beta_7 transit\ corr\ \ rail * landlocked + \varepsilon \end{aligned}$$

In equation 3 it is observed that coefficient for transit road infrastructure for all countries of Sub-Saharan Africa is insignificant. The interaction term between density of roads of a transit country and the landlocked dummy is positive and significant at a 10% significance level. For landlocked countries, an additional kilometre of roads in the countries of transit lead to 6.7% increase in GDP per capita. The explanatory power of the model including variables for transport infrastructure in transit countries increases from 0.342 to 0.463. 46% of variations in the GDP per capita among the countries in Sub-Saharan Africa can be explained by the level of domestic savings, life expectancy, available transport infrastructure in the country itself and road density in the countries of transit.

Hypothesis four is not rejected. Better road facilities of the countries of transit corridors increase the value of GDP per capita in landlocked countries.

Model 4 concludes that density of domestic rail lines has a strong significant effect on the economic performance of countries; the effect even exceeds the influence of density of road network.
Equation 4 shows no sign of significant influence of density of railways on the economic performance of landlocked countries. Interaction term has positive, but not significant coefficient.

The statistical results illustrate the current situation of railways in Africa. Ambitious plans for creation of international railways connection in Africa were recently created but none of them were implemented. Railways in Africa remains fragmented, connecting mainly large cities with ports in the same country. The only significant international railways are the North African network, the Eastern African network, connecting Tanzania, Uganda and Kenya and rail lines stretching from South Africa to Malawi, the Democratic Republic of Congo and Tanzania (Bullock, 2009). Low integration of the railways in the region might prevent the development of positive impact of railways on economic performance of landlocked countries.

The regression equations were tested with respect to assumptions of OLS. PP-plots showed normal distribution of errors, according to the scatterplots there are no signs of heteroscadesticity. The regression equations include seven predictor variables, so the critical value for the upper boundary of Durbin-Watson test is 1.932. Estimated values for all the equations exceed the upper boundary, showing absence of serial correlation, but equations 1 and 4 should be interpreted with care as the values lie close to the boundary. Data for density of railways and road networks were estimated in similar way, applying basic formula, which resulted in strong multicollinearity between the values of transit_road and transit_rail, so it was decided to estimate the effect of the transit rail lines and roads in separate equations.

In model 5 it was suspected that domestic transport infrastructure (density of operating railways and primary road network) might be a subject of endogeneity; countries with stronger economic performance might have higher investment into new transport infrastructure. There are no reasons to suspect that transport infrastructure of the neighbouring countries might suffer from endogeneity issue.

New four equations were introduced excluding from the regression equations variables for domestic rail and road infrastructure. The equations of the models are presented in Appendix equations 5-8. The results of performed regressions are summarised in table 7.

	Equation 5		Equation 6		Equation 7		Equation 8	
	β	Sig.	β	Sig.	β	Sig.	β	Sig.
Constant	2.875	0.038	2.437	0.069	1.119	0.372	1.288	0.314
Life_exp	0.046	0.062	0.059	0.019	0.084	0.000	0.083	0.001
Savings_ppc	0.000	0.012	0.000	0.018	0.000	0.012	0.000	0.016
landlocked	-0.164	0.580	-0.971	0.064	-0.330	0.228	-0.495	0.154
Tr_corr_road	0.048	0.002	0.024	0.192	-	-	-	-
Tr_corr_road*landlocked	-	-	0.057	0.064	-	-	-	-
Tr_corr_rail	-	-	-	-	0.122	0.000	0.080	0.183
Tr_corr_rail*landlocked	-	-	-	-	-	-	0.052	0.425
Adjusted R square	0.400		0.445		0.573		0.516	
Durbin-Watson	2.231		2.173		1.994		1.893	

Table 7, output equations 5-8 Dependent variable: lnGDP per capita

The performed regression analysis leads to new findings. Excluding the variables for domestic transport infrastructure does not lead to severe decrease in explanatory power; the results differ between rail and road network.

The assumptions of OLS regression are met, but require some improvements. In the estimated regression equations the residuals are close to being normally distributed, showing some signs of deviation from normality; no signs of heteroscadesticity are detected. For equations 5&7 and 6&8 the upper boundaries of Durbin-Watson test for the sample of 39 observations are 1.789 and 1.859 respectively. Obtained test results give no right to reject the null hypothesis of no autocorrelation.

Regarding density of road network in transit countries the higher explanatory power was obtained using the equation 6 than in equation 5; 44.5% of the variations in GDP per capita can be explained using the model including density of transit road infrastructure and including the interaction term between landlocked geographical position and road density. The interaction term between road density and landlocked geographical position is positive and significant at 10% significance level. Increasing density of road network in transit countries leads to higher GDP per capita of landlocked states. In equation 5 it can be observed that density of road network in transit states has positive significant effect for all countries, not only landlocked ones, however this effect turns insignificant when the interaction term is added to the equation. From the equations 3 and 4 it can be concluded that density of road connections in the countries of transit has a positive effect on the economic performance as a lot of goods are delivered to the ports using roads and that has special importance on the landlocked states.

Equation 8 shows that adding interaction term between railways and landlocked geographical position decreases explanatory power comparing to results achieved in the equation 7. Density of railways in neighbouring countries has strongly significant positive effect on GDP per capita of all countries of Sub-Saharan Africa; increase in density of rail network in neighbouring countries by 1 kilometre per thousand square kilometres leads to 12.2% increase in GDP per capita of the states.

The results signals that development of efficient, operating and well-maintained international system of railway connection might lead to better economic performance of the entire Sub-Saharan Africa.

From performed analysis it s complicated to draw unambiguous conclusions. Density of rail infrastructure in transit countries does not lead to better economic performance in only landlocked countries, but has strong positive significant effect on the level of GDP per capita for all the countries in Sub-Saharan Africa.

Hypothesis five cannot be rejected. Nevertheless the obtained results differ from the expectations of positive influence of density of rail network of the transit countries on economies of landlocked states.

The comparison between efficiency of rail and road transportation lies beyond the extent of this research paper. However it should be admitted that the density of operating rail network is lower than road density, so marginal effect of additional kilometre of rail lines lead to higher economic benefits for the entire region.

Model 7

In the next step of the regression analysis, impact of main trade product was analysed. Two different dummies for oil and diamonds as main product of export are added to the analysis.

Equation 1:

$$lnGDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ primary\ road + \beta_5 density\ operating\ railways + \beta_6 dummy_{export_{diamonds}} + \varepsilon$$

Equations 2:

$$lnGDP_{per\ capita} = \alpha + \beta_1 savings_{per\ capita} + \beta_2 life\ expectancy + \beta_3 dummy_{landlocked} + \beta_4 density\ primary\ road + \beta_5 density\ operating\ railways + \beta_6 dummy_{export_{oil}} + \varepsilon$$

Unexpected results were achieved with analysis of the dummy variable of diamonds and precious metals. The dummy variable for diamonds appeared to be insignificant at a 10% significance level and does not change the effect of other prediction variables, such as the dummy for landlocked geographical position. Addition of the dummy for landlocked geographical position only decreases the explanatory power of the model. It follows from the analysis that solely extracting valuable natural resources does not lead to a better economic performance of the country.

Hypothesis six is rejected. Export of diamonds does not alter the effect unfavourable geographical position on the economy. Extracting expensive natural resources is not sufficient for offsetting the negative impact of landlocked geographical position.

The hypothesis of the importance of the export product was drawn from the example of Botswana. More than 40% of the total export of the country is non-industrial diamonds (World Bank, 2012). Even though the country is landlocked, its GDP per capita five times exceeds the average value for Sub-Saharan Africa. Outstanding economic performance of Botswana is a consequence of political stability, relatively low level of corruption[5] and wise use of natural resources. Botswana managed to apply constraints on its political and social elite, protecting the country from high level of corruption and inequality; it preserved the social and governmental institutions through the times of the colonies and used them efficiently after becoming independent (Acemoglu, Johnson, & Robinson, 2002). Furthermore, Botswana accepted the plan of extraction of natural resources, which helped to sustain high levels of economic performance through years.

On the contrary, some countries of the region endowed with diamonds were not able to make efficient use of it. Diamonds account for 27% of the total export of Sierra Leone (World Bank, 2012). The civil war started in 1991 and lasted till 2002, absence of political and social stability in the country led to deplorable consequences; in 2008 GDP per capita was equal to 200 US dollars, nearly four times lower than Sub-Saharan average. Unlike oil or cobalt, diamonds are available to a large number of people even without special equipment; small, but extremely expensive diamonds can be smuggled through the border and traded on the black market. Absence of governmental control and stability led to extremely poor economic performance of the country despite rich deposits of diamonds (Reno, 2003).

The only export dummy appeared to be significant is oil as the main product of export. Table 8 gives an overview of obtained results.

	β	Sig.
Constant	3,257	0.037
Savings_ppc	0.000	0.009
Life_exp	0.041	0.131
landlocked	0.082	0.785
Density_op_rail	0.084	0.038
Corr_prim_roads	0.004	0.040
Dummy_export_oil	0.634	0.050
Durbin-Watson	2.131	

Table, output Model 8. Dependent variable lnGDP per capita

[5] In 2008 it was put on 36th place in the world's list of corruption perception index, while most of the African countries are located at the bottom of the list (Transparency International, 2008)

The regression equation meets the assumptions of OLS, the residuals are normally distributed, scatterplot shows no evidence for presence of heteroscadesticity and the null hypothesis of presence of no autocorrelation is not rejected (2.131>1.859).

As can be seen from the output table, the significance and coefficients of the predictors did not change after the introduction of the dummy variable for oil as main product of export. The dummy is significant at a 10% significance level and shows that on average countries exporting oil have 63% higher GDP per capita than other countries holding everything else constant.

Oil export has a strong positive impact on economic performance. Nevertheless, the effect of oil export operates separately from the landlocked geographical position and corresponding transport infrastructure. Oil is present in landlocked and coastline countries and does not intervene the influence of analysed predictor variables on economic performance of the countries. The analysis of the influence of main product of export on economies goes beyond the extent of this paper.

Overall the main product of export solely cannot explain economic development of the country. Deposits of natural resources only in combination with a low level of corruption, governmental control, peace, political stability and efficient management of the resources will contribute to economic growth and well being.

Conclusion

This research aimed to address the issue of slow economic development in Sub-Saharan Africa through analysis of geographical position and transport infrastructure. Investigation of importance of transport infrastructure for economic well being of countries of Sub-Saharan Africa might help to find appropriate solutions to decrease the poverty in the least developed countries of the world.

After analysis existing literature on the topic, stated hypotheses were evaluated in order to answer the research question. Investigation was performed using a sample of 39 countries of Sub-Saharan Africa, including 15 landlocked states.

Performing regression analysis of the first models proved that indeed landlocked countries suffer from its geographical position. It was found that on average landlocked states of Sub-Saharan Africa performed worse than states with direct access to the sea.

In the following steps the importance of domestic transport infrastructure on economic performance and effect of landlocked geographical position was inspected. Performed analysis proved that both density of domestic roads and rail lines has positive significant effect on economic performance. On the large scale creating new rail lines or construction of new road networks might have considerable positive impact on economic performance of the countries in Africa. Including domestic transport infrastructure into analysis makes the dummy for landlocked geographical positions insignificant. The explanation of the differences between the economic performances of the countries is dependent on the differences between transport infrastructures rather than its geographical location.

From the analysis of the existing reports on infrastructure of Sub-Saharan Africa it follows that a substantial number of rail lines in countries of analysis are out of order and thus their existence by any means cannot contribute to the development of economic performance.

Combining achieved results for domestic transport infrastructure, it can be concluded that sufficient transport infrastructure in landlocked countries might alter the disadvantages from unfavourable geographical position. All countries of Sub-Saharan Africa will benefit from increasing the density of operating rail lines through construction of new tracks and repairing existing non-operating and increasing the density of primary roads.

Apart from challenges typical for the countries of Sub-Saharan Africa, such as AIDS, high level of corruption, frequent military conflicts, landlocked countries of the region suffer from distant location from world trade. The economies of the landlocked states are strongly related to the availability of transport infrastructure in the neighbouring countries.

Regression analysis performed in the research paper showed that in general economies of all countries of Sub-Saharan Africa are not dependent on availability of railways and roads in the surrounding countries. It appears that the same results hold for landlocked countries, as an average of transport infrastructure of all neighbouring countries does not provide any useful information about access to the coast.

On the contrary, analysis of only transport infrastructure related to transit corridors showed that density of primary roads has a positive effect on GDP per capita of all the countries in Sub-Saharan Africa, but in particular on the performance of the landlocked states. The density of railways showed very strong positive effect on the economic development of all the countries in Sub-Saharan Africa; the positive effect of increased rail density exceeds the influence of road network. Investment creation and maintenance of international rail connections might lead to rise in economic growth for all the countries in the region.

Finally, some additional investigation disproved the statement that solely the type of export product might have significant influence on economic performance. Using the example of outstanding performance of landlocked country Botswana, it was suspected that extraction of some types of natural resources might surpass the landlocked geographical position, as land transportation does not play significant role for export of diamonds. Nevertheless it was proven that only combination of political and social stability, well-developed governmental institutions and efficient extraction of natural resources led to economic success of Botswana and this particular example cannot be used for general conclusion. It was found that countries with oil as primary product of export have better results for GDP per capita. However countries with oil as the main product of export face similar disadvantages due to unfavourable geographical position.

From the performed investigation it can be concluded that landlocked geographical position has a strong negative effect on the economic performance of a country. Developed transport infrastructure in the country itself and in the neighbouring states influences the economic situation positively and improvement of the transport *connections might decrease the negative externalities of having an unfavourable geographical position.*

Poverty in Africa can be addressed in different ways. Efficient investments in transport infrastructure might contribute to the development of economic performance of African countries and can potentially help to solve with extreme poverty in the region. Governments of African countries and international organisations should aim to invest into the repair of non-operating rail lines and construction of new routes, working on creating of new primary roads in the country achieving a higher density.
The countries of Sub-Saharan Africa should not only be considered separately but rather as a region in general. Nowadays intra-continental integration is low, but the there is potential for development. Construction of international road and rail connections will open new trade opportunities beneficial for all countries in the region, but in particular on landlocked countries, helping them to overcome the disadvantaged geographical position.

Limitations and suggestions for further research

The performed research on impact of transport infrastructure and landlocked geographical position leaves some opportunities for further improvement of the studies.

Cross sectional analysis could be replaced by working with panel data. Analysis of different countries through years could give better understanding of dynamics of the changing impact of transport infrastructure. Results of increase in transport facilities might be lagged in time and facilitate higher economic performance in the future. Furthermore, using panel data analysis would enable to see the effect of military conflicts and civil wars on economic development of the countries. Panel data analysis was not possible for this research due to the lack of available data. Collecting up-to-date information about existing transport facilities is a complicated process, coming at a high costs and is not done frequently.

Secondly the small sample size might lead to biased results. The sample includes all counties of Sub-Saharan Africa for which information regarding transport infrastructure was found for the reference year. Due to differences in economic and social performance countries of Northern African and Republic of South Africa could not be included in the analysis. The number of observations satisfies the general rule of thumb for the sample size, but might not be able to correct for all the biases, so the results obtained should be treated with care. One of the possible ways to increase the number of observations is to use regional data. Using this method will increase the sample size and give more detailed information about particular regions of different countries in Sub-Saharan Africa. Additionally, multicollinearity was detected throughout the analysis. In particular, values of export per capita showed strong correlation with density of road network and forced to exclude the value of export per capita, decreasing explanatory power of the model.

Issues related to trustworthiness of the data are typical for the region. Most of the data was obtained through official sources, such as the World Bank and African Development Bank group, however local authorities have possibilities to affect the data.

Finally, applying OLS techniques is very useful for investigation of the topic but might not be advanced enough to disclose the effect of landlocked geographical position and transport infrastructure to its full extent.

Further development of the topic

The performed research showed the importance of transport infrastructure for all countries of Sub-Saharan Africa and in particular for countries located far away from the coast. In further research the financial side of the question could also be examined; if investment in rail lines and road networks are profitable, which mean of transportation leads to higher return and how long does it take for countries to start received benefits from construction of new ways of transportation.

Furthermore, it is useful to analyse benefits and drawbacks of development of transportation for society. Construction of new means of transportation might lead to faster economic development of the country, decrease of unemployment through creation of new working places and better access of population to urban facilities. Combined all those factors might decrease poverty and lead to better standard of life. However improvement in transport infrastructure might come at a cost of disturbing agricultural regions and interfering the life of local communities. All the advantages and disadvantages should be analysed carefully for all countries of Sub-Saharan Africa to find the best way to decrease poverty and to improve life of the local population.

Finally, the issue of economic geography can be addressed in more details for investigation of any other socio-geographical characteristics typical for the African continent, which might have an effect on poor economic development of the region, for instance tropical climate or high diversity of ethical groups living on the continent. Addressing these issues might help to find the possible causes of poor performance of the African countries and suggest ways for improvement.

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Appendix

Appendix

Tables:

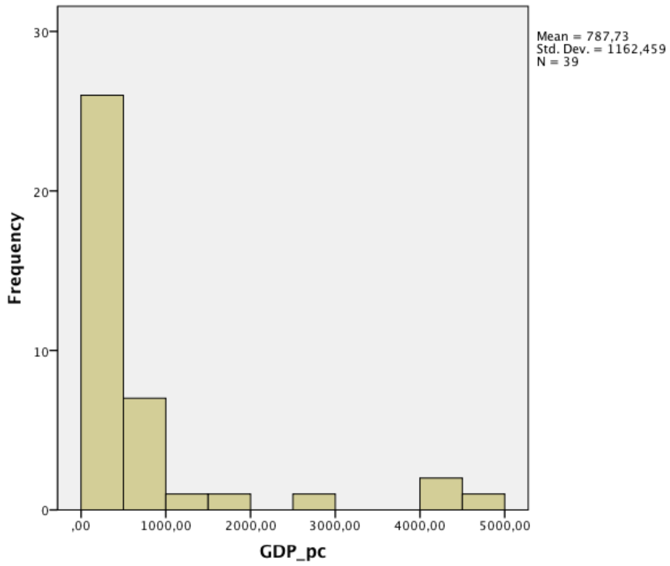
1	Angola
2	Benin
3	Botswana*
4	Burkina Faso*
5	Burundi*
6	Cameroon
7	Central African Republic*
8	Chad*
9	Congo DR
10	Congo Rep.
11	Cote d'Ivoire
12	Eritrea
13	Ethiopia*
14	Gabon
15	The Gambia
16	Ghana
17	Guinea
18	Kenya
19	Lesotho*
20	Liberia
21	Madagascar
22	Malawi*
23	Mali*
24	Mauritania
25	Mauritius
26	Mozambique
27	Namibia
28	Niger*
29	Nigeria
30	Rwanda*
31	Senegal
32	Sierra Leone
33	Sudan
34	Swaziland*
35	Tanzania
36	Togo
37	Uganda*
38	Zambia*
39	Zimbabwe*

Appendix Table 1; list of countries used in the analysis.
** marks landlocked countries*

Variable	Description	Formula
lnGDP_per_capita	Logarithmic transformation of the dependent variable of analysis	$\ln(GDP\ per\ capita)$
Corr_total roads	Density of total roads, including classified, non-classified and urban	$\frac{total\ km\ of\ roads}{(\frac{area\ of\ the\ country}{1000})}$
Corr_prim_roads	Density of primary roads	$\frac{primary\ roads}{(\frac{area}{1000})}$
Dens_good	Density of primary roads, which are classified as good by AICD	$\%good * corr\_prim\_roads$
Density_fair Density_poor	Calculated in similar way	
Density_rail	Density of the total rail lines (operating and non-operating)	$\frac{kilomtres\ of\ total\ rail\ lines}{(\frac{area}{1000})}$
Densi_op_rail	Density of operating rail lines	$\frac{kilometres\ of\ op.rail\ lines}{\frac{area}{1000}}$
Transit_road	Density of roads of all neighbouring countries	$\frac{Sum\ of\ prim.roads\ of\ all\ neigh.count}{(\frac{sum\ of\ area\ of\ all\ neigh.count}{1000})}$
Transit_rail	Density of railways of all neighbouring countries	$\frac{Sum\ of\ op.rail\ of\ all\ neigh.count}{(\frac{sum\ of\ area\ of\ all\ neigh.count}{1000})}$
Tr_corr_road	Density of roads for transit countries	$\frac{Sum\ of\ prim.road\ of\ transit\ count.}{(\frac{sum\ of\ area\ of\ all\ neigh.count}{1000})}$
Tr_corr_rail	Density of railways for transit countries	$\frac{Sum\ of\ op.rail\ of\ transit\ count.}{(\frac{sum\ of\ area\ of\ all\ neigh.count}{1000})}$
CPI	Corruption Perception Index	
Exp_per_cap	Export per capita	$\frac{export}{population}$

Appendix Table 2, variables used in analysis

Graphs:



Appendix table 1
Histogram of GDP per capita. The dependent variable is not normally distributed.

Equations
Equation 5:

$$lnGDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \beta_2 savings_{per\ capita} + \beta_3 life\ expectancy + \beta_4 transit\ \ corr\ road$$

Equation 6:

$$lnGDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \beta_2 savings_{per\ capita} + \beta_3 life\ expectancy + \beta_4 transit\ \ corr\ road\ + \beta_5 transit\ corr\ \ road * landlocked + \varepsilon$$

Equation 7:

$$lnGDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \beta_2 savings_{per\ capita} + \beta_3 life\ expectancy + \beta_4 transit\ \ corr\ rail$$

Equation 8:

$$lnGDP_{per\ capita} = \alpha + \beta_1 dummy_{landlocked} + \beta_2 savings_{per\ capita} + \beta_3 life\ expectancy + \beta_4 transit\ \ corr\ rail\ + \beta_5 transit\ corr\ \ rail * landlocked + \varepsilon$$

Output tables:

Tests of Normality

	Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
GDP_pc	,389	39	,000	,544	39	,000

a. Lilliefors Significance Correction

Appendix output 1,
Test for normality of GDP per capita

Correlations

			landlocked	export_ppc
Kendall's tau_b	landlocked	Correlation Coefficient	1,000	-,225
		Sig. (2-tailed)	.	,094
		N	39	39
	export_ppc	Correlation Coefficient	-,225	1,000
		Sig. (2-tailed)	,094	.
		N	39	39

Appendix output 2

Correlation between landlocked geographical position and value of export

Correlations

		export_ppc	corr_prim_road	density_op_rail
export_ppc	Pearson Correlation	1	,575**	,209
	Sig. (2-tailed)		,000	,202
	N	39	39	39
corr_prim_road	Pearson Correlation	,575**	1	-,011
	Sig. (2-tailed)	,000		,947
	N	39	39	39
density_op_rail	Pearson Correlation	,209	-,011	1
	Sig. (2-tailed)	,202	,947	
	N	39	39	39

**. Correlation is significant at the 0.01 level (2-tailed).

Appendix output 3

Correlation table between the value of export, density of primary roads and density of operating rail

Output tables
Model 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.254	.190		32.987	.000
	landlocked	-.386	.306	-.203	-1.264	.214

a. Dependent Variable: ln_GDPpp

Output table for Model 1.
Sample of 39 countries

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	6.254	.162		38.612	.000
	landlocked	-.754	.281	-.419	-2.689	.011

a. Dependent Variable: ln_GDPpp
Output for Model 2
Sample of 36 countries

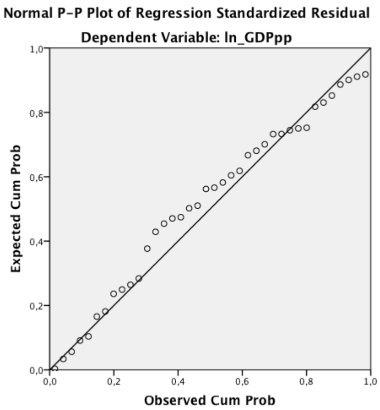
Model 2

Output table Model 2

Coefficients[a]

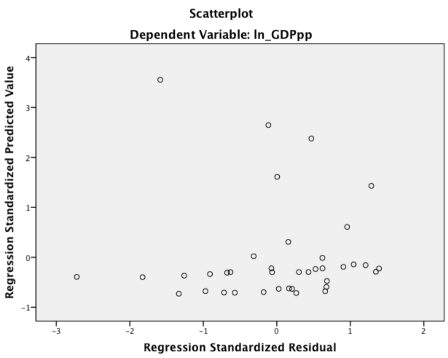
Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	5,791	,821		7,054	,000
landlocked	-,287	,167	-,150	-1,716	,096
savings_ppc	4,847E-005	,000	,040	,496	,623
life_exp	-,001	,015	-,005	-,055	,957
export_ppc	,001	,000	,871	9,981	,000

a. Dependent Variable: ln_GDPpp



PP-plot for residuals.

Residuals show normality of distribution



Scatterplot for residuals

Homoscedasticity of distribution

Model 3

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,352	1,659		2,020	,052
	life_exp	,044	,030	,277	1,472	,151
	savings_ppc	,000	,000	,377	2,568	,015
	landlocked	,004	,332	,002	,013	,990
	density_total_rail	,030	,032	,136	,942	,353
	corr_total_road	,001	,001	,208	1,286	,208

a. Dependent Variable: ln_GDPpp

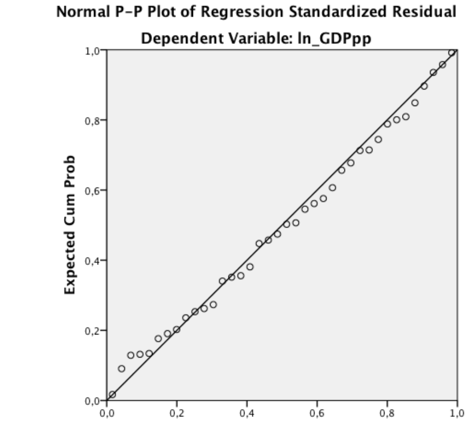
Output model 3, total rail and total roads

Model Summary[b]

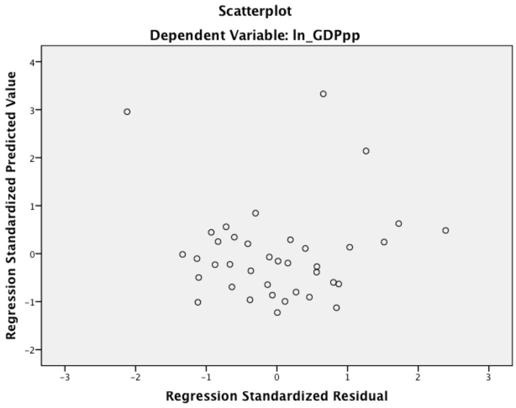
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,585[a]	,342	,239	,82751	1,944

a. Predictors: (Constant), corr_total_road, savings_ppc, density_total_rail, landlocked, life_exp

b. Dependent Variable: ln_GDPpp



PP plot for residuals. Residuals are normally distributed



Scatterplot model 3

No signs of heteroscadesticity

<u>Model 4</u>

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,452	1,564		2,207	,035
	life_exp	,042	,028	,262	1,486	,147
	savings_ppc	,000	,000	,386	2,828	,008
	landlocked	-,068	,304	-,035	-,223	,825
	density_op_rail	,086	,041	,288	2,109	,043
	corr_prim_road	,004	,002	,265	1,745	,091

a. Dependent Variable: ln_GDPpp

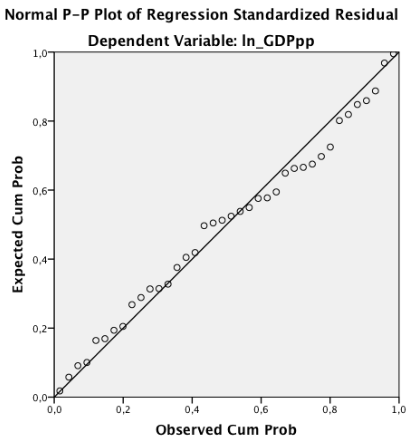
Output Model 4

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,657[a]	,431	,342	,76934	2,049

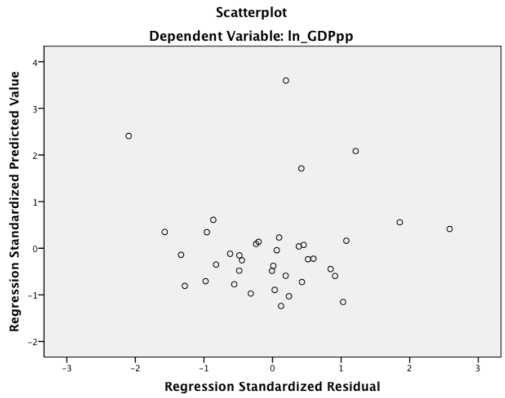
a. Predictors: (Constant), corr_prim_road, density_op_rail, savings_ppc, landlocked, life_exp

b. Dependent Variable: ln_GDPpp



PP plot for residuals of Model 4

Residuals are normally distributed



Scatterplot model 4, no signs of heteroscadesticity

Model 5
Equation 1

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,644	1,595		2,284	,029
	life_exp	,038	,029	,242	1,351	,186
	savings_ppc	,000	,000	,381	2,801	,009
	landlocked	-,074	,303	-,038	-,243	,810
	density_op_rail	,082	,041	,277	2,027	,051
	dens_good	,002	,001	,282	1,818	,078

a. Dependent Variable: ln_GDPpp

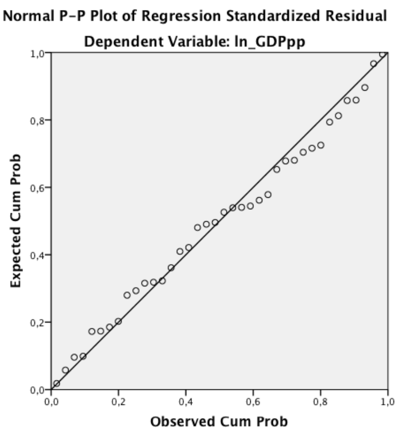
Output Model 5, predictor variable of attention: density of roads of good quality

Model Summary[b]

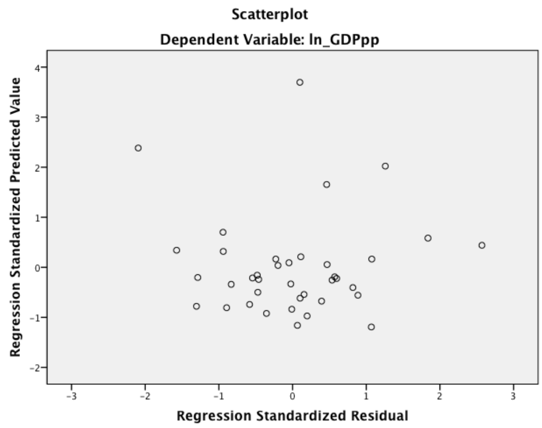
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,660[a]	,435	,347	,76652	2,040

a. Predictors: (Constant), dens_good, density_op_rail, savings_ppc, landlocked, life_exp

b. Dependent Variable: ln_GDPpp



PP-plot for residuals
No evidence of non-normality



Scatterplot. No presence of heteroscadesticity

Equation 2:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,571	1,588		2,250	,031
	life_exp	,039	,028	,249	1,387	,175
	savings_ppc	,000	,000	,386	2,835	,008
	landlocked	-,074	,304	-,039	-,243	,809
	density_op_rail	,080	,041	,270	1,968	,058
	dens_good_and_fair	,002	,001	,274	1,774	,086

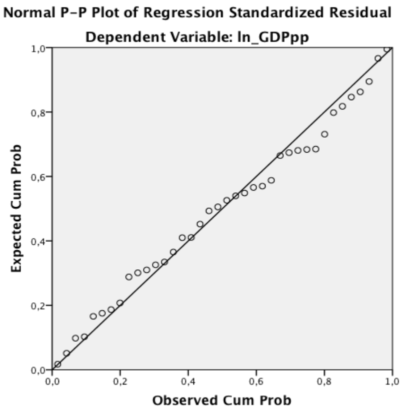
Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,658[a]	,433	,344	,76822	2,028

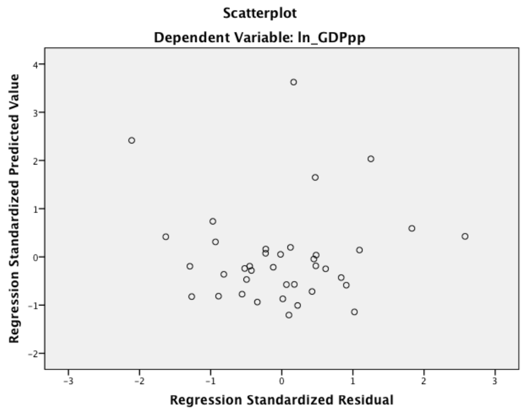
a. Predictors: (Constant), dens_good_and_fair, savings_ppc, density_op_rail, landlocked, life_exp

b. Dependent Variable: ln_GDPpp

Output Model 5, predictor variable of attention: density of roads of good and fair quality



P P-plot for residuals
No evidence of non-normality



Scatterplot model 5
No evidence of heteroscadesticity

Model 6
Equation 1:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,414	1,659		1,455	,156
	life_exp	,059	,028	,375	2,094	,045
	savings_ppc	,000	,000	,371	2,816	,009
	landlocked	-,437	,528	-,228	-,828	,414
	density_op_rail	,043	,044	,145	,975	,337
	corr_prim_road	,001	,003	,101	,424	,675
	tr_road_all	,014	,031	,127	,458	,650
	int_tr_road_landlocked	,044	,037	,369	1,186	,245

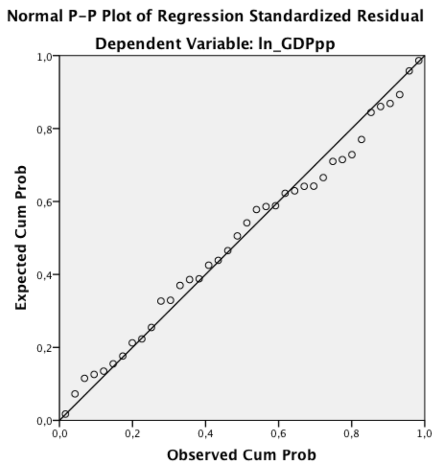
a. Dependent Variable: ln_GDPpp

Model Summary[b]

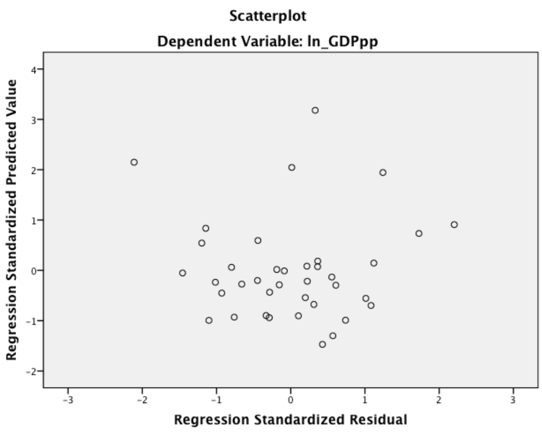
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,711[a]	,506	,390	,74064	1,992

a. Predictors: (Constant), int_tr_road_landlocked, corr_prim_road, savings_ppc, density_op_rail, life_exp, landlocked, tr_road_all

b. Dependent Variable: ln_GDPpp



P P-plot for residuals
No evidence of non-normality



Scatterplot model 6; equation 1
No evidence of heteroscadesticity

Equation 2:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,279	1,526		1,493	,146
	life_exp	,062	,027	,389	2,269	,031
	savings_ppc	,000	,000	,366	2,863	,008
	landlocked	-,173	,347	-,091	-,500	,621
	density_op_rail	,027	,045	,090	,592	,558
	corr_prim_road	,003	,002	,200	1,364	,183
	tr_rail_all	,086	,064	,387	1,342	,190
	int_tr_rail_landlocke	,009	,075	,041	,123	,903

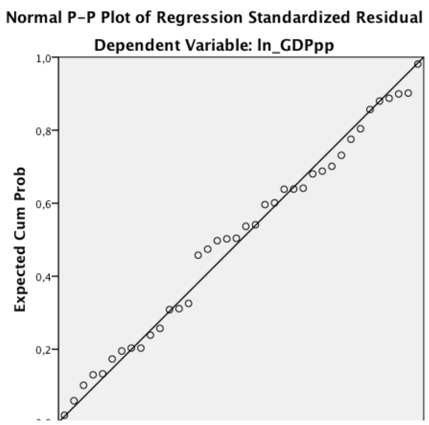
a. Dependent Variable: ln_GDPpp

Model Summary[b]

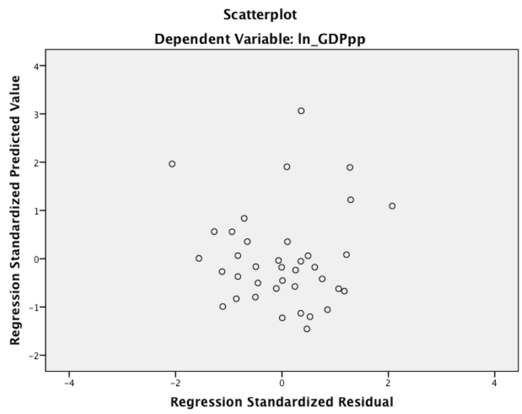
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,733[a]	,537	,430	,71644	2,003

a. Predictors: (Constant), int_tr_rail_landlocked, corr_prim_road, savings_ppc, density_op_rail, landlocked, life_exp, tr_rail_all

b. Dependent Variable: ln_GDPpp



P P-plot for residuals
No evidence of non-normality



Scatterplot, no evidence for heteroscadesticity

Equation 3:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
	(Constant)	2,994	1,500		1,996	,055
	life_exp	,051	,026	,321	1,983	,057
	savings_ppc	,000	,000	,331	2,645	,013
	landlocked	-1,146	,590	-,598	-1,941	,062
1	density_op_rail	,052	,039	,173	1,337	,191
	corr_prim_road	,003	,003	,219	1,019	,316
	tr_corr_road	,003	,028	,026	,102	,919
	int_tr__corr_road_landlocked	,067	,036	,700	1,858	,073

a. Dependent Variable: ln_GDPpp

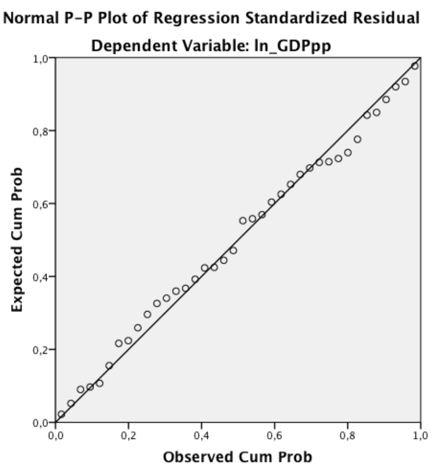
Output Model 6, equation 3

Model Summary[b]

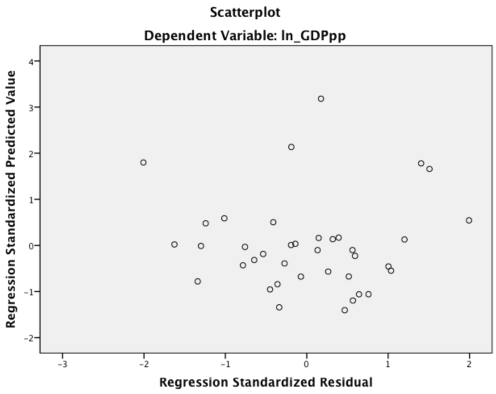
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,751[a]	,564	,463	,69540	2,149

a. Predictors: (Constant), int_tr__corr_road_landlocked, corr_prim_road, savings_ppc, density_op_rail, life_exp, tr_corr_road, landlocked

b. Dependent Variable: ln_GDPpp



PP plot for residuals no signs of deviation from normality



Scatterplot model 6; equation 3
No evidence of heteroscadesticity

Equation 4:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,130	1,379		1,545	,133
	life_exp	,065	,025	,408	2,642	,013
	savings_ppc	,000	,000	,321	2,724	,011
	landlocked	-,472	,338	-,247	-1,398	,172
	density_op_rail	,026	,038	,088	,690	,496
	corr_prim_road	,003	,002	,201	1,531	,136
	tr_corr_rail	,086	,058	,439	1,476	,150
	int_tr__corr_rail_landlocked	,028	,066	,150	,431	,670

a. Dependent Variable: ln_GDPpp

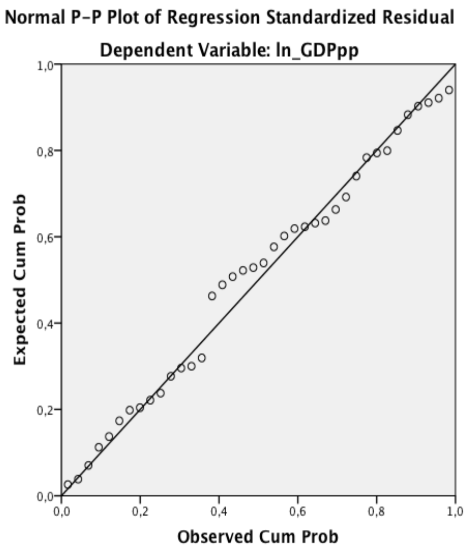
Output Model 6, equation 4

Model Summary[b]

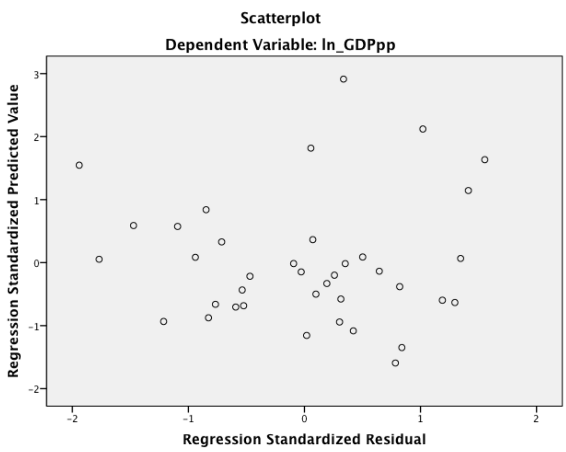
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,785[a]	,617	,527	,65219	1,987

a. Predictors: (Constant), int_tr__corr_rail_landlocked, corr_prim_road, savings_ppc, density_op_rail, life_exp, landlocked, tr_corr_rail

b. Dependent Variable: ln_GDPpp



PP plot for residuals, no deviation from normality



Scatterplot model 6; equation 4
No evidence of heteroscadesticity

Equation 5:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,875	1,327		2,166	,038
	savings_ppc	,000	,000	,346	2,660	,012
	life_exp	,046	,024	,289	1,930	,062
	landlocked	-,164	,294	-,086	-,559	,580
	tr_corr_road	,048	,014	,434	3,284	,002

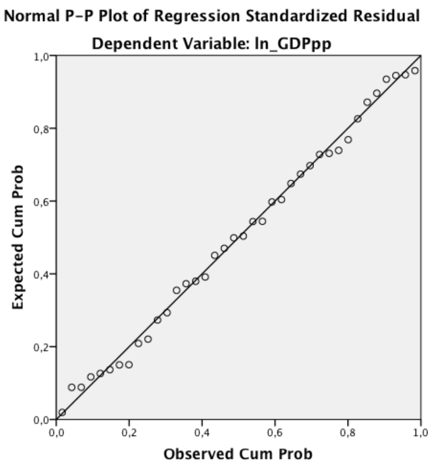
a. Dependent Variable: ln_GDPpp

Model Summary[b]

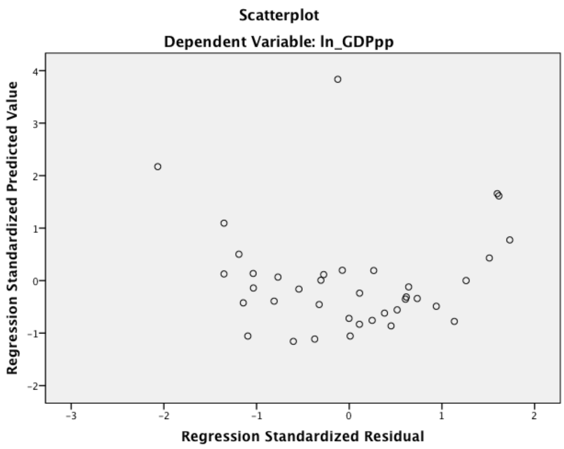
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,682[a]	,465	,400	,73484	2,231

a. Predictors: (Constant), tr_corr_road, savings_ppc, life_exp, landlocked

b. Dependent Variable: ln_GDPpp



P P-plot for residuals
No evidence of non-normality



Scatterplot model 6; equation 5
No evidence of heteroscadesticity

Equation 6:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	2,437	1,297		1,879	,069
	savings_ppc	,000	,000	,315	2,495	,018
	life_exp	,059	,024	,373	2,481	,019
	landlocked	-,971	,506	-,507	-1,919	,064
	tr_corr_road	,024	,018	,224	1,334	,192
	int_tr__corr_road_landlocked	,057	,030	,592	1,921	,064

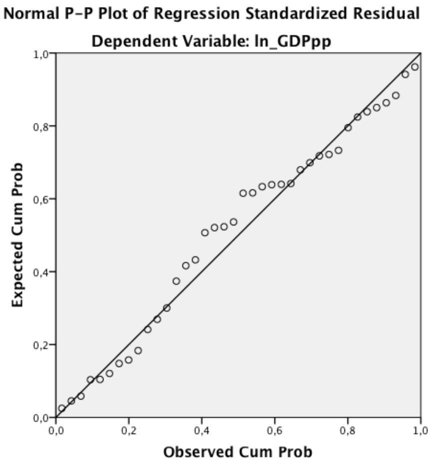
a. Dependent Variable: ln_GDPpp

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,721[a]	,520	,445	,70659	2,173

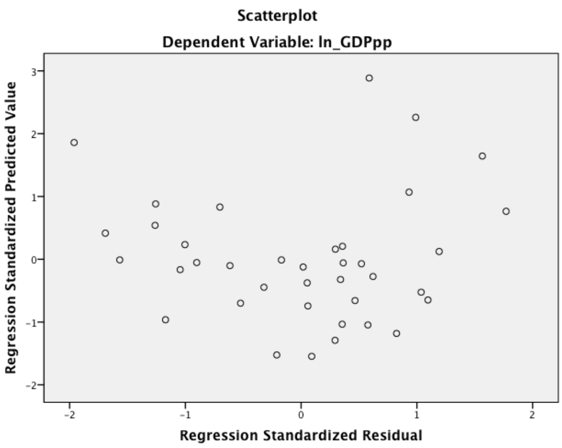
a. Predictors: (Constant), int_tr__corr_road_landlocked, savings_ppc, life_exp, tr_corr_road, landlocked

b. Dependent Variable: ln_GDPpp



PP plot for residuals

Some deviation from normality can be observed



Scatterplot

No signs of heteroscadesticity

Equation 7:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1,119	1,236		,905	,372
	savings_ppc	,000	,000	,311	2,665	,012
	life_exp	,084	,022	,528	3,887	,000
	landlocked	-,330	,269	-,172	-1,228	,228
	tr_corr_rail	,122	,026	,621	4,672	,000

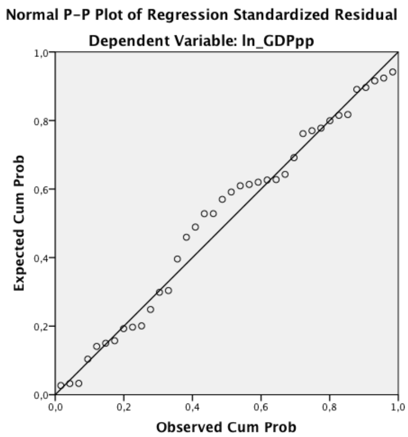
a. Dependent Variable: ln_GDPpp

Model Summary[b]

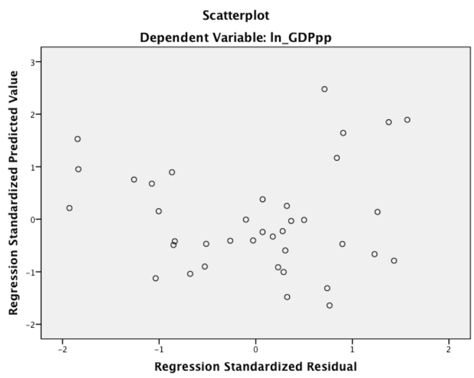
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,757[a]	,573	,521	,65665	1,944

a. Predictors: (Constant), tr_corr_rail, savings_ppc, life_exp, landlocked

b. Dependent Variable: ln_GDPpp



PP plot for residuals, , small deviation from normality



Scatterplot, no signs of heteroscadesticity

Equation 8:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1,288	1,260		1,022	,314
	savings_ppc	,000	,000	,301	2,553	,016
	life_exp	,083	,022	,520	3,792	,001
	landlocked	-,495	,339	-,258	-1,462	,154
	tr_corr_rail	,080	,059	,406	1,361	,183
	int_tr__corr_rail_landlocked	,052	,065	,278	,808	,425

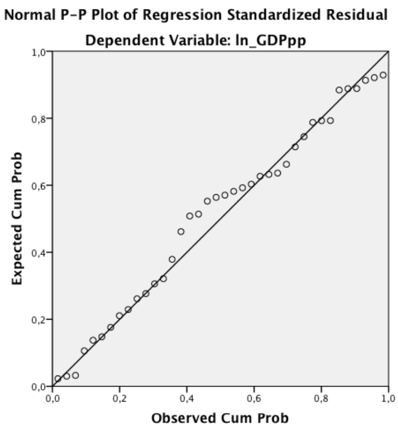
a. Dependent Variable: ln_GDPpp

Model Summary[b]

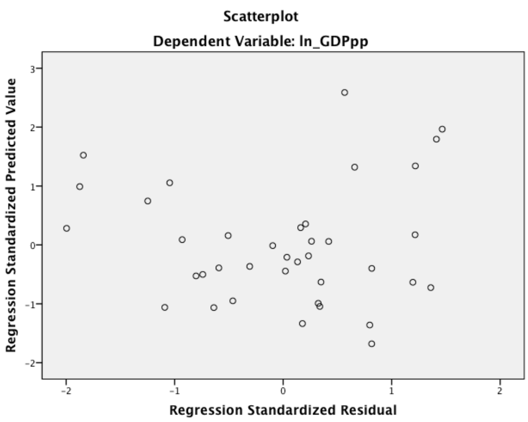
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,762[a]	,581	,516	,66014	1,893

a. Predictors: (Constant), int_tr__corr_rail_landlocked, savings_ppc, life_exp, landlocked, tr_corr_rail

b. Dependent Variable: ln_GDPpp



PP plot for residuals, , small deviation from normality



Scatterplot, no signs of heteroscadesticity

Model 7

Diamonds

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	3,265	2,310		1,413	,176
life_exp	,044	,041	,255	1,069	,300
savings_ppc	,000	,000	,459	2,233	,039
landlocked	-,066	,428	-,034	-,154	,879
density_op_rail	,048	,103	,097	,466	,647
corr_prim_road	-,002	,010	-,037	-,178	,861
exp_diamonds_and_gold	,713	,498	,318	1,433	,170

a. Dependent Variable: ln_GDPpp

Oil:

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	3,257	1,495		2,178	,037
	life_exp	,041	,027	,261	1,552	,131
	savings_ppc	,000	,000	,366	2,800	,009
	landlocked	,082	,299	,043	,275	,785
	density_op_rail	,084	,039	,282	2,161	,038
	corr_prim_road	,004	,002	,314	2,139	,040
	exp_oil	,634	,311	,276	2,041	,050

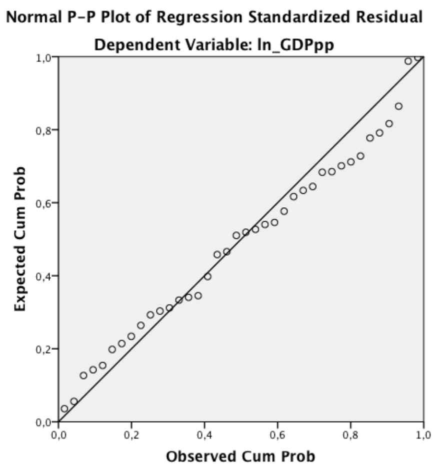
a. Dependent Variable: ln_GDPpp

Model Summary[b]

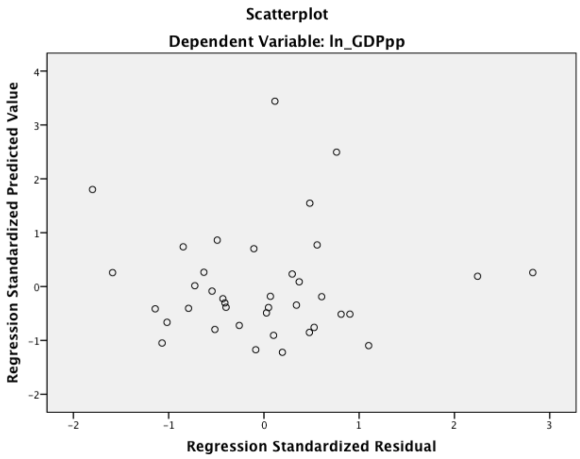
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	,706[a]	,498	,401	,73390	2,131

a. Predictors: (Constant), exp_oil, density_op_rail, savings_ppc, corr_prim_road, landlocked, life_exp

b. Dependent Variable: ln_GDPpp



P P-plot for residuals
No evidence of non-normality



Scatterplot model 7;
No evidence of heteroscadesticity