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EDITORIAL LINE

Journal of Applied Economics and Management of Organizations (JAEMO) publishes scientific manuscripts in the field of economics and management sciences as well as in very close fields. Nowadays, economics and management sciences have progressed a lot to the point that they have made alliances with neighboring sciences. This journal aims to promote very specialized, original and innovative scientific research.

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LIGNE EDITORIALE DE LA REVUE

Journal of Applied Economics and Management of Organizations (JAEMO) publie les manuscrits scientifiques dans le domaine des sciences économiques et de gestion ainsi que dans les domaines très proches. De nos jours, les sciences économiques et de gestion ont beaucoup progressé au point qu'elles ont fait des alliances avec les sciences voisines. Cette revue se veut faire la promotion de la recherche scientifique très pointue, originale et innovante.

Actuellement, la revue publie dans deux langues qui sont le français et l'anglais. La revue JAEMO est semestrielle (un numéro le mois de juin et le second en décembre). Les articles à publier par la revue doivent porter sur une problématique très claire dans les domaines tels que définis ci-dessus, présenter le cadre conceptuel, la méthodologie bien fournie, les données de qualité avec un traitement rigoureux et les résultats pouvant contribuer à la recherche scientifique et aux politiques appliquées.

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PARUTION ET FORMAT

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SUMMARY / SOMMAIRE

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Infrastructure, economic performance and poverty reduction in Mali

Infrastructures, performance économique et réduction de la pauvreté au Mali

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Abstract

This study analyzes the relationship between infrastructure, economic performance, and poverty reduction in Mali. A simultaneous equation model was employed, as it is well suited for capturing the trilateral relationship between growth, inequality, and poverty. We used World Development Indicator data from the World Bank. The results indicate a negative effect of inequality on economic performance. Health expenditure and private investment positively influence economic performance, which, in turn, reduces poverty. Investments in road and water infrastructure contribute to reducing inequality and poverty, whereas electricity and ICT infrastructure indirectly increase the poverty rate. Economic policies should prioritize reducing inequality through targeted investments in road, water, and electricity infrastructure as well as by increasing health and education expenditures.

Keywords: Infrastructure – Economic performance – Poverty – Mali

JEL code: H54 – I32 – O43 - 011

RESUME

L'objectif de ce papier est d'analyser la relation entre les infrastructures, la performance économique et la pauvreté au Mali. Avec les données de la banque mondiale et l'usage d'un modèle d'équations simultanées pour les analyses, les résultats montrent un effet négatif des inégalités sur la performance économique. Les dépenses de santé et d'investissements privés influencent positivement la performance économique, et ce dernier diminue la pauvreté. Les investissements en infrastructures routières et en eaux diminuent les inégalités et la pauvreté. Quant aux infrastructures d'électricité et des TIC, elles augmentent indirectement le taux de pauvreté. Les politiques économiques doivent prioriser la réduction des inégalités à travers, d'une part, les investissements en infrastructures routières, en eau et en électricité, et d'autre part en augmentant les dépenses de santé et d'éducation.

Mots clés : Infrastructure – Performance économique – Pauvreté – Mali

Code JEL : H54 – I32 – O43 - 011

1. Introduction

Public infrastructure plays a crucial role in enhancing economic performance and reducing poverty, particularly in developing regions (Fagbemi et al. 2022). Research highlights a bidirectional relationship between infrastructure development and poverty reduction, indicating that improved infrastructure not only fosters economic growth, but also enhances public sector performance, thereby facilitating further investments in infrastructure. Studies emphasize that improved access to essential infrastructure, such as water and health services, is a key element in reducing poverty, particularly in rural areas (Chen & Kuang, 2023). According to Timilsina et al. (2020), infrastructure investments are typically linked to economic growth as they enable better resource allocation and improved productivity. More broadly, the development of infrastructure in sectors such as energy, transportation, health, and education are a key instrument for achieving sustained economic growth. It also contributes to reducing inequalities and combating poverty and is of critical importance in shaping economic policies in developing countries (Adjovi and Codo, 2019).

Infrastructure contributes to not only economic growth but also human development (Fay & Morrison, 2005). It plays two primary roles in the economy. First, it provides essential basic services, such as drinking water, electricity, and mobility, which enable individuals to engage in productive activities. Second, it generates positive externalities that benefit the overall economic activity. This is accomplished by facilitating connections between different markets (Jacquet & Charnoz, 2003). In other words, they constitute factors of production, productivity, and poverty reduction. Endogenous growth theories emphasize the importance of infrastructure in the long-term economic development process. Similarly, empirical studies argue that investment in infrastructure has an impact on long-term growth (Romer, 1986; Lucas Jr, 1988).

The positive externalities of infrastructure are diffused within the economy through various mechanisms (DFID, 2002; Booth et al., 2000) relating to both demand and supply dynamics (Barro, 1990). This diffusion occurs through the investment costs of both channels. The first channel relies on the complementarity between public capital and private investment, while the second involves the reduction in costs associated with the reallocation of capital between sectors. In relation to economic growth, some studies identify two conventional channels through which infrastructure can affect economic growth (Agénor & Moreno-Dodson, 2006). The second channel exhibits a short-term crowding-out effect, leading to an increase in public capital stock. This, in turn, can move or crowd out private investments. In addition to its contribution to economic performance, the role of infrastructure in development has been extensively examined. An increasing body of literature on poverty underscores the importance of infrastructure in reducing poverty (Ogun, 2010; Lenz et al., 2017).

Infrastructure largely explains the regional differences in poverty within countries. Its impact on disadvantaged populations can be understood in three ways (Willoughby 2002). First, infrastructure expands local and national markets by integrating them into larger ones, broadening the spectrum of economic opportunities that poor populations can seize. Thus, according to Jacquet and Charnoz (2003), infrastructure helps reduce transaction costs and allows markets to function more efficiently. Second, the establishment of basic infrastructure and services (transport, health, energy, irrigation, etc.) reduces the vulnerability of populations to shocks and crises, which generally constitute a major obstacle to economic development. Finally, infrastructure is likely to increase agricultural productivity in developing countries, thereby improving household income, nutrition, health, education, and other key aspects of wellbeing. This shows that all dimensions of human development are, somehow, affected by infrastructure. This has been highlighted in many developing countries such as India, Nigeria, and Rwanda

(Ravallion & Datt, 2002; Ogun, 2010; Lenz et al., 2017). Some studies argue that functioning infrastructure, which enables a country to operate effectively, is a prerequisite for development and growth, and is also a fundamental condition for poverty reduction (Mills et al., 2017). This is of paramount importance in developing countries, where there is generally an unequal distribution of basic goods and services. However, this importance of infrastructure is not reflected in the endowment of developing countries, much less so in their pitiful state (Mills et al., 2017).

In Africa, two-thirds of the population (600 million people) do not have access to electricity, while 75% of the population in East Asia has access. For example, in sub-Saharan Africa, two-thirds of the installed electricity capacity is in just one country: South Africa. In terms of access to roads, much remains to be done on this continent. Only one-third of the rural population in Africa is within 2 km of an all-weather road, whereas this figure is as high as two-thirds in other developing regions (Mills et al., 2017). Mali is not an exception to this gloomy infrastructure picture, although there has been a slight increase over the last ten years. In view of the evolution of infrastructure indices in Mali, we note an increase in all infrastructure from 2000 to 2018. The water infrastructure followed a gradual increase without a decrease from 48.74 in 2000 to 79 in 2018. Those of ICT, which remained constant and low until 2011 at 0.80, will experience a remarkable increase until reaching 12.20 in 2015, decrease slightly in 2016, and then reach 18.66 in 2018. In terms of roads and electricity, we noted an increase respectively from 0.19 and 0.48 2000 2.35 and 2.09 2018.

The evolution of the infrastructure indices does not follow the same dynamics as the performance of the Malian economy, which follows a sawtooth evolution with an average of 3%. Over the study period, it reached its lowest rate in 2012 (− -0.83% and the highest rate (15 %) in 2001. Even though the Malian State has prioritized the fight against poverty through the Strategic Framework for the Fight against Poverty, the poverty rate experienced a sharp decline between 2000 and 2002, falling from 68% to 44%, and has since remained almost constant over the rest of the period at 47%. It should be noted that for more than two decades, through the strategic framework for combating poverty (CSLP) initiated by the IMF and the World Bank, the Malian State has placed poverty reduction at the heart of the country's development policies. According to the World Bank (2019), the extreme poverty rate fell slightly from 43.4% to 41.3% between 2017 and 2019. This indicates that despite this slight decline in poverty, it remains very high in Mali, especially in rural areas where it reaches up to 55.2% [1]. Economic performance did not reveal good economic dynamics in Mali. Due to the spread of insecurity in the central and northern regions, economic growth slowed, reaching a rate of approximately 5.47% in 2018. Household and business investment also slowed after a sharp decline in 2013 and stood at 8.51% of GDP in 2018. Social indicators, which are also key elements in poverty analysis, remain weak. Thus, the adult literacy rate increased from 33.1% in 2015 to 35.5% in 2018, while the primary school enrollment rate decreased by 1.82 points from 77.2% in 2014 to 75.8% in 2015. Life expectancy at birth improved by 0.86 points between 2017 and 2019, increasing from 58.45 years to 59.31% (World Bank database, 2019). This overview of development and poverty highlights the need to question poverty-reduction policies in Mali.

Although several studies have examined the impact of infrastructure development on growth and poverty reduction, little is known about their relationship in Mali. This study seeks to fill this gap by examining the effects of infrastructure development on poverty reduction through economic performance in Malaysia. The relevance of this study stems from the fact that several policies have been implemented in Mali to strengthen the economy. The most recent is the Economic Recovery and Sustainable Development Framework (2016-2018) and (2019-2023).

[1] http://www.instat-mali.org/contenu/eq/ranuel16_eq.pdf

One of the objectives of this policy is to improve inclusive growth and the structural transformation of the economy to better combat poverty.

After this introduction, the rest of the article is organized around literature review, methodology, results, and discussion, followed by the conclusion and bibliography.

2. Evidence of infrastructure effects on development

This section reviews the literature on infrastructure as a factor in development, its effects on economic growth, and the reduction of poverty and inequalities.

Infrastructure and poverty

Since the work of Aschauer (1989), several studies have been conducted to understand the role of infrastructure in development. Some authors have focused on analyzing the effects of infrastructure development on poverty reduction (Yao, 2003). Rural infrastructure has been established to promote market access and development (Yao, 2003). This may include access to education and food and health services. This reinforces the statements that physical and social infrastructure contribute to improving indicators of living standards, and therefore poverty (Nugroho et al., 2015; Marinho et al., 2017). These empirical investigations suggest that massive investments in social and economic infrastructure can reduce poverty. This is the case in Nigeria (Ogun, 2010), where social and physical infrastructure has contributed to significantly reducing poverty by improving indicators of living standards. Similar results were observed in Indonesia (Nugroho et al., 2015; Marinho et al., 2017). These studies have highlighted poverty alleviation through infrastructure (roads, electricity, schools, health, etc.) at both the rural and urban levels. They also emphasize the indirect relationship between infrastructure and poverty. In other words, in addition to directly alleviating poverty, infrastructure affects poverty through economic growth. Other studies (Isaurralde, 2017 ; OECD, 2007) have examined the relationship between reforms in infrastructure development and poverty alleviation. These studies show that the expansion of services would lead to poverty reduction if infrastructure development were affordable for the poor. Beyond the effects of infrastructure on poverty, literature highlights its role in reducing inequalities. Several studies have shown the importance of public capital in reducing poverty in developing countries (Ogun 2010).

Infrastructure and inequality

Public capital is both an engine of growth and a key element in the distribution of wealth, income, and well-being (De Ferranti, 2004; Zhang & Fan, 2004; Lopez, 2004; Servén & Calderón, 2004). In this sense, public investments can increase wealth inequality over time regardless of their financing. However, the evolution of income inequality over time is very sensitive to financing policies and is often characterized by significant intertemporal trade-offs. This intertemporal relationship between infrastructure and income inequality has been highlighted in several studies (Chatterjee and Turnovsky 2012; Bajar and Rajeev 2015; Aghion et al. 2016; Hooper et al. 2018). Short- and long-term relationships depend mainly on the influence of externalities on allocation decisions, financing policies, and the period of implementation of infrastructure projects. Empirically, depending on the type of infrastructure, there is a negative correlation between infrastructure spending and the Gini index. For example, this is the case in the United States for highway and higher education spending (Hooper et al., 2018). This finding suggests a causal relationship between the effects of infrastructure spending growth on reducing inequality. These findings are also valid in developing countries. For example, Sarkodie and Adams (2020) stated that access to electricity improves income and reduces income inequality in South Africa. While economic development is crucial for achieving access to electricity, the question remains as to how to ensure energy security. To this question, Sarkodie and Adams (2020) emphasize that effective financing and investment climate are not enough on their own to ensure energy security, but proper policies, good governance, and quality institutions are needed. In short, this literature supports the idea that infrastructure has a positive impact on reducing inequality, especially in developing countries.

Infrastructure and growth

The energy, water, transport, and telecommunication network infrastructure play a crucial role in the functioning of the economy (Aschauer, 1989). In general, infrastructure positively affects economic growth (Gachunga and Kuso, 2019; Sarkodie and Adams, 2020). This positive relationship between infrastructure and growth is also recognized at the regional level. For example, evidence of a long-term relationship between growth and infrastructure was established in the *Middle East and North Africa (MENA*) region (Cetin et al., 2017). Indeed, these authors state that infrastructure has a positive and significant impact on growth in 29 developing countries. However, the effect of infrastructure on growth varies over time depending on the type of infrastructure and country (Sutherland et al., 2009). Specifically, infrastructure investment in the telecommunication and electricity sectors (but not in rail and road networks) has a positive influence on growth.

3. Methodological approach

3.1. Theoretical Framework

The theoretical framework used in this study is a multidimensional analysis of poverty. Indeed, there are several approaches to address poverty. Considering these approaches in the analysis of poverty plays a crucial role in targeting the poor. Generally, these different approaches are grouped into two broad categories: the monetary or unidimensional approach and the multidimensional or non-monetary approach. However, it should be noted that the unidimensional approach does not capture all aspects of poverty. The literature highlights a few limitations of this approach (Koloma, 2008). First, it is based on utilitarianism, which assumes that the utility levels are comparable between individuals. Second, utilitarianism is only concerned with the aggregation of utilities and their sum without considering how utility is distributed among individuals. Third, the utilitarian position assumes the use of a single indicator of well-being and utility, which seems to be too intricately linked to individual elements to be considered by society. The recognition of the inability of the monetary approach to capture all aspects and needs necessary for the achievement of the well-being of the individual leads to a new conception of poverty based on multidimensional or non-monetary analysis. There are two main approaches to non-monetary poverty: the basic needs approach and the capabilities approach. These approaches are considered multidimensional because they include, in addition to income, several dimensions of people's lives, such as access to water, nutrition, health, and other basic services. Thus, unlike monetary poverty, they are based on a set of criteria and on human, economic, social, and other dimensions that are specific to individuals. For these reasons we go through basic needs approach theoretical framework to analyze the relationship between infrastructure and poverty alleviation, since it has been told that infrastructure affects basic services for poor people.

For a certain quality of life, the basic needs approach considers that the missing thing in the lives of the poor is a small subset of goods and services, called basic goods. These goods and services are specifically named and perceived as meeting the basic needs of all human beings. They are basic because satisfaction is considered a prerequisite for achieving a certain quality of life. However, they are not perceived as necessarily contributing to well-being. Instead of utility, emphasis is placed on the individual needs for basic commodities. In the traditional basic needs approach, commodities include food, clean water, sanitation, housing, basic health and education services, and public transport services. However, it should be noted that the subset of basic commodities is not uniform across space and time. It varies with age and sex. For example, children and women need health services, and basic education for a 7-years-old may mean going to primary school, while it may mean functional literacy for an adult. This variability in the subset of commodities raises valuation problems in relation to nature and the level of goods and services. One of the main problems facing this approach is the determination of basic needs.

3.2.Empirical Framework

Infrastructure can have both direct and indirect effects on poverty (Xianbin 2003). Direct effects are observed through increased agricultural production and non-agricultural employment. Indirect effects were observed through improved economic growth. Therefore, it would be more interesting to simultaneously consider these two effects of infrastructure on poverty when analyzing the relationship between them. This has been undertaken relatively little so far. Thus, to better understand the relationship between infrastructure, economic performance, and poverty, we used a structural model with simultaneous equations. This choice is motivated by the fact that the effects of infrastructure on poverty first depend on its effect on economic performance, then on the interaction between economic growth and inequalities, and finally on the effects of these factors on poverty (Vincent, 2019). In addition, some variables, such as infrastructure, population growth rate, public expenditure, and private investment, simultaneously affect economic performance and poverty alleviation. In this context, estimating a structural simultaneous equation model that endogenizes economic growth, inequality, and poverty, and where infrastructure is considered exogenous, allows us to consider this interdependence and to significantly reduce biases equation by equation (Vincent, 2019).

Therefore, the empirical model in this study is based on the trilateral relationship between growth, inequality, and poverty. This model was inspired by (Borensztein et al. (1998) and Forbes (2000) for the growth equation bouncier (1983) and Deininger and Squire (1998) for the inequality equation, and finally by (Gohou and Soumaré (2012) and Lehnert et al. (2013) for the poverty equation. Now, it is proper to explain each of these equations using common and specific variables.

The Growth Equation

From the “standard” growth models of (Borensztein, et al., 1998; Forbes, 2000; Barro, 2001), we retain the following speciation:

$$TCE = \alpha_0 + \alpha_1 Gini + \alpha_2 Rout + \alpha_3 Elect + \alpha_4 Tic + \alpha_5 Acc_{eau} + \alpha_6 Dep_{edu} + \alpha_7 Dep_{sant} + \alpha_8 Invest_{pr} + \alpha_9 Infla + \alpha_{10} Pop_{act} + \mu_t \quad (1)$$

Where *TCE* measures the economic growth rate; *Gini*, the inequality index; *Rout*, road infrastructure; *Elect*, electricity; *ICT*, new technology infrastructure; Acc_{eau}, access to water and sanitation; Dep_{Edu}, education expenditure; $Dep_{sant,}$ health expenditure; $Invest_{pr}$, private investment; *Infla*, inflation and Pop_{act}, the active population.

The equation of inequality

The functional form of the inequality equation is taken from the work of (Bornschier, 1983; Deininger & Squire, 1998; Lundberg & Squire, 2003), as follows:

$$GINI = \beta_0 + \beta_1 TCE + \alpha_3 Rout + \alpha_4 Elect + \alpha_5 Tic + \alpha_6 Acc_{eau} + \beta_2 Ouv_{com} + \beta_3 Confl + \beta_4 Cred + \beta_5 TCDém + \gamma_t (2)$$

Where *Ouv* $_{com}$ measures trade openness; *Cred,* credit; *TCDem* , the population growth rate.

The Poverty Equation

$$Pauv = \gamma_0 + \gamma_1 TCE + \gamma_2 Gini + \alpha_4 Rout + \alpha_5 TIC + \alpha_6 Elec + \gamma_7 Acc_{eau} + \gamma_8 FBCF_{pr} + \gamma_9 Ouv_{com} + \gamma_{10} Pop_{act} + \gamma_{11} Cred + \gamma_{12} TCDém + \varepsilon_t (3)$$

From these 3 equations, we derive the following system of simultaneous equations:

$$\begin{cases} TCE = B_1 Gini + E_1 Infra + D_1 X + \mu & (4.1) \\ Gini = A_2 TCE + E_2 Infra + D_2 W + \gamma & (4.2) \\ Pauv = A_3 TCE + B_3 Gini + E_3 Infra + D_1 Z + \varepsilon & (4.3) \end{cases} \quad (4)$$

Where X is the vector of variables specific to economic growth, composed of education spending, health spending, inflation and the labor force. W, is composed of trade openness, credit and population growth rate. It is a vector of inequality-specific variables. Z, is a vector of poverty-specific variables. It is composed of gross fixed capital formation, price, trade openness, labor force, credit and population growth rate. It should be noted that the Infra (infrastructure) variables include road, electricity, ICT and water and sanitation access infrastructures.

The endogenous variables are Poverty measured by the poverty rate; the TCE is the growth rate of gross domestic product per capita and the Gini which is the GINI coefficient. The exogenous variables of the model are connected through their multifaceted roles in economic and social development. Firstly, road infrastructure is represented by the density of the road network, which is measured as the length of paved roads in kilometers per 10,000 inhabitants. This eases mobility and connectivity. Secondly, electricity production, which includes both domestic and imported energy, is quantified in kilowatt hours per capita per hour, highlighting its critical role in powering economic activities. In addition, innovative technology infrastructure considers the number of fixed and mobile telephone subscribers per 100 inhabitants, the proportion of the population with internet access via mobile phones or computers, and the total international bandwidth capacity in megabits per second (Mbps), emphasizing its contribution to digital inclusion.

Furthermore, access to water and sanitation is captured through a composite index measuring access to 20 liters of drinking water per person per day within one kilometer of home and effective wastewater disposal facilities, underscoring its importance for public health. Likewise, education expenses represent public expenditure on education as a percentage of total government spending, reflecting investments in institutions, administration, and grants to private entities. Similarly, health expenses encompass public and private spending on preventive and curative services, family planning, nutrition, and emergency aid, although they exclude investments in water and sanitation facilities.

Moreover, private investment is an indicator of financial support for companies that lack access to public capital markets, including bank loans, leasing, and inter-company credit. Additionally, inflation denotes the depreciation of currency alongside a general price increase caused by supply-demand imbalances, directly impacting economic stability. Trade openness, in turn, serves as an indicator of a country's economic integration, calculated as the average of exports and imports divided by GDP.

On the other hand, credit access highlights business financing mechanisms, such as loans, leasing, and capital market funding, which are essential for enterprise growth. Finally, population growth rate is represented by the natural surplus rate, calculated as the difference between birth and death rates or the ratio of the natural balance to the average population, providing insights into demographic changes.

These variables are intricately linked, collectively shaping the dynamics of economic performance, inequality, and poverty reduction.

3.3.Estimation Methods

The data

Data used come from World Development Indicators 2018 database of the World Bank and Africa Infrastructure Development Inex (AIDI) of the African Development Bank Group (AfDB). The socio-economic data poverty, gain, growth rate, education expenditure, health expenditure, private investment, inflation, trade openness, labor force, are taken from the World Development Indicator database; as for the infrastructure data, they are taken from the AIDI dataset.

Descriptive statistics of variables

This subsection gives a brief descriptive analysis of the variables, table 1. One can note that the standard deviations are generally low.

Table 1: Descriptive statistics of the variables

Variable	Obs	Average	Standard deviation	Min	Max
Poverty	19	47.31029	5.756361	43.6315	68.3
Gini	19	34.91228	3.676174	30.5	40.3
Growth rate	19	4.909635	3.506942	-.8361788	15.37624
Road infrastructure	19	1.776741	.7972764	.1954869	2.736755
Electricity infrastructure	19	.7029039	.4456646	.1200514	2.011467
New technology infrastructures	19	3.645854	5.899717	.0002697	18.66085
Water and sanitation infrastructure	19	64.47148	9.78474	48.74513	79.94453
Education expenditure	19	3.440257	.3464839	2.65845	3.87281
Health expenditure	19	4.045886	1.45608	2.187613	6.853464
Private investment	19	9.762075	3.246536	5.214	15.84543
Inflation	19	3.343368	3.890577	-7.594284	12.15342
Commercial opening	19	-.0894293	.0322395	-.1482646	-.0196003
Labor force	19	64.85011	1.187035	62,546	66,734
Access to credit	19	407668.9	369206	10652	1220079
Population growth	19	3.119526	.1663285	2,852	3.394

Source: Authors calculation based on WDI, ACLED, AIDI datasets

According to table 1, it should be noted that, in general, the standard deviations are globally low, except for the variables of information and communication technology (ICT) and trade openness which are particularly high.

Identification conditions

The estimation method of simultaneous equation models depends on the model identification criterion (Bourbonnais, 2015). Generally, three cases are identified; either the model is under-identified, or it is just identified, or it is over-identified. If the model is under-identified, no estimation is possible. The model must then be respecified. For the just-shown model, indirect least squares or two-stage least squares can be applied. Finally, if the model is over-identified, two-stage least squares are applied.

The identification conditions can be the subject of a complex development (Bourbonnais, 2015). Here, we limit our identification to test the order and rank conditions. Thus, we verify that each of the three specified equations satisfies both the order condition (the necessary condition) and the rank condition (the necessary and sufficient condition) of identification.

Table 2: Test of identification conditions

Identification conditions				
Identification rank condition for equation **j**				
	K_j	M_j	K_j et M_j	Conclusion
Equation 1 (C)	4	2	$4 > 2$	Over-identified
Equation 2 (I)	5	2	$5 > 2$	Over-identified
Equation 2 (P)	3	3	$3 = 3$	Just identified
Identification rank condition for equation **j**				
	The sub-matrices			Conclusion
Equation 1 (C)	$\begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{pmatrix}$			identified
Equation 2 (I)	$\begin{pmatrix} 0 & 1 & 1 & 1 & 1 \\ 1 & 0 & 0 & 1 & 0 \end{pmatrix}$			identified
Equation 2 (P)	$\begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 0 \end{pmatrix}$			identified

Source : Authors calculation

According to (Greene, 2000; Falloul & Saadallah, 2014) equation j satisfies the identification order condition if K_j (the number of exogenous variables excluded from equation j) is superior than or equal to M_j (the number of endogenous variables included in equation j). The rank condition, on the other hand, imposes a restriction to a submatrix of the reduced-form coefficient matrix to ensure that there is exactly one solution for the structural parameters given the reduced-form parameters. The procedure is as follows:

- Construct a matrix in which each row represents an equation and each column represents a variable in the simultaneous equations model;
- When a variable appears in an equation, it is marked with a "1" and if a variable does not appear in an equation, it is marked with a "0";
- Delete the line of the equation that you are trying to identify;
- Form a submatrix from the columns corresponding to the elements containing "0"s in the row that was deleted;
- For this submatrix, if we find at least $(G - 1)$ rows and columns that are not all zero, the equation is identified. Otherwise, the equation is unidentified (G being the number of endogenous variables).

The results of these tests for our different equations, in Table 2, show that the equations of the model satisfy the order and rank conditions. Thus, the system is therefore correct and over-identified, and we can therefore choose the appropriate method to proceed with the estimation of the model.

Estimation technique

Since equations are correct and over-identified, they can be appropriately estimated by the DMC and/or TMC estimators (Bourbonnais, 2015). Then, in the context of our study, both DMC and TMC have the advantage of reducing the simultaneity bias speciffically the reverse causality ones. Indeed, there are strong reciprocal causalities between infrastructure, economic growth, inequality and poverty, which brings us back to the problems of endogeneity (Ntita

Ntita, et al., 2017). In doing so, about our model, DMC could present a major limitation with regard to the correlation of the residuals of the different equations. Therefore, the solution to obtain an efficient estimation would lie in an estimator capable of correcting the correlation bias of the residuals while admitting the endogenous exogenous variables. This description corresponds to the TMC method which is a systemic method, for which all the parameters of the model are estimated jointly. First, it estimates each equation by two-stage least squares. Then, it generates the residuals from the results of the first stage and uses them to estimate the relationship between the hazards of the different equations. Finally, it applies generalized least squares to estimate the entire model globally, taking into account the information derived in the second stage.

4. Results and discussion

Our econometric model highlights the role of infrastructure through the estimation of interactions within the growth-inequality-poverty triangle. First, we note that the specified model is globally significant. Indeed, the adjustment coefficients R^2 of the growth, inequality and poverty equations are high (42.80%, 94.16% and 70.50%) and closer to 1. Similarly, we then observe the p-values, which represent the probability of the and x^2F-stat tests in order to reject the zero hypothesis of spurious regression, are significant at 1% threshold for the GINI index and the poverty rate but significant at 10% threshold for the growth rate. Finally, the RMSE (Root Mean Square Error) statistics, which give the deviation between the simulated values of the variables compared to the observed values, are very low (2.58; 0.86 and 3.04).

Table 3: Estimation of the simultaneous equation

Variables	Growth rate	Gini	Poverty
Growth rate		0.027	0.476***
		(0.117)	(0.172)
Gini	-2.208***		0.543
	(0.854)		(0.599)
Road infrastructure	-9.520*	-2.589**	-5.314*
	(5.116)	(1.082)	(3.133)
Electricity infrastructure	8.164	0.546	3.193*
	(4,993)	(2.115)	(1,734)
New technology infrastructure	-0.614	-0.223	0.988***
	(0.481)	(0.180)	(0.331)
Water and sanitation infrastructure	0.199	-0.191	-0.497***
	(0.453)	(0.127)	(0.109)
Education expenditure	-2.083		7.836***
	(2.292)		(0.933)
Health expenditure	-2.169***		2.211***
	(0.750)		(0.504)
Private investment	-1.282**		3.263***
	(0.588)		(0.331)
Labor force	-0.629		-2.932***
	(0.865)		(0.483)
Inflation	0.0517		
	(0.201)		
Commercial opening		16.56**	
		(8.417)	
		(0.00387)	(0.00352)
Access to credit		4.09e-06*	-3.51e-06
		(2.23e-06)	(3.71e-06)
Population growth		-2.766	-81.44***
		(1,798)	(5.326)
Constant	151.7**	60.40***	442.1***
	(74.47)	(6,973)	(44.45)

Observations	19	19	19
R-squared	0.430	0.942	0.984

Source: Authors

Note : Values in parentheses are Student's t-tests and (***), (**) and (*) denote the 1%, 5% and 10% variables respectively.

First, regarding to the growth equation, the Gini index, road infrastructure, health expenditure and investment have negative and significant effects on growth. The negative effect of the Gini index corroborates with the study of (Barro, 2000) which shows that inequalities play a negative role on growth, when GDP per capita is less than $2,000 and positive if GDP per capita is superior more than this amount. Indeed, Barro (2000) makes a distinction between poor countries and rich countries regarding to the effects of inequalities on growth. He highlights that income inequalities can slowdown growth in poor countries. (Ostry, 2014) also provided empirical evidence by showing that a lower level of inequality is robustly correlated with faster and more sustainable growth, for a given level of redistribution. Inequality in Mali, certainly has started to fall but remains high. It decreased from 53% in 1991 to 24% in 2018 (RESAKSS, 2018). Regarding infrastructure, in general, a positive effect is theoretically expected (Aschauer, 1989). This is confirmed by (Yılmaz & Çetin, 2018), showing the positive and significant effects of infrastructure. In our case, the negative effects of road infrastructure can be explained by its geographical distribution. Indeed, in Mali, road infrastructure, although insufficient, is more concentrated in main cities compared to rural areas. This can raise problems for the supply and distribution of agricultural products. For example, during production season (harvest season particularly), some products (mangoes, potatoes, sweet potatoes, market gardening products) rot in rural areas due to a lack of road infrastructure and at the same time as demand remains high and unsatisfied in others regions. This is the case, for example, in the regions of Sikasso and Ségou (agricultural production zones in excellence) and those in the north as Tombouctou, Gao, Kidal, where fewer agricultural products are produced. This problem is also observed within the regions themselves. Beyond 7 km from the central municipalities, farmers have difficulty obtaining inputs and to sell their agricultural products. These contribute to increasing production costs, which, in turn, leads to a decrease in productivity, added value and therefore economic and social development.

Literature reveals a positive relationship between health expenditure and growth in developing countries (Kocoglu & David, 2012). This relationship is reflected in two channels, direct and *indirect*. First, the improvement of health has a positive effect on growth through life expectancy and productivity gains. Then, research and development in the health sector positively impacts growth through innovations. However, our results show a negative effect of health expenditure on growth in Mali. This can be explained by the poor allocation of resources in the sector. In Mali, health expenditure is predominantly allocated to administrative operations, often at the expense of curative care, staff training, and the development of health infrastructure.

Private investment has negative and significant effects. These results contradict the literature which notes a positive effect of private investments on growth (Bendoma & Essomba, 2017). The negative effect of private investment on growth in Mali can be explained mainly by its small size but also by the structure of the economy. Indeed, private investment, which depends on a part of public investment, represents only 9.5% of GDP. Also, public investment is even lower and represents only 8.7% of GDP[2]. In addition, it should be noted that the Malian economy remains structurally little industrialized with a very little developed manufacturing sector.

[2]See AfDB, 2019, Economic Outlook for Mali, available at the following link: https://www.afdb.org/ .

Secondly, regarding the Gini index equation, we note that the growth rate has a positive but not significant effect, however road infrastructure has a negative and significant influence. Similarly, new technology infrastructure, water and sanitation have negative but not significant effects. This means, in general, that in Mali, infrastructure endowments contribute to reducing income and consumption inequalities. This observation confirmed the results of (Sumedha & Meenakshi, 2015), showing that the relationship between infrastructure and inequality depends not only on the type of infrastructure but also on income. This is the case of electricity infrastructure which tends to increase inequalities in Mali. Trade openness and the rate of credit granted to businesses tend to increase inequalities. These are not conformed to what have been observed in the literature stating that trade openness plays a key role in the reduction of inequality within countries through its effect on the prices of goods and factors. Indeed, participation in foreign trade modifies household incomes due to changes in relative prices, reallocations of resources and the introduction of new production techniques (Daymon, 2012).

Third, according to the poverty equation, the results show that, economic growth contributes to reducing poverty, in line with the conclusions of (Nandori, 2010) related to the effect of economic growth on poverty in Eastern Europe. Inequality increases the poverty rate, as indicated by the theory. This is confirmed by (Herrera, 2017) emphasing that reduction of poverty will only be possible if the different types of inequalities are reduced or limited, because it is unacceptable that more than 10% of the world's population live in extreme poverty or that only eight people have the same wealth as half of humanity. Providing electricity and water and sanitation infrastructure contributes to reducing poverty, this is argued by (Granados & Noyolitzin, 2015), on the effect of infrastructure construction in reducing poverty. They state that highways have more influence on poverty in times of economic contraction. Trade openness, population growth and the granting of credit to private companies negatively influence poverty and are all significant. This is in line with (Robleh, 2015) analyzing the effects of microfinance on poverty reduction in Djibouti. Findings show that microcredit facilitates the creation of fairly significant individual savings which ultimately makes its microcredit beneficiaries autonomous and also develops the institution's credit portfolio to make it sustainable in the long term.

5. Conclusion

The objective of this study was to analyze the relationship between infrastructure, economic performance, and poverty in Mali, using an empirical model based on the trilateral relationship between growth, inequality, and poverty. A simultaneous equation model was employed, which revealed three interlinked equations: one central equation for poverty and two auxiliary equations for the GINI index and the economic growth rate. These equations were estimated using the Three-Stage Least Squares (3SLS) method.

The findings indicate that a high level of inequality negatively impacts economic performance. While road infrastructure indicators have indirect effects on economic performance, this impact is limited by the lack of access for rural populations to these infrastructures (TANGARA, et al., 2019). Conversely, electricity infrastructure positively influences growth. Health and private investment expenditures also indirectly contribute to economic performance. Road infrastructure helps reduce inequalities, whereas trade openness and access to credit exacerbate them. This is due, on one hand, to the higher volume of imports relative to exports in Mali and, on the other hand, to the challenges faced by a predominantly agricultural economy in accessing credit.

Economic performance was found to significantly reduce poverty. However, electricity and ICT infrastructure indirectly increase poverty due to uneven territorial distribution, with most of these infrastructures concentrated in urban areas. Conversely, road and water infrastructure contribute to poverty reduction. Private investments, trade openness, an active population, access to credit and population growth were also shown to significantly reduce poverty.

In light of these findings, economic policies in Mali should prioritize reducing inequalities by focusing on investments in road, water, and electricity infrastructure while simultaneously increasing expenditures on health and education. These measures are crucial for achieving improved economic performance and fostering sustainable development in Mali.

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