

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

Ouattara SOHALIO

PHD Student in Economic Policy and Modelling in the Faculty of Economic and management sciences at the Alassane Ouattara University in Bouaké (Côte d'Ivoire). <https://orcid.org/0009-0004-0690-7014>

ABSTRACT: In the face of increasing fiscal policy pressure in developing countries, one possible solution is to increase the efficiency of public spending. The digitalization of public administrations plays a crucial role in improving the efficiency of the public sector. The objective of this article is to analyze the impact of e-government on the efficiency of public spending on education. The study covers a sample of six countries of the West African Economic and Monetary Union (WAEMU) over the period 2003-2021. We use a two-step approach. The first method uses data envelopment analysis (DEA) to estimate the efficiency scores of public expenditures on education, the second uses an ARDL model to analyze the short- and long-term relationships between e-government and these efficiency scores. Overall, the results indicate that public spending on education is inefficient in the WAEMU. In the long term, e-government and e-participation have a positive impact on the efficiency of public expenditure on education in WAEMU. On the other hand, corruption, student-teacher ratios, and political instability undermine the effectiveness of public spending on education in the long run.

KEYWORDS: digitalization of administrations, education spending, DEA, ARDL, WAEMU

INTRODUCTION

Human capital is a critical factor in long-term economic growth. It promotes innovation and makes households that own them more productive (Romer, 1990). The accumulation of human capital is possible through quality education. The authors of endogenous growth insist on the importance of education by recommending that states give priority to productive public spending, particularly on education. Indeed, public expenditure on education is expected to improve education sector outcomes such as gross enrolment ratio, basic skills acquisition, human capital development and reduce the number of students per teacher. These results will reduce social inequalities and increase GDP per capita. According to Musgrave (1959), as per capita income increases, the demand for goods and services provided by the state tends to increase, forcing governments to increase spending on these goods and services. However, in a context of fiscal pressure, the countries of the West African Economic and Monetary Union (WAEMU) are facing growing budget deficits limiting their ability to increase access to education.

Despite their continued efforts to increase spending in this sector, educational outcomes remain mixed, highlighting possible inefficiency in the allocation of public resources. In addition, increasing public spending on a sector may not yield the expected results, due to inefficiencies that typically plague public sectors. WAEMU gradually increased public spending on education from 2010 to 2021. Indeed, the countries of the union allocated 3.69% of GDP in 2010, 4.34% of GDP in 2015 and 4.10% of GDP in 2021. Individually, in 2021, Burkina Faso, Côte d'Ivoire, Mali, Niger, Senegal and Togo devoted 5.30%, 3.61%, 3.58%, 3.18%, 5.01% and 3.94% of GDP to the education sector, respectively. As for educational results related to the human development index, WAEMU countries posted 0.42 in 2010, 0.45 in 2015 and 0.47 in 2021. As for the gross primary school enrolment rate, it fell from 84% to 89% from 2010 to 2015 before falling in 2021 to 85%. Countries such as Niger and Mali, in 2021, recorded a gross enrolment rate below the EU average, precisely 65% and 51% respectively. As for the student-teacher ratio, it continues to increase, from 18 in 2010 to 32 in 2021. It can be seen that as the ratio of public expenditure on education increases; educational outcomes remain low.

In a context of inefficiency in the public sector, several studies have examined the essential factors for improvement, particularly the use of digital tools in administrations. Thus, recent studies, in particular (Bayona, 2017; Mensah, 2020; Yildiz, 2007) have proven that the digitalisation of public administrations plays a driving role in performance, effectiveness and efficiency. Indeed,

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

the work of (Mensah, 2020; Yildiz, 2007) argue that e-government is the same as the integration of ICT into public administrations with the aim of improving public services to citizens, internal efficiency and transparency, while reducing the costs of administrative services and corruption. Setyawan, (2024) maintains that e-government enhances public services through improved transparency and the reduction of corruption and abuse of power. As a result, the digital transformation is a crucial element in improving the efficiency of the public sector in general and public spending in particular. Moreover, the study Bayona, (2017) concludes that e-government boosts the efficiency of overall public spending and administration in OECD countries. On the other hand, the impact of e-government is insignificant to the effectiveness of public spending on health and education.

In the WAEMU, the development of e-government remains uneven, with significant progress made in some countries such as Senegal and Côte d'Ivoire, while others are lagging behind due to the technological, institutional and financial gap. In 2022, there was an e-administration score of 0.456 for Senegal, 0.437 for Côte d'Ivoire, 0.413 for Benin, 0.401 for Togo, 0.387 for Burkina Faso, 0.369 for Mali, 0.322 for Niger and 0.298 for Guinea-Bissau (EGDI, 2022). While public spending is increasing as well as the use of information and communication technologies in public administrations, educational outcomes remain unsatisfactory.

Such an observation invites us to examine the impact of e-government on the effectiveness of public expenditure on education within the WAEMU.

To answer this research question, this article sets an objective, namely to analyze the effect of e-government on the efficiency of public expenditure on education in the WAEMU. The rest of the article is structured as follows: Section 2 presents existing work on the factors of public expenditure efficiency and especially its relationship with e-government. The methodology is presented in Section 3. Section 4 elaborates on the results followed by their discussion. The conclusion and implications of economic policies are presented in Section 5.

II. LITERATURE REVIEW

A synthesis of the major literature provides a better understanding of the evolution of work on the efficiency of public spending and the factors that influence it. The relationship between e-administration and the efficiency of public expenditure on education is the subject of a literature that is not very developed at the international level and remains non-existent in the WAEMU zone to our knowledge.

Table 1: Summary of the literature review

Author and date	Study area	Model	Results
(Miningou, 2019)	Examines the effectiveness of public spending on education through the lens of access to quality education in a panel of 130 countries (high, middle- and low-income)	Stochastic frontier approach (SFA) and the correlation matrix	On average, high-, middle- and low-income countries have public expenditure efficiency scores on education of 0.97, 0.84 and 0.75, respectively. It highlights that low-income countries face challenges, including insufficient allocation of resources to the education sector and wasteful resources. Aid to education, governance and labour market conditions influence the effectiveness of these expenditures
(Brun & Compaore, 2021)	Determines education expenditure effectiveness scores and their determinants in 67 developing countries between 1980 and 2010	-Partial frontier estimator Output: Gini index of education Input: public expenditure on education per capita in purchasing power parity. -Logit regression model	Developing countries can reduce their education inequalities by 30% without changing their public spending on education. GDP, government stability, democracy and urbanization influence the effectiveness of public spending on education, while corruption and FDI have no impact.
(Andayani & Nuryanto, 2024)	Explores the literature on factors affecting	PLS-SEM using qualitative data.	Strategic planning, the quality of equipment and infrastructure as well as the quality of school accreditation positively affect the

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

	the quality of primary education in developing countries		quality of primary education in developing countries.
(Sriningsih, et al, 2024)	Assesses the efficiency scores of government spending on education and health in the West province of Nusa Tenggara in Indonesia between 2012 and 2021.	-Output-oriented DEA with variable scale efficiency. Input: public expenditure on education Outputs: net enrolment rate and the average number of years of schooling.	The results indicate that public spending on education is inefficient. The government's ability to finance education, population density, and income inequality of people have positive effects on the efficiency of education spending, while student-teacher ratios in middle and high schools have negative effects. On the other hand, GDP per capita seems to have a neutral effect.
(Trang & Tien, 2025)	Determines the public expenditure efficiency scores on education and their determinants in 6 Asian countries between 2015 and 2021	-Output-oriented DEA with constant and variable return to scale. Inputs: public expenditure on education as a percentage of GDP and public expenditure on education as a proportion of total public expenditure. Outputs: gross primary enrolment ratio, gross secondary enrolment ratio -Tobit	The results indicate that Singapore, Thailand and Vietnam are effectively managing resources allocated to education. Foreign aid and GDP per capita negatively affect the efficiency of public spending, while trade openness contributes positively to it.
(Agasisti, 2011)	Calculates the efficiency scores of higher education systems in the OECD (2002-2006)	-Output-oriented DEA -FDH analysis Inputs: total expenditure on tertiary education, tertiary entry rate, student-teacher ratio Outputs: graduation rate, number of graduates employed, international students enrolled out of total students	Only the higher education systems of Switzerland and the United Kingdom are more efficient. The public sector (public resources allocated to education) plays a key role in the efficiency of the system.
(Jibir et al, 2024)	Assesses the effectiveness of public spending on education and health and its determinants in Nigeria between 2000 and 2022	-DEA with variable efficiency of scale oriented output and input. Input: ratio of sectoral public expenditure to overall public expenditure Output: gross enrolment ratio at the primary and secondary levels (education sector). -Tobit and Logit	The average efficiency scores for public spending on health and education are 0.979 and 0.912, respectively. Thus, public spending on health is relatively efficient than that on education. GDP per capita, government efficiency, and population growth have positive effects on the efficiency of education spending, while the money supply, corruption, and political accountability have negative effects. On the other hand, political stability seems to have a neutral effect.

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

(Amos & Jibir, 2024)	Assesses the effectiveness of public spending in five sectors in Nigeria between 2010 and 2022	Variable Scale Performance DEA Input: public expenditure by each sector Output: GDP	Economic sectors have an average score of 0.45. The efficiency scores are 0.88, 0.90, 0.94, 0.91 and 0.93 respectively for the health, administration, education, agriculture, transport and communication sectors.
(Agbidinoukoun, et al. 2023)	Determines WAEMU public expenditure efficiency scores (2000-2020)	Data envelopment analysis (DEA: VRS-output). Input: public expenditure on education Output: gross primary and university enrolment ratio, gross primary completion rate	The efficiency scores of public expenditure on education vary between 0.51 and 0.95. Guinea Bissau is the most efficient in terms of public spending on education
(Sangaré & N'Zué, 2023)	the impact of ODA on school performance in WAEMU between 2002-2021	ARDL	Official development assistance improves school performance, while governance (corruption and political instability) undermines it.

Source: Author

Several studies have determined the efficiency scores of public expenditure on education, such as (Agasisti, 2011; Agbidinoukoun et al, 2023; Amos & Jibir, 2024). These studies concluded that public spending is inefficient, especially in developing countries. Other studies have estimated the determinants of the effectiveness of public expenditure on education using a two-step method, including: (Bayona, 2017; Jibir et al, 2024; Trang & Tien, 2025). In addition, Bayona, (2017) uses the DEA and FDH models to calculate the efficiency scores of public spending allocated to each state function according to the United Nations classification in 25 European countries over the period 2007 - 2012. The author then proves that there is a positive relationship between e-government and the efficiency of public administrative spending, while the relationships between e-government and the efficiency of public spending on education and health are insignificant

It appears that the effectiveness of public spending is a challenge for all countries, especially developing countries. Unfortunately, there are fewer studies for WAEMU countries. At the international level, the relationship between e-government and the effectiveness of public expenditure on education is less addressed. At the regional level, no studies have examined this relationship, although some studies have addressed the factors that influence this effectiveness. Moreover, with the exception of the study Bayona (2017), the e-administration factor is missing from existing research analysing the effectiveness of public expenditure on education, which leaves a gap to be filled. In addition, the results of the determinants of the efficiency of public spending on education remain controversial. For example, (Jibir et al., 2024; Sangaré & N'Zué, 2023) have shown that GDP per capita and official development assistance have a positive and significant effect on the effectiveness of public expenditure on education. Conversely, the study of Trang & Tien, (2025) concluded that GDP per capita and foreign aid have negative effects on this effectiveness.

III. METHODOLOGY

In this part, we present the models used to test our hypothesis. As a result, we present on the one hand the model used to evaluate the effectiveness of public expenditure on education. On the other hand, we present the model used to estimate the effects of e-government on the efficiency of public expenditure on education in the WAEMU.

DEA Model

We use the output-oriented Data Envelopment Model (DEA). In addition, according to Bayona (2017), the DEA model is more suitable for assessing the effectiveness of public organizations. This method is more suitable when the identification of the functional form of the production function is unknown or difficult to model. We support output maximization goals with a given input, as the education sector typically pursues non-profit goals. In other words, it is a question of a country maximizing its outputs without modifying its input, i.e. identifying specific opportunities to improve its efficiency. Thus, we opt for the output-oriented constant and variable scale DEA models. The difference in the efficiency scores obtained by these two methods measures the relevance of the unit's scale and indicates that it is not operating at an optimal scale (Coelli, 1998). These techniques help identify

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

opportunities for improvement and provide a fair comparison between countries, allowing inefficient countries to learn from the practices of those that are effective. Drawing on the work of (Tyagi et al., 2009) Effectiveness is defined as:

$$TE_k = \frac{\sum_{r=1}^s u_r y_{rk}}{\sum_{i=1}^m v_i x_{ik}} \quad (1)$$

Where TE_k is the technical efficiency of the country k Using m input (public expenditure on education) to produce S outputs (the gross primary enrolment ratio, the average primary and secondary repetition rate and the pupil-teacher ratio), y_{rk} the quantity of the output r produced by the country k , x_{ik} the amount of input i used by the country k , u_r the weight of the output r , v_i the weight of the input i , m the number of inputs, s the number of outputs. Retaining the DEA model with a constant output oriented return to scale, according to (Coelli, 1998) Program 1 becomes:

$$\begin{aligned} \text{Max: } & \phi_k + \varepsilon \sum_{r=1}^s s_r + \varepsilon \sum_{i=1}^m s_i \\ \text{S.C } & \phi_k y_{rk} - \sum_{j=0}^n \lambda_j y_{rj} + s_r = 0 \quad r = 1, \dots, s \\ & x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} - s_i = 0 \quad i = 1, \dots, m \\ & \lambda_j, s_r, s_i \geq 0 \quad \forall j = 1, \dots, n; r = 1, \dots, s; i = 1, \dots, m \end{aligned} \quad (2)$$

Where λ_j corresponds to the weight associated with the input and outputs of the country j , $1 \leq \phi_k \leq \infty$, $1/\phi_k$ is the output-oriented technical efficiency score of the country k varying between 0 and 1, ε corresponds to the smallest value of the positive real numbers. In an output-oriented constant return to scale DEA model, a country is efficient if and only if $1/\phi_k = 1$ and slacks and $s_r, s_i = 0$, $\forall r = 1, \dots, s$ and $i = 1, \dots, m$ assumes that all countries reach their optimal scale. However, a country may not operate at its optimal level in the face of institutional failures, excessive bureaucracies and structural constraints. The DEA model with variable scale efficiency solves this assumption by calculating both pure and scale technical efficiency. This method is presented as follows:

$$\begin{aligned} \text{Max: } & \phi_k + \varepsilon \sum_{r=1}^s s_r + \varepsilon \sum_{i=1}^m s_i \\ \text{S.C } & \phi_k y_{rk} - \sum_{j=1}^n \lambda_j y_{rj} + s_r = 0 \quad r = 1, \dots, s \\ & x_{ik} - \sum_{j=1}^n \lambda_j x_{ij} - s_i = 0 \quad i = 1, \dots, m \\ & \lambda_j, s_r, s_i \geq 0 \quad \forall j = 1, \dots, n; r = 1, \dots, s; i = 1, \dots, m \end{aligned} \quad (3)$$

The estimation of Programs 2 and 3 is used to determine the efficiency scores of public expenditure on education, which may differ if the country suffers from a major problem, i.e. when the country is not operating at its optimal level. An efficient country with a constant return to scale DEA model is necessarily effective with a variable scale yield DEA model, but the reverse is not always true.

Regression model

After determining the technical efficiency scores, we retain those from the program (3) to estimate the impact of e-government on the efficiency of public expenditure on education in the WAEMU. Several works, including (Brun & Compaoré, 2021; Jibir et al., 2024; Trang & Tien, 2024) used Logit or Tobit models or both to analyze the factors that influence the efficiency of public spending. These authors justify their choice by the fact that the endogenous variable is bounded between 0 and 1 and therefore censored. In contrast to this work, we believe that it is necessary to examine the statistical properties of all the variables of the model before

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

the methodological choice. In addition, although a censored variable is usually stationary, this does not guarantee the stationarity of the explanatory variables, which can be integrated of order $I(1)$. However, in a model where there are some variables $I(0)$ and others $I(1)$, it is possible that there is a cointegration, and therefore a long-term relationship. In such a context, ARDL models are more suitable than logit and tobit models, as they allow to estimate short- and long-term relationships. Therefore, in this study, our approach begins by examining the properties of the variables in each estimated regression model.

Thus the theoretical model is presented as follows:

$$\text{Efficiency} = f(Ead, Epart, X) \quad (4)$$

Where *Ead* and *Epart* do e-government and *X* control variables represent.

If some variables are $I(1)$ and others $I(0)$ and they are cointegrated, then there is a long-term relationship between them. In this case, we adopt an AutoRegressive Distributed (ARDL) model. Thus, according to Pesaran et al. (1999), equation 4 can be written as follows:

$$\begin{aligned} \Delta y_{it} = & \alpha_0 + \phi_i y_{i,t-1} + \alpha_{i1} Ead_{i,t-1} + \alpha_{i2} Epart_{i,t-1} + \alpha_{i3} X_{i,t-1} + \sum_{j=1}^{m-1} \lambda_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{n-1} \beta_{ij} \Delta Ead_{i,t-j} \\ & + \sum_{j=0}^{o-1} \beta_{ij} \Delta Epart_{i,t-j} + \sum_{j=0}^{p-1} \beta_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \end{aligned} \quad (5)$$

Equation 5 is estimated three times, with the first estimate corresponding to model 1, and the second and third estimates corresponding to models 2 and 3 respectively. The endogenous variable is the technical efficiency score of public spending on education (ESE), the variables of interest are e-participation (Epart) and e-administration (Ead), and the control variables are GDP per capita (GDP), population growth rate (PGR), student-teacher ratio (STR), regulatory quality (QR) and corruption perception index (CPI), political stability (PS) and Voice and Accountability (VA).

Estimating procedure

DEA model

In this model, we use like the from (Amos & Jibir, 2024; Trang & Tien, 2024; Sriningsih et al, 2024) expenses the ratio of the pupil teacher to education is used as the input variable and the gross primary enrolment ratio, the average repetition rate for primary and secondary education, and the pupil-teacher ratio as output variables. The estimation of the models will make it possible to detect the WAEMU countries that are most effective in managing the resources allocated to education, i.e. those that have been able to achieve their objectives with the resources available.

ARDL model

Like time-series studies, panel studies require the application of certain preliminary tests to analyze the characteristics of the variables and ensure the reliability of the results. Among the tests used in this study are the coefficient homogeneity test, the cross-sectional dependence test, the unit root test, the cointegration test, the endogeneity test, the heteroscedasticity test, and the serial correlation test. The results of these tests are reported in Tables 1 and 2.

The results of these preliminary tests of our various models can take the form of an ARDL model. Indeed, this specification has two essential advantages: on the one hand, it jointly estimates the short-term and long-term coefficients and, on the other hand, it allows the introduction of integrated variables $I(0)$ and $I(1)$ or co-integrated into the model. According to (Pesaran et al, 1999) four distinct estimation methods such as the Mean Group (MG), the Pooled Mean Group (PMG), the Fixed or Random Effects Estimator (DFE), and the Generalized Moments Method (GMM) are applicable to the ARDL model. However, the DFE or GMM estimation methods require the homogeneity of the parameters, with the exception of the constant term, which may differ from one country to another in order to capture the specific effects. However, in one panel, a variable may have a favorable effect in one subsample and an unfavorable effect in the other subsample, in this case, when these methods impose a single coefficient for the entire panel, this could lead to the non-significance of the coefficient.

Moreover, it is reasonable to assume that the effectiveness of public expenditure on education may differ from country to country because of differences in e-government. In addition (Im, Pesaran, & Shin, 2003), argue that the GMM estimator is appropriate when the individual dimension (N) is large and the time dimension is limited. However, we have a relatively small sample of 6 countries. As a result, we opt for the more recent estimation methods using the Pooled Mean Group (PMG) and Mean Group (MG) estimators, proposed by (Pesaran et al., 1999), respectively. According to these authors, the MG estimator makes it possible to estimate the parameters for each country and the average for the panel. However, they also showed that if the long-run coefficients are homogeneous between individuals, a more efficient estimator, the Pooled Mean Group (PMG), can be used, which allows the short-run parameters to vary from one country to another but forces the long-term ones to be homogeneous.

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

Nevertheless, we use the PMG and MG estimators and let the Hausman joint test choose to determine the best estimator. When the null hypothesis (homogeneity of the long-run coefficients) is rejected, the MG estimate is retained. However, if the null hypothesis is accepted, the PMG is used.

Data presentation

We use public expenditure on education as an input variable, and the gross primary enrolment ratio, the average repetition rate of primary and secondary education as well as the student-teacher ratio as output variables of the DEA model. GDP per capita, population growth rate, quality of regulation and corruption perception index, political stability, and voice and accountability. All of these variables are from WDI (2023). E-administration and e-participation are taken from the E-government Development Index database (EGDI, 2023)

IV. RESULTS AND DISCUSSION

We first present the results of the data wrapping model, then those of the preliminary tests of the second model, and finally the results of the ARDL model.

The results in Table 2 reveal that public expenditure on education is inefficient within WAEMU regardless of the specification used. However, technical efficiency scores differ from one specification to another. Notably, the results show scores of 95.7% and 99.6% respectively for the CRS and VRS specification. They indicate that Burkina Faso and Mali are the only countries that make effective use of public resources allocated to education regardless of the specification chosen. The other countries are inefficient in following the CRS specification with scores of 97.5% ; 98.4% ; 94% and 95.7% for Côte d'Ivoire, Niger, Senegal and Togo respectively. On the other hand, according to the VRS specification, Niger is considered effective.

Table 2: Summary of technical efficiency scores for public spending on education

Country	CRS Score	VRS Score	Scale efficiency	Type of output (RED/REC)
Burkina Faso	1,000	1,000	1,000	-
Côte d'ivoire	0,975	0,994	0,981	RED
Mali	1,000	1,000	1,000	-
Niger	0,984	1,000	0,984	RED
Senegal	0,940	1,000	0,940	RED
Togo	0,957	0,996	0,960	RED
WAEMU	0,957	0,996	0,978	

Source: Author using WDI data (2023)

Note: RED, REC, - stands for decreasing, increasing, constant return to scale respectively

The technical efficiency results of the two specifications indicate a divergence in scores, confirming the presence of variable returns to scale for public expenditure on education in the WAEMU. Similarly, countries that are deemed inefficient do not operate at an optimal scale, they experience a diminishing return to scale. Moreover, by adjusting their size, Côte d'Ivoire could reduce its public spending on education by about 1.9%, Niger could reduce it by 1.6%, Senegal could reduce it by 6%, and Togo could reduce it by 4% and produce the same educational outcomes. Moreover, an improvement in the management of public expenditure on education within the WAEMU should make it possible to reduce this expenditure by 0.4% (VRS model) and produce current results. Moreover, if these countries adjust their size, they will reduce this expenditure by 2.2% and achieve the same results.

Table 3 presents the results on the use of public resources allocated to education. These results provide the countries studied with objective information to inform their decisions. Burkina Faso and Mali, considered efficient, spend an average of 3.69% and 4.04% of GDP respectively on education. With this ratio, Burkina Faso has 125.11% of the gross primary school enrolment rate, 15.08% of the average primary and secondary repetition rate and about 35 students per teacher. Similarly, with a rate of 4.04% of GDP, Mali records 123.76% of the gross primary school enrolment rate, 16.76% of the average primary and secondary repetition rate and about 33 students per teacher.

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

Table 3: Results on the use of public spending on education

DMU	Benchmarks	Initial values				Projected values			
		Input		Output		Input		Output	
		DE	GPER	STR	RPSE	DE	GPER	STR	RPSE
BF		3,69	125,11	34,30	15,08	3,69	125,11	34,30	15,08
CI	BF (0.88), SE (0.12)	3,76	124,35	34,12	14,27	3,72	125,25	34,32	14,35
MA		4,04	123,76	32,47	16,76	4,04	123,76	32,47	16,76
NI		4,07	124,32	31,92	16,57	4,07	124,32	31,92	16,57
SE		3,96	126,27	34,45	8,86	3,96	126,27	34,45	8,86
TO	NI (0.56), BF (0.44)	4,02	124,20	32,43	8,86	3,90	124,67	32,97	15,91

Source: Author using WDI data (2023)

Note: DE are the public expenditure on education on GDP, the gross primary enrolment ratio (GPER), the average repetition rate for primary and secondary education (RPSE), the pupil-teacher ratio (STR), BF, CI, MA, NI, SE and TO indicate respectively Burkina-Faso, Côte d'Ivoire, Niger, Senegal and Togo

Considered inefficient, Côte d'Ivoire and Togo should reduce the share of this expenditure in GDP, from 3.76% of GDP to 3.72% and from 4.02% to 3.90% respectively, in order to maintain their current results. In addition, with their current levels of public expenditure on education (3.76% and 4.02% of GDP), Côte d'Ivoire is expected to produce 125.25% of the gross primary school enrolment rate and Togo is expected to record 124.67%. To improve its efficiency, Côte d'Ivoire should, for example, follow in Burkina Faso's footsteps. With this strategy, Côte d'Ivoire could increase its efficiency by 88%.

Table 4: Summary of descriptive statistics and correlation matrix

Period	2006-2010	2011-2015	2016-2021	2003-2021	ESE	Ead	Epart
ESE	0.985	0.987	0.998	0.986	1.000		
Ead	0.198	0.201	0.251	0.207	-0.102 (0.279)	1.000	
Epart	0.079	0.145	0.399	0.173	-0.071 (0.450)	0.587 (0.000)	1.000

Note: Efficiency spending education (ESE), E-administration (Ead), E-participation (Epart)

On average, the efficiency of public spending on education is increasing in the WAEMU region, as is the digitization of administrations and the online participation of citizens. The correlation matrix shows a negative relationship between e-administration, e-participation and the efficiency of public spending on education within the WAEMU. However, these correlations are not statistically significant. On the other hand, there is a strong positive and significant correlation between e-administration and e-participation, indicating that these two dimensions of digitalization are evolving together.

Table 5: Summary of preliminary test results

CD-test			Models	Fisher Test	Hausman Test	Modified Wald Test	Wooldridge Test
Variable	CD-test	P-Value					
Efficiency spending education (ESE)	3.02	(0.003)	Model 1	0.41	6.38	262.92	4,06
E-administration (Ead)	8.71	(0.000)		(0.915)	(0.271)	(0.000)	(0.099)
E-participation (Epart)	14.52	(0.000)					
GDP per capita (GDP)	15.50	(0.000)	Model 2	0.56	6.97	612.84	3.41
Population growth rate (PGR)	1.51	(0.131)		(0.786)	(0.223)	(0.000)	(0.124)
Student-teacher ratio (STR)	5.27	(0.000)					
Quality of regulation (QR)	-1.42	(0.155)	Model 3	12.02	7.16	872.61	3.81
Corruption perception index (CPI)	2.59	(0.009)		(0.000)	(0.209)	(0.000)	(0.108)
Voice and Accountability (VA)	1.57	(0.115)					
Political stability (PS)	-0.31	(0.760)					

Source: Author using WDI data (2023)

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

Note: Fisher's, Hausman's, Wald's, Wooldridge's, and CD-test correspond respectively to tests of homogeneity between coefficients, endogeneity, heteroscedasticity, serial correlation and dependence of individuals.

Table 5 presents the results of the preliminary tests. The panel's cross-sectional dependence test indicates the presence of cross-country dependence for some variables (ESE, Ead, Epart, GDP, STR, CPI) although no dependence is observed for the other variables. As a result, we use the first-generation unit root test (Im, Pesaran and Shin, 2003) for variables that do not show cross-sectional dependence, and for the other variables, a second-generation unit root test (CIPS-Pesaran test, 2007).

The results of the unit root tests (Table 6) show that the efficiency of public expenditure on education (ESE) and e-government are stationary at the level. On the other hand, the other variables are stationary in first difference and therefore integrated of order 1 (I(1)). We have a heterogeneous panel sample with cross-country dependence and independent variables that are stationary in first difference. Thus, it is essential to test the cointegration between the variables to take into account possible long-term relationships.

Table 6: Summary of root tests

First-generation unit root tests						
At level			In first difference			decision
Variable	Z-t-tilde-bar	P-Value	Variable	Z-t-tilde-bar	P-Value	
PGR	3.759	(0.999)	Δ PGR	-1.930	(0.026)	First difference stationary
QR	0.617	(0.731)	Δ QR	-5.310	(0.000)	First difference stationary
VA	0.669	(0.748)	Δ VA	-4.363	(0.000)	First difference stationary
PS	0.352	(0.637)	Δ PS	-5.502	(0.000)	First difference stationary
Second-generation unit root test						
At level			In first difference			
	CIPS	CV (5%)		CIPS	CV (5%)	
ESE	-3.697	-2.34	Δ ESE	-4.967	-2.34	Stationary at level
Ead	-5.315	-2.34	Δ Ead	-6.190	-2.34	Stationary at level
Epart	-2.237	-2.34	Δ Epa	-3.718	-2.34	First difference stationary
GDP	-1.790	-2.34	Δ GDP	-3.432	-2.34	First difference stationary
STR	-2.170	-2.34	Δ STR	-5.129	-2.34	First difference stationary
CPI	-2.308	-2.34	Δ CPI	-3.523	-2.34	First difference stationary

Source: Author using WDI data (2023)

Several cointegration tests exist in the literature. For example, we have the Pedroni, Kao and Westerlund tests. In this study, we opt for Westerlund's (2008) cointegration test, which has good asymptotic properties, particularly with our sample. Indeed, this choice is justified by the structure of our T>N sample, as well as by the presence of heterogeneity between panel countries and cross-sectional dependence.

Table 7: Summary of the Westerlund cointegration test

Westerlund's cointegration test	Modèle 1		Modèle 2		Modèle 3	
	T-stat	P-Value	T-stat	P-Value	T-stat	P-Value
Variance Ratio	-1.606*	(0.0541)	-1.969**	(0.0245)	-1.674**	(0.047)

Source: Author using WDI data (2023)

*Note: **and * indicate rejection of the null hypothesis at the 10% and 5% thresholds respectively, presence of a long-term relationship.*

The results of the Westerlund cointegration test in Table 7 confirm a long-term relationship between the study variables for each model at the 10% and 5% thresholds respectively. We can therefore estimate an ARDL model. The Hausman test accepts fixed-effect models, while rejecting random-effect models. Overall, the results reveal that our data are heterogeneous and non-stationary. We therefore estimate an ARDL model with the MG and PMG estimators, and apply the Hausman test to select the efficient and consistent estimator.

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

Table 8 : Summary of estimation results for the ARDL model using the PMG estimator

E-administration and the efficiency of public spending on education							
Long-term relationship					Short-term relationship		
	Model 1	Model 2	Model 3		Model 1	Model 2	Model 3
E-administration (Ead)	0.017		-0.023	Δ (Ead)	-0.093		-0.019
E-participation (Epart)	0.036**	0.037***	0.037**	Δ (Epart)	-0.031	-0.027	-0.070**
Population growth rate		-0.004	-0.021***	Δ (PGR)		0.106	0.084
GDP per capita (GDP)			-3×10 ⁻⁵	Δ (GDP)			-0.0002
Student-teacher ratio		-0.007***		Δ (STR)		-0.0007	
Quality of regulation	0.027***			Δ (QR)	-0.085*		
Corruption (CPI)	-0.033**			Δ (CPI)	-0.013		
Accountability (VA)			-0.008	Δ (VA)			-0.021
Political stability (PS)		0.005**		Δ (PS)		-0.003	
ECM	-0.819***	-1,004***	-1.028***	Constant	0.801***	1.024***	1.112***
Hausman Test	2.55	9,42	7.02				
Prob(Hau)	(0.636)	(0.052)	(0.218)				

Source: Author using WDI data (2023)

Note : *, ** and *** indicate significance at the 10%, 5% and 1% thresholds respectively, Population growth rate (PGR), Student-teacher ratio (STR), Quality of regulation (QR), Corruption perception index (CPI), Voice and Accountability (VA).

According to the results of the DEA model in Table 2, public expenditure on education is not effective in WAEMU. These results support the thesis that public spending on education is inefficient in developing countries. These results corroborate those of (Agbidinoukoun et al., 2023; Brun & Compaoré, 2021; Miningou, 2019).

E-administration does not contribute significantly to the efficiency of public spending on education. This situation can be explained by the weakness of institutional quality, which is often accompanied by resistance to change on the part of public officials, particularly those who benefit from the traditional system based on opacity and sometimes corruption. In WAEMU countries, there is also a lack of coordination between administrative departments. Added to this is the lack of digital skills on the part of many public servants, which calls for appropriate training. In addition, the high cost of the Internet, the low level of digital literacy among citizens and limited access to information technologies are holding back the potential of e-administration to boost the efficiency of public spending in the education sector. This finding is in line with the conclusion of (Bayona, 2017).

The results in Table 8 (Model 2) show that e-participation contributes favourably to the efficiency of public expenditure on education in the long term. An increase of 1 unit in online participation leads to an increase of 0.037 units in the efficiency of public expenditure on education. This result can be explained by the fact that e-participation improves the relevance of public resource allocations to the extent that citizens are involved in public decision-making processes. This involvement improves transparency and strengthens the accountability of public authorities, thus constituting a lever in the fight against corruption. The population growth rate, the student-teacher ratio and corruption generate significant negative effects at the 1% threshold in the long term. Indeed, an increase of 1 unit in the population growth rate leads to a decrease of 0.021 units in the efficiency of public expenditure on education. This results is in line with those of (Trang & Tien, 2025), and reject those of (Jibir et al., 2024; Sriningsih et al., 2024). Similarly, a 1% increase in the student-teacher ratio leads to a 0.007 decrease in the efficiency of public spending on education at the 1% threshold. This result suggests that a high number of students per teacher promotes teacher inefficiency and thus reduces the quality of teaching. This result underlines the need to increase the number of teachers in the education system in WAEMU countries. This result corroborates the conclusion of (Sriningsih et al., 2024).

In addition, corruption negatively and significantly affects the effectiveness of public spending on education. A 1 unit increase in corruption causes a decrease of 0.033 units in the long run. This result can be explained by the persistence of corruption within the WAEMU. This can lead to the misappropriation of education funds or over-invoicing and the poor quality of school infrastructure, eroding the effectiveness of public spending on education. This result confirms the nuisance of corruption and is consistent with the results of the (Jibir et al., 2024; Sangaré & N'Zué, 2023).

Finally, the current level of regulatory quality is detrimental to the efficiency of public spending on education in the short term. In the long term, regulatory quality favors the efficiency of public spending on education in the WAEMU. Furthermore, a 1 unit increase in regulatory quality leads to a 0.027 unit increase in the efficiency of public spending on education. This result suggests the need to strengthen the quality of regulation in WAEMU countries to mitigate its short-term negative impact and boost the

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

efficiency of public spending on education in the union's member countries. Similarly, political stability has a positive and significant impact at the 5% threshold on the efficiency of public spending on education in WAEMU countries over the long term. Indeed, a 1 unit increase in political stability produces a 0.005 unit increase in the efficiency of public spending. This result disagrees with those of (Jibir et al., 2024).

V. CONCLUSION

The authors of endogenous growth recommend that governments give priority to basic public spending, particularly that allocated to education. Improving educational outcomes thus becomes a backbone of development strategies around the world, justifying the substantial public resources devoted to achieving this goal. However, it is reasonable to ask whether the simple fact of increasing public spending on education is enough to guarantee better educational outcomes or to guarantee their effectiveness? It is in this context that this article attempts to provide answers, by setting the objective of determining the efficiency scores of public expenditure on education and then analysing the impact of e-government on these scores.

To achieve this goal, we employ a two-step approach. The first consists of estimating the efficacy scores using a DEA model and the second, analyzing the short- and long-term impact of e-administration on these scores using an ARDL model. The study covers a sample of six WAEMU countries covering the period 2003-2021.

The results indicate that, on average, public spending in WAEMU is inefficient. Only Burkina Faso and Mali have optimal efficiency scores. The other countries of the union would benefit from drawing inspiration from their practices to improve the efficiency of their public spending on education. In addition, it appears that e-participation has a positive and significant impact on the efficiency of these expenses. Thus, a policy aimed at strengthening the efficiency of public spending on education for WAEMU countries could consist of encouraging the development of information and communication technologies in public administrations, while encouraging citizens to appropriate digital tools in a participatory and responsible approach.

Finally, the limitations of this research are related to the relatively small size of the data available and the failure to take into account the different components of e-government. Future work could further this analysis by exploring the specific effects of each of these components on the effectiveness of public expenditure on education.

REFERENCES

- 1) Agasisti, T. (2011). Performances and spending efficiency in higher education : A European comparison through non-parametric approaches. *Education Economics*, 19(2), 199-224.
- 2) Agbidinoukoun, T. A., Houssou, K. P., Agbokpanzo, A. T., Zogbasse, S., & Alinsato, A. S. (2023). Efficiency of public expenditure on education in Benin : A comparative analysis with the countries of WAEMU. *Creative Education*, 14(9), 1811-1825.
- 3) Amos, A., & Jibir, A. (2024). Government spending efficiency in Nigeria : A comparison of economic sectors from 2010-2022. *African Journal of Social and Behavioural Sciences*, 14(1), 180-192.
- 4) Andayani, S., & Nuryanto, U. W. (2024). Literature Review Perspective of Factors Affecting the Quality of Primary School Education in Developing Countries. *Asian Journal of Multidisciplinary Studies*, 7(1), 195-209.
- 5) Banerjee, A., Marcellino, M., & Osbat, C. (2004). Some cautions on the use of panel methods for integrated series of macroeconomic data. *The Econometrics Journal*, 7(2), 322-340.
- 6) Bayona, L. V. L. (2017). *Determination of the public expenditure efficiency and analysis of technological aspects : A cross-country study* (PhD Thesis). Universidad de Murcia.
- 7) Brun, J.-F., & Compaore, C. T. (2021). Public expenditures efficiency on education distribution in developing countries.
- 8) Coelli, T. (1998). A multi-stage methodology for the solution of orientated DEA models. *Operations Research Letters*, 23(3), 143-149.
- 9) Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. *Journal of econometrics*, 115(1), 53-74.
- 10) Jibir, A., Bello, A., & Amos, A. (2024). An Assessment of Public Spending Efficiency of Health and Education in Nigeria. *Lapai Journal of Economics*, 8(1), 14-34.
- 11) Mensah, I. K. (2020). Impact of Government Capacity and E-Government Performance on the Adoption of E-Government Services. *International Journal of Public Administration*, 43(4), 303-311
- 12) Miningou, E. W. (2019). Quality education and the efficiency of public expenditure : A cross-country comparative analysis. *World Bank Policy Research Working Paper*, (9077).
- 13) Pesaran, M. H., Shin, Y., & Smith, R. P. (1999). Pooled Mean Group Estimation of Dynamic Heterogeneous Panels. *Journal of the American Statistical Association*, 94(446), 621-634.

The Impact of E-Government on the Efficiency of Public Expenditure on Education in WAEMU

- 14) Romer, P. M. (1990). Endogenous Technological Change. *Journal of Political Economy*, 98(5), 71-102.
- 15) Sangaré, I., & N'Zué, F. F. (2023). How Effective Is the Official Development Assistance in the Education Sector? Evidence from the WAEMU Countries. *Open Journal of Social Sciences*, 11(11), 551-571.
- 16) Setyawan, A. C. (2024). Enhancing Public Service Delivery through Digital Transformation: A Study on the Role of E-Government in Modern Public Administration. *Global International Journal of Innovative Research*, 2(10), 2439-2453.
- 17) Sriningsih, S., Harianto, T., & Solihin, A. (2024). Determinants of Spending Efficiency for Education and Health Functions. *JEJAK: Jurnal Ekonomi dan Kebijakan*, 17(1), 27-41.
- 18) Tyagi, P., Yadav, S. P., & Singh, S. P. (2009). Relative performance of academic departments using DEA with sensitivity analysis. *Evaluation and Program Planning*, 32(2), 168-177.
- 19) Trang, T. N., & Tien, T. D. (2024). Governmental expenditure on education : Efficiency analysis in Asean countries, period 2015–2021. *Science & Technology Development Journal: Economics-Law & Management*, 8(4),
- 20) Westerlund, J. (2008). Panel cointegration tests of the Fisher effect. *Journal of Applied Econometrics*, 23(2), 193-233.
- 21) Yildiz, M. (2007). E-government research : Reviewing the literature, limitations, and ways forward. *Government information quarterly*, 24(3), 646-665.



There is an Open Access article, distributed under the term of the Creative Commons Attribution – Non Commercial 4.0 International (CC BY-NC 4.0) (<https://creativecommons.org/licenses/by-nc/4.0/>), which permits remixing, adapting and building upon the work for non-commercial use, provided the original work is properly cited.